Broadband Mapping Study

Knox County, Missouri

January 10, 2022

Finley Engineering
CCG Consulting

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EXECUTIVE SUMMARY

This study was funded by the Northeast Missouri Regional Planning Commission. The purpose of the study was to provide a detailed analysis of the state of broadband in Knox County. We believe that this report will provide the raw facts needed for any Internet Service Provider (ISP) that wants to pursue broadband grants to upgrade broadband infrastructure in the county. One of the first requirements of any broadband grant is the requirement to show the need for better broadband.

The best way to describe the broadband story for the county is that even after accounting for fiber construction that we know is coming that over 40% of the homes and businesses in the county are considered as unserved by broadband. The goal for the county would be to find one or more ISPs to bring broadband to these 1,216 locations.

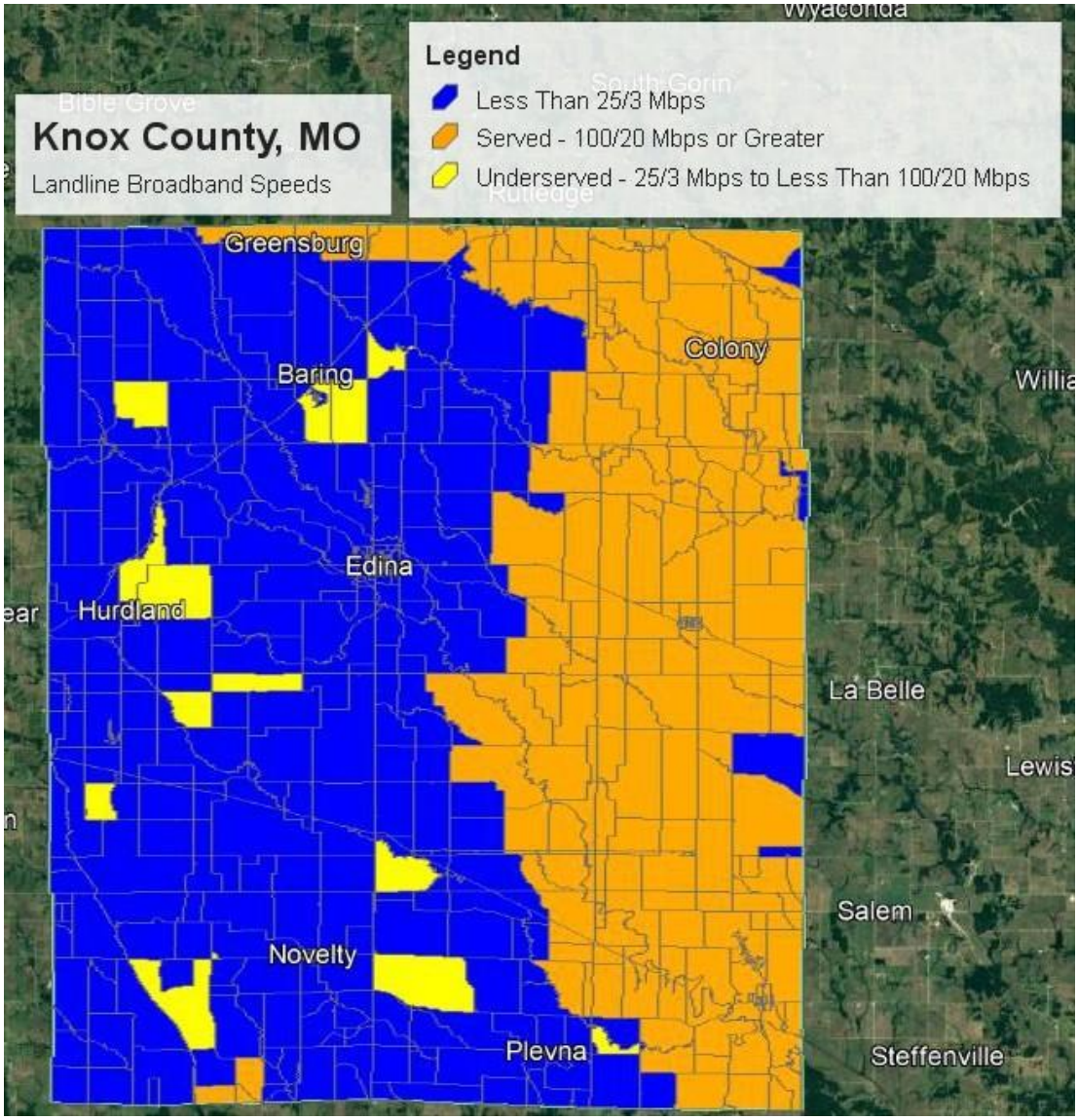
There are a number of existing Internet Service Providers in the county. The bulk of the county is served by the combination of Mark Twain Rural Telephone Company and Mark Twain Communications. The telephone company is in the process of upgrading all of its telephone company areas to fiber broadband. AT&T is the telephone company in the center of the county, including Edina. AT&T doesn't claim broadband technology to the FCC, and we were unable to find all but a tiny presence of AT&T DSL. Northeast Missouri Rural Telephone Company serves a small portion of the northern county and has built fiber. CenturyLink serves some areas around the eastern border of the county but claims very little DSL coverage. Some rural customers in the county are served with satellite or cellular broadband.

We analyzed the state of broadband in several ways. We started by looking at the speeds that existing ISPs report to the FCC. This is relevant because most grants start with the assumption that the speeds reported to the FCC are accurate.

We then investigated the actual broadband speeds in the county in several ways. We talked to the ISPs in the county about the broadband offered today, along with future plans. Finley Engineering made a physical inspection of broadband technology available in the county to see if it matches what is being reported to the FCC. We also conducted surveys and interviews to understand the broadband experiences of people in the county. We gathered County GIS mapping data so that we could quantify the households with and without broadband.

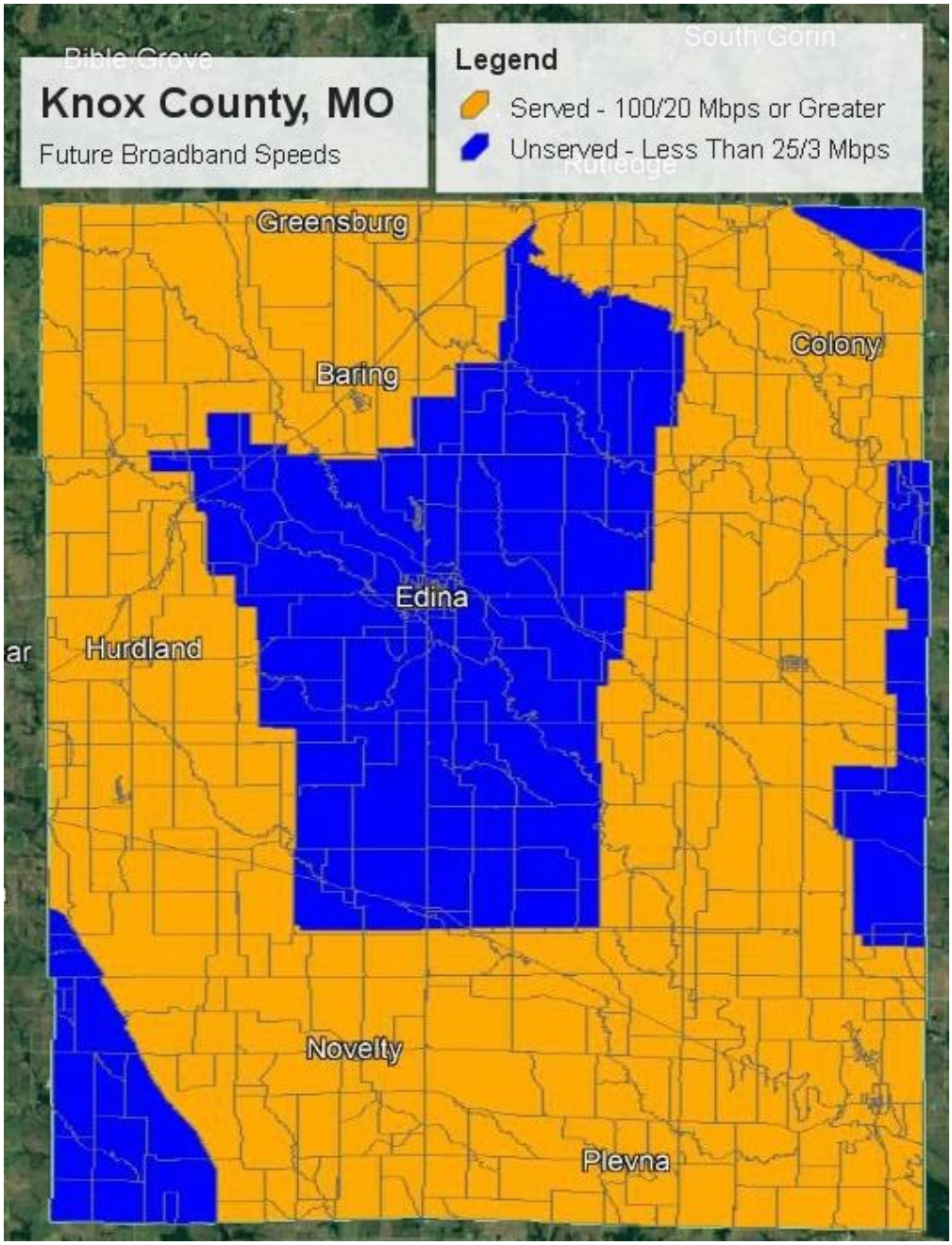
Probably the easiest way to show the state of broadband is using two maps. The first map below reflects the broadband speeds that are reported today by the various ISPs to the FCC. Finley Engineering has overlaid passings (residence and business locations) on this map and counted customers using three designations of served, underserved, or unserved. These categories are important in the industry because they define the eligibility for broadband grants. On this map, the blue areas are considered unserved, and the orange areas are considered to have adequate broadband. This table is a quantification of the data in Map 8.

	Speeds	Passings
Unserved	Less than 25/3 Mbps	1,887
Underserved	From 25/3 Mbps to 100/20 Mbps	228
Served	100/20 Mbps or faster	828
Total		2,943



The second map following reflects the broadband upgrades that we know are coming. This involves reflecting the fiber upgrades planned by Mark Twain Rural Telephone. After this change, the revised count of passings is as follows:

	Speeds	Passings
Unserved	Less than 25/3 Mbps	1,216
Underserved	From 25/3 Mbps to 100/20 Mbps	0
Served	100/20 Mbps or faster	1,727
Total		2,943



We think this report will be useful for ISPs in several ways:

- ISPs must often prove that areas are unserved. This comes about because some of the big telephone companies like AT&T can challenge grant requests by claiming that areas have broadband. This report details our research in detail of how we determine the unserved parts of the county. This report should suffice for any ISP that needs such proof.
- Finley Engineering has counted the passings in the unserved areas – something that is not easy for an ISP to do. This allows an ISP interested in a grant filing to know the potential number of customers.

The report serves several other purposes. This report can be used by local politicians and the public to grasp the scope of the areas of the county that don't have good broadband today and which are not on any ISP's plan to improve. For the first time, the county now knows that there are 1,216 homes and businesses in the county that still need a broadband solution.

We also hope that this report provides a good primer for anybody that wants to understand the broadband picture in the county. A reader will see that the report uses a lot of unfamiliar acronyms and terms, and we've done our best to write this report in plain English to try to demystify the state of broadband in the county.

I. Existing ISPs

There are a number of ISPs operating in Knox County today. The following is a short description of each ISP along with the broadband products and prices each ISP offers in the county today.

AT&T is the incumbent landline telephone provider in the center portion of the county including Edina. AT&T is not claiming DSL broadband in its service territory. We verified this by visual inspection, and we see no more than minor evidence that AT&T offers DSL.

Even if the company offered DSL, AT&T announced in October 2020 that it will no longer connect a new DSL customer anywhere in the country. For now, existing customers can keep DSL, but nobody can add the product.

CenturyLink (Lumen) is the third-largest incumbent telephone company in the country, with headquarters in Monroe, Louisiana. The company is the incumbent telephone company along the eastern border of the county.

The company grew over the years through the acquisition of telephone properties, including Qwest, which was formerly Mountain Bell and U.S. West. At the end of the third quarter of 2021, the company had 4,589,000 broadband customers. The company has a small number of cable TV customers but announced in 2020 that it is phasing out of that business line and only bundles with DirecTV.

In August 2021, the company announced it is selling the broadband properties in twenty states, including Missouri, to Apollo Global Management. Apollo is acquiring 7 million passings. The sale will include "CenturyLink-branded assets", which include "consumer and small businesses, fiber and copper networks, tower site connectivity and central offices." CenturyLink will retain its competitive CLEC business, which includes a national fiber network and sales to business customers in larger cities. It may take up to a year for the purchase to be completed and the properties to change hands.

CenturyLink DSL. CenturyLink sells broadband using DSL technology. The company offers a lot of specials on its website for new customers, but as typical with most big ISPs, a subscriber's rates revert to list prices at the end of a special promotion.

Residential DSL. Following are the list prices for residential DSL. Note that the quoted speeds offered by CenturyLink DSL are "best effort" speeds, meaning they are not guaranteed. In fact, rural customers typically get speeds significantly slower than the advertised speeds.

Pure DSL is the brand name for a DSL line that is not bundled with telephone or DirecTV. There is one price for the first year, a higher price for the second year, and after that, the customer pays the list price:

	1st Year	2nd Year	List
1.5 Mbps download, 896 Kbps upload	$30.00	$40.00	$42.00
7 Mbps download, 896 Kbps upload	$35.00	$45.00	$47.00
12 Mbps download, 896 Kbps upload	$40.00	$50.00	$52.00
20 Mbps download, 896 Kbps upload	$50.00	$60.00	$62.00

40 Mbps download, 896 Kbps upload	$60.00	$70.00	$72.00

Pure DSL also requires a DSL modem. The charge for this seems to be negotiated and ranges from $1.95 to $6.95.

We don't think there is any DSL in Knox County faster than 20 Mbps, but in many places, delivered speeds are a lot slower.

Business DSL

CenturyLink no longer publishes business DSL prices. The company negotiates a price with each business customer based upon how many other products are purchased, as well as the length of the contract.

Mark Twain Rural Telephone Company is the incumbent telephone company in the eastern and western parts of the county. Mark Twain Rural Telephone Company still mostly provides DSL broadband in the county but has started the process of upgrading all customers to fiber.

Residential DSL Internet	
10/1 Mbps	$44.95
15/1 Mbps	$54.95
25/3 Mbps	$64.95
50/5 Mbps	$74.95
Installation (modem included)	$65.00

The company does not advertise business DSL prices.

Fiber Internet	
Plans start at	$49.95
Installation (modem included)	$65.00

Customers must contact the company for pricing and speed quotes.

Business Fiber	
Plans start at	$99.95
Installation (modem included)	$65.00

Customers must contact the company for pricing and speed quotes.

Northeast Missouri Rural Telephone Company (NEMR) was founded in 1952, with headquarters in Green City, Missouri. Founded initially as a telephone company in 2011, it rebranded to NEMR Telco and began providing additional services. NEMR provides voice, video, and internet through fiber-optic cables. NEMR provides its services in northern Knox County.

Business and Residential Internet	
12/1 Mbps	$ 65
30/30 Mbps	$ 70
50/50 Mbps	$ 90
100/100 Mbps	$145
Router Maintenance	$2.95
Secure Advantage Package	$3.95

Mark Twain Communications is a subsidiary of Mark Twain Rural Telephone Company that provides fixed wireless broadband outside of the telephone company boundaries.

Residential Fixed Wireless	
5 Mpps / 512 Kbps	$ 49.95
10/1 Mbps	$ 59.95
20/2 Mbps	$ 69.95
30/3 Mbps	$ 79.95

Business Fixed Wireless	
5/1 Mbps	$ 99.95
10/2 Mbps	$109.95
15/3 Mbps	$119.95
25/5 Mbps	$129.95

For Both	
Installation (no contract)	$250.00
Installation (1-year contract)	$150.00
Installation (2-year contract)	$100.00
Modem included in installation	

Chariton Valley Wireless is a fixed wireless internet provider. The company is a subsidiary of Chariton Valley Telephone Company from Macon, Missouri. The telephone company was founded in 1952. The company offers two slow broadband products, which is a sign that this is an older wireless technology.

Residential Internet	
Unlimited Standard - 3/1 Mbps	$50
Unlimited Premium - 5/2 Mbps	$80
Modem	$ 7

Business Internet
Businesses must contact for business internet pricing.

Fixed Cellular Data

There are three primary cellular companies in the country - AT&T, Verizon, and T-Mobile. Additionally, Knox County is served by U.S. Cellular.

The traditional cellular plan using 4G LTE broadband has been labeled as hotspots. These plans have data caps similar to traditional cellular plans.

More recently, the cellular companies have introduced fixed cellular plans that use the new spectrum each company is labeling as 5G. These plans are still only available in places where each carrier would have upgraded cellular cell sites to use the new spectrum, but also where the new product is open for marketing. It's unlikely today that all of these products are available in the county, but over the next year, most are coming.

U.S. Cellular was founded in 1983 by TDS and is headquartered in Chicago, IL. The company is the fourth-largest cellular provider with five million customers at the end of the first quarter of 2021. The fixed cellular products are sold by the amount of data provided rather than speeds.

Residential Internet	
25 GB of data	$ 55.00
55 GB of data	$ 75.00
75 GB of data	$100.00
105 GB of data	$130.00
150 GB of data	$160.00
Modem	$ 5.95

AT&T has historically offered hotspot plans. More recently, it is offering fixed wireless plans that use the new bands of spectrum labeled as 5G.

4G Hotspots		
15 GB of data	$35	
100 GB of data	$55.	
Additional 1 GB	$10	
5G Fixed Wireless		
25/1 Mbps	$60	350 GB Data Cap
Additional 50 GB	$10	

Verizon has historically offered hotspot plans. More recently, it is offering fixed wireless plans that use the new bands of spectrum labeled as 5G.

4G Hotspots	
15 GB o data	$ 20
50 GB of data	$ 40
100 GB of data	$ 90
150 GB of data	$110

Once the data cap for the plan has been met, the speeds revert to 3G speeds.

5G Fixed Wireless	
With Verizon cellphone Plan	$55
Standalone	$75

Discount for autopay	$ 5
Unlimited usage.	

Reviews have said that speeds generally vary between 25 and 50 Mbps download, although speeds aren't guaranteed.

T-Mobile has historically offered hotspot plans. More recently, it is offering fixed wireless plans that use the new bands of spectrum labeled as 5G.

4G Hotspots	
5 GB of data	$20
10 GB of data	$30
30 GB of data	$40
50 GB of data	$50
Discount for autopay	$ 5

Speeds revert to 3G speeds when the cap has been met. The plans include unlimited texting.

5G Fixed Wireless	
Up to 100 Mbps	$65
Discount for autopay	$ 5
Unlimited usage	

We find it unlikely that the speeds in rural areas will be anywhere near 100 Mbps, except perhaps for customers that live within a mile of a cellular tower.

Satellite Broadband

There are two geostationary satellite broadband providers available across the county. Both Viasat and HughesNet utilize satellites that are parked at a stationary orbit over 22,000 miles above the earth.

There are a few problems that customers consistently report with satellite broadband. Customers complain that satellite costs too much (Viasat claimed in their most recent financial report for May 2021 that the average residential broadband bill is $93.06). Customers also hate the high latency, which can be 10 to 15 times higher than terrestrial broadband. The latency is due to the time required for the signals to go to and from the satellites parked at over 22,000 miles above earth – that adds time to every round-trip connection to the web. Most real-time web connections, such as using voice-over-IP or connecting to a school or corporate server prefer latency of less than 100 ms (milliseconds). Satellite broadband has reported latency between 400 ms and 900 ms.

The other customer complaint is about the tiny data caps. As can be seen by the pricing below, monthly data caps range from 10 gigabytes to 150 gigabytes. To put those data caps into perspective, OpenVault announced recently that the average U.S. home used 434 gigabytes of data per month in the second quarter of 2021, up from 380 gigabytes in 2020 and 344 gigabytes in 2019. The small data caps on satellite broadband make it impractical to use for a household with school students or for a household that wants to use broadband to work from home.

Viasat (was formerly marketed as Exede or Wildblue). Viasat satellite broadband has gotten better over time. The broadband on the ViaSat-1 satellite launched in 2011 was relatively slow, with speeds as fast as 25 Mbps. The company markets speeds as fast as 100 Mbps download on the ViaSat-2 satellite launched in 2017. The company plans three new ViaSat-3 satellites with even high capacity, with the first to launch sometime in 2022.

Prices are high compared to other broadband products. The latest pricing from the company is as follows:

	Price	Speed	Data Cap
Unlimited Bronze	$84.99	12 Mbps	40 GB
Unlimited Silver	$119.99	25 Mbps	60 GB
Unlimited Gold	$169.99	100 Mbps	100 GB
Unlimited Platinum	$249.99	100 Mbps	150 GB
Equipment Fee	$ 12.99		

A customer must sign a 2-year contract to get these prices, with a fee of $15 per remaining month if a customer breaks a contract. Online reviews say that speeds can be throttled to as slow as 1 Mbps once a customer reaches the monthly data cap.

HughesNet is the oldest satellite provider. They have recently upgraded their satellites and now offer speeds advertised as 25 Mbps download and 3 Mbps upload for all customers. Prices vary according to the size of the monthly data cap. These packages are severely throttled after meeting the data caps. The packages are as follows:

10 GB Plan	$ 59.99
20 GB Plan	$ 69.99
30 GB Plan	$ 99.99
50 GB Plan	$149.99

Starlink. There has been a lot of recent news concerning the three new satellite companies that will be offering broadband. First is Starlink, owned by Elon Musk. The company is in beta test mode and has been selling broadband across the U.S. for $99 per month, including a $500 price for the receiver. The company has taken over 500,000 deposits of $99 on a waiting list. The company has over 2,000 satellites in orbit but needs 11,000 for the completed first constellation. Starlink download speeds in beta tests have been between 50 Mbps and 150 Mbps – a great upgrade for customers using rural DSL or fixed wireless broadband.

OneWeb, owned by the British government and various large private investors, says it will begin testing broadband in the far northern hemisphere in early 2022 and plans to cover the world by the end of the year. There is no news yet of speeds or prices.

Project Kuiper, owned by Jeff Bezos, says it will be in service within a few years, although it has yet to launch any satellites. But the company is being fully funded by Bezos and Amazon and is expected to catch up to the other two providers.

II. THE MAPPING STORY

The easiest way to visualize the current state of broadband in a county is through the mapping of available broadband data. This section of the report will look at publicly available broadband mapping data. As will be discussed below, we know that a lot of the FCC mapping data is out of date or inaccurate. CCG Consulting and Finley Engineering have together created maps that we think portray the real state of broadband in the county.

The primary source of broadband data comes from the Federal Communications Commission (FCC). This section of the report will begin with the broadband data as reported to FCC. We'll then modify the FCC maps to layer on known corrections and updates. The final map (included in the Executive Summary) shows the parts of the county that should be eligible for future broadband grants.

A. The FCC Defines Broadband

Any analysis of the availability of broadband begins with broadband data collected by the FCC. The FCC has been tasked by Congress to report every year on the state of broadband in the country. That responsibility has prompted the agency to take two important steps, which will be discussed below. First, the FCC felt compelled to create a definition of broadband – otherwise, the agency couldn't report the number of homes that have or don't have broadband. Second, the FCC began collecting data twice a year from internet service providers (ISPs) that reports on broadband deployment. The FCC requires ISPs to report broadband coverage area and broadband speeds using the Form 477 process. Since the FCC collects broadband statistics by Census blocks, it's relatively easy to translate the FCC database into maps to get a visual understanding of the deployment of broadband.

The following discussion looks at how the FCC gathers broadband data and discusses the specific broadband data for Knox county. We also look at the repercussions for cases where the FCC data is inaccurate.

FCC Definition of Broadband

The FCC established the definition of broadband as 25/3 Mbps (that's 25 Mbps download and 3 Mbps upload) in 2015. Prior to then, the definition of broadband was 4/1 Mbps, set a decade earlier. The FCC defines broadband to meet a legal requirement. Congress established a requirement for the FCC in Section 706 of the FCC governing rules that the agency must annually evaluate broadband availability in the country. Further, the FCC must take action to improve broadband if the agency decides that broadband is not being deployed in a timely manner.

The FCC reports the state of broadband to Congress every year.[1] In these reports, the FCC compiles data about broadband speeds and availability and offers an opinion on the state of broadband in the country. In every report to date, the FCC has acknowledged that there are shortcomings in the broadband data, but

[1] The 2020 FCC report to Congress was published in two documents found at https://docs.fcc.gov/public/attachments/FCC-20-50A1.pdf and https://docs.fcc.gov/public/attachments/FCC-20-50A2.pdf.

the FCC has never determined that the problems are so bad that it needed to take extraordinary measures to close any broadband gaps. As you will see below, the FCC's annual reports to Congress often portray a picture of broadband that differs significantly from is experienced by customers in the real world.

The FCC didn't use empirical evidence like speed tests in setting the definition of broadband speed in 2015. They instead conducted what is best described as a thought experiment. They listed the sorts of functions that a "typical" family of four was likely to engage in, and then determined that a 25/3 Mbps broadband connection was fast enough to satisfy the broadband needs of a typical family of four.

The FCC asked again in 2018 and 2020 if 25/3 Mbps was still an adequate definition of broadband. The agency took no action and decided that 25/3 Mbps was still a reasonable definition of broadband. There were comments filed by numerous parties in that docket that thought that the definition of broadband speed should be increased.

Later in this report is a section that looks at the various broadband gaps in the county. In that discussion, we'll show why a definition of broadband at 25/3 Mbps is outdated compared to what is needed by households and businesses today.

FCC Broadband Data

The FCC fulfills its obligation to track broadband for Congress by collecting data from ISPs about broadband speeds and deployment. The FCC collects broadband data using the Form 477 process. The FCC collects data from every landline and fixed wireless ISP in the country. The FCC collects speed information from cellular carriers in a separate format. The FCC does not collect information about satellite broadband but will in the near future. The FCC collects the following data twice per year from every ISP (even though we know there are small ISPs that don't participate).

- ISPs report broadband customer counts by Census Block. A Census Block is a finite geographic area defined by the U.S. Census Bureau that typically includes between 60 and 120 homes. In a city, a Census block might be a city block, and in a rural area it might cover a large portion of a county. Most ISPs report only those Census Blocks where they have broadband customers, but some ISPs report Census Blocks where they are willing to sell service but have no customers.
- For each Census Block, the ISP reports a single broadband speed. Some ISPs report the fastest actual speeds delivered to customers, while other ISPs report the fastest speed that is marketed to customers - which can be much higher than actual speeds.

The FCC makes some of this data available to the public. This data can be easily mapped, and so the FCC data collection effort has been colloquially called FCC mapping data – although the FCC rarely maps the data. In reporting to Congress, the FCC has arbitrarily decided to segregate broadband availability into a few speed tiers, such as customers able to receive broadband of 25/3 Mbps, 100/10 Mbps, or gigabit.

We know from many years of gathering real broadband speeds that the FCC 477 data is often exaggerated due to three reasons:

- ISPs often report marketing speeds to the FCC rather than actual speeds. As an example, we recently saw a wireless ISP report 100 Mbps marketing speed to the FCC while delivering speeds of less than 5 Mbps.

- The FCC reporting assumes that an ISP that serves at least one customer in a Census block serves the entire Census block. This results in FCC coverage areas being exaggerated. For example, all of the Census blocks around a town with a cable provider generally are shown as if everybody in the Census blocks can buy cable broadband. In reality, cable companies rarely extend networks past where housing density is high. The bottom line is that the FCC mapping overstates the cable company serving area as well as counting homes as having good broadband when they don't.
- Finally, there are no penalties for ISPs that claim coverage of a Census block where they don't have any customers. We've seen cases where a wireless ISP claims coverage for a whole county but where extensive customer surveys didn't find a single customer for that ISP.

These reporting problems are widespread, and the net results can be extreme. We know of rural counties where almost nobody has broadband as fast as 25/3 Mbps, but where the FCC reporting shows that most, or even everybody in the county has good broadband.

There is a lot of documentation about the inadequacies of the FCC mapping data. For example, the state of Georgia undertook an effort to accurately map broadband availability in the state. Like many states, Georgia understood that the FCC's broadband maps badly overstate broadband coverage. The goal of the state mapping effort was to define areas that don't have good broadband to stimulate broadband investment where it's needed most.

Georgia measured broadband speed in two ways. First, the state confronted ISPs about what it viewed as faulty FCC reporting. The state also solicited speed tests from the public to find out the real speeds being delivered across the state. While there can admittedly be issues with the accuracy of a single speed test, when taken in mass, speed tests can create an accurate picture of broadband availability and speeds.

Georgia then created a map[2] that shows a side-by-side comparison between FCC speeds and the speeds that the state thinks are correct. The differences between the two maps are astounding. There are entire counties that the FCC believes have access to 25/3 or faster broadband but that show only limited coverage on the state version of the map. The overall results from the mapping effort were stunning. The State map shows that over 507,000 homes and businesses and 1 million people in the state don't have access to 25/3 Mbps broadband. That is double the 252,000 homes identified by the FCC as not having access to 25/3 Mbps broadband.

The FCC doesn't monitor what is reported and has allowed big reporting errors into the mapping databases. The FCC's 2018 Broadband Deployment Report reached the conclusion that the state of rural broadband was improving rapidly. It turns out there was a huge error in the data supporting that FCC report. A new ISP in New York, Barrier Free, had erroneously reported that it had deployed fiber to 62 million residents in New York. Even after the FCC was forced to correct the error, they still drew the same conclusions that broadband was getting better, even though the revised report showed millions of fewer homes without good broadband. This raises a question about what defines "reasonable and timely deployment of broadband" if having fiber to 62 million fewer people doesn't change the answer.

All these factors taken together mean that the FCC broadband databases and maps created from the data are often inaccurate.

[2] https://broadband.georgia.gov/fcc-vs-gbdi-broadband-comparison

FCC to Revise Maps

In January of 2020, the FCC voted to revise its data gathering process, and Congress finally provided the money in the American Recovery Plan Act at the end of 2020 for this to happen. The best change in the new reporting is that ISPs must draw polygons around areas where customers either have service or where the ISP is willing to provide service within ten days of a request. This means specific service areas will be identified and that whole Census blocks won't be shown being served due to one or two fast customers. This will clean up two problems. It will draw lines around areas where cable company coverage stops at the edge of towns. Today, reporting by Census block often shows cable coverage extending far into the rural areas surrounding towns. Second, the polygons ought to make it harder for rural WISPs and telcos to claim coverage where they can't provide service in ten days.

Unfortunately, the FCC is keeping one of the worst features of the original data, and ISPs can continue to report the fastest advertised broadband speed. This is the primary problem in rural areas today where the big telcos claim 25/3 Mbps advertised speeds and then deliver a 2 Mbps product. It's our opinion that rural mapping might not improve much due to this rule.

The revised mapping rules will allow for a two-tier challenge process – a challenge by governments or tribes and a challenge by consumers. The government challenge is complex in that a challenger must draw its own versions of the polygons in an area being challenged. It will be difficult or impossible for local governments to gather the huge volume of consumer data needed to sustain such a challenge. A government might gather a thousand speed tests in a rural county and still be unable to draw an accurate polygon of the coverage area. This challenge process looks heavily slanted in favor of ISPs.

The consumer challenges also won't have much power. A consumer can challenge that an ISP is willing to serve their home, and if they win, the ISP must redraw the polygon to exclude the customer from the polygon. A consumer can't challenge the speeds being claimed – just the coverage.

Consequences of Inaccurate FCC Maps

It's likely that 90% or more of counties in the country have at least some overstated broadband coverage on the FCC maps. If the FCC were to acknowledge the real state of rural broadband, it would likely be required by a Congressional mandate in Section 706 rules to undertake extraordinary efforts to fix the broadband problems. The bad maps have allowed the FCC to issue a report to Congress every year that states that rural broadband coverage has problems but is improving.

Unfortunately, the speeds reported by the FCC data have other real-life implications. For example, the FCC constantly cites the statistics from the broadband mapping system when developing various policies or making decisions that impact rural broadband. The FCC is fully aware of the inadequacies of their data, and yet it often cites its own faulty data as proof that broadband isn't as bad in rural America as critics might suggest.

Probably the biggest impact of the poor FCC data is that many federal broadband grant programs rely on the FCC mapping data to determine where federal broadband grants can or cannot be awarded. If the FCC

data overstates the broadband speeds in a neighborhood, there is a good chance that neighborhood will be excluded from eligibility for federal grants.

B. FCC 477 Data In Knox County

Even with the many faults, there is still some good information in the FCC broadband data. If nothing else, the FCC 477 maps are a starting point for trying to define the ISPs that serve any given area and the speeds they claim to be providing.

The following series of maps look at the FCC 477 data for each ISP in Knox County. The maps show the coverage area claimed by each ISP in the county. In cases where an ISP reports multiple speeds, we've color-coded the data by speed. At the end of this section, we'll show some composite maps of all of the ISPs together. Finally, we'll create a map that we think paints the composite picture of the broadband in the county today.

CenturyLink (Map 1)

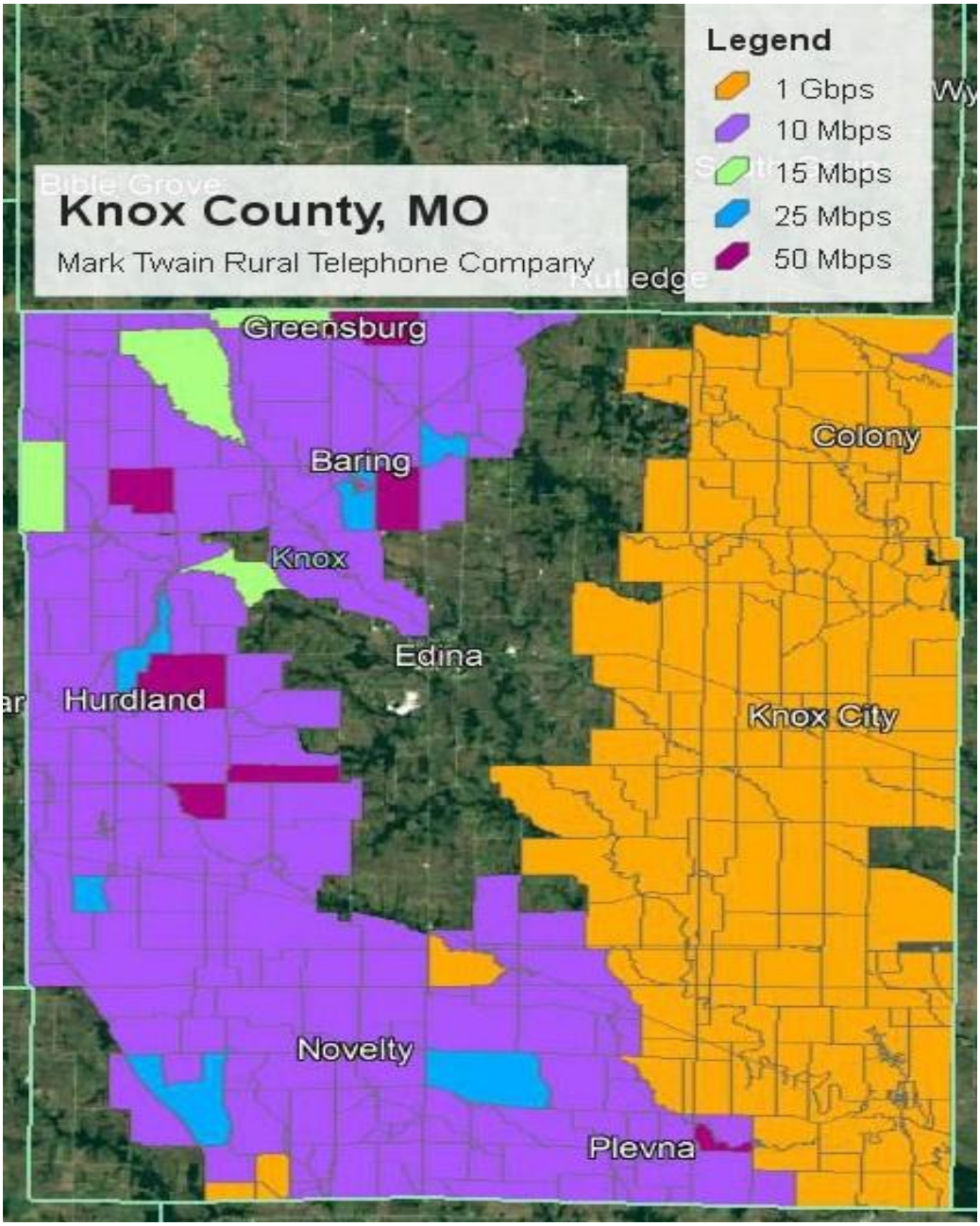
The map below shows the broadband data reported by CenturyLink to the FCC in the Form 477 process. As the incumbent telephone company in the eastern part of Knox County, the company provides only DSL technology on copper telephone wires. CenturyLink claims to provide service to two census blocks in Knox County. CenturyLink claims to provide 20 Mbps in the grey area in the map below. CenturyLink claims to provide 3 Mbps in the red area in the map below.

Map 1 – CenturyLink FCC 477 Data

Mark Twain Rural Telephone Company

The map below shows the latest broadband reporting by Mark Twain Rural Telephone Company to the FCC in the Form 477 process. The company still offers DSL in most of its western service territory, but as can be seen by the orange areas on the map, it has already updated its eastern service area. The company plans on upgrading its entire service area to fiber.

Map 2 – Mark Twain Rural Telephone Company FCC 477 Data

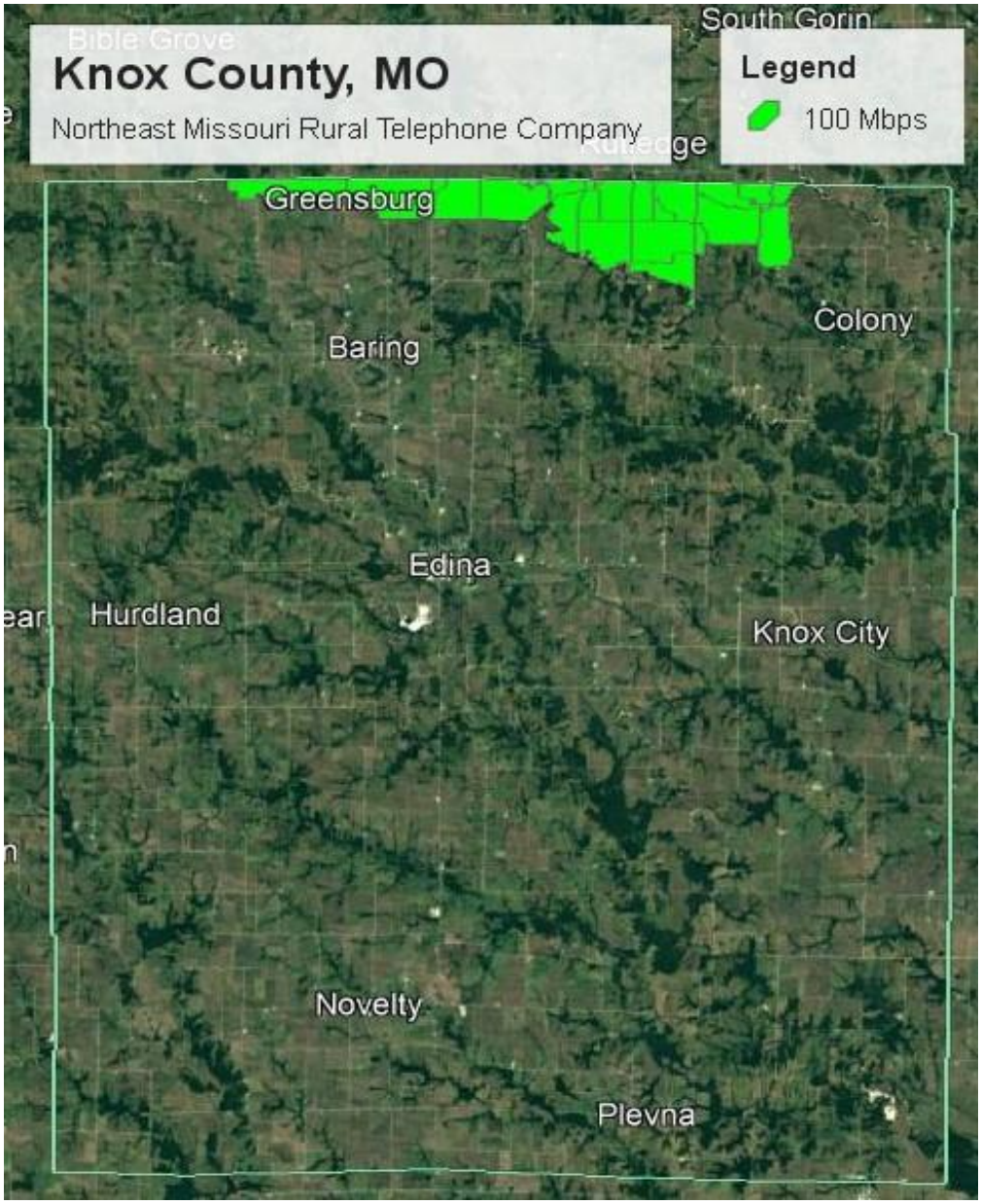


Northeast Missouri Rural Telephone Company

The following map shows the broadband reporting by Northeast Missouri Rural Telephone Company (NEMR) to the FCC in the Form 477 process. The company has already upgraded to fiber in its telephone exchange boundary in northern Knox County.

For now, the company is reporting speeds to the FCC of up to 100 Mbps. The company plans to change the speeds in the FCC reporting to show gigabit capability after it finishes upgrading the fiber backhaul capabilities to the county.

Map 3 – Northeast Missouri Rural Telephone Company FCC 477 Data

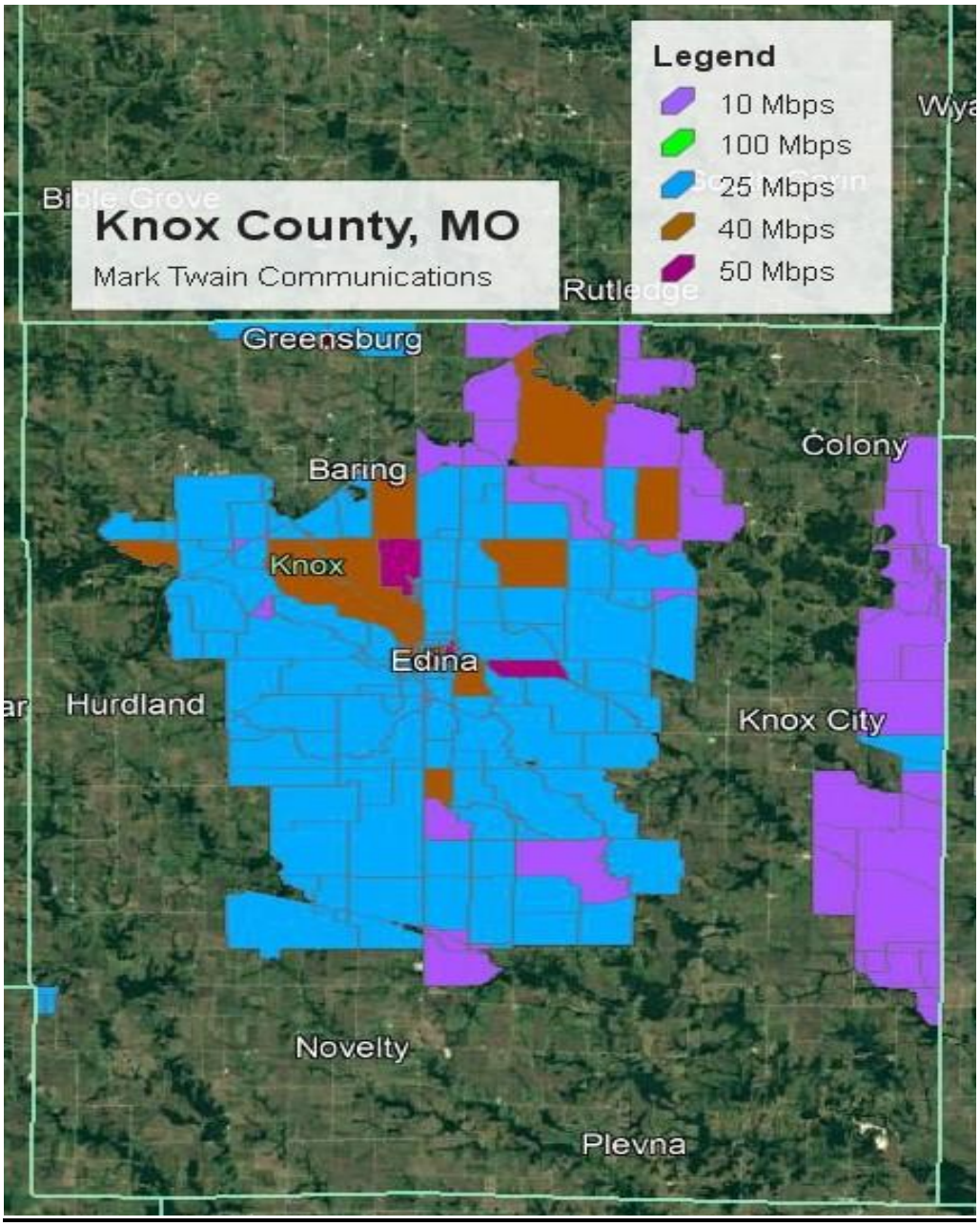


Mark Twain Communications

Mark Twain Communications is the competitive arm of the Mark Twain Rural Telephone Company and reports broadband coverage separately from the telephone company. The company provides fixed wireless broadband to a large portion of the county.

The map uses different colors to show the different speed tiers the company reports to the FCC. Speeds range from less than 10 Mbps up to 100 Mbps.

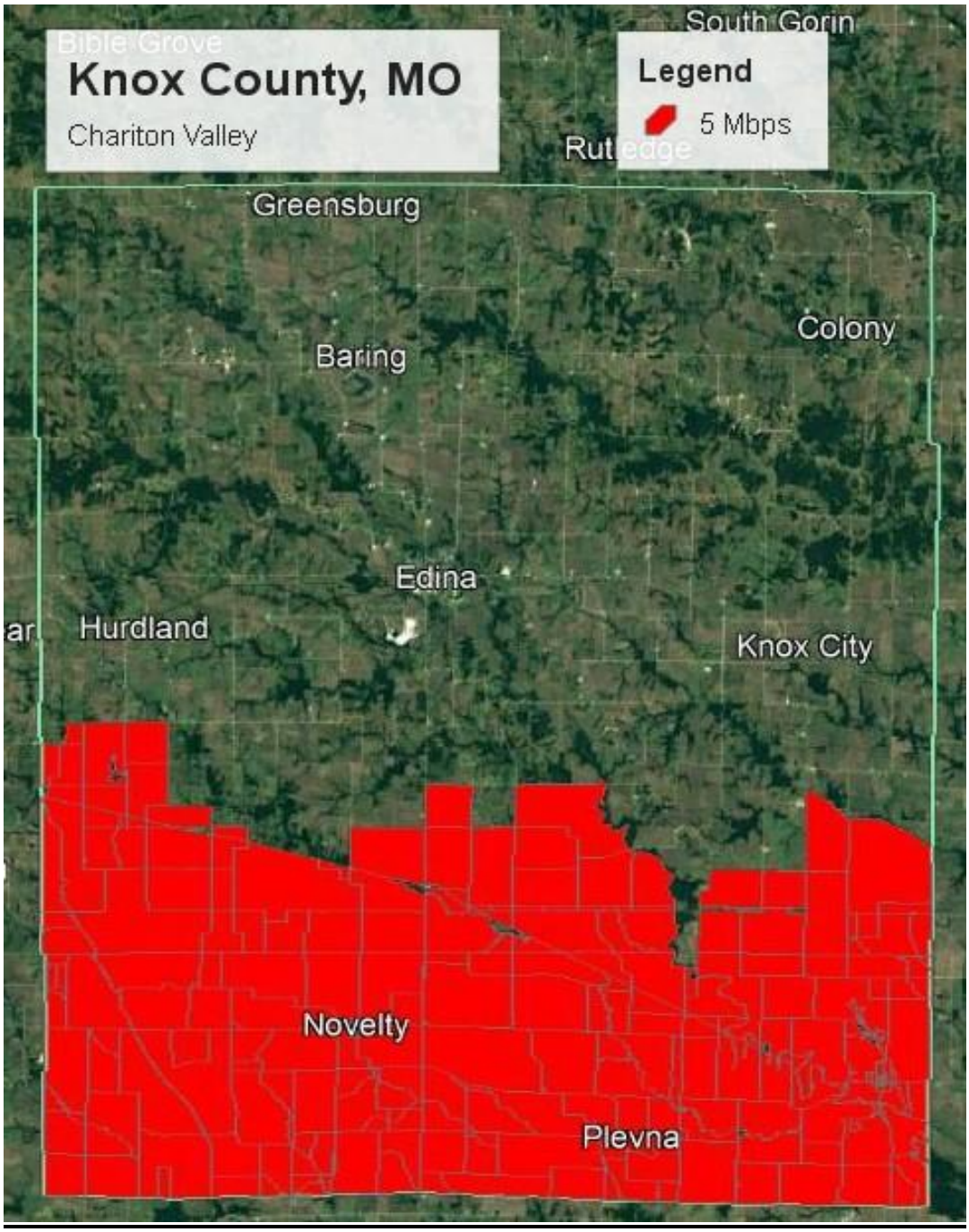
Map 4 – Mark Twain Communications FCC 477 Data



Chariton Valley

Chariton Valley offers fixed wireless broadband in the southern part of the county. The following map is what is reported to the FCC in the Form 477 process. The company reports broadband speeds of 5 Mbps for its entire coverage area.

Map 5 - Chariton Valley FCC 477 Data



U.S. Cellular

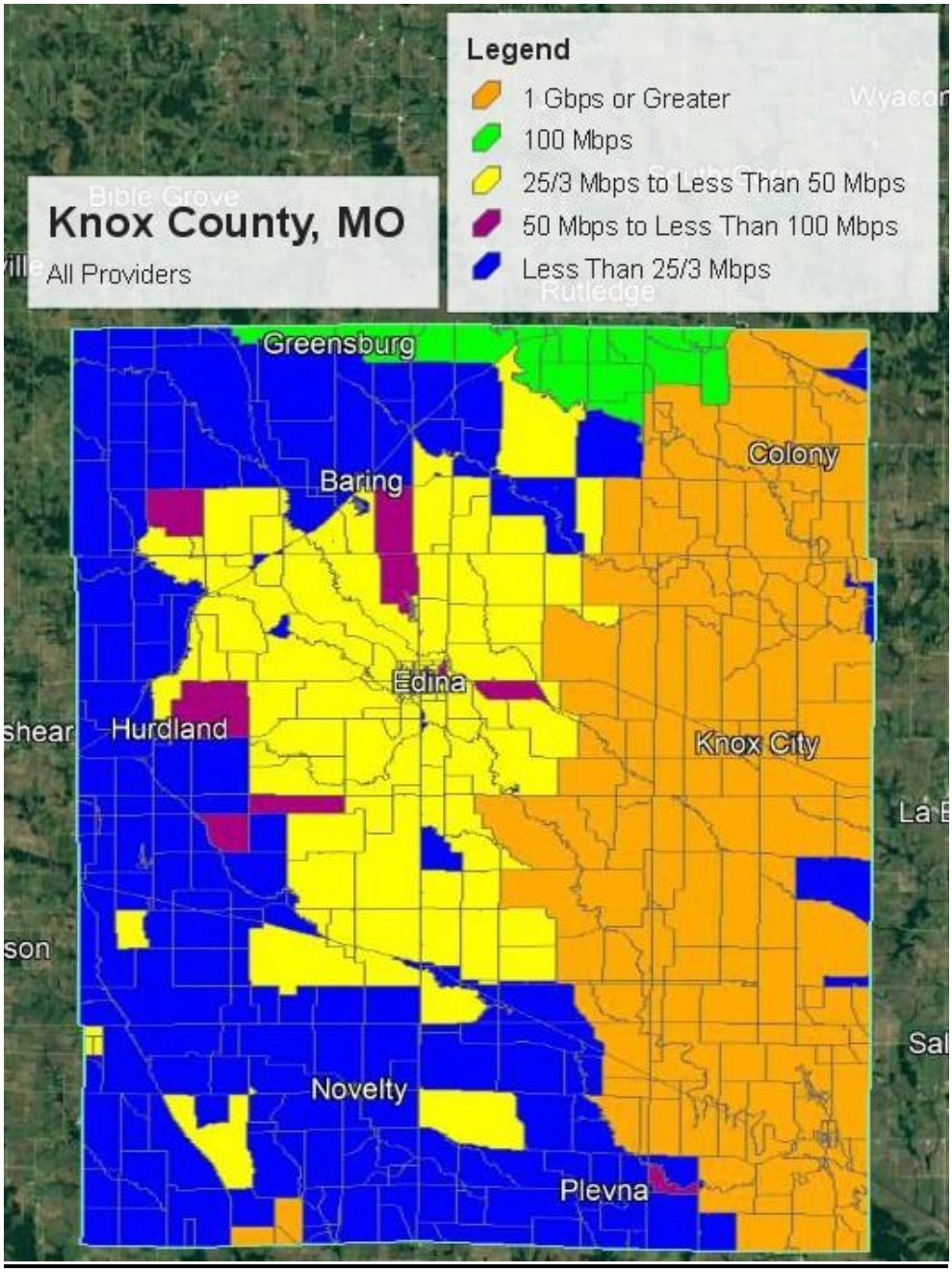
U.S. Cellular reports coverage of the entire county with broadband using its 4G LTE or 3G EVDO cellular spectrum. The company sells a fixed home broadband connection. While this uses the same cell towers as cellular broadband for cellphones, the technology used to receive the broadband signal is different. According to the FCC 477 data, U.S. Cellular is reporting speeds of 5 Mbps or less for the entire county. It's likely that these speeds are not available everywhere since there are likely places in the county with poor cellular coverage.

Map 6 – US Cellular FCC 477 Data

Composite FCC Maps

The following map shows the fastest broadband speed that is reported for each Census Block in the county. If this map was accurate, the only areas where customers can't buy 25/3 Mbps broadband are the areas shown in blue. This is an important map because it is a visual summary of what the FCC reports to Congress to explain the availability of broadband in the county. The FCC is telling Congress that almost everybody in the county has access to broadband faster than 25/3 Mbps.

Map 7 – Composite of all FCC 477 Broadband Reporting

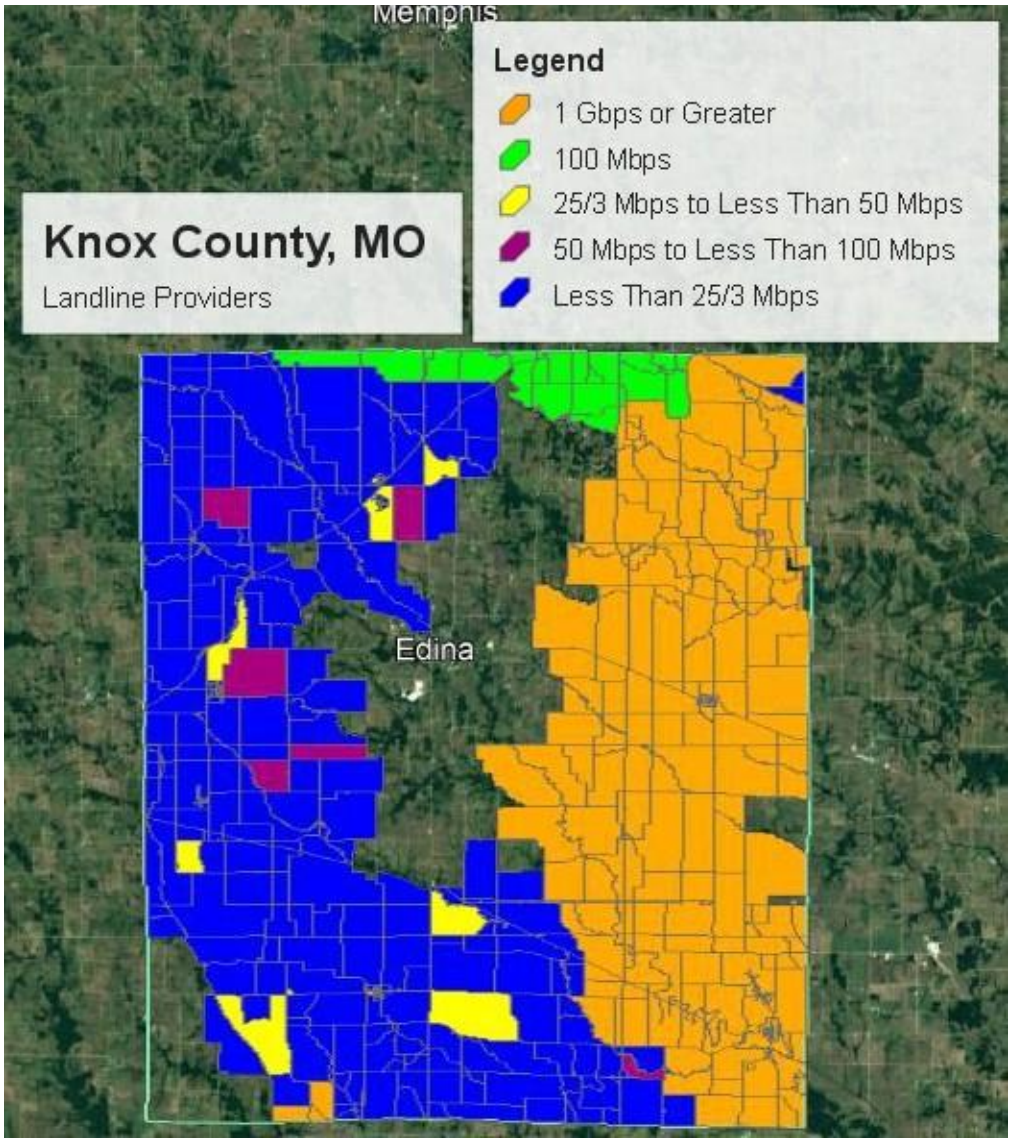


Landline Broadband Map – Grant Eligibility

Probably the most important map created in this report shows landline broadband coverage because this is the data that most federal and state grants use in deciding areas that are eligible for broadband grants. One of the primary purposes of this study was to identify those places in the county that need better broadband and for which grants might become available.

Landline broadband is defined as coverage by DSL, cable company HFC technology, or fiber. Grants almost universally ignore fixed wireless and fixed cellular broadband when determining grant eligibility. Grants in most cases also ignore the availability of satellite broadband, which is available almost everywhere. The following map shows the FCC 477 coverage today for the landline technologies. This is the same as Map 7 above – less fixed wireless and fixed cellular broadband.

Map 8 – FCC Landline Broadband Coverage from 477 Data



In summary, the FCC uses Map 7 to report the state of broadband in the county to Congress. Federal and state grant programs use an updated version of Map 8 for determining the eligibility for grants. Federal agencies are free to choose the basis for defining broadband for grant purposes, but most use Map 7 created from the FCC data. Unfortunately, these maps don't tell the true story of broadband in the county. The following discussion involves steps needed to get an accurate picture of broadband.

Updating the Landline Broadband Map

There are a number of changes that must be made to Map 8 to properly show the state of landline broadband.

Edge Distortions. The map includes distortions along the edges of the ISP service areas. This is true around the areas served by Northeast Missouri Telephone and Mark Twain Rural Telephone. The reason for this is simple – the service areas of the various ISPs don't follow or match up with Census block boundaries. This means that most Census blocks along a border of two ISP has many Census blocks that have some customers from both ISPs. Map 8 should be corrected to remove FCC broadband coverage that doesn't exist.

Known Upgrades. We know of upgrades to broadband coming due to federal and state grants and subsidy awards. These upgrades are either underway or will be coming in the next few years. Map 8 should be upgraded to reflect the following:

- Mark Twain Rural Telephone has received federal ACAM funding to build fiber in its entire service area in the eastern and western parts of the county.
- Mark Twain Communications won the CAF II reverse auction to build broadband in the southwestern and northeastern corners and a southeastern part of the county.

Possible Upgrades. LTD Broadband won the RDOF reverse auction to build broadband in a few small areas of the county. However, the FCC has not made these awards. There is a lot of controversy with the LTD grant award and there is some chance that the award might not be made.

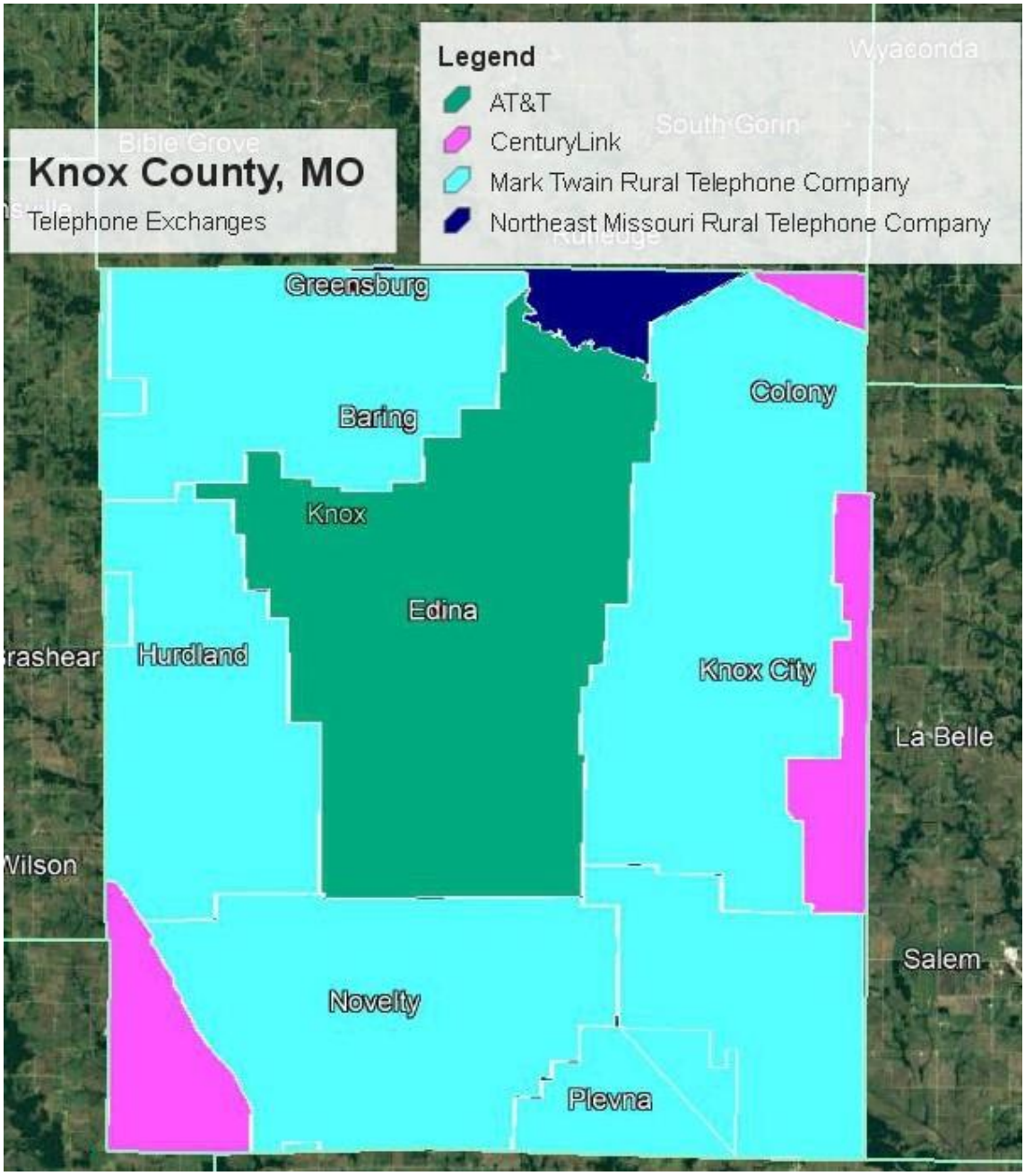
The Edge Issue

Telephone Company Exchange Boundaries.

The incumbent telephone companies in the county are CenturyLink, Northeast Missouri Rural Telephone Company, Mark Twain Rural Telephone Company, and AT&T. The map below shows the historical monopoly boundaries for each telephone company. These boundaries were formally recognized by the Missouri Public Service Commission and each telephone company was given monopoly status within the borders shown on the map.

The 477 reporting doesn't accurately reflect these exchange boundaries since the FCC data shows an entire Census block to be served even if only one customer has broadband. This means the 477 coverage along the borders of Northeast Missouri and Mark Twain are distorted and show coverage in areas where those two companies don't have customers. Following is a map showing the exchange boundaries of the four telephone companies in the county:

Map 9 – Telephone Exchange Boundaries



Grants and Upgrades

Following are maps that show where grants have already been awarded to provide faster broadband in parts of the county.

ACAM Program. The ACAM program is a subsidy program created by the FCC to assist rural telephone companies like Northeast Missouri Rural and Mark Twain Rural to upgrade rural broadband. Telephone

companies had several options about how to elect to get these subsidies. The FCC subsidies are flowing to the telephone companies over ten years, starting in 2017 and ending in 2026.

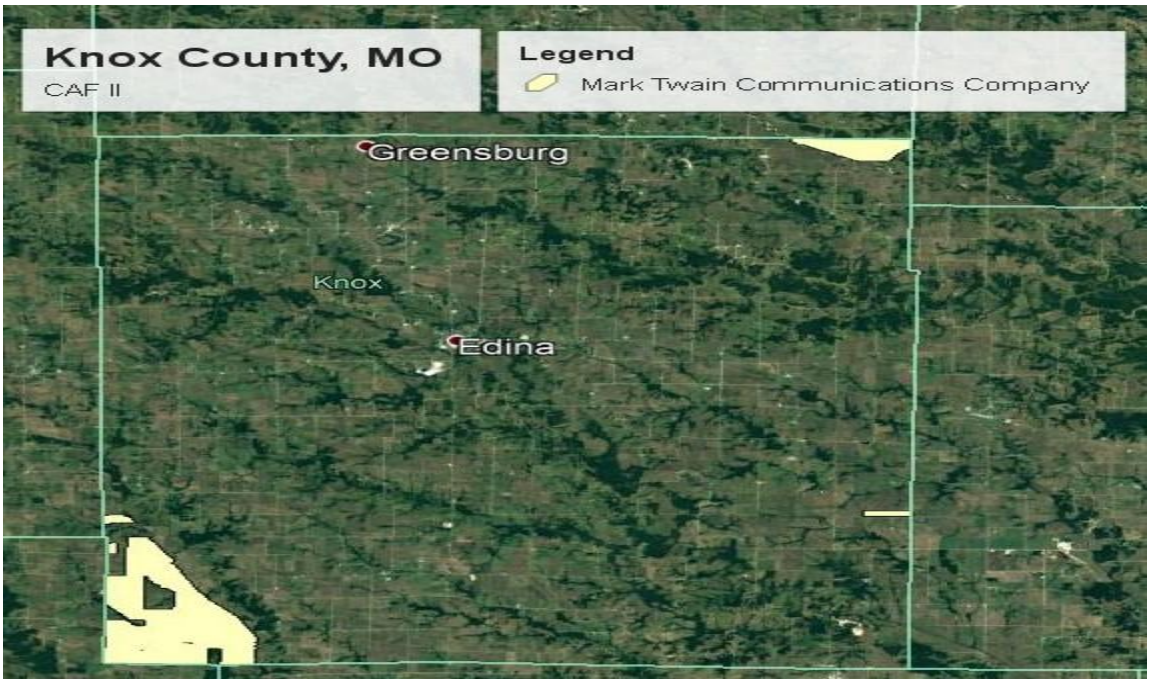
The ACAM program expects the telephone companies to use the funding to improve broadband speeds in rural areas to speeds of at least 25/3 Mbps. However, many telephone companies, including Northeast Missouri Rural and Mark Twain Rural elected to use this subsidy to borrow the money to upgrade from telephone copper to fiber. Telephone companies have until 2026 to complete any planned upgrades, but there are completion deadlines for some portion of completion for each year starting in 2022. Many small companies, including the two in this county, are upgrading faster than the FCC upgrade schedule. Northeast Missouri has already completed the upgrade to fiber in the county.

The Connect America Fund

CAF II Reverse Auction

In August of 2018, the FCC held a reverse auction to award broadband funding to some of the most rural places in America. This auction was referred to as Auction 903 of the Connect America Fund Phase II. In that auction, Mark Twain Communications Company, a fixed wireless provider, won $163,465.60 in Knox County to be collected over ten years for bringing broadband to 31 rural homes in the county. That's an award of $5,273 per home. The areas won by Mark Twain Communications are shown in the map below:

Map 10 – CAF II Reverse Auction



FCC Rural Digital Opportunity Fund (RDOF)

This program is funded by the FCC from the Universal Service Fund. The first phase of this auction was conducted in the form of a reverse auction that concluded near the end of 2020. The auction was supposed to award $16 billion in grants but ended up awarding a little over $9 billion. The remaining $7 billion, along with another $4 billion, will supposedly be auctioned at some later date.

In a reverse auction, the ISP willing to take the least amount of subsidy is awarded the funding. A reverse auction lasts multiple rounds, with ISPs lowering bids until only one ISP remains. The RDOF allowed a wide range of technologies from DSL through fiber. There were weightings assigned to each technology to provide more bidding priority for the fastest technologies. The RDOF subsidy will be paid out over ten years. A winner is expected to complete construction within six years, with completion milestones starting with the third year.

The FCC has awarded only a small portion of the RDOF at the time that this report was finalized. The agency is wrestling with several controversies.

- Some RDOF areas were included in error. For example, there were some major urban airports included in what was supposed to be a program for rural America.
- Three of the top ten winners were funded to provide gigabit fixed wireless technology. There was a huge outcry in the industry because nobody believes that there is a wireless technology that can deliver a gigabit of speed to everybody in a rural Census block where customers are far apart and where there are a lot of physical impediments to the line-of-sight needed for the technology. The consensus is that the FCC erred by allowing these technologies to bid at this tier because that made the technology functionally equivalent to fiber. Where fiber can deliver a symmetrical gigabit product to every household in a Census block, it's likely that fixed wireless might bring that speed to a handful of households, bring something significantly slower to most households, and would be unable to serve many households due to line-of-sight issues.
- There was also a big outcry when Starlink was a major winner. Many feel that low-orbit satellite is an unproven technology and that there is no guarantee that Starlink will ever launch the needed satellites. There were also complaints that the technology, by definition, is already going to be available everywhere and doesn't need a government subsidy to deploy.
- There were also a few winners that many believed should not have been allowed to win huge amounts of grant funding. The biggest of these is LTD Broadband, a small wireless carrier from Minnesota with fewer than 100 employees. The company won over $1.2 billion in grants and promised to build fiber-to-the-premise. Many doubt that a company of this small size is up to such a gigantic construction challenge. Even more importantly, nobody thinks that a company this small can borrow the billions in funding needed to match the grant funds. There have been estimates that LTD might need to raise $5 - $8 billion to build what it pledged.

There was one RDOF auction winner in Knox County.

- LTD Broadband was awarded $15,300 for 1 location in Knox County. We find it impossible to believe that the company will try to serve this tiny area with any broadband technology. For purposes of this study, we are ignoring this award, other than to show it in the map below.

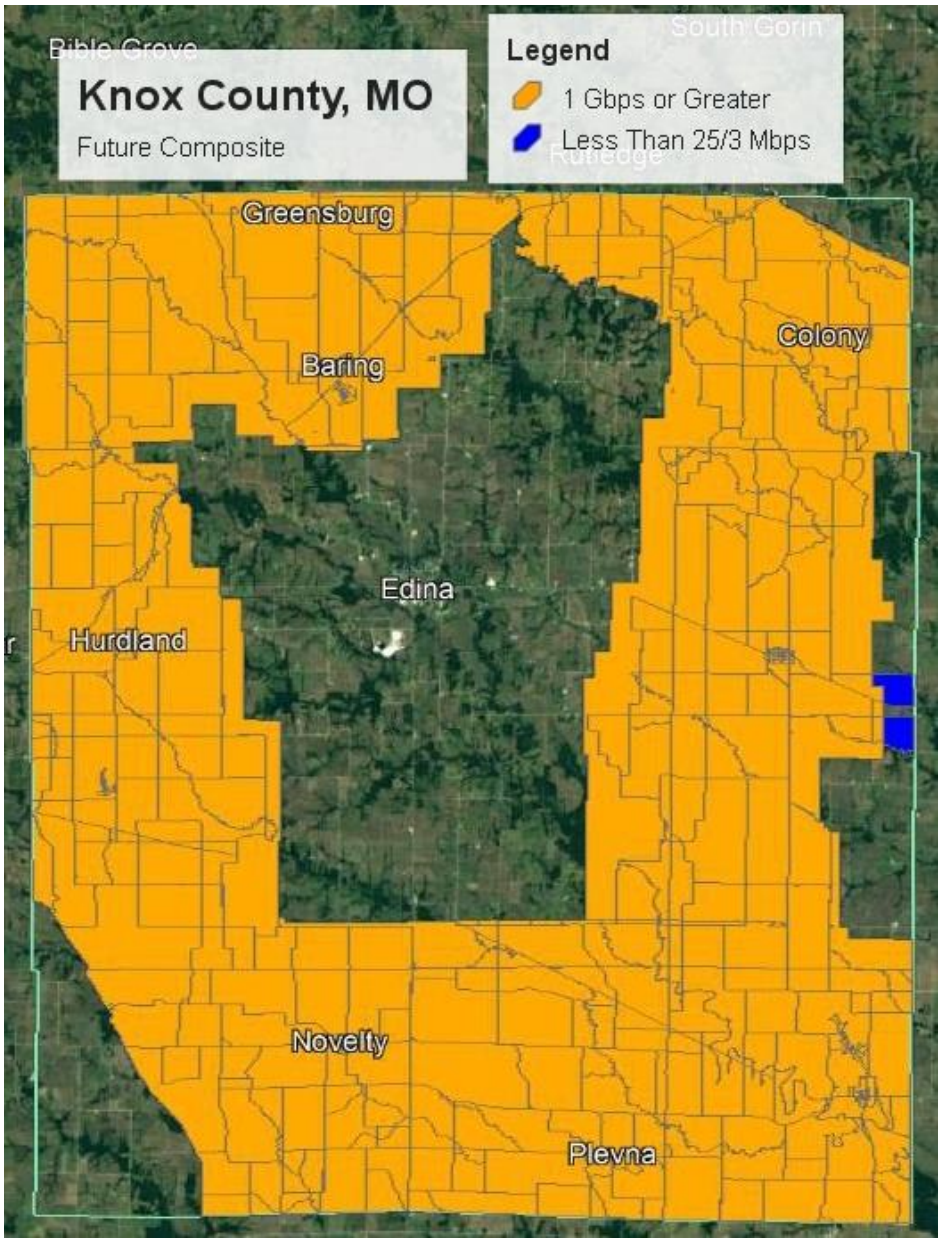
Map 11 – FCC RDOF Reverse Auction

A Revised Landline Broadband Map

The following map corrects all of the above issues. We believe this is the most accurate portrayal of landline broadband. This reflects fiber that's already been built, and fiber that we know is supposed to be built. The only controversial area on this map is the small area where LTD Broadband won RDOF funding – which might not be awarded.

The empty areas and the areas in blue on this map are ones that could be eligible for future broadband grants. In the blue areas, the telephone company broadband is provided by DSL. In the empty areas, there is no landline broadband provided. There are places where there is fixed wireless provided by Mark Twain Communications that provide broadband faster than 25/3 Mbps. However, most federal and state grants disregard the presence of fixed wireless when determining areas that can be funded by grants.

Map 12 – Corrected Landline Broadband Coverage (Areas Available for Grants)



III. Other Research

A. The Broadband Speed Story

The mapping analysis above shows the coverage areas of the various ISPs in the county, and the broadband speeds they say are being delivered. This section of the report is going to look in more detail at the speed question. We will look at speed data from various sources that tell us about the actual broadband speeds in the county.

We specifically want to understand the speeds in the parts of the county that are eligible for broadband grants. The goal of this discussion is to provide contact and facts to help anybody that wants to seek grant funding to improve broadband in the county.

Microsoft Speed Data

Microsoft is in an interesting position when it comes to looking at broadband speeds. A large majority of computers in the country download sizable upgrade files from Microsoft. Even many Apple computers are loaded with Microsoft Office products like Word, Excel, and PowerPoint.

Microsoft decided a few years ago to record download speeds of software upgrades. There is probably no better way to measure a broadband connection than during a big file download. Most speed tests only measure broadband speeds for perhaps 30 seconds. There are a lot of ISPs in the country that deploy a technology generally referred to as "burst." This technology provides a faster download for a customer for the first couple of minutes of a web event. It's easy for a customer to know if their ISP utilizes burst because, during a long download, such as one updating Microsoft Office, the user can see the download speeds drop to a slower speed after a minute or two. This burst technology has great benefits to customers since most web activities don't take very long. When customers visit a website, open a picture, or even take a speed test, the customer only needs bandwidth for a short time. The burst technology gives customers the impression that they have a faster download speed than they actually have (or it could be conversely argued that they have a fast speed, but just for a minute or two).

Microsoft measured downloads starting in September 2018 and found:

- The 2019 FCC data claimed that 14.5 million people in the U.S. don't have access to download speeds of at least 25/3 Mbps. In October 2020, Microsoft claimed that 120.4 million people were downloading data at speeds slower than 25/3 Mbps.
- The FCC claimed in 2019 that 65.07% of the people in Knox County had access to broadband of at least 25/3 Mbps. In October 2020 Microsoft reported that only 26.9% of the downloads made in the county used broadband of at least 25/3 Mbps. That is an eye-opening difference.

It's important to note that the FCC and Microsoft are not measuring the same thing. The FCC is measuring the percentage of homes that have access and can purchase 25/3 Mbps broadband. Microsoft is measuring the actual speeds of downloads. There are a few reasons why the speeds might be different:

- Some people opt to buy broadband products slower than 25/3, even when faster broadband is available.
- Some households receive slower speeds due to issues in the home, like poor-quality WiFi routers.

- The biggest difference is probably due to the ISPs overstating the speeds to the FCC that they make available to the public. As stated elsewhere in this report, the FCC doesn't challenge speeds reported to them by ISPs.

The differences noted by Microsoft are likely to become material over time as homes and businesses now often use broadband streams that last for a long time – as opposed to the bursty data we used in the past that was largely satisfied by burst technology. For example, when a home or business makes a connection to a school or work server, they tie up an amount of bandwidth for the duration of the connection. We are seeing more technologies, including gaming at homes and vendor portals at businesses that create long VPN connections.

Take the example of a business that has twenty employees connected to the server all day from home. That business is likely eating a non-stop 50 Mbps of broadband in both the upload and download direction all day – something they didn't do in the past – but something that might kill broadband for other purposes. Both DSL and cable company broadband technologies have slow upload speeds, so these kinds of activities and connections can kill a company's broadband connection and capability.

FCC Adoption Rate

Earlier in the report, we discussed how ISPs report broadband data to the FCC.

The following statistics look at the FCC's overall reporting for Missouri. The adoption rate is the percentage of households that have purchased broadband that meets or exceeds various speed thresholds.

Below are statistics from the most recent FCC report for 2020, which was released in January of 2021. This data represents FCC data from 2018. This means two things. The overall adoption rates are understated because we know that the overall number of homes buying broadband increases every year. However, since the data used in the FCC report comes from the Form 477 data, the percentage of customers who are buying a given broadband speed is likely overexaggerated. That makes for some confusing results, but since the same issues affect every state, the overall rankings of broadband adoption by state are probably reasonable.

In the 2020 annual report to Congress, the FCC reported the following broadband adoption rates for Missouri (meaning the percentage of customers who can buy the listed speeds at their home):

Homes buying at least 10/1 Mbps	65.1%
Homes buying at least 25/3 Mbps	57.1%
Homes buying at least 50/5 Mbps	55.5%
Homes buying at least 100/10 Mbps	50.0%
Homes buying at least 250/25 Mbps	9.7%

To put the FCC numbers into perspective, the percentage of homes that get at least 10/1 Mbps broadband (65.1%) puts Missouri at the lower end of broadband adoption compared to other states. Only Alabama (62.8%), Arkansas (55.3%), Idaho (59.6%), Iowa (61.3%), Louisiana (64.0%), Mississippi (50.4%), New Mexico (55.7%), Oklahoma (62.0%), and West Virginia (51.7%) are lower than Missouri. The highest adoption rate is in Delaware at 92.7%.

The FCC also looks at the availability of broadband by county. The following is what the FCC reported to Congress about Knox County in January of 2021:

Rural population:	3,959
% that can buy at least 25/3 broadband	65.1%
% with 4G LTE coverage at 5/1 Mbps	99.5%
% with both	64.8%

According to the FCC data, 1,382 residents of Knox County can't buy broadband of at least 25/3 Mbps. That's approximately 576 households. We know from the analysis above that the FCC claimed broadband coverage is overstated significantly and that there are a lot more homes with poor broadband than are being counted by the FCC.

As a side note, the FCC data also shows that all except 20 residents of the county can receive at least 5/1 Mbps cellular broadband. The chances are that assessment is greatly understated and it's likely that there are a lot more homes that can't get good cellular coverage inside of homes.

Actual Speeds by Location

This discussion requires the introduction of a new term – passings. The industry uses passings to mean any home or business that can become a broadband customer.

According to the FCC data most recently reported to Congress and cited immediately above, the FCC believes that only about 560 passings in the county can't buy broadband of at least 25/3 Mbps. The FCC finding comes from the FCC data that is shown in Map 8. On that map, only the blue areas can't buy broadband today of at least 25/3 Mbps.

Finley Engineering gathered GIS data from the county so that we can count the number of passings in any given Census block. The GIS data shows the location of every home and business in the county. Finley is able to overlay the passing data for each Census block and can count the number of passings to match all of the various maps shown earlier in the report.

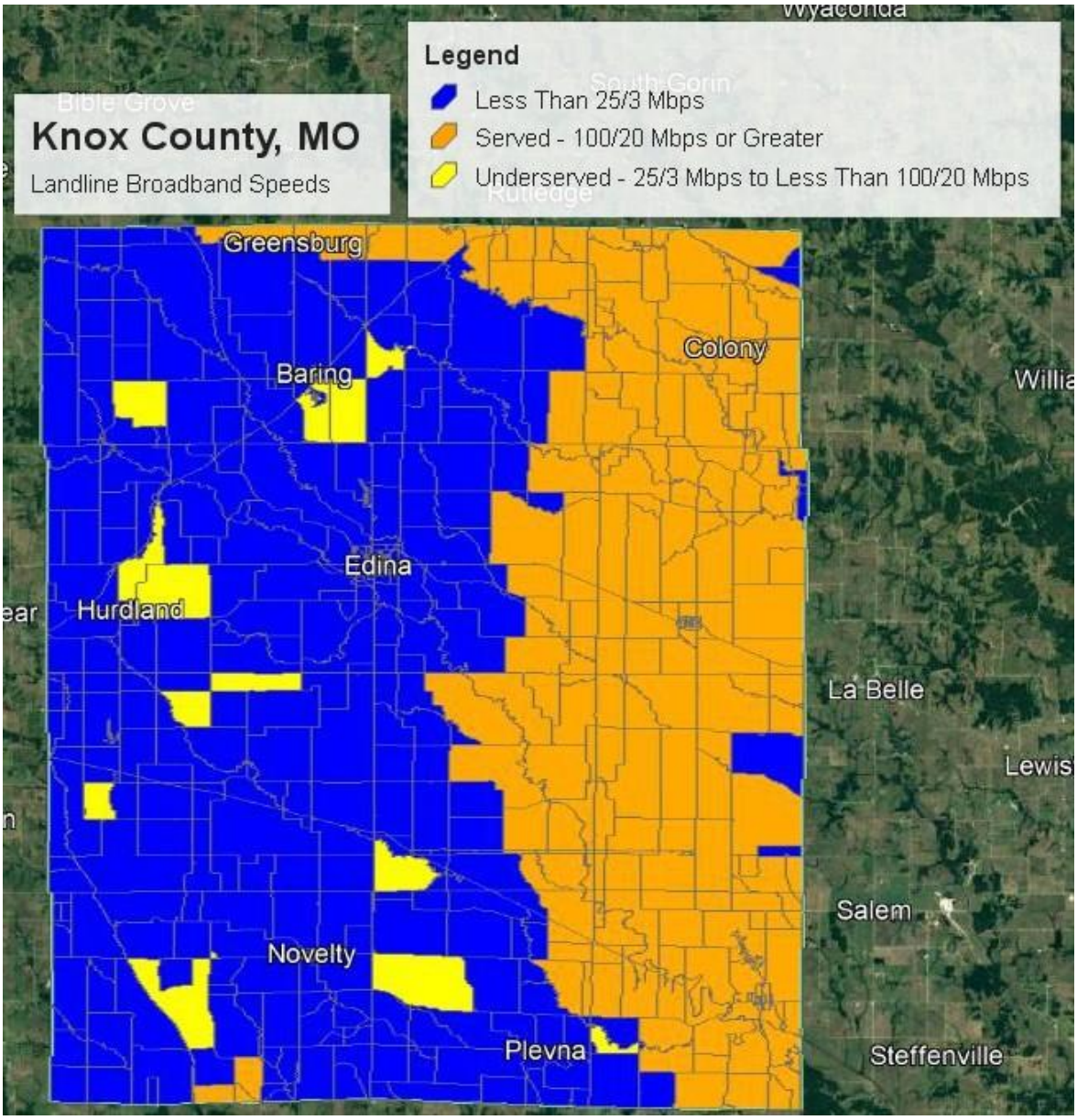
If we only want to consider landline broadband speeds – since that is how many grants are judged – the passings by speeds can be categorized as follows. The following table categorizes broadband speed in the same manner used for most current federal grants. Most current grants defined unserved to mean broadband speed that is less than 25/3 Mbps. Underserved is used to define broadband speeds between 25/3 Mbps up to and including 100/20 Mbps. Served is considered to be any passing that can buy a broadband product with a speed greater than 100/20 Mbps.

Using current FCC data and the three categories of speeds produces the following count of passings by speed category. This table is a quantification of the data in Map 8.

	Speeds	Passings
Unserved	Less than 25/3 Mbps	1,887
Underserved	From 25/3 Mbps to 100/20 Mbps	228
Served	100/20 Mbps or faster	828
Total		2,943

Following is Map 8 restated to reflect the three grant speed categories:

Map 13 – Landline Broadband According to Current FCC 477 Data

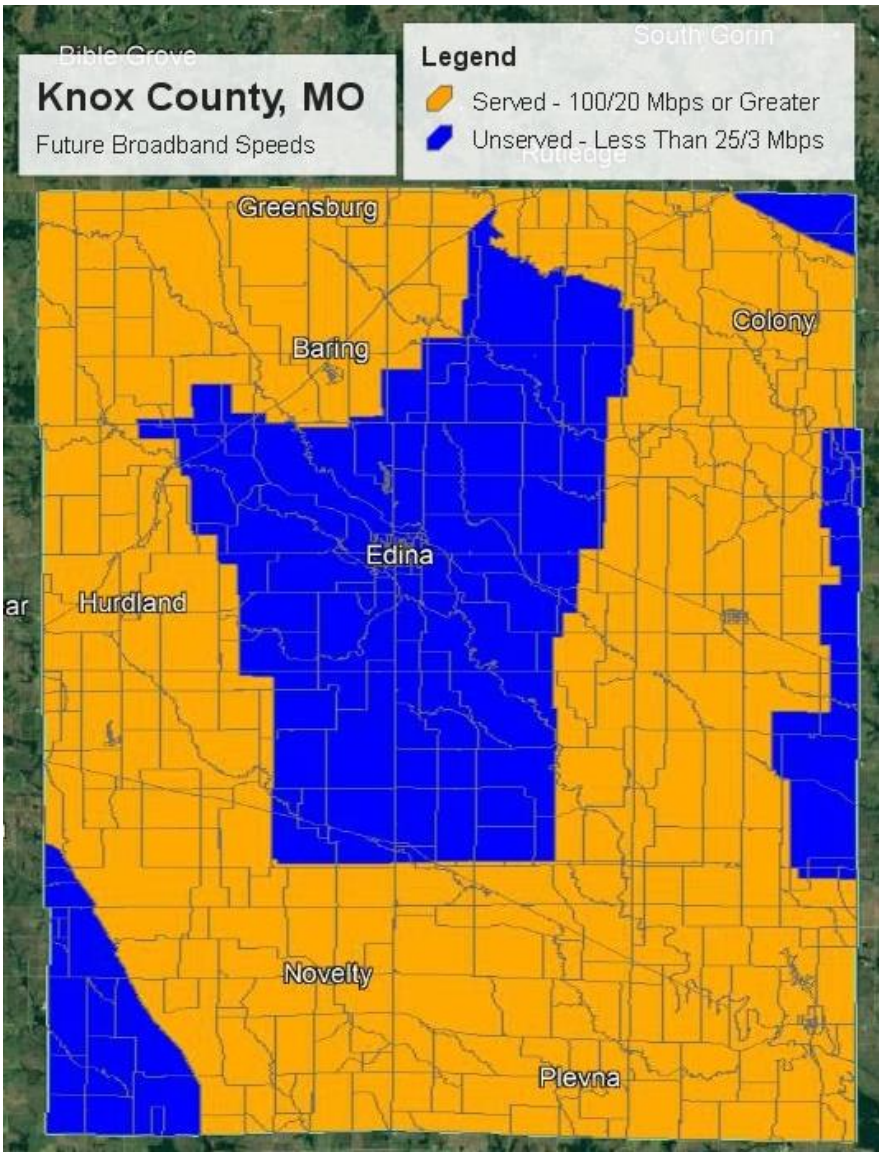


We know the map above is not an accurate representation of today's broadband due to known changes to the mapping data:

- We know that Northeast Missouri Telephone Company and the Market Twain Rural Telephone are both in the process of upgrading the historical telephone serving areas to fiber. Those areas should be considered as served (speeds of at least 100/20 Mbps).
- There are a few areas that have received grants that will be updated to fiber once constructed. Those areas should also be considered as served.
- Most federal grants allow for grants to be used to overbuild fixed wireless. This is a controversial topic, and not everybody agrees, but the definitions of eligible grant areas in most grants only consider landline broadband speeds. According to such grants, some of the areas covered by Mark Twain Communications would be considered as eligible for grant funding.

Making these changes produces a revised broadband map that we think represents the area in the county that are eligible today for federal broadband grants. That map is as follows:

Map 14 – Landline Broadband Coverage Including all Known Upgrades



On Map 14, the areas in blue are eligible for federal broadband grants. This map can be summarized using the following table.

	Speeds	Passings
Unserved	Less than 25/3 Mbps	1,216
Underserved	From 25/3 Mbps to 100/20 Mbps	0
Served	100/20 Mbps or faster	1,727
Total		2,943

Comparing Knox County with the Rest of Missouri

The broadband coverage in Missouri varies widely when compared to other states we've looked at. There are two counties in the state – Bollinger, and Ozark – for which the FCC says there is less than 10% broadband coverage. In total, Missouri has 12 counties under 50% coverage. According to the FCC data, Knox County has one of the lower amounts of broadband coverage in the state.

B. Surveys / Interviews

Online Residential Survey

We conducted an online residential survey. The results of online surveys are not statistically valid, meaning that the survey cannot be relied upon to answer numerical questions like the percentage of homes that would buy broadband from a new provider. This is because the survey is not conducted randomly and does not reach a representative number of homes that don't have broadband. With that said, an online survey is useful for measuring sentiment. For instance, we can learn something useful from responses that talk about how residents feel about current broadband and existing ISPs in the county.

An online survey also tends to attract respondents who care the most about broadband. Statisticians call this a selection bias, meaning that most of the respondents that reply to an online survey do so because they are interested in the topic. This implies that respondents to the online survey care about broadband as a topic more than the average citizen.

Broadband Customers. 83% of survey respondents said that they have a home broadband connection today. The FCC says that the national broadband penetration rate is around 86%.

We only received responses from customers of Mark Twain Rural Telephone Company, Mark Twain Communications, and households in the rural areas that don't have any broadband today. This is not surprising since the two Mark Twain companies have the vast majority of broadband customers in the county. We think that both AT&T and CenturyLink have barely any customers, if any. There is also a small pocket of customers of Northeast Missouri Rural Telephone. There are likely households using cellphone broadband or wireless from Chariton Valley, but they we didn't hear from these few customers in the survey.

Two-thirds of the customers without broadband said that prices stopped them from buying broadband. One-third said there was no good broadband option at their home.

Cable TV Penetration

About half of the respondents buy cable TV service from one of the satellite providers Dish Networks or DirecTV.

29% of the survey respondents claim to be cord-cutters that watch all content online. There is not yet any reliable count of the nationwide market share of cord-cutters, but most estimates put this over 30% of households. The percentage of cord-cutters is growing rapidly, so it is expected that the number of homes with traditional cable in the city will continue to drop over time. Another 21% of respondents get TV from an antenna.

Telephone

24% of respondents have a landline telephone. That is close to the nationwide average that's estimated to be at around 25%.

Uses of Broadband

71% of respondents say that somebody in their homes uses the Internet to work from home. That is made up of those working at home full-time (17%), those that work several days per week (23%), and those that work from home occasionally (31%). The number of people working from home has increased significantly during the pandemic – before the pandemic, we rarely saw more than 10% of homes with somebody working from home. 37% of respondents report having somebody in the home using broadband for schoolwork.

38% of respondents with school children said that their internet was sometimes inadequate to support online schoolwork.

31% of respondents reported that the cellular coverage at their home is inadequate.

Satisfaction with Existing Broadband

We asked about satisfaction with existing broadband.

- 17% are unhappy with download speeds.
- 10% are dissatisfied with customer service.
- 35% are don't think they are getting value for the price they have to pay.

Support for a Fiber Network

One of the key questions asked in the survey is if respondents support the idea of the county trying to get better Internet access. 71% of survey respondents support the idea, with another 26% who said they might support the idea but need more information. Only 3% of respondents actively dislike the idea.

We asked the reasons why respondents support bringing a new network to the county.

- 43% want more competition.
- 51% hope for lower prices.

- 37% hope for faster speeds.
- 417 would like to see better customer service.
- 26% hope for more reliable service.

Switching Service to a New Network

In probably the most important question of the survey, we asked households if they would buy Internet service from a new fiber network. 31% of respondents said they definitely would buy. 17% said they probably would buy. 23% said they might buy. 28% said they were unlikely to buy from a new ISP.

Interpreting the Results of the Survey

There are a few key takeaways from the survey.

- Compared to the surveys in the other counties, there is a lot less dissatisfaction with current ISPs. We don't know specifically why, but we conjecture that there is general overall satisfaction with the Mark Twain companies.
- The biggest issue in the county is broadband prices, with over half of respondents hoping for lower prices. speeds. 10% of all survey respondents are not buying broadband because it is too expensive.
- Another 43% of respondents want more competition, which we generally also interpret as wanting better prices.
- There is a big support for getting fiber broadband. 71% of respondents support the idea and only 3% of respondents oppose the idea. That's extraordinarily low.
- The survey didn't ask a specific question about upload speeds. However, 38% of homes with students were unhappy with home broadband. We interpret that to likely mean they are unhappy with upload broadband.
- 31% of respondents said they definitely would buy broadband from a new fiber network. Another 17% said they probably would buy.
- 31% of survey respondents said that cellular coverage was inadequate at their homes.

C. Field Review

Providers

AT&T

The AT&T regulated service area is approximately 23% of the landmass and 39% of the residential/business locations in Knox County. AT&T does not offer any internet service in their trade territory in Knox County.

Our field review did not find the assets required in rural areas to support any internet service from AT&T.

CenturyLink

The CenturyLink regulated service area encompasses approximately 6% of the landmass and 2% of the residential/business locations in Knox County. Currently, in Knox County, CenturyLink provides access to broadband speeds of 25/3 Mbps to less than 1% of their regulated service area. As was discussed at

length in the discussion on mapping, many of the rural DSL customers have speeds far slower than 25/3 Mbps.

CenturyLink accepted Connect America Fund (CAF) obligations to upgrade rural DSL to at least 10/1Mbps broadband to many locations in the county. That work was to be completed by the end of 2020. Finley could not locate any CenturyLink assets that indicate that CenturyLink made the required investments in Knox County.

Northeast Missouri Rural Telephone Company (NEMR)

The NEMR regulated service area encompasses approximately 2% of the landmass and 1% of the residential/business locations in Knox County. NEMR has received Universal Service Funds (USF) since 1996 to help provide telephone and broadband service. In 2016, as these funding programs changed, NEMR elected to receive Connect America Fund-Broadband Loop Support (CAF-BLS) to continue to build broadband infrastructure with obligations to provide 25/3Mb, 10/1Mb, or 4/1Mb broadband within their service territory.

In 2010, NEMR received grant funding from the Broadband Technologies Opportunity Program (BTOP) and began building fiber to the home in parts of its service territory. Since 2010, NEMR has made annual investments in its FTTH network by upgrading its legacy copper network to fiber. In 2021 NEMR completed its all-fiber infrastructure in nine counties in northeast Missouri. NEMR now offers symmetrical speeds up to 1 Gbps to any customer within its regulated telephone service area.

NEMR has begun expanding its FTTH infrastructure outside its regulated service area, offering symmetrical speeds of 30 Mbps, 50 Mbps, 100 Mbps, and 1 Gbps speeds. In 2020 NEMR was awarded funding from the Missouri Broadband Grant Program to build FTTH in the Spring Lake area.

In Knox County, NEMR plans to expand its all-fiber network outside its NEMR regulated service area if the company can obtain broadband grants. Grant funds are needed due to the high cost of deployment in rural areas with low customer density and challenging terrain for construction. In addition to the high cost for expansion, NEMR also faces supply chain issues, increasing the time needed for expansion.

NEMR is eager to work with Knox County to understand how they may work together to enable robust broadband solutions in Knox County.

Mark Twain Telephone (MTRT)

MTRT has received Universal Service Funds (USF) since 1996 to help provide telephone and broadband service. In 2016 as these funding programs changed, Mark Twain participated in the FCC program Alternative Connect America Cost Model (ACAM). With this program, Mark Twain could elect to receive a specific amount of capital to build broadband infrastructure within its service territory. The program requires ISPs to provide speeds of 25/3Mbps, 10/1Mbps, or 4/1Mbps and complete the project in 8 years. MTRTC used the funds to upgrade its network to FTTH, and the project is expected to be completed by the end of 2026. The Mark Twain regulated service area encompasses approximately 68% of the landmass and 58% of the residential/business locations in Knox County.

By upgrading to a fiber network, Mark Twain will be capable of providing 1 Gbps broadband to any customer inside their regulated service area. In Knox County, Mark Twain has completed 40% of the mainline FTTH construction in its regulated service area, and some customers have been transitioned to the FTTH network. The customers who cannot connect to the FTTH network can still receive broadband from MTRTC's legacy DSL network. The legacy DSL network provides speeds up to 15 Mbps in the rural parts of Knox County.

Mark Twain has developed a comprehensive multi-year plan to complete the FTTH network. Through planning and forecasting with vendors and contractors, Mark Twain has largely avoided any of the current supply chain issues facing the broadband industry.

Funding to continue network upgrades and expansion is always needed, and Mark Twain notes that funding is required to continue its broadband network expansion.

MTRT is eager to work with Knox County to understand how they may work together to enable robust broadband solutions in Knox County.

Mark Twain Communications (MTCC)

In 2003, MTCC began providing fixed wireless Internet in areas outside its regulated telephone exchange. MTCC can transmit wireless services from over 25 locations in northeast Missouri. MTCC has continued to invest in fixed wireless broadband technology by investing in tower structures for fixed wireless access points and most recently in licensed spectrum and a fiber backhaul network.

In 2020, the FCC conducted an auction for 80 MHz of spectrum in the Citizens Band Radio Spectrum (CBRS). The spectrum does not require a clear line of sight, which is desirable for fixed wireless technology. Fixed wireless is often limited by its ability to have a clear line of sight from the transmitter to the receiver. Since the CBRS spectrum does not require a clear line of sight, it is necessary for areas with dense trees and rolling terrain like Knox County.

In the 2020 FCC auction, MTCC was the winning bidder for 40 MHz of the CBRS spectrum in Knox County, with a total investment in spectrum of almost $100,000. The investment, along with other required investments in tower structures and fiber backhaul facilities, will give MTCC the ability to offer up 100Mb broadband service in some areas. Mark Twain is currently undertaking a wholesale swap and upgrade of the fixed wireless equipment in its network to take advantage of the newly purchased spectrum.

In Knox County, it will be difficult for MTCC to offer 100 Mbps to every customer in its service area. This is mainly due to limitations of radio frequencies and terrain impediments like heavily wooded areas and rolling hills. Customers closest to the transmitting towers will get the fastest speeds. Those far away from the tower are unlikely to receive speeds of 100 Mbps but will still get faster speeds than are available today.

Mark Twain Communications was the winning bidder in FCC Auction 903, the Connect America Fund Phase II (CAFII) auction. Mark Twain Communications will provide at least 25/3 Mbps speeds to 31 locations in Knox County. MTCC is deploying fixed wireless broadband and fiber backhaul facilities to fulfill the CAFII requirements and expects to complete the network in 2022.

MTCC is committed to pursuing additional grant funds for expanding broadband and is eager to work with Knox County to understand how they may work together to enable robust broadband solutions.

D. Broadband GAP Analysis

A broadband gap is a situation where there are some residents are at a disadvantage to others in terms of using the Internet. This report will look at the different kinds of broadband gaps as described below.

- The Gap in Broadband Adoption / Availability. This is talking about homes with no broadband options that meet the FCC's 25/3 Mbps definition of broadband.
- The Gap in Broadband Affordability. In every community, there are households that don't subscribe to broadband because of the cost.
- The Gap in Computer Ownership. There are households that don't subscribe to broadband because they can't afford a computer.
- The Gap in Broadband Skills. There are citizens who don't buy broadband because they lack the skills needed to operate in the digital age.
- Future Broadband Gaps. Even where there is adequate broadband today, we can look forward to the natural progression of technology that will create new broadband gaps that don't exist today.

After describing the different broadband gaps, this report will look at the consequence of the broadband gaps and will ask the question if there are any practical solutions to the broadband gaps that the county could facilitate.

The Gap in Broadband Adoption / Availability

The broadband availability gap was the focus of mapping analysis. Map 10 shows the area of the county where there is no existing landline option for buying broadband of at least 25/3 Mbps.

Discussions of the broadband availability gap are often tied to the terms 'unserved' and 'underserved'. These terms have been used in the past to describe two different levels of broadband availability. The two terms were first introduced in 2009 in the grants that were issued as a result of the American Recovery and Reinvestment Act of 2009, colloquially called the stimulus grants. In those grants, unserved was defined as any home that had broadband slower than 10/1 Mbps. Underserved was defined as a home with broadband over 10/1 Mbps but below 25/3 Mbps. The grants provided higher levels of funding for serving unserved locations.

Over time, the definition of the two terms has changed. In more recent grants, like the RUS ReConnect grant, unserved is defined as any broadband under 25/3 Mbps. Some of the new grants are counting any connection slower than 100/20 Mbps as underserved. These terms only apply to grant funding – there is no official FCC definition of the two terms, and various state and federal grants define the terms differently. It's always vital when considering a grant to understand what the specific grant accepts in terms of eligible speeds.

Broadband availability has also been looked at in other ways. For example, the National Telecommunications and Information Administration (NTIA) released the results of a survey in 2019 that looked at households that don't use the Internet.[3] The survey says there were around 28 million households in the U.S. that don't use broadband at home. Some of these homes fall into the following circumstances:

- The most drastic case is homes that have no landline broadband options. Such homes are limited to getting broadband from high-orbit satellites (assuming they can see the portion of the sky where the satellites sit), or from cellular data from their cellphone plans. Almost every rural area has some homes that have no landline broadband options.
- The broadband availability gap also refers to homes that can't get broadband that meets the FCC definition of broadband – 'unserved' homes.

The Gap in Broadband Affordability

The FCC reports that broadband adoption for the country is around 87%. Even after accounting for the rural areas that have no broadband option, there are many millions of customers that can get broadband at home, but don't buy it. Numerous studies and surveys have asked people why they don't buy broadband when it's available. The number one reason is almost always price – people say they can't afford broadband.

Statistics on Affordability

In larger cities, it's somewhat easy to equate broadband penetration rates to household incomes. This is because a Census block in a city might be as small as a block or two, and it's easy to match Census data to broadband data from the FCC.

An analysis of recent FCC 477 data shows a direct correlation between household income and buying a home broadband connection. The table below is from the 2020 FCC Broadband Report and shows that only 38.4% of households in the lowest quartile of earnings buy broadband of at least 10/1 Mbps. The percentage that buys faster broadband speeds drop to only 4.7% of households buying broadband of at least 250/25 Mbps.

[3] The NTIA survey results are at: https://www.ntia.gov/blog/2019/unplugged-ntia-survey-finds-some-americans-still-avoid-home-internet-use

Fig. 12
Average County Overall Adoption Rate for Fixed Terrestrial Services by County Level Demographic Variable (December 31, 2019)[166]

	10/1 Mbps	25/3 Mbps	50/5 Mbps	100/10 Mbps	250/25 Mbps
Median Household Income					
First Quartile (Lowest Median Household Income)	38.4%	28.3%	23.4%	20.2%	4.7%
Second Quartile	51.6%	41.6%	36.4%	31.0%	6.0%
Third Quartile	58.8%	47.6%	42.2%	35.2%	6.2%
Fourth Quartile (Highest Median Household Income)	71.2%	61.3%	56.7%	43.8%	8.1%
Population Density					
First Quartile (Lowest Population Density)	48.8%	34.2%	26.8%	22.7%	8.0%
Second Quartile	43.9%	34.3%	30.1%	25.0%	4.8%
Third Quartile	55.1%	46.5%	42.6%	36.0%	5.0%
Fourth Quartile (Highest Population Density)	72.0%	63.6%	58.8%	46.1%	7.8%
Household Poverty Rate					

There are studies available for those who want to dig deeper into quantitative and qualitative research into broadband affordability for low-income households. The first was published by the Benton Foundation and authored by Dr. Colin Rhinesmith.[4] The second report is issued by the Quello Center and is authored by Bianca Reisdorf.[5] This report looks at a study conducted in three low-income neighborhoods of Detroit.

Both reports say that low-income households with a limited budget appreciate the advantage of having broadband at home but can't fit it into their budgets. They find it difficult or impossible to prioritize broadband compared to paying rent or buying food. These studies indicate that a big part of the solution for getting broadband into homes without it is going to have to involve finding a way to pay for the monthly broadband access.

The Pew Research Center shows a direct correlation between income and broadband adoption. They've had an ongoing investigation into broadband-related issues since 2000[6]. Pew shows that as of February 2021 that only 57% of homes with household incomes less than $30,000 have broadband, compared to 92% of homes with household incomes over $75,000.

[4] Digital Inclusion and Meaningful Broadband Initiatives. https://www.benton.org/publications/digital-inclusion-and-meaningful-broadband-adoption-initiatives

[5] Broadband to the Neighborhood. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3103457

[6] Demographics of Internet and Home Broadband Usage in the United States | Pew Research Center

Low-Income Broadband Programs

Federal Lifeline Program

CenturyLink, Chariton Valley, Mark Twain Communications Company, Northeast Missouri Rural Telephone Company, and U.S. Cellular participate in the FCC's Lifeline program that is part of the Universal Service Fund. With the program, a customer can receive a discount in Missouri of $9.25 per month off a telephone bill or a broadband bill for qualifying customers. The program works by the telephone companies providing a discount to customers, and the FCC then reimburses the companies for the discount. This means it costs the telephone companies nothing to offer the discount – the discount is funded by the FCC.

To qualify, a customer must participate in one of the following programs: Medicare, SNAP (formerly Food Stamps), SSI, Federal Section 8 housing, VA Veterans pension, or VA survivor's pension. The FCC has recently established a web portal where participating carriers can check the eligibility monthly of households to meet one of the above tests.

The telephone company doesn't aggressively pursue giving this discount to eligible households – but they will enroll anybody that qualifies and who asks for the discount.

FCC Emergency Broadband Benefit (EBB) Program.

The EBB program went into effect in May 2021. The funding came from the $1.9 trillion American Rescue Plan Act. The program was funded for $3.2 billion. The program will last until six months after the end of the federally declared Covid-19 emergency period or until the funds run out of money.

The EBB provides a discount of up to $50 per month towards broadband service for eligible households and up to $75 per month for households on qualifying Tribal lands. Eligible households can also receive a one-time discount of up to $100 to purchase a laptop, desktop computer, or tablet from participating providers if they contribute more than $10 and less than $50 toward the purchase price.

The Emergency Broadband Benefit is limited to one monthly service discount and one device discount per household.

A household is eligible if a member of the household meets one of the criteria below:

- Has an income that is at or below 135% of the Federal Poverty Guidelines or participates in certain assistance programs, such as SNAP, Medicaid, or Lifeline;
- Approved to receive benefits under the free and reduced-price school lunch program or the school breakfast program, including through the U.S.DA Community Eligibility Provision in the 2019-2020 or 2020-2021 school year;
- Received a Federal Pell Grant during the current award year;
- Experienced a substantial loss of income due to job loss or furlough since February 29, 2020 and the household had a total income in 2020 at or below $99,000 for single filers and $198,000 for joint filers; or
- Meets the eligibility criteria for a participating ISP's existing low-income or COVID-19 program.

For a household to get this discount, its ISP must be a plan participant. Households apply through its ISP.

Affordable Connectivity Program

This is a new program was created by the $14.5 billion in funding from the Infrastructure Investment and Jobs Bill. The program starts in early 2022 and provides a $30 monthly discount on broadband bills for homes that make up to 200% of the federal definition of poverty. To put that into perspective, in 2021, that would equate to a household of three making less than $44,000 per year.

The program must work through ISPs. An ISP provides the $30 discount to qualifying customers and then get reimbursed by the federal program. This program will be operated through the current FCC Lifeline mechanisms.

The Computer Gap

One of the things that digital inclusion advocates have learned is that it's not enough to get affordable broadband to a home if they can't afford a computer or other devices to use the broadband. It's also now clear that cellphones are good tools for things like shopping online, but they are inadequate for students trying to do homework. Any plan to close the digital divide must find solutions for closing the computer gap.

A survey by Pew Research Center in 2021 shows a huge disparity between income and technology adoption. Consider the following results of that poll:

	Less than $30,000	$30,000 to $100,000	Over $100,000
Home Broadband	57%	83%	93%
Smartphone	76%	87%	97%
Desktop	59%	84%	92%
Tablet	41%	53%	68%
All the Above	23%	42%	63%

Other studies have shown that the percentage of homes that have any of these technology tools shrinks significantly for homes making under $25,000 per year.

A big problem for low-income homes is that they can't afford both broadband and the cost of buying and maintaining a computer or similar device. Computers are some of the shortest-lived electronics we can buy and typically must be replaced every 3 or 4 years.

The above numbers highlight the problem of getting broadband into low-income homes – a solution is needed for both broadband and for a computer. As will be discussed below, low-income homes also often need computer training.

The historical solution to a lack of computers was to put computers in libraries and public places. However, in communities in the rural parts of the counties, this solution is inadequate for many reasons. First, it requires students to travel to where the computers are. In communities where a lot of students

don't have computers, it's difficult to have enough to meet the demand. There is the additional issue that rural libraries often don't have good enough broadband to support multiple simultaneous users.

However, the best reason to get computers into homes compared to libraries is that numerous studies have shown that computers in the home have a huge positive impact on students compared to any other alternative. Computers have the biggest positive impact on students when they are part of daily life and are convenient to use when needed.

We can't forget that computers aren't only for students. Adults need computers today just to participate in the modern world. Computers are needed to hunt for a job. Computers are needed to pursue online training and education. Computers are needed to consider jobs where all employees work from home. Computers are needed today to interface with many government programs.

The Gap in Broadband Skills

The current U.S. job market appears to be robust due to the low unemployment rate, which is low by historical standards. However, a closer look at the statistics tells a different story.

Workers with upper-income jobs are faring extremely well. For example, demand for starter jobs for new computer science, engineering, and similar tech graduates are at an all-time high. It's a good time to be a high-tech worker. However, over half of all job openings in the country are classified as middle-skill jobs (with the three categories being high-skilled jobs, middle-skill jobs, and unskilled jobs). These jobs generally don't require a college degree. An analysis by the Benton Foundation a few years ago showed that over 80% of middle-skill jobs require some degree of digital literacy. Unfortunately, a lot of people seeking middle-skill jobs lack the digital skills needed to land these jobs.

This lack of sufficient digital literacy to find middle-skill jobs is perhaps the best way to describe the broadband skills gap. These are not jobs that need coders, but rather need people to know basic computer skills like knowing how to use Microsoft Word or Excel. It means being able to type fast enough to do data entry, write emails, or do other computer-related tasks in the average workplace.

In the early days of the computer age, the federal government operated many training programs that taught basic computer skills. Today it seems to be assumed that students graduate from high school with these skills. However, a student who has never had a home broadband connection or a computer and who only did homework on a cellphone probably doesn't have the needed digital skills. Since the federal and most state governments don't offer any significant training programs in computer literacy, it's up to local communities to find their own solutions.

A Pew Research Center survey in 2016 showed that a lot of adults were interested in digital training. 60% of adults were interested in learning how to use online resources to find trustworthy information. In today's world of misinformation, I would think that percentage is even higher today. 54% of adults were interesting in training that would make them more confident in using computers and the Internet.

Future Broadband Gaps

This gap analysis so far has discussed existing broadband gaps. It's important to realize that there will be new broadband gaps coming in the future that we can already predict. One of the issues to consider when

looking forward is that broadband speeds are a moving target – that is, the demand for residential and business bandwidth grows every year. This is not a new phenomenon, and the need for bandwidth has been growing at nearly the same rate since the early 1980s. Home and business need for bandwidth has been doubling every 3 to 4 years since then.

As an example, 1 Mbps DSL felt really fast in the late 1990s when it was introduced as an upgrade from dial-up Internet. The first 1 Mbps DSL connection was nearly 20 times faster than dial-up, and many people thought that speed would be adequate for many years. However, over time, households needed more speed, and the 1 Mbps connections started to feel too slow; ISPs introduced faster generations of DSL and cable modems that delivered speeds like 6 Mbps, 10 Mbps, and 15 Mbps. Cable modem speeds continued to grow in capacity and eventually surpassed DSL, and in most cities, the cable companies have captured the lion's share of the market by offering internet speeds starting between 100 Mbps and 200 Mbps.

Bandwidth requirements are continuing to grow. Firms like Cisco and Opensignal track broadband speeds achieved by large numbers of households by examining the Internet traffic that passes through the major Internet POPs. Both companies estimate that home internet need for bandwidth, as well as the need for broadband speed is growing currently at about 21% annually. Business use of bandwidth is currently growing at 23% annually.

This report earlier discussed how the FCC set the definition of bandwidth in 2015 at 25/3 Mbps. If you accept that speed as an adequate definition of bandwidth in 2015, then growing the requirements for speed every year by 21% would result in the following speed requirements by year.

Download Speeds in Megabits / Second

2015	2016	2017	2018	2019	2020	2021
25	30	37	44	54	65	79

This is somewhat arbitrary because it assumes that the broadband needs in 2015 were exactly 25 Mbps. For example, if the actual broadband need for the average household in 2015 was 22 Mbps, then the predicted speed for 2021 would be 79 Mbps. What is not arbitrary is that the need for bandwidth and speed increases over time.

If we accept the premise that 25 Mbps was the right definition of broadband in 2015, then it's reasonable to believe that the definition of download broadband today ought to be at least 80 Mbps. That would infer that there is a broadband availability gap today for any household that can't buy 80 Mbps broadband.

Broadband is not only measured by speed, and there are firms that track the volume of data that households and businesses use. The firm OpenVault measures total usage by households using software deployed by the biggest ISPs around the country and around the world. Consider the following statistics that show the average nationwide broadband usage by homes. These numbers include combined download and upload usage.

1st Quarter 2018	215 Gigabytes
1st Quarter 2019	274 Gigabytes
1st Quarter 2020	403 Gigabytes

1st Quarter 2021	462 Gigabytes

This data shows several things. First, it shows extraordinary growth in the average use of broadband across the country. From the first quarter of 2018 to the first quarter of 2019, the average use of household broadband grew by 27%. Usage skyrocketed due to the pandemic. From the first quarter of 2019 to the first quarter of 2020, during the pandemic, the average use of household broadband grew by an astonishing 47%. During the pandemic in 2020, the average household broadband usage grew by another 20%. From the first quarter of 2020 to the first quarter of 2021, the average use of household broadband usage increased by 15%.

OpenVault only recently began reporting upload and download speeds separately. At the end of the third quarter of 2020, the average home downloaded 359 gigabytes of data and uploaded 25 gigabytes of data. By the end of the fourth quarter, this had grown to an average of 452 gigabytes of download data and 31 gigabytes of upload data. In the second quarter of 2021, download data dropped to 405 gigabytes, and upload data dropped to 28 gigabytes.

One of the most startling numbers to come from OpenVault is what they call power users – homes that are using more than 1 terabyte of data per month. Consider the following statistics showing the percentage of homes that use a terabyte of data per month:

4th Quarter 2018	4.0%
4th Quarter 2019	7.3%
4th Quarter 2020	14.1%

Within these numbers are also what OpenVault calls extreme power users, which are households that use more than 2 terabytes of data per month. That's grown from 0.3% of households in 2019 to 1% of all households at the end of the third quarter of 2020. Extreme power users doubled in the fourth quarter of 2020 to 2.2% of all households. Extreme power users dropped to 1.8% in the first quarter of 2021 and 1.5% in the second quarter of 2021.

The demand for faster broadband products has also leaped upward due to the pandemic. At the end of August 2021, the percentage of homes subscribing to gigabit data products jumped to 10.5% of homes, up from 8.5% in 2020, up from 2.8% at the end of 2019, and up from 1.9% in 2018. OpenVault says that 32.4% of U.S. homes subscribe to speeds of 200 Mbps or faster at the end of August 2021, up from 28% in 2020, up from only 13% year earlier.

The OpenVault data also validates what's been reported widely by ISPs – that the pattern of broadband usage is changing by the time of day. In the recent past, the peak period for broadband usage – the busy hour – was always in the evenings. During the pandemic, the amount of usage in the evenings has remained flat, and all of the increased usage came during the daytime as employees and students used broadband and video conferences to function.

OpenVault says that nationwide usage peaked in the third week of March 2020. It will be interesting going forward to see the how home usage changes. OpenVault doesn't have any better crystal ball than the rest of us, but they are predicting that broadband usage will never return to the historical patterns. They predict that a lot of people will continue to work from home, meaning increased broadband demand during the

day. They believe there will be continued pressure on the upload data paths. People who have learned to videoconference during the recent months are likely to continue that practice in the future. Companies and employees that realize they can be productive at home are likely to work more from home, even if only on a part-time basis.

These various statistics are a clear indication that the FCC should be periodically increasing the definition of broadband. The agency looked at broadband speeds in a docket in 2018 and concluded that they were going to keep the definition at 25/3 Mbps. However, there were a lot of compelling filings in that docket that argued that the definition of broadband should be 50 Mbps to 100 Mbps.

The point of this section of the report is that we can't get hung up on the FCC's definition of broadband when looking at the broadband gap. Practically every home that uses broadband would acknowledge that they download and upload a lot more data today than they did just a few years ago.

It's also important to look towards the future when considering broadband needs. For example, if an ISP builds a new broadband solution today, that solution should be prepared to handle the broadband requirements a decade from now. Consider the following chart that predicts broadband needs moving forward. This applies the 21% historical annual growth rate for bandwidth to the broadband speed predicted by cisco for 2020. Forward predictions are always criticized for being too aggressive, but when considering that the need for broadband has been growing at roughly the same rate since 1980, it's not a big stretch to predict broadband needs into the future.

Download Speeds in Megabits / Second

2020	2021	2022	2023	2024	2025	2026	2027
65	79	95	115	139	169	204	247

The download speeds in this table get even larger if extended further into the future. If the demand for broadband download speed continues to grow at 21% annually, then the need in 2030 would be 438 Mbps, in 2035 would be 1.1 Gbps, and in 2040 would be 2.9 Gbps. It's easy to say that such future speeds are not possible, but recall that just 20 years ago, a 1 Mbps DSL connection was considered a blazingly fast broadband connection.

A fiber network will be able to keep up with this kind of future demand. There is already fiber gear today that can deliver 10 Gbps broadband to residential customers. It's possible that the cable company networks could also keep up with this demand, but it would require several major upgrades in technology to do so. Cable networks can deliver download speeds up to a gigabit today. However, the secret that cable companies don't want to talk about is that they can't give that much speed to everybody unless they build a lot more fiber and further reduce node sizes. Cable companies would need to upgrade to DOCSIS 4.0 to get speeds faster than 1 gigabit.

It's not hard to put this prediction into perspective. Cable companies that serve around 65% of all broadband customers in the country already advertise minimum speeds today of between 100 Mbps and 200 Mbps. Those speeds vary by market due to the condition of local coaxial networks. But in markets where the coaxial cable is in good condition, big cable companies already provide 200 Mbps broadband today as the target speed for their introductory broadband product.

It's not hard to imagine that seven years from now that the national definition of broadband ought to be around 250 Mbps. That doesn't mean that the FCC will continue to increase the regulatory definition. In 2020 the FCC rejected numerous filings asking them to increase the 25/3 Mbps definition. There is a political downside if the FCC increases the definition of broadband – it would reclassify numerous homes as not having broadband. Today the 25/3 Mbps definition of broadband is lower than the reality of what many homes need, but my guess is that there will have to be an even bigger difference before the FCC will react and change the definition.

One of the conclusions that can be reached by this analysis is that any new network built today ought to be capable of meeting the expected broadband speeds of the next decade. The only technologies capable of meeting the projected future needs for bandwidth are fiber-to-the-premise, cable company hybrid-fiber technology, and some wireless technologies using millimeter wave spectrum.

Cable companies will only be able to provide speeds above 1 gigabit by implementing another round of expensive upgrades. There is a lot of speculation in the industry that cable companies would upgrade to fiber-to-the-home rather than make such an upgrade.

The Consequences of the Broadband Gaps

There was a time when academics theorized about the impacts of poor broadband. We don't need to theorize today because you can go to any rural community with poor broadband, and residents and businesses will fill your ear with stories of the negative consequences of having poor broadband. The problems with the lack of broadband got magnified during the COVID-19 crisis.

Impact of Poor Broadband for Citizens

Lack of good broadband causes major problems for rural homeowners:

- Lower Property Values: There are numerous studies showing that homes without broadband are worth less than similarly placed homes with broadband. Realtors have been reporting across the country that broadband is at or near the top of the wish list for most homebuyers today. From everything we hear, it is now difficult to attract people to move to rural places that don't have good broadband. That is a big negative for the small towns without good broadband. Without a broadband solution, the rural parts of Knox County will become undesirable places to live, and this is only going to get worse over time as broadband speeds keep increasing in the places that have broadband.

- Education: The concern for the schools is that they are unable to send computer-based work home with students since they know that many of them don't have good home Internet. It's incredibly hard to raise kids today in a home without adequate broadband. The issue is not just data speeds, but also the total amount of downloaded data that even elementary school students need to do homework. This is one of the major problems with satellite broadband, which has speeds up to 50 Mbps, but with tiny data caps and high latency the satellite broadband is inadequate for doing homework. The same is true with cellular data; we have heard horror stories of people with kids ending up with astronomical broadband bills for using broadband from cellphone hotspots for homework.

Schools want students to be able to use broadband outside the school. An increasingly common practice in places with adequate broadband is to have students watch video content at home as homework and then discuss it later in the classroom. That frees valuable classroom time from watching videos in class. The whole education process is increasingly moving to the web, and kids without access to the web are lacking the tools that their peers take for granted.

There was a major study performed to look at what is being called the homework gap by the National Center for Education Statistics (NCES),[7] an agency within the U.S. Department of Education. That study compared test scores for 8th-grade students both with and without a home computer. The results showed:

- On tests of reading comprehension, students who have a computer at home had an average score of 268 compared to a score of 247 for students without a computer.
- In testing for mathematics, students with a computer at home scored 285, while those without scored 262.
- In testing science, students with a computer scored 156 compared to 136 for students without a computer.
- In testing competency in information and communication technology, students with a home computer score 152, compared to 128 for students without a home computer.

Education is not only for K-12. Adults are using broadband to train for new job skills or to take advanced courses online. There is a huge range of undergraduate and advanced degrees that can be achieved mostly online. Online training courses require decent broadband speeds but also low latency since the training is usually done live.

The COVID-19 crisis has highlighted the need for good home broadband for students since in many places in the country, both K-12 and college students were sent home to complete the school year online. This has instantly created a crisis in rural homes that don't have enough broadband to allow students to successfully do schoolwork from home.

A connection between a student and a school is typically activated through the creation of a VPN (virtual private network). This is a dedicated connection of bandwidth that is carved out of the Internet path, and that remains open for as long as the connection to the school WAN is in use. One of the important aspects of a VPN is that it carves out upload bandwidth as well as download bandwidth. Most of the types of broadband available in Knox County have much slower upload speeds than download speeds, and even homes with adequate download bandwidth might not be able to establish a VPN connection due to the inadequacies of the upload path.

Many school systems are trying to recreate the classroom feel using videoconferences where a teacher and all of the students can see each other. That requires a 2-way video connection that can use a 1 – 3 Mbps connection for both upload and download. Students without good home broadband are not going to be able to participate in this kind of remote classwork.

[7] https://nces.ed.gov/pubs2017/2017098/index.asp

Both VPN connections and video conferencing require reasonable latency (delay) to maintain a connection. This makes it nearly impossible to make either kind of connection reliably over satellite broadband – one of the more common kinds of rural broadband connection.

Doing schoolwork from home is also going to use a significant amount of bandwidth during a month, and that raises the issue of data caps and data overage charges. Both satellite broadband and cellular broadband have small data caps – and all data usage above the data caps can be expensive.

- Working at Home: More and more jobs today can be done at home, even if only part-time. But people without adequate home broadband can't participate in this part of the economy. Increasingly, companies are willing to hire people who work out of their homes. The beauty of such jobs is that they can be done from anywhere.

  Working from home is one of the fastest-growing parts of the national economy. Many of your residents could find work that would allow them to work at home and to make a larger income than they can make today locally – if they have great broadband. After years of experiments with telecommuting, companies have seen that employees are often more productive from home due to missing the various distractions that are in the work environment.

  The COVID-19 crisis highlighted the need for good home broadband when as many as 30% of the nationwide workforce was sent home to work in early March. Across the country, employees that live in rural areas were unable to work from home due to inadequate broadband.

  Working at home requires an encrypted VPN connection for most corporate and government WANs, in the same manner as described above for connecting to school WANs. Working at home is also coming to mean connecting by video conference with others as an alternative to face-to-face meetings. This requires a dedicated 1 – 3 Mbps connection for both upload and download – again, something that is a challenge for somebody working from home with a slow Internet connection.

  Both VPN connections and video conferencing require reasonable latency (delay) to maintain a connection. This makes it nearly impossible to make either kind of connection reliably over satellite broadband.

  What's become painfully obvious due to the coronavirus crisis is that homes need more than the ability for a student to do homework or a person to work from home – because many homes have multiple students and possibly also more than one adult all trying to function on the Internet at the same time.

- Medical: We are finally starting to see a big uptick in the use of telemedicine. This is the process of using broadband to connect patients to specialists without having to make the long drive in for an appointment. Patients can talk to doctors using a video connection if the home has adequate broadband. The biggest benefit of telemedicine is being able to talk to a specialist without having to make a long trip to some distant city.

One of the best uses that have been found for telemedicine is for administering non-intrusive assistance for things like counseling. Patients can make scheduled appointments without major disruption to work schedules.

A growing area of telemedicine is the use of medical telemetry devices, which can monitor patients after they've had medical procedures. For example, Saint Vincent Health System in Erie, Pennsylvania, has been using these technologies and has lowered readmission rates of patients after surgery by 44%. CoBank recently sponsored a trial in Georgia for rural diabetes patients and showed a significant improvement for patients who could be monitored daily and who could communicate easily with doctors.

The coronavirus crisis has highlighted the need for telemedicine. Doctor's offices and clinics all across the country have shifted some of their office "visits" to video meetings on Zoom or other video platforms in order to reduce contact between doctors and patients when it can reasonably be avoided. There have been widespread reports that some doctors require video connections for all non-emergency visits. Councilors and mental health workers also report largely migrating most or even all contacts with clients online. It's immediately become clear that patients without home broadband or without a strong cellular signal can't make the needed video connection. There is a lot of speculation that video meetings and telemedicine are going to become mainstream by the end of the coronavirus crisis once doctors understand how effective it can be in many cases.

- Taking Part in the Modern World: People with good broadband have access to features of the web that require bandwidth. Households with good bandwidth routinely use broadband for things like watching videos on services like Netflix, talking to friends and family on services like Skype, playing video games (many of which have largely moved online), taking online courses from numerous colleges, or even just browsing today's video-rich Internet. Many of the businesses people now interact with (utilities, insurance companies, shipping companies, etc.) assume that people have a broadband connection. Many people's social lives, for better or worse, have moved to the web; it is not uncommon to now have friends all over the country based upon some shared interest instead of based upon geographic proximity. Homes without broadband can't participate in any of these many activities and services available on the web.

  Taking part in the modern world has grown to mean a lot more than just watching videos. Consider some of the following ways that a lot of households routinely use bandwidth:
  - Security. Millions of homes now have video cameras at the front door or elsewhere on their property that they can view remotely. A video camera requires a 1 – 3 Mbps upload connection for low-resolution cameras and up to 16 Mbps upload for an HD quality camera.
  - Machine-to-Machine Traffic. Our devices often connect with the Internet without human intervention. Our computers and smartphones automatically upgrade software and apps. Many homes have files automatically backed-up in cloud storage. Numerous appliances and devices in our home periodically connect with the cloud, whether providing updates or just to make sure that the connection is still live. Many cars now communicate with the cloud when they get into range of a home broadband connection to provide a log of all car sensors and to upload driving data that can later be used by the car owner. Cisco predicted

early this year that this traffic would represent over 50% of all the traffic on the web by 2023.

- Online Everything. Many of the functions we do have migrated to being only online – we couldn't even begin to make a full list of things that are largely now online. This includes both major and minor functions, including things like applying for a job, applying for government benefits, making insurance claims, making reservations for a restaurant, banking, and a slew of other activities. Homes without broadband are being left out of numerous activities that everybody else takes for granted.

- Keeping Talent at Home. An issue we often hear about in rural communities is what is called the "rural brain drain." Most rural counties don't have enough good-paying jobs to keep recent graduates home, and so large percentages of each graduating class migrate to larger cities and towns to pursue careers. One of the promises of fiber is the ability to create new jobs and to also provide the opportunity for people to either work at home or to create new businesses that allow them to stay where they want to live.

Impact of Poor Broadband for Businesses

There are numerous consequences of poor broadband for businesses. While some businesses have unique and specific requirements, there are a number of problems caused by poor broadband that affect most businesses.

Impact on Day-to-day Operations. Just like with households, most businesses are seeing their broadband needs growing rapidly each year. Each one of the following routine business functions requires decent bandwidth. Businesses without adequate bandwidth must forgo or compromise on how they communicate with the world and function day-to-day.

- To Communicate with Customers. Businesses routinely have portals that make it easy for customers to place and track orders and to communicate with the business. Inadequate broadband means lower sales. The old days of calling purchasing agents are slowly passing away, and most commerce between companies is becoming automated – which improves accuracy and speeds up the ordering process. Businesses that operate busy eCommerce ordering sites need big amounts of bandwidth to make sure that all customers have a successful purchasing experience. A concern in the rural parts of the county is that businesses may not even have sufficient broadband to consistently process credit card transactions.
- To Communicate with Vendors. Businesses also routinely use the portals of their own vendors to buy whatever they need to operate.
- To Communicate with Other Branches of the Company. Many businesses are branches of a larger corporation, and maintain open data connections to communicate with other parts of the company and with headquarters.
- Working in the Cloud. It's now common for companies to work in the cloud using data that's stored somewhere offsite. This can be in one of the big public clouds like the ones offered by Amazon, Google, or Microsoft, or it can be a private cloud available only to employees of the business. This is the change in the way that companies operate that has probably created the most recent growth in bandwidth. A business doesn't need to be highly sophisticated to work in the cloud. Today banking is routinely done in the cloud. A lot of basic software like Microsoft Office

has migrated to the cloud. Even interfaces with local, state, and federal governments have migrated to the cloud.

- Security Systems. Businesses often have their network and computer security monitored by offsite firms. Security today also means the use of video surveillance cameras, which requires uploading video streams to be viewed outside of the business.
- Sending and Receiving Large Data Files. Most businesses report that the size of data files they routinely transmit and receive has grown significantly larger over the last few years. Some surprisingly small businesses like photographers, architects, engineers, and others routinely want to send and receive big data files.
- VoIP. Many businesses now provide voice communications between their various branches using Voice over IP. A reliable VoIP system needs to have dedicated bandwidth that is guaranteed, and that won't vary according to other demands for bandwidth within the business.
- Communicating via Video. We've finally reached the time when employees routinely communicate via video both inside and outside the business. We saw a huge surge in this during the COVID-19 crisis as students and employees increasingly used video conferencing services, but these services had already become routine for businesses before the crisis.
- Email and Advanced Communications. While many businesses still rely on email, many have gone to more advanced communications systems that let parties connect in a wide variety of ways. Businesses are using collaborative tools that let multiple employees from various locations work on documents or other materials in real-time. These services require good download and upload bandwidth.
- Supporting Remote Employees. Many businesses now save money by allowing employees to work from home full or part-time. They need reliable broadband links to provide home-based employees the same access to systems that are on site. A complaint heard often from rural businesses is that they must physically carry files to their homes or other places with good broadband to conduct routine business.
- Data Back-Up. Companies are wary of hacking and ransomware and routinely maintain several remote copies of all critical data to allow them to restore data after a problem. Data backup requires a steady and reliable upstream broadband connection.
- Internet of Things Sensors. Companies of all sizes now routinely use devices that include sensors that communicate with the Internet. One common function of this sort is burglar alarm systems that monitor physical security and sensors inside equipment that monitors data security. Routinely used office equipment like printers, copiers, postage machines, and many others only function when connected to the Internet.

Entrepreneurship. The fastest growing segment of many local economies is the growth of small businesses, many of which start in the home. Small businesses often begin with a few employees and grow over time as they succeed. Start-up businesses generally are highly reliant upon good broadband. Lack of adequate bandwidth and reliable broadband connections means that small businesses have a difficult or impossible time starting in rural parts of the county.

Agriculture / Other Industries: Every industry has specific requirements for broadband. Perhaps the easiest way to demonstrate this is to talk about how broadband is transforming one specific industry—agriculture. A similar list can be made of the specific uses of broadband for numerous other industries.

- The most data-intensive farming application is the creation of real-time variable rate maps of fields. Farmers can use smart tractors or drones to measure and map important variables that can

affect a current crop, like the relative amounts of key nutrients, moisture content, and the amount of organic matter in the soil. This mapping creates massive data files that are sent off-farm. Expert agronomists review the data and prepare a detailed plan to get the best yields from each section of the field. The problem farmers face today is getting the data to and from the experts in a timely manner. Without fast broadband, the time required to get these files to and from the experts renders the data unusable if the crop grows too large to allow machines to make the suggested changes.

- Using sensors for monitoring livestock is becoming common, and there are now dairy farms that measure almost everything imaginable about each milking cow. There are also advanced sensor systems monitoring pigs, chickens, egg farms, and other food animals. Ranchers that have good cellular data coverage over range areas can track the location of every member of their herds.
- There has been a lot of progress in creating self-driving farm implements. These machines have been tested for a few years, but there are not a lot of farmers yet willing to set machines loose in the field without a driver in the cab. But the industry is heading towards the day when driverless farming will be an easily achievable reality. Smart devices have moved past tractors and now include things like automated planters, fertilizer spreaders, manure applicators, lime applicators, and tillage machines. Machinery now comes with sensors that will alert a farmer of a problem and can even automatically order a replacement part before a working machine fails.
- One of the more interesting trends in farming is to record and report on every aspect of the food chain. When the country stopped eating romaine in late 2018 because of contamination at one farm, the industry started to develop a process where each step of the production of crops is recorded, with the goal to report the history of food to the consumer. In the not-too-distant future, a consumer will be able to scan a package of lettuce or other crops and know where the crop was grown, how it was grown (organic or not), when it was picked, shipped, and brought to the store. This all requires creating a blockchain with an immutable history of each crop, from farm to store, and making this history immediately available to stores and to consumers.
- The industry has been developing soil sensors that can wirelessly transmit real-time data on pH, soil moisture, soil temperature, transpiration, etc. These sensors are still too expensive today to be practical – but the cost of sensors is expected to drop drastically with sales volumes. Research is even being done to create low-cost sensors that can measure the health of individual plants in orchards and similar environments.
- The smart farm today measures an immense amount of data on all aspects of running the business. This includes gathering data for non-crop parts of the business, such as the performance of vehicles, buildings, and employees.

Economic Development and Jobs: Reliable and affordable broadband is still one of the key elements in traditional economic development to lure new companies to a community or to keep existing companies from leaving. As vital as broadband is to residents, it's even more vital to businesses. Businesses want more than just fast broadband. They often require multiple feeds of broadband from different ISPs, on diverse routes to guarantee that they don't lose connectivity.

Many businesses now want their employees to have broadband at home so that they can work from home as needed while gaining access to data in company servers. A new business will consider the whole broadband profile of an area before deciding to locate there. There are numerous municipal fiber businesses that claim significant economic benefits from fiber networks. Many of them have been able to lure new businesses or have seen existing businesses expand.

IV. Background Information

A. Broadband Technologies

Existing Technologies

There are at least six broadband technologies used in the county today to deliver broadband. Each of these technologies will be explained below.

- Northeast Missouri Rural has converted the entire footprint in the county to fiber. Mark Twain Rural intends to upgrade to fiber.
- There is still DSL provided over copper telephone wires, CenturyLink still uses the technology almost entirely, while Mark Twain Rural Telephone Company will be converting all DSL to fiber.
- There are fixed wireless carriers in the county, including Mark Twain Communications and Chariton Valley Wireless.
- There is fixed cellular service provided by the major cellular providers. Some residents also are getting all of their broadband from their cell phone data plans.
- Homes can buy broadband from satellites.

CCG recently reviewed each of these technologies and realized that every technology in use for broadband is better now than three years. Consider fiber. We recently have been recommending that new fiber builders consider XGS-PON. While this technology was around three years, ago it was originally too expensive and cutting edge to consider for most ISPs. But AT&T and Vodaphone have built enough of the technology that the prices for the hardware have dropped to be comparable to the commonly used GPON technology. This means we now need to start talking about FTTP as a 10-gigabit technology – a huge increase in capacity that blows away every other technology.

There have been big improvements in fixed wireless technology. Some of this improvement is due to the FCC getting serious about providing more broadband for rural fixed wireless. During the last three years, the agency has approved CBRS spectrum and white space spectrum that is now being routinely used in rural deployments. The FCC also recently approved the use of 6 GHz WiFi spectrum that will add even more horsepower. But there have also been big improvements in the radios. One of the improvements that isn't mentioned much is new algorithms that speed up the wireless switching function. Three years ago, we talked about fixed wireless speeds of 25 Mbps to 50 Mbps, and now we're talking about speeds over 100 Mbps in ideal conditions.

Cellular data speeds in the city have likely increased drastically in the last three years. The national average cellular speeds are now double to triple the speeds of just a few years ago. This is mostly due to the cellular carriers introducing new cellular frequencies.

Three years ago, the low-orbit satellites from Starlink were just hype. Starlink now has over 1,600 satellites in orbit and is in beta test mode. Customers are reporting download speeds from 50 Mbps to 150 Mbps. We also see serious progress from One Web and Jeff Bezos's Project Kuiper, so this industry segment is on the way to being a reality. There is still a lot of hype, but that will diminish when homes can finally buy satellite broadband. High-orbit satellite speeds have improved as Viasat has launched new satellites – although there is nothing that can be done to eliminate the high latency.

Three years ago, Verizon was in the early testing stage of the fiber-to-the-curb product it calls Verizon Home. After an early beta test and a pause to improve the product, Verizon is now talking about offering broadband to 25 million homes with this technology by 2025. This product uses mostly millimeter-wave spectrum to get from the curb to homes. For now, the speeds are reported to be about 300 Mbps, but Verizon says this will get faster.

We've also seen big progress with millimeter-wave mesh networks. Siklu has a wireless product that they advertise as an ideal way to bring gigabit speeds to a small shopping district. The technology delivers a gigabit connection to a few customers, and the broadband is then bounced from those locations to others.

Cable company technology has also improved over the last three years. During that time, a lot of urban areas saw the upgrade to DOCSIS 3.1 with download speeds of up to a gigabit. CableLabs also recently announced DOCSIS 4.0, which will allow for symmetrical gigabit or faster speeds, but won't be available for 3-5 years.

While there is not a lot of press about DSL technology, speeds over telephone copper have gotten better. There are new versions of G.Fast that are being used to distribute broadband inside apartment buildings with speeds up to 500 Mbps – for short distances.

Interestingly, the product that got the most hype during the last three years is 5G. If you believe the advertising, 5G is now everywhere. There is no actual 5G yet in the market yet, and this continues to be marketing hype. The cellular carriers have improved their 4G networks by overlaying additional spectrum, but we're still not going to see 5G improvements for another 3-5 years.

Wired Internet

Fiber-to-the-home Service (FTTH)

Passive Optical Fiber (PON) Technology

This is the most commonly deployed technology for serving last-mile residential fiber networks. In a passive network, one laser at the transmitter communicates with up to 32 customers. This leads to one of the biggest advantages of the technology since the sharing of fibers can reduce a lot of expensive fiber construction.

Like most broadband technologies, a PON network shares bandwidth between customers. The most commonly deployed PON technology is GPON – the technology shares 2.4 gigabits download and 1 gigabit upload data for a neighborhood group of up to 32 customers. The newest version of the technology is called XGS-PON, which delivers 10 Gbps downstream and 2.5 Gbps upstream to the same-sized node.

One consideration when designing PON networks is that the maximum distance between the core transmitter (called an Optical Line Terminal, or OLT) to the customer is 20 km (12.4 miles). That distance limitation would rarely be a problem in city network but can be a challenge in rural areas.

Active Ethernet (Active E)

An Active E network is essentially a fiber "home run" from the central electronics core, meaning that one fiber goes from the core electronics directly to each customer. This technology has several advantages and is well-suited for serving large businesses where the customer requires more stringent network uptime and higher bandwidth. This technology is also referred to as Metro Ethernet and is the technology used in the county to provide broadband to schools, cell sites, and large business customers.

An Active E network can provide symmetrical (same upload and download) data speeds up to 10 gigabits. The downside to the technology is that there can be a lot larger fibers in the network since customers is served by a single fiber strand. Electronic costs are generally higher than PON technology since there is a dedicated laser at both ends of the connection to every customer. Where a PON has a 12-mile limit between the core electronics and the customer, an active connection can reach over 50 miles.

Hybrid Fiber Coaxial Network

The technology used by a cable company is referred to as Hybrid Fiber Coaxial (HFC). Hybrid refers to the fact that an HFC network uses a fiber backbone network to bring bandwidth to neighborhoods and a copper network of coaxial cable to deliver service to customers.

Coaxial copper wires in networks are aging since most coaxial networks were built in the 1970s. Coaxial cable networks exhibit signs of aging sooner than telephone copper networks because the wires act as a huge antenna, and older networks attract a lot of interference and noise, making it harder to transmit the signals through the wires. There is a distance limitation on coaxial cable. Unamplified signals are not generally transmitted more than about 2.5 miles over a coaxial network from a network node.

HFC is a shared bandwidth technology, and all of the customers in a given node share the broadband. This means that the number of customers sharing a node is a significant factor—the fewer the number of customers, the stronger and more reliable the broadband signal. Before cable systems offered broadband, nodes often had over 1,000 customers. But today, the sizes of the nodes have been split by building fibers deeper into neighborhoods so that fewer homes share a fiber data feed for a given neighborhood. The architecture of using neighborhood nodes is what has given cable companies the reputation that data speeds slow down during peak usage times, like evenings. However, if nodes are made small enough, then this slowdown doesn't have to occur.

The technology that allows broadband to be delivered over an HFC system follows a standard called DOCSIS (Data Over Cable Interface Specification) that was created by CableLabs. Most of the large cable companies upgraded about a decade ago to the DOCSIS 3.0 standard that allows them to bond together enough channels to create broadband speeds as fast as about 250 Mbps download. By now, most big cable companies have upgraded their networks a second time to a new standard, DOCSIS 3.1. Most cable companies with this technology offer a maximum download speed between 500 Mbps and 1.2 Gbps

One limitation of a DOCSIS network is that the standard does not allow for symmetrical data speeds, meaning that download speeds are generally much faster than upload speeds. An upload speed crisis has

arisen during the pandemic due to the increased number of people working and schooling from home, as many customers to want to use the upload network at the same time.

CableLabs has developed the new DOCSIS 4.0 standard that was released in March 2020. The DOCSIS 4.0 standard allows for symmetrical broadband – meaning fast upload speeds. Equipment using this standard probably won't be available for at least four years. At that time, the cable companies will have a hard choice. An upgrade to DOCSIS 4.0 isn't going to be cheap. It means replacing all existing electronics in a rip-and-replace upgrade. That includes cable modems at every customer premise. DOCSIS 4.0 will require network capacity to be increased to at least 1.2 GHz. This likely means replacement of power taps and network amplifiers throughout the outside plant network. There is industry speculation that some cable companies will upgrade to fiber rather than upgrade the copper another time.

DSL over Copper Wires

AT&T, Mark Twain Rural Telephone Company, and CenturyLink provide broadband using DSL (Digital Subscriber Line). It's worth noting that AT&T stopped selling new customers using this technology in October 2020. DSL is used to provide a broadband path over telephone copper wire. These networks were mostly built between the 1950s and early 1970s. The copper networks were originally expected to have an economic life of perhaps 40 years and have now far exceeded the economic life of the assets. The copper networks are deteriorating as a natural process of decay due to sitting in the elements. Maybe even more importantly, the copper networks have deteriorated due to neglect. The big telcos started to cut back on the maintenance of copper in the 1980s as the companies were deregulated from some of their historical obligations. At some point, the copper networks will die, and AT&T's decision to stop selling on the network is a good sign that it is planning for the end of copper.

DSL works by using frequency on the copper that sits just above the frequencies used for telephone service. There are different kinds of DSL standards, each of which has a different characteristic in terms of how much bandwidth they deliver and how far the signal will travel. The most efficient forms of DSL can deliver up to 24 Mbps service over a single telephone wire. Most of the DSL in Knox County is of older varieties and delivers slower speeds.

The most important characteristic of DSL is that data speed delivered to customers decreases with the distance the signal travels. The general rule of thumb is that most of the types of DSL can deliver a decent amount of bandwidth for about two miles over copper – that's miles of copper wires, not two miles as the crow flies. DSL signal strength is also affected by the quality of the copper. The newer the copper and the larger the gauge of the copper wires, the better the signal and the greater the bandwidth. Many of the copper wires in the county are likely to be 50 to 70 years old and have outlived their original expected service life.

Wireless Internet

Fixed Wireless Technology

The network generally consists of radios placed at a tower or other tall location, and connections to homes and businesses are beamed wirelessly. There are several current frequencies of spectrum that can be used for this purpose and more that will be coming on the market in the next few years. The spectrum most in

use today includes WiFi with frequencies at 2.4 GHz, 5.7 GHz, and CBRS Spectrum at 3.5 GHz. The FCC has approved a new WiFi spectrum at 6 GHz that will likely get built into wireless networks. The FCC has also approved white space spectrum. This is spectrum that is in the same range as TV channels 13 through 51 and can be used for broadband in places where it is not being used for television transmission.

This technology has a mixed performance in deployment. There are a number of wireless ISPs (WISPs) that deliver broadband of only a few Mbps speed. But a network with the latest technology can deliver download speeds as fast as 100 Mbps. There are several factors that are needed to get the best performance out of the technology:

- Using Multiple Frequencies. The newest radios are much improved over radios from just a few years ago because they use spectrum bands including 2.4 GHz, 3.5 GHz, and 5.0 GHz. Radios are now starting to integrate white space spectrum and CBRS spectrum. Having more spectrum matters because each frequency band has different operating characteristics in terms of distance and ability to penetrate obstacles. Having multiple frequencies available means an increased opportunity to find a good solution for each customer in the service area.
- Adequate Backhaul. The best fixed wireless coverage comes when there is fiber at the transmitter that supplies the needed bandwidth. Customer broadband speeds are diminished if a tower doesn't receive enough bandwidth – lack of backhaul bandwidth is the primary reason why many WISPs deliver speeds under 10 Mbps.
- Terrain/Topology. The biggest downside to the technology is that a wireless signal can be blocked by physical impediments like hills or impaired by obstacles like trees. There are often physical barriers like hills or heavy woods that can limit or block customer bandwidth.

Cellular Broadband

There are rural homes in Knox County using their cellphone data plans for home Internet access.

The cellular companies also have offered data plans that were designed for home broadband and not for cell phones. These 4G cellular plans have been labeled as hotspots. Customers have disliked these plans because they have tiny data caps, as described above in the pricing section. Unless a customer lives very close to a cell site, these plans have also been slow, often under 10 Mbps.

Most recently, the cellular companies have introduced a new technology which they are calling 5G cellular. The companies are launching this plan by activating new spectrum at a cell site. From an engineering perspective, this new spectrum is not 5G since it doesn't use the 5G specifications yet, but it is a new set of spectrum that has allowed cellular carriers to offer more broadband. The industry is generally referring to this as 5G fixed cellular.

This new technology is not yet available in a lot of rural America, but the cellular carriers say it's coming to most places. A carrier has to update each rural cell site to enable it to use the new bands of spectrum. The product still might not be available until a cellular company is ready to market and service the product in a given market. Subscribers to this new broadband product are supplied with a cellular router capable of receiving the new spectrum (which is the same spectrum that appears on newer cellphones as 5G).

Satellite Broadband.

There are two satellite technologies in use today. There are currently two satellite providers using geostationary satellites – Viasat (which was formerly marketed as Exede or Wildblue) and HughesNet. For both, the availability depends upon having a clear line of sight from a satellite dish at a customer location to a satellite.

The most limiting aspect of geostationary satellite broadband is latency, which means a delay in the signal. These satellites are parked at over 22,000 miles above the earth, and when an Internet connection must travel to and from a satellite, there is a noticeable delay; that delay makes it hard or impossible to do real-time transactions on the web. Current satellite latency can be as high as 900 milliseconds. Any latency above 100 milliseconds creates problems with real-time applications such as streaming video, voice-over-IP, gaming, online education, or making connections to corporate WANs (for working at home). When the latency gets too high, such services won't work at all. Any website or service that requires a constant connection will perform poorly, if at all, with a satellite connection. Satellite broadband also comes with tiny data caps, meaning a customer is highly limited by the amount of data they can send or receive during a month.

The newest satellite option is low earth orbit (LEO) technology that uses satellites that orbit between 200 and 800 miles above the earth. Low-orbit satellites have one major benefit over geostationary satellites. By being significantly closer to the earth, the data transmitted from low-orbit satellites will have a latency between 25 and 35 milliseconds—about the same as experienced in a cable TV broadband network. One of the most interesting aspects of the technology is that a given satellite passes through the horizon for a given customer in about 90 minutes. This means that there must be a large fleet of satellites so that there is always one in the sky over a given customer.

Starlink now has over 1,600 satellites in orbit and says it will begin offering regular service by the end of 2021. Starlink claims it will eventually launch 30,000 satellites, with over 11,000 in the first constellation. Starlink download speeds in beta tests have been between 50 Mbps and 150 Mbps – a great upgrade for customers using rural DSL or cellular hotspots.

Another industry player is Jeff Bezos and Project Kuiper. The company has contracted with United Launch Alliance, a joint Boeing-Lockheed Martin venture, to launch around 500 satellites into orbit – including the company's first test satellites. There have been no announced dates for the nine launches, but speculation is that launches will start late this year or early next year. Project Kuiper has plans to launch 3,236 satellites, and the company says it will need 578 satellites to begin offering limited service. The company reached an agreement with the FCC to launch half of the total satellites before 2026, although it appears the company intends to get to that number sooner.

The third major player is OneWeb. The company is owned by Eutelsat, the U.K. government, and Bharti Global, a large cellular carrier in India. The company recently launched 36 satellites, bringing it to a total of 182 satellites in orbit. The company says it will be able to start serving the U.K., Alaska, northern Europe, Greenland, Iceland, and northern Canada after two more launches and plans to be able to serve the whole planet by the end of 2022.

Future Technologies

Fiber-to-the-Curb

One of the most intriguing technologies hitting the market is fiber-to-the-curb. Currently, the company pioneering this technology is Verizon. Verizon refers to the technology as fixed wireless access (FWA). The technology consists of building fiber along streets and beaming broadband wirelessly to customers using millimeter-wave spectrum. Verizon introduced the technology in 2018 and deployed small trials in Houston, Indianapolis, Los Angeles, and Sacramento.

The first-generation technology required mounting an antenna on the outside of the home to receive the signal. The new technology hangs a receiver on the inside of a window that faces the transmitter on the pole outside the home. Verizon claims the new technology can be self-installed by customers. One of the key requirements for using the technology is that there must be a good line-of-sight between the transmitter on the pole and the customer, which means no intervening trees, shrubs, or other impediments.

Verizon claimed that the first-generation equipment technology could deliver speeds up to 300 Mbps for up to 2,000 feet from a pole. Many engineers in the industry guessed that the more realistic distance was 1,000 feet or less. Verizon claims the new technology can deliver speeds up to a gigabit, but Verizon is no longer making any distance claims. The industry consensus is that this new technology also is likely limited to perhaps 1,000 feet from transmitter to customer window. Early reports from customers are still reporting speeds in the range of 300 Mbps. The receiver in the window needs to "see" the transmitter on a pole, so this is a line-of-sight technology where only homes within sight range of a pole can receive the broadband.

From a deployment perspective, this is an expensive technology. It requires building fiber deep into residential neighborhoods. The industry analysts at MoffetNathanson looked at the first-generation equipment and didn't see how the technology could be any cheaper than building fiber-to-the-home. The expensive component of a FTTH network is the fiber along a street, and that is still needed for this technology as well.

This technology doesn't make sense everywhere. It's a technology aimed at streets with single-family homes or rows of small businesses. It's not going to handle apartment buildings where there are units that don't have a street-facing window. The technology doesn't work well in neighborhoods where utilities are buried since this needs to be on poles. This could be placed on light poles, but it's more expensive to get fiber to light poles than it is to utility poles. The technology won't work well on streets with heavy vegetation or streets that are highly curved. This technology will be hard to justify in places with neighborhoods with large lots and lower housing density, and this technology makes no sense in rural areas.

Faster PON Technology

The largest fiber ISPs, chip manufacturers, electronics vendors have agreed upon the specifications of 25 Gbps PON technology being called 25GS-PON.

This technology can be implemented as an overlay on newer FTTP platforms. In an overlay network, a GPON owner can continue to operate GPON for residential networks, could operate XGS-PON for a PON of businesses with larger bandwidth requirements. The 25GS-PON would be used for the real heavy hitters or perhaps to create a private network between locations in a market.

The 25GS-PON technology might become commercially available as early as the end of 2022. There have already been field trials of the technology. There's already research underway for faster PON technology with a debate about whether the next generation should be 40-gigabit or 100-gigabit.

B. Broadband Grants

There are several current and future grant funding opportunities for broadband upgrades. As stated above, grants are a common way to fund broadband upgrades, and currently, there are a number of new funding opportunities. The recent pandemic showed how important having access to good broadband has become in today's world, and the government is releasing several new funding opportunities to address the digital divide.

This section will discuss the current and future grant opportunities at both the federal and state level.

Federal Broadband Grants. There are several federal broadband grant programs that might benefit the county.

American Rescue Plan Act. Congress gave $350 billion directly to states, cities, towns, counties, and townships to be used to combat issues created by the pandemic. One of the many allowed uses of this funding is for fixing broadband issues directly related to the pandemic. Many communities have already used this funding to buy computers and hotspots for students and other immediate pandemic-related needs. But the money can be used for longer-term solutions that can be tied to the pandemic. Cities are considering using the money to tackle projects like bringing broadband to low-income housing or low-income neighborhoods. Cities are thinking about building fiber to business districts or industrial parks that were decimated by the pandemic.

The rules for using this money were developed by the U.S. Department of the Treasury. The rules are loose enough to give local governments the leeway to be creative with the funding, but governments must take the time to be careful to meet the rules in order to not be challenged by ISPs.

The Treasury rules encourage communities to consider broadband affordability. Communities are encouraged to concentrate on last-mile connections. And communities are encouraged to use the funding for projects that are operated by or affiliated with local government, non-profits, and cooperatives.

There are still three years left to use the funding, so there is no need to rush to use the money. Interestingly, the giant $42.5 billion BEAD grants will allow this to be used as grant matching.

A local government might have to get creative to use this money for broadband, but there is a good opportunity to do so.

Broadband Equity, Access, and Deployment Program (BEAD). This is the official name of the $42.5 billion grant program approved by Congress in early November 2021. This grant program was established by the Infrastructure Investment and Jobs Act. Congress established the following high-level requirements for this grant program—but there will be refinements over the next year as the details are ironed out.

- Likely to Start in Late 2022. This funding is going to flow between the NTIA and States and on to grant projects. The Act gives the NTIA 180 days to come up with a plan for inviting states to apply for the funding. After the NTIA approves state plans, the states will have to develop and announce grant programs. It's unlikely that there will be any grant applications due to states until the end of 2022 and maybe into 2023. States will get at least $100 million each, with the rest distributed based upon the number of unserved households in each state. It wouldn't be surprising for a state as large as Missouri to get $1 billion in total funding.
- Definition of Broadband. Grants must adhere to two key definitions of broadband. Unserved are places with broadband speeds under 25/3 Mbps. Underserved are areas with speeds between 25/3 and 100/20 Mbps. Grants must first go to unserved areas in the state before being used for underserved areas. Funding for anchor institutions is only after serving underserved areas.
- Technology Must be at Least 100/20 Mbps. Anything built with the network must deliver speeds of at least 100/20 Mbps.
- 5-Year Funding Period. States have five years to disperse the funds. We don't know what that means. It could mean a series of grants over a few years, or it could mean one giant grant process at the beginning, with payments stretched out over time.
- Other Uses of the Grants. Grants don't have to all go for broadband to unserved and underserved areas. Grants can be made to connect eligible community anchor institutions. States can use the money for data collection, broadband mapping, and planning. Funding can go to serve qualifying multi-family apartments with WiFi or low-cost broadband.
- Eligible to All. Unlike the recent NTIA program, BEAD doesn't give priority to any class of grant recipients. The grants can't exclude cooperatives, non-profit organizations, public-private partnerships, private companies, public or private utilities, public utility districts, or local governments from eligibility.
- Several Grant Priorities. States must give priority to grants that are deployed in counties with persistent poverty. Grant projects must provide speeds of at least 100/20 Mbps, and faster broadband speeds must be prioritized. Projects that are shovel-ready will be given priority. Projects that pledge to pay Davis-Bacon wages will get priority.
- Challenge Process. Incumbent ISPs can challenge the validity of a grant area. Interestingly, the NTIA can override states in these challenges.
- Grants up to 75%. Grant applications must provide at least a 25% matching for the cost of the project. Matching may include CAREs funding and ARPA funding. Matching can also come from state grants.
- Requires Two 9's Reliability. Deployed technology must only meet two 9's reliability—meaning that it can be out for two days per year and still be considered adequate.
- Construction Must be Complete in Four Years. Grants must cover every home in a coverage area within four years of receiving the grant.
- Low-Price Option. Grant recipients must provide at least one low-cost broadband option for eligible households. The NTIA is expressly forbidden to regulate rates in any manner.
- No Middle-Mile. Interestingly, any fiber built along highways must include access points at "regular and short intervals." This money is not for middle-mile fiber.

- Public Awareness Campaign. Grant recipients must carry out public awareness programs in grant areas extolling the benefits of better broadband.
- Plenty of Paperwork. Grant recipients must file semiannual reports tracking the effectiveness of the grant funding.

ReConnect Grants.[8] In the 2017 Farm Bill, Congress created a grant program called ReConnect. The program awarded $200 million in grants, $200 million in loans, and $200 million in a combination of grants and loans in 2019. Congress reauthorized an additional $600 million to be awarded in 2020.

There is a new round of ReConnect grants currently underway that will award $1.15 billion in funding, with grants due in February 2022. Following is a highlight of the rules for the new round of grants – many rules are different than in previous years.

- Speeds. This is the first federal grant program that will consider as grant-eligible any area not served today by 100/20 Mbps broadband. But note that there is a big grant scoring penalty for serving areas with existing speeds greater than 25/3 Mbps. This means the grant allows serving areas with existing speeds greater than 25/3 Mbps but penalizes an applicant for doing so. The grants do not automatically adhere to FCC mapping data, but an applicant needs to be prepared to demonstrate why an area is eligible. To challenge the FCC mapping requires an opinion from an engineer who has examined technology in the field or a rigorous online survey that demonstrates slow speeds.
- Eligible Entities. Almost anybody is eligible, but a big preference is given to tribes and to "local governments, non-profits, and cooperatives as applicants and additional points to those applications (including for projects involving public-private partnerships where the local government, non-profit, or cooperative is the applicant)."
- Must be Rural. Grant-serving areas must be rural and remote. There is a ReConnect mapping tool[9] that will tell you if an area is eligible. To be eligible for funding, the grant area must be "15 minutes or more from an urban area of 2,500-9,999 people; 30 minutes or more from an urban area of 10,000-24,999 people; 45 minutes or more from an urban area of 25,000-49,999 people; or 60 minutes or more from an urban area of 50,000 or more people." Additionally, there is a density test.
- Pandemic Matters. Applicants must be prepared to demonstrate how the grant area was hit particularly hard by the pandemic.
- Economic Need. The grants favor bringing broadband to Socially Vulnerable Communities. On first reading, this looks like it's going to take some effort to meet this test.
- Prefers Open Access. Retail rates must be affordable and non-discriminatory. There are grant points awarded to those willing to offer "wholesale rates," which is another way of describing open access. Most network owners are not going to be willing to invite a competitor into a serving area.
- Strong Labor Standards. While the grant doesn't require Davis-Bacon prevailing wages, there are grant points awarded for agreeing to pay the prevailing wages or higher.

[8] https://www.usda.gov/reconnect

[9] https://ruraldevelopment.maps.arcgis.com/apps/webappviewer/index.html?id=1e82a64056fc46e4a28361c5e9447246

- Net Neutrality. Applicants must be willing to adhere to net neutrality. I don't know any smaller ISPs that don't automatically do this, but this could discourage larger ISPs from applying.
- Can be Used in RDOF Areas. This is one of the more confusing rules and will need clarification. It seems likely that this will allow somebody already getting RDOF to use these funds if it accelerates the construction timeline. I doubt that funding will be awarded to overbuild an RDOF award area.
- Can Overbuild an RU.S. Borrower. This is new and has never been allowed. It's hard to think that the RU.S. will really give funding to bury an existing RU.S. borrower that still owes money to the RU.S..

EDA Grants. The U.S. Economic Development Administration (EDA) has been able to make broadband grants in the past—often as part of larger economic development initiatives. EDA grants are reserved for the poorer parts of the country, based upon wages in a region.[10]

Broadband Adoption Grants. The recently enacted Infrastructure Investment and Jobs Act (IIJA) created two new grant programs to address digital equity and inclusion. This section of the IIJA recognizes that providing broadband access alone will not close the digital divide. There are millions of homes that lack computers and the digital skills needed to use broadband. The grant programs take two different approaches to try to close the digital divide.

The State Digital Equity Capacity Grant Program will give money to states to then distribute through grants. The stated goal of this grant program is to promote the achievement of digital equity, support digital inclusion activities, and build capacity for efforts by states relating to the adoption of broadband.

The Act allocates $1.5 billion to the states for this program—that's $300 million per year from 2022 through 2026. Before getting any funding, each state must submit a plan to the NTIA on how it plans on using the funding. States will have to name the entity that will operate the program, and interestingly, it doesn't have to be a branch of government. States could assign the role to non-profits or others.

The amount of funding that will go to each state is formulaic. 50% will be awarded based upon the population of each state according to the 2020 Census. 25% will be awarded based upon the number of homes that have household incomes that are less than 150% of the poverty level, as defined by the U.S. Census. The final 25% will come from the comparative lack of broadband adoption as measured by the FCC 477 process, the American Community Survey conducted by the U.S. Census, and the NTIA Internet Use Survey.

The second new grant program is called the Digital Equity Competitive Grant Program. These are grants that will be administered by the NTIA and awarded directly to grant recipients. The budget for this grant program is $1.25 billion, with $250 million per year to be awarded in 2022 through 2026.

These grants can be awarded to a wide range of entities, including government entities, Indian Tribes, non-profit foundations and corporations, community anchor institutions, education agencies, entities that engage in workforce development, or a partnership between any of the above entities.

[10] This website shows the current EDA assistance programs. The website is updated frequently. https://www.eda.gov/funding-opportunities/

This will be a competitive grant program, with the rules to be developed by the NTIA. While the broadband infrastructure grant in the Act includes a long list of proscribed rules, Congress is largely letting it up the NTIA to determine how to structure this grant program.

Other 2021 Grants**.** There are numerous smaller grants that can be used for broadband and broadband-related areas in the community that came out of the $1.9 trillion American Rescue Plan Act (ARPA).

As an example, there are nearly a dozen grants that could be used to assist libraries. The biggest is a $200 million grant to the Institute of Museum and Library Services. This is an independent federal agency that provides grant funding for libraries and museums. $178 million of the $200 million will be distributed through the states to libraries. Each state is guaranteed to get at least $2 million, with the rest distributed based upon population. This is by far the largest federal grant ever made directly for libraries. There are other grants that can be used to pay for hotspots, modems, routers, and laptops.

There are other grants aimed at schools, rural health care facilities, and tribal lands that could be used partially for broadband.

There are also new possibilities out of the Infrastructure Investment and Jobs Act. In addition to broadband, the federal infrastructure plan has created a big pool of grant funding to beef up the electric grid. One of the key elements of improving electric grids is to connect substations, generation facilities, and other local electric infrastructure to fiber. Any such investments can be combined with other broadband funds to help pay for a network. Another possibility out of the program is that the huge money being allocated to fixing roads could also include building conduit.

e-Connectivity Grant Program. In March of 2017, Congress passed a one-time $600 million grant/loan program to build rural broadband. The project was labeled as the e-Connectivity Pilot. There is a lot of hope that Congress will continue this program.

Community Connect Grants.[11] This program specifically targets the poorest parts of the country and ones with little existing broadband. This program awarded $34 million in 2018 and $30 million in 2019. Grant awards for the program are generally between $100,000 and $3 million and require at least a 15% matching from the grant recipient.

BroadbandU.S.A Program.[12] This program is part of the Department of Commerce's National Telecommunications and Information Administration (NTIA). The agency provides an annual database of grants that can sometimes be used for broadband (and are often used for other purposes). Examples include the Appalachian Regional Commission and the Community Development Block Grant (CDBG) Program.

HUD Community Development Block Grants (CDBG). Grants under this program can be used to build fiber or wireless networks to areas lacking broadband access. Any grant application must meet all three of the following objectives:

[11] https://www.rd.usda.gov/programs-services/community-connect-grants
[12] https://www.broadbandusa.ntia.doc.gov/new-fund-search

- The project must benefit low- or moderate-income neighborhoods
- The project must eliminate "slums / blight."
- The project must demonstrate urgent need.

The last criterion is fairly easy to demonstrate in any community without adequate broadband – years ago, this was a hard challenge for using this money for broadband. The big hurdle for many grant applicants is the second objective of eliminating blight. We've seen an argument made that improving broadband improves incomes, which ultimately improves impoverished communities. For example, using broadband to lure tenants to occupy closed storefronts meets this test.

The CDBG grants have wide latitude in considering grant applications and can be used in the following ways that benefit broadband:

- The acquisition, construction, reconstruction, rehabilitation, or installation of public facilities and improvements (which include fiber or wireless infrastructure improvements).
- The acquisition, construction, reconstruction, rehabilitation, or installation of distribution lines and facilities of privately-owned utilities, which includes the placing underground of new or existing distribution facilities and lines.
- Digital literacy classes as a public service.
- Economic development – grants/loans to for-profit businesses, particularly businesses that focus on broadband/Internet access and technology.

It's worth noting that the CDBG program also makes block grants to states which then can administer grants. These state grants must still follow the same federal guidelines for eligibility as listed above. It's hard to use this money to support a widespread network that serves different neighborhoods, but it can be useful to supplement other grants to serve any pockets of the county that can meet the three tests.

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The infrastructure legislation includes more than $15 billion in grants and another $12 billion in low-cost loans aimed at the electric grid. Just like with the broadband grant funding, this money is intended to be spent between 2022 and 2026. The federal grants will be administered by the Department of Energy. The following are some of the specific pots of funding coming available:

- There is a $5 billion grant program aimed at grid hardening to protect the grid against extreme weather events.
- There is a new $3 billion Smart Grid Investing Matching Grant program that is aimed at deploying technologies that enhance the flexibility of the electric grid.
- There is $2.5 billion of funding split between a Transmission Facilities Fund and a Transmission Facilities Program, aimed at beefing up the major electric transmission routes (these are the electric grid version of middle-mile).
- There is $6 billion for grid reliability and resilience research and development. At least $1 billion of this must be spent on rural electric grid research. The purpose of this funding is to explore innovative programs that improve transmission, distribution, and storage projects.
- $500 million is being given to the State Energy Program that allows states to better plan and coordinate transmission and distribution.

If the electric company in an area is willing to work with ISPs and/or communities, there is a chance to leverage fiber build for various smart grid projects that could also be used for broadband. This requires collaboration.

Broadband Equity, Access, and Deployment Program Grants (BEAD)

This is by far the largest broadband grant ever. Congress approved a grant of $42.5 billion to improve broadband. Following are high-level grant rules which won't be finalized until sometime in 2022.

- You don't need to rush to be ready to file for BEADA grants. This funding is going to flow between the NTIA and States and on to grant projects. The Act gives the NTIA 180 days to come up with a plan for inviting states to apply for the funding. After the NTIA approves state plans, the states will have to develop and announce grant programs. I find it highly unlikely that there will be any grant applications due to states until the end of 2022, more likely in 2023. States will get at least $100 million each, with the rest distributed based upon the number of unserved households in each state. This is a good time to remind everybody that the lousy FCC maps are going to unfortunately play a big role in this distribution.
- As expected, grants must adhere to two key definitions of broadband. Unserved are places with broadband speeds under 25/3 Mbps. Underserved are areas with speeds between 25/3 and 100/20 Mbps. Grants must first go to unserved areas before being used for underserved areas. Funding for anchor institutions is only after serving underserved areas.
- Grants don't have to all go for broadband to unserved and underserved areas. Grants can be made to connect eligible community anchor institutions. States can use the money for data collection, broadband mapping, and planning. Funding can go to serve qualifying multi-family apartments with WiFi or low-cost broadband.
- Unlike the recent NTA program, BEADA doesn't give priority to any class of grant recipients. The grants can't exclude cooperatives, nonprofit organizations, public-private partnerships, private companies, public or private utilities, public utility districts, or local governments from eligibility.

- States must give priority to grants that are deployed in counties with persistent poverty. Grant projects must provide speeds of at least 100/20 Mbps, and faster broadband speeds must be prioritized. Projects that are shovel-ready will be given priority. Projects that pledge to pay Davis-Bacon wages will get priority.
- There is a challenge process where incumbent ISPs can challenge the validity of a grant area. Interestingly, the NTIA can override states in these challenges.
- Grant applications must provide at least a 25% matching for the cost of the project. Matching may include CAREs funding and ARPA funding. Hang on to those funds for a while! Matching can also come from state grants.
- Deployed technology must only meet two 9's reliability – meaning that it can be out for two days per year and still be considered adequate.
- Grants must cover every home in a coverage area within four years of receiving the grant.
- Grant recipients must provide at least one low-cost broadband option for eligible households. The NTIA is expressly forbidden to regulate rates in any manner.
- Interestingly, any fiber built along highways must include access points at "regular and short intervals". This money is not for middle-mile fiber.
- Grant recipients must carry out public awareness programs in grant areas extolling the benefits of better broadband.
- There is plenty of paperwork. Grant recipients must file semiannual reports tracking the effectiveness of the grant funding.

State Grant Programs

Missouri Broadband Program.[13] The Office of Broadband Development is part of the Department of Economic Development in Missouri. The stated goals of the agency are to:

- Increase broadband data collection and utilization
- Accelerate broadband infrastructure and access.
- Leverage partnerships to accelerate broadband efforts.
- Increase broadband adoption & awareness
- Promote efficiencies and opportunities in broadband development

Missouri Broadband Grants.[14] This grant program was established in 2018. For now, this is only a rural broadband grant program because it will only fund projects in places where broadband speeds are 10/1 Mbps or less. The grant funds can be used to build basically any technology because a project must deliver speeds of only 25/3 Mbps. The funding for the grants must be approved each year by the legislature. The projects funded in 2020 were all small, with the largest at less than $500,000 and many much smaller. It seems unlikely that this fund will ever be available for fiber in cities.

As this report was being written, Missouri Governor Michael Parson announced that he will ask the legislature in January of 2022 to use $400 million of the state's share of the American Rescue Plan Act for broadband. This money, if approved, would likely be administered through this grant program, although the rules on what can be funded would change. We'll have to see the rules for this funding

[13] https://ded.mo.gov/content/broadband-development

[14] https://ded.mo.gov/content/missouri-broadband-grant-program

because it's possible that some of this funding could be used for reaching low-income neighborhoods or other uses – but all to be defined by the legislature and the Office of Broadband Development.

C. Industry Trends

Some of these trends are covered elsewhere in the report and are included here again.

Broadband Usage Continue to Grow Rapidly

This was discussed in more detail in the Broadband Gap analysis. OpenVault tracks average broadband usage by households and reports the following trend of average monthly broadband usage:

1st Quarter 2018	215 Gigabytes
1st Quarter 2019	274 Gigabytes
1st Quarter 2020	403 Gigabytes
1st Quarter 2021	462 Gigabytes

From the first quarter of 2018 to the first quarter of 2019, the average use of household broadband grew by 27%. Usage skyrocketed due to the pandemic - from the first quarter of 2019 to the first quarter of 2020 during the pandemic, the average use of household broadband grew by an astonishing 47%. During the pandemic in 2020, the average household broadband usage grew by another 20%. From the first quarter of 2020 to the first quarter of 2021, the average use of household broadband usage increased by 15%.

One of the most startling numbers to come from OpenVault is what they call power users – homes that are using more than 1 terabyte of data per month. Consider the following statistics showing the percentage of homes that use a terabyte of data per month:

4th Quarter 2018	4.0%
4th Quarter 2019	7.3%
4th Quarter 2020	14.1%

Within these numbers are also what OpenVault calls extreme power users, which are households that use more than two terabytes of data per month. That's grown from 0.3% of households in 2019 to 1% of all households at the end of the third quarter of 2020. Extreme power users doubled in the fourth quarter of 2020 to 2.2% of all households. Extreme power users dropped to 1.8% in the first quarter of 2021 and 1.5% in the second quarter of 2021.

The demand for faster broadband products has also leaped upward due to the pandemic. At the end of August 2021, the percentage of homes subscribing to gigabit data products jumped to 10.5% of homes, up from 8.5% in 2020, up from 2.8% at the end of 2019, and up from 1.9% in 2018. OpenVault says that 32.4% of U.S. homes subscribe to speeds of 200 Mbps or faster at the end of August 2021, up from 28% in 2020, up from only 13% a year earlier.

Pandemic Exposed the Upload Crisis

The pandemic exposed the fact that upload speed for technologies other than fiber was inadequate. The upload speeds in telephone company DSL rarely is any faster than a few Mbps. Nationwide, we see upload speeds on cable company networks in the range of 10-15 Mbps. These speeds have always been a problem for residents and businesses that need fast uploads, but the average home never cared much about upload speeds before the pandemic.

The cable company upload speeds were most troubling to homes that had multiple people trying to conduct online work or schooling at the same time. Many such homes found that connection to work and school servers were often dropped. People had trouble making Zoom calls, which requires a dedicated upstream path during the entire call.

There is a second aspect of cable company upload speed that came to bear during the pandemic but is not widely understood. Cable company networks operate using a range of radio frequencies delivered inside of the copper wires. It turns out that the cable companies have placed broadband upload speeds in the portion of the network that has the most noise and interference. Uploading uses the same frequencies that historically were used for television channels 2 through 5, and this part of the cable network uses frequencies that are interfered with a wide range of real-life devices like microwave ovens, vacuum cleaners, lawnmowers, etc. The relatively high interference in the upload stream means that broadband is degraded and doesn't perform as well as would be expected from the speed test. When a data packet hits interference, the packet dies, and the originating site on the Internet has to resend the packet a second time.

The final issue with upload speeds on cable systems comes from the fact that upload bandwidth is shared among everybody in a neighborhood. A cable network is designed in neighborhood nodes, which might mean 100 to 300 homes that collectively share the same total bandwidth. During the pandemic, it became common in the daytime for an entire neighborhood upload path to be 100% full. At that point, additional people can't get onto the network. When fully busy, a network also experiences a lot of problems due to what is called packet collisions – too many packets of data are trying to be delivered to the neighborhood at the same time.

We don't think ISPs are trying to improve upload broadband. Many ISPs mostly seem to be hoping that people and students stop working in the home. However, it seems like a sizable portion of workers might now always be working from home. Just like with download usage, the amount of usage for upload functions also increases every year – so the upload path will grow busier as we move into the future.

Supply Chain Issues

AT&T reported recently in an investor conference that supply chain issues will likely mean that the company will only achieve 2.5 million of the 3 million planned new passings for the year. AT&T didn't name the vendor that was the primary reason for the slowdown, but it's likely that it's either Corning or CommScope. ISPs everywhere that are ordering fiber are seeing this same phenomenon, with reports of waiting times of up to a year for new orders for fiber.

Supply chain issues are arising for a variety of reasons, all of which might come together to create a perfect storm for the industry. One reason for shortages is manufacturing capacity. For example, Corning saw revenues jump by 21% in the recently ended second quarter compared to a year earlier. Factories that are already working at or near capacity and can't flip a switch to produce 20% more fiber. Demand is going to grow a lot more. The consulting firm RVA LLC recently predicted that the industry has plans to build fiber past 61 million homes between now and 2025 – that's far more fiber than has ever been built. See a partial list of known fiber projects in the following item below.

Supply chain issues are also still suffering from the lack of the raw ingredients needed to manufacture key components. This is one of the key issues behind the chip shortage and the shortage of electronics cases that are made from resin. Much of the global supply chain has not recovered from the impacts of the pandemic – and as the delta variant sweeps the world, this issue is far from behind us.

There are also more mundane supply chain issues. There is still a shortage of truck drivers and port capacity to deliver the glut of materials and products hitting the market as the economy is rapidly improving. Apparently, during the break from the pandemic, many truckers decided they were tired of life on the road, and are pursuing something else. The industry is having a hard time training new truckers at the needed pace, and truck driving schools are working overtime.

There are also more subtle changes behind the scenes. For example, many manufacturers have quietly looked for sources other than China during the pandemic. Many companies have come to realize that their own success was tied too closely to supply chains that were wholly within specific regions of China. Switching supply sources to other countries is not something that happens overnight, and many of these new relationships are still growing and maturing.

Some of these issues will get solved over time. It seems like the backlogs at ports are already easing some. But the bigger issue of unprecedented demand is likely going to plague us for much of the next decade.

Fiber Construction Plans Explodes

One of the main issues driving the supply chain problems is the unprecedented plans in the country to build more fiber. Consider all of the following initiatives that will build fiber in 2022 and beyond:

- The construction for the $9 billion RDOF awards will start in 2022 or 2023.
- It's anticipated that much of the $10 billion of the ARPA plan that was dedicated to broadband and sent to states will result in fiber construction over the next two years. It's also expected that a substantial amount of fiber will be built from the $350 billion in ARPA funds that went directly to cities, counties, and states. .
- The $600 million from the recent NTIA grants expects fiber construction in 2022.
- The U.S.DA ReConnect grants will award $700 million for fiber construction to start sometime in 2022. This fund might get increased by $2 billion from the recent infrastructure Act. Construction from past grants is still ongoing.
- At least some portion of the $3 billion in EDA grants will be used for fiber over the next three years.
- Verizon has plans to 25 million homes by 2025 with fiber to support its Verizon Home fiber-to-the-curb service.

- AT&T now passes 16 million homes. It recently announced that it plans to pass 30 million homes with fiber by the end of 2025.
- Altice recently announced plans to upgrade 1.5 million homes from cable technology to fiber.
- Fronter announced plans to pass 6 million homes with fiber by the end of 2025.
- CenturyLink has been steadily passing about 400,000 new premises with fiber each year, and the company is still expanding its middle-mile fiber network.
- Consolidated Communications plans on passing 400,000 homes per year with fiber.
- Windstream announced plans to invest $2 billion in fiber over the next five years.
- Numerous smaller telcos like Ziply, TDS, and Cincinnati Bell have aggressive fiber expansion plans.
- Smaller telcos are continuing to build fiber.
- Dozens of electric cooperatives are building FTTP.
- States are making unprecedented broadband grants from $100 million in some states up to almost $4 billion in California. State grants generally expect construction within two years.
- Independent fiber builders across the country like Google Fiber, MetroNet, and numerous municipalities quietly continue to build fiber projects.
- Cellular companies continue to build fiber to replace cellular transport leases and to expand small cell deployment.
- Zayo and other long-haul fiber network owners continue to build new middle-mile networks.
- Electric companies are aggressively expanding smart grid networks.
- Cable companies use significant fiber every year to split nodes.

This all adds up to an unprecedented amount of fiber construction and is off the scale in terms of magnitude.

Shortage of Fiber Technicians

Eleven different industry trade associations wrote a joint letter to Congress and the White House this year asking that any new infrastructure funding include training for telecom technicians.[15] The letter included support from the Competitive Carriers Association (CCA), the Fiber Broadband Association (FBA), INCOMPAS, NATE: The Communications Infrastructure Contractors Association, NTCA - The Rural Broadband Association, Power & Communication Contractors Association (PCCA), the Telecommunications Industry Association, U.S.Telecom – The Broadband Association, the Wireless Infrastructure Association (WIA), the Wireless Internet Service Providers Association (WISPA), and the CTIA.

The letter says that the industry needs 850,000 new man-years of technician time to meet the expectation of building fiber through 2025. To put that number into perspective, the industry currently employees 672,000 technicians with an average salary of $77,500. The industries also collectively expect to add another 2.1 million jobs to support the new industries like 5G and new fiber ISPs.

[15] https://wia.org/wp-content/uploads/workforce-letter-jan-2021_biden_final.pdf

The Emergence of New Broadband Technologies / Competitors

Over time the county might see the following new and/or improved technologies.

- Improved cellular speeds. The cell companies are now delivering download speeds in the range of 100 Mbps in many cities. They are now selling fixed cellular plans for relatively low prices in the range of $50 per month – and this is going to be available everywhere. This is going to be an attractive broadband alternative for homes looking to save money.
- Wireless Mesh Networks. This starts with strong fiber bandwidth at a transmitter and bounces broadband from customer to customer. There are companies like Starry seeing speeds of 200 Mbps with the product.
- Fiber-to-the-Curb. The only ISP currently doing this is Verizon. The technology involves building fiber along streets and then using wireless to get from the street to the home. For now, this delivers speeds around 200 Mbps, but expectations are that this will approach gigabit speeds.

It's Raining Grant Funding

The specific grants were discussed in the funding discussion immediately above. There is an unprecedented amount of grant funding that presents a one-in-a-lifetime to get fast broadband to every part of the county.

Big Telcos Trying to Walk Away From Copper

It's clear that AT&T wants out of the copper telephone business when it stopped selling new DSL customers in October 2020. Verizon has been loudly saying this for five years. CenturyLink recently sold off twenty states of copper lines. It's not hard to look out five years and see a time when AT&T cancels all DSL customers.

Triple Play Trends

There are clear trends going on with telephone and video products:

- Landlines Continue to Drop. The industry is still steadily losing about 4 million telephone lines per year. Nationwide telephone penetration rates are now under 30%. But most businesses still have a landline telephone.
- Traditional Cable Cord Cutting Accelerating. The ISP industry lost over 1.3 million traditional cable customers in the third quarter of 2021 and almost 4.3 million customers for the year. This drops the nationwide cable TV penetration rates down to 56%, from a one-time high of 80%.
- Cable Prices Climbing Faster than Inflation. Cable companies continue to increase the price of cable TV, which is largely driven by programmers that have never stopped raising rates for content.
- The Explosion of Online Video. One of the big drivers of home broadband usage is that millions more people each year are getting video content from the web.

5G Trends

- New 5G Spectrum Making a Noticeable Difference. The cellular carriers have introduced new frequencies that they are labeling as 5G. These new frequency bands do not yet use the 5G technologies, but the carriers are operating the new frequencies as a separate data-only network

using 4G LTE technology. Customers with 5G-capable phones can receive the new frequencies and get faster cellular data speeds.

The new frequencies have resulted in a big increase in cellular data speeds. In cities, cellular data speeds have more than doubled in the last two years. Each of the major carriers has launched a home broadband product using the new 5G frequencies. These products have limited reach today but should be available to most homes within a year or two. This could provide a low-end broadband competitor with speeds of around 100 Mbps download.

- Cable Companies Making Noise in Cellular Market. The big cable companies currently have over 3 million cellular customers are growing quickly. While that's not a giant part of the market, it's putting a lot of pressure on the big cellular companies since the cell companies are competing with low prices. Charter current has a nationwide campaign to sell an unlimited $29.95 per line cellphone plan for somebody buying two lines.
  Industry pundits have coined a new phrase, 'convergence apocalypse to describe the increasing competition between cellular companies and telcos. The phrase assumes that the competition will be to the mutual detriment of both parties. We haven't had widespread competition in the broadband industry since the period from 2000-2005 when DSL and cable modems had comparable speeds. But we might see real competition as telcos continue to build fiber and cellular companies counter by selling cellular phones.
- Small Cell Sites Becoming Commonplace. Small cell sites are popping up in towns of all sizes. The big cell companies are finding it smarter to put small cell sites in the neighborhoods that need better coverage rather than build new tall towers. This is one of the major reasons for faster cellular data speeds.

Regulatory Trends

- FCC Likely to Tackle Broadband Regulation. It's expected that the FCC will tackle the reintroduction of broadband regulation in 2022. The FCC under Ajit Pai eliminated Title II regulation of broadband, which effectively stopped the FCC from regulating most broadband issues. The action taken to defeat broadband regulation was labeled as a fight against net neutrality rules, but it was really a move to remove regulation of broadband. It can be argued that broadband is the most important industry in the country, and it's one that is dominated by large ISPs. Comcast, Charter, Verizon, and AT&T have over 75% of all broadband customers in the country and are largely unregulated.
- Federal Government Likely to be Anti-merger. The Biden administration appears to be skeptical of the need for giant corporate mergers. There have been a bunch of large mergers in the telecom industry in recent years, such as Charter merging with Time Warner Cable, And T-Mobile merging with Sprint. It appears that mergers will be harder to get approved in the next few years.
- Attempts to Change Section 230 Rules Going Nowhere. Social media is full of discussions about regulating the content in platforms like Facebook and Twitter. The big web companies are shielded from prosecution for user-generated content on their sites due to Section 230 of Telecom and FCC rules. While there will continue to be a lot of talk on the topic, it seems unlikely that this fundamental principle of the web will be overturned or modified.

Technology Trends

- Expect Long-time Ban on Chinese Electronics. The U.S. Government has gotten aggressive about keeping Chinese fiber and cellular electronics out of the U.S. Market. The trend is for this effort to strengthen and to ban even more Chinese gear over time. This was originally driven by the fear that Huawei routers and switches included back doors allowing for espionage, but over time was extended to all FTTP and cellular gear.
- 10-Gigabit PON Easily Available and 25-Gigabit PON on the Horizon. XGS-PON that delivers 10-gigabit broadband to neighborhoods in a passive optical network technology is now easily and affordably available. AT&T and Vodaphone have built enough of the technology to drop prices for the rest of the industry. There have recently been field trials of 25-gigabit PON technology that might be a natural add-on. Vendors have designed networks where a single chassis could accommodate the different types and speeds of PON technology on the same network.
- 6 GHz Spectrum Will Make a Difference. The FCC approved the use of 6 GHz spectrum for WiFi. This is going to bring big technology breakthroughs in two areas.

  This technology will enhance rural fixed wireless technology by adding a wide set of broadband channels into the mix. The 6 GHz frequency won't carry as far as lower frequencies, but it will make up for this with wider channels allowing some customers to get much faster broadband speeds.

  The biggest change from 6 GHz frequency will be a new home WiFi environment. There will be a huge improvement in WiFi performance due to a lessening of interference. For example, the current 5 GHz WiFi operates on six 80 GHz channels and two 160 GHz channels. Interference comes when multiple devices in the home (or at neighbors) try to use the same channels. The new 6 GHz spectrum adds seven 160 GHz channels, which could be divided into as many as 59 20 GHz channels. We'll be able to segregate a big bandwidth device like a computer to its own channel. WiFi 6 also allows for orthogonal frequency-division multiple access (OFDMA), which allows devices to transmit to a channel simultaneously. Currently, only one device at a time communicates with a WiFi router.
- Mesh Wireless Technology Has Legs. Wireless mesh networks operate by bouncing a signal from customer to customer. This technology is now available in the city because it is being deployed by Starry. If fiber is brought to each neighborhood mesh, theoretically, the technology will be able to deliver gigabit speeds – with the caveats that the wireless signals struggle with vegetation and require nearly perfect line-of-sight.
- Biggest ISP Developing Proprietary Technology. Some of the biggest ISPs in the industry have been developing proprietary technology used only by themselves. High up on the list is Comcast and Verizon. The downside to the biggest ISPs using unique technology is that these technologies are not available to smaller ISPs, and the prices won't drop like would happen in an open hardware environment.
- Will Satellite Technology Make a Difference? There are a number of companies launching broadband satellites. It's too early to know how well these new technologies might perform and if they will make a dent in anything other than rural markets.