APRIL 18, 2022

ARKANSAS BROADBAND MASTER PLAN

ASSESSMENT AND RECOMMENDATIONS

BROADBAND DEVELOPMENT GROUP

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Introduction

Historically, Arkansas has had less available broadband internet access than other states. Our largely rural population has lacked the broadband infrastructure necessary to take advantage of the technologies needed to access healthcare and education and compete and prosper in the 21st Century. Authoritative sources, such as FCC Form 477, confirm that many families and businesses in the state lack reliable, affordable, high-quality broadband internet access. Policymakers across the state are aligned to address this issue and ensure that all households in Arkansas have access to what is now considered a basic necessity, regardless of where they live.

Under the leadership of Governor Asa Hutchinson, Arkansas embarked on an ambitious program to bridge the digital divide in Arkansas through the creation of the Arkansas Rural Connect (ARC) program. Early success in the program highlighted the need for even more funds and more projects to provide broadband internet access to underserved areas of the state.

When the COVID-19 pandemic began, most schools and many employers temporarily closed. With children needing continued instruction and for those employees able to work from home, the need for broadband became a stark and urgent reality. Federal funds became available to strengthen and support the state's commitment, and more projects were funded to address the needs of rural Arkansans. The pandemic also revealed that many areas of the state were alarmingly underserved, even those not considered rural.

Soon, there were several federal programs and funding sources for projects, some of which overlapped or competed against each other. Those responsible for approving, allocating, and administering those funds wanted to ensure we were investing wisely and being good stewards of available resources while striving to meet the needs of all Arkansans.

This project and report are the direct results of policymakers collaborating on the necessity for a forward-looking plan that addresses the concerns of all stakeholders. It is part inventory, part engineering study, part technology assessment, part financial analysis; part community involvement; and part public policy. Each part is necessary, but no one part is sufficient. These elements combine to provide the beginning of a vision that can move Arkansas into a national leadership position in delivering the technological future to all our residents.

We set out to answer three basic questions:

- What is the true state of broadband coverage?
- What is the most effective and efficient way to fund network deployment to bridge broadband gaps?
- What should a plan to disperse funds look like?

Our method was to:

- Develop build simulations and internet service provider (ISP) financial models for several broadband coverage scenarios to quantify the problem and identify the most efficient options to fill the gaps.
- Recommend an approach to program administration most likely to achieve goals, considering various funding sources and best practices from other programs.

We approached this project as a business case. To that end, we determined the scope of the problem, evaluated solutions to the problem, including the financial implications of possible designs, and created an implementation strategy. In addition, we developed a grassroots program that sought input from those affected in the communities around the state. Our team interviewed, met with, talked to, and debated with stakeholders about their needs, expectations, and opinions regarding broadband internet access. To ensure the transferability of the information we received, we met with people from all walks of life and all corners of the state.

This report is presented in several layers.

- The **full report** is available in both a document and a presentation format.
- There is an **executive summary** presentation.
- There is a **spatial database** with details of technical and financial requirements at the census block group (CBG) level.
- There is a **spreadsheet** containing the **project's data, analysis, and financial models**.

This comprehensive study sets a tone and direction for making wise use of these once-in-a-generation resources.

Executive Summary

In October 2021, Broadband Development Group was hired to develop a comprehensive master plan for how the state of Arkansas should approach the inequitable availability of broadband service across the state.

RESEARCH

To develop our key findings and recommendations, we conducted the following research and community outreach from October 2021 to March 2022:

- We reviewed FCC Form 477 mapping data, recent federal and state grant awards, provider network data (GIS shapefiles, address/service lists, fiber/RF coverage maps), and directly researched address-by-address service availability on provider websites to update current and planned broadband coverage for all census blocks.
- We hosted or attended more than 300 community meetings in all 75 counties and received more than 18,000 surveys from residents in every county across the state.
  - Several Arkansas legislators participated in these meetings to ensure a variety of voices were heard during the community fact-finding portion of our research.
  - Arkansas Farm Bureau, Arkansas Municipal League, Arkansas State Chamber of Commerce, Arkansas Department of Education, Arkansas State Library Association, Association of Arkansas Counties, Arkansas Sheriffs Association and several other association groups helped set up community meetings.
- We consulted with nearly 30 broadband providers to learn more about their perspectives on the program's effectiveness, how they would improve the program, their views on competition and regulation, their build plans, what additional grants they anticipate receiving or requesting, and their needs going forward.

KEY FINDINGS

Based on our research and analysis, this report can be summed up by three key findings:

- **Significant progress has already been made to overcome the state's broadband problem with plans in place to make even more progress.**
  - The 2020 FCC Form 477, which influences most federal funding, states that Arkansas has 251,000 households lacking adequate broadband access.
    - Underserved households are those with less than 100+ Mbps access.
  - Our research has corrected the FCC map by identifying mischaracterized reports to reduce this number to about 210,000 households.
  - Furthermore, the state has worked through various state and federal programs to create coverage for about another 100,000 households.
  - The remaining 110,000 households are not currently addressed by any identified programs at any level. We estimate the cost of covering these households at about $500 million.
  - However, 31,000 of the households are currently covered under Rural Digital Opportunity Fund (RDOF) grants to wireless providers, of which we have some concerns. Federal rules prohibit further funding to serve these locations. We think there is

significant risk that these households will not be served in a timely or technologically sufficient manner.

- **Arkansas should focus its efforts on providing broadband service to the remaining 110,000 underserved households not currently served by any federal grants. The expected cost for this effort is roughly up to $550 million and can be funded through American Rescue Plan Act (ARPA) and Infrastructure Investment and Jobs Act (IIJA) grants.**
  - A few options exist to provide broadband services to these households:
    - If we tap into forthcoming federal funds in the range of $254 to $358 million, we should be able to reduce the remaining 110,000 households down to about 10,000 underserved households within three years.
    - The final 10,000 homes, which represents less than one percent (0.83%) of Arkansas households, however, would be the toughest barrier to overcome since many of these homes are in some of the most rural and sparsely populated areas of the state.
    - We estimate it would require more than $200 million or approximately 30 to 40% of the remaining additional federal funds to get to zero, or roughly $20,000 for every remaining household.

- **The existing ARC program, with some modifications, will help us get there.**
  - **We recommend the state put in place competitive bidding for grants.**
    - Currently, providers tell the state how much they need for a project. Under the modified plan, however, the state should solicit multiple proposals for each project.
  - **We recommend requiring affordability on rates.**
    - Survey results from potential subscribers statewide indicate that affordable service is thought to be roughly $50 or less per month.
    - The business case for suggested subsidy levels in this report uses $50 per month as an affordable rate that predicts a 15% IRR for providers.
  - **We recommend future proofing the technology deployment so we don't have to do this again in five to seven years.**
    - We know that fiber optics technology is the key in giving us the ability to ramp up speeds in the future.
    - We don't want the state to fall behind again, and that's why future proofing with fiber optics is such a critical investment for the state.

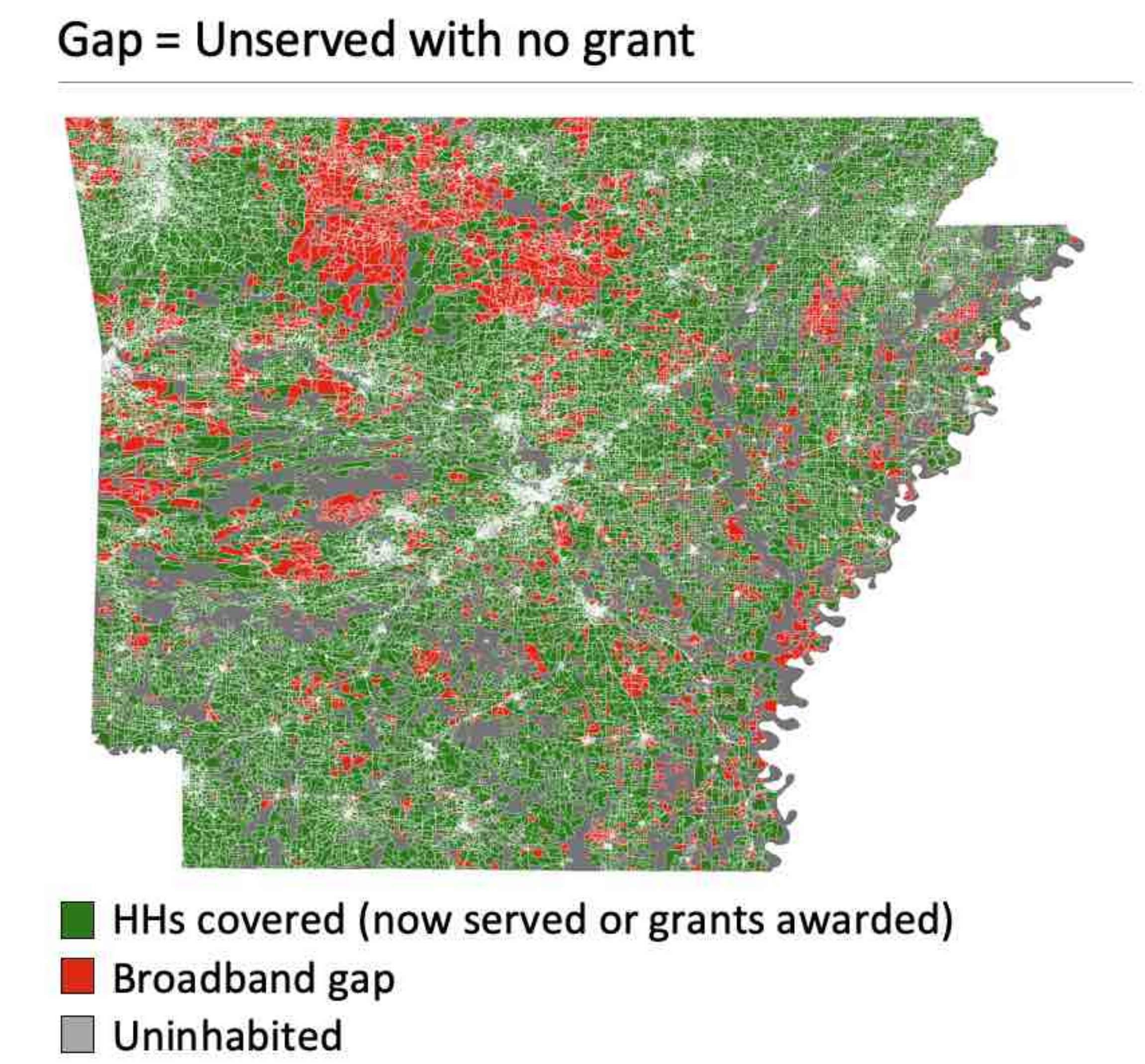
WHY IS THIS IMPORTANT?

From buying groceries and changing our thermostat to connecting with loved ones and scheduling medical visits, we live in a digital world where everything we need is only a click away. At least some of us do. Unfortunately, too many households across Arkansas are still unable to access high-quality broadband internet, which limits their options to participate and succeed in our rapidly changing way of life.

The last two years have served as a much-needed impetus for change. When the COVID pandemic began, life as we knew it came to a screeching halt. Kids logged in for school from their kitchen table. Employees tuned in for daily Zoom calls. Small businesses were forced to pivot or establish ecommerce sites, and many were left scrambling to keep operations going while being forced to temporarily close their physical structures. This once-in-a-lifetime pandemic served as a sobering realization of the importance of reliable, high-speed broadband internet access, and should reinforce the need to provide all Arkansans with access to the most basic human services.

WHAT'S NEXT?

Thanks to federal funding, our goal to drastically reduce the number of Arkansas households without access to adequate broadband is well within reach. In the Arkansas Broadband Master Plan, we present our findings, walk through various issues to be resolved and outline key challenges moving forward. For the full report, visit broadband.arkansas.gov.



Acronym Glossary

ACAM: Alternative Connect America Cost Model

ARC: Arkansas Rural Connect

ARPA: American Rescue Plan Act

ARPU: Average Revenue Per User

ASBO: Arkansas State Broadband Office

AWS: Amazon Web Services

CAF II: Connect America Fund

CARES Act: Covid Aid, Relief, and Economic Security Act

DOCSIS: Data-Over-Cable-Service-Interface-Specification

DSL: Digital Subscriber Line

FCC: Federal Communications Commission

FWA: Fixed Wireless Access

FTTH: Fiber to The Home

GIS: Geographic Information System

HH: Households

IIJA: Infrastructure Investment and Jobs Act

IRR: Internal Rate of Return

ISDN: Integrated Services Digital Network

ISP: Internet Service Provider

LEO: Low Earth Orbit

NTIA: National Telecommunications and Information Administration

RDOF: Rural Digital Opportunities Fund

USDA: United States Department of Agriculture

Current Broadband Coverage

To assess coverage, it is first necessary to define the threshold speed separating households considered *served* from those considered *underserved*. With a defined threshold, we can then classify all households accordingly.

Defining the Broadband gap

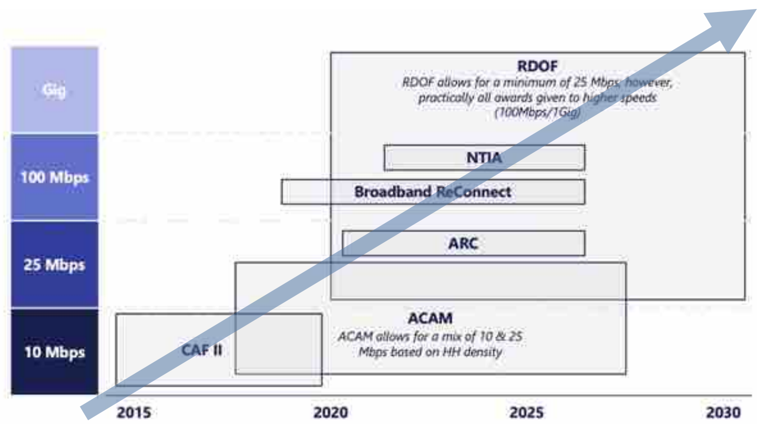


Figure 1. Federal broadband programs keep increasing the definition of the broadband gap speed

The speed threshold that defines those in the broadband gap keeps shifting to higher speeds. The federal CAF II funding program defined the target speed for upgrades at 10/1 Mbps, while the later federal A-CAM program defined the gap as a mix of 10/1 and 25/3 Mbps. Arkansas's ARC program targeted areas unserved by at least 25/3 Mbps while USDA's ReConnect program considered speed less than 100 Mbps to be underserved. NTIA prioritized 25/3, then 100/20 speed thresholds in their 2021 broadband program and has set the same guidance for their forthcoming IIJA BEAD program. The $9.2-billion RDOF Phase 1 program awarded grants to upgrade service over a range from 25/3 to 1000/500 Mbps.

It is no surprise that the threshold for underserved broadband keeps shifting to higher speeds. The Internet as a consumer product has brought increasing access speeds for three decades. Dial-up modems grew from 2.4 Kbps to 9.6, 14.4, 28.8 and finally topped out at 56 Kbps. This was followed by ISDN (Integrated Services Digital Network) offering 64 and 128 Kbps and then DSL (Digital Subscriber Line) at 1.5 Mbps. DSL increased speeds up to 100 Mbps, but availability for top-end speed is limited to those near the telephone company hub, with most households relegated to sub-10 Mbps service. In urban areas, cable TV companies were lucky that the coaxial cable they had installed years ago for television service was upgradeable to provide broadband at high speed (75, 150, 300+ Mbps) with DOCSIS (Data-Over-Cable-Service-Interface-Specification) cable modems that dominate broadband in urban areas but leave a gap in rural areas where cable TV networks were never deployed due to infeasible economics. A decade ago, Google Fiber decided to spur faster Fiber-to-the-Home (FTTH) deployment, offering 1 Gbps (in urban areas) for $70 per month. Since then, many firms have followed suit and now offer FTTH at 1 Gbps and higher speeds.

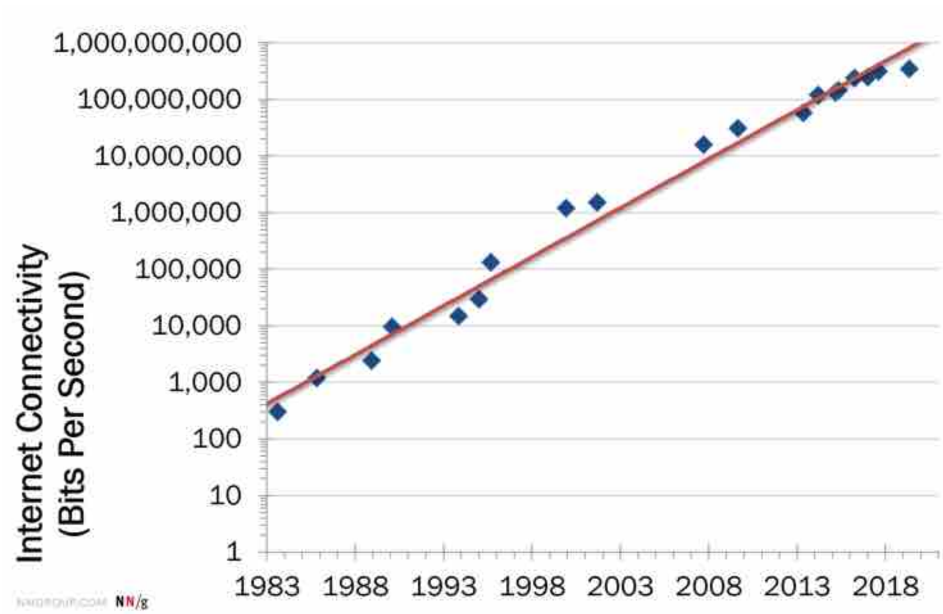


Figure 2. Nielsen's Law of home broadband speed

Engineer Jakob Nielsen plotted home Internet speed availability over the past 30 years (Figure 2) and found very consistent growth of about 50% annually, which translates to a 57x speed increase every decade. This principle is now called “Nielsen’s Law” and parallels the more famous “Moore’s Law” that has accurately predicted growth in computer chip power of 60% annually. It’s difficult for people and policy to keep pace with this exponentially growing phenomenon.

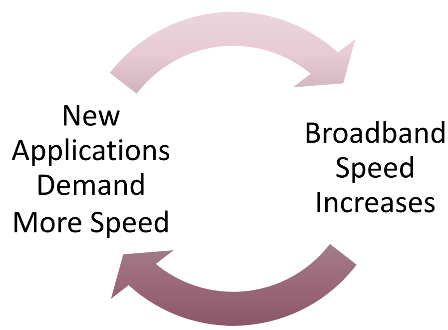


Figure 3. Virtuous cycle of applications and broadband speed

The tech industry is in a “virtuous cycle” whereby increased bandwidth stimulates the creation of more demanding applications which in turn drives demand for more bandwidth. In the early days of the consumer internet, the web was mostly text and still images, but as access speeds increased, sites served up audio and then video content. As the bandwidth increased to accommodate these demands, video streaming emerged. We then we saw the quality of video (and bandwidth consumption) increase from SD (2-3 Mbps) to HD (5-8 Mbps) to 4K (15-25 Mbps), and now we see 8K (40-50 Mbps) on the horizon. Simultaneously, we anticipate futuristic technology like holographic displays and 360-degree extended reality goggles that will doubtlessly demand even higher speed. Given this moving target, what speed should define the broadband gap for the purpose of defining which households are eligible for grant programs to upgrade their speed?

The FCC publishes a bandwidth usage guide shown in Figure 4 that accounts for typical usage and concludes that families need up to 80 Mbps today, which is an argument for at least 100 Mbps service.

FCC Minimum Download Speeds

Activity	Minimum Download Mbps
General Browsing and Email	1
Student / Telecommuting	5-25
Social Media	1
Streaming SD Video	3-4
Streaming HD Video	5-8
Streaming Ultra HD 4K Video	25
Personal Video Call	1 – 1.5
HD Video Teleconferencing	6
Connected Game Console	3
Online Multiplayer	4

Service Provider Minimum Speeds

Service Provider	Minimum Download Mbps
Zoom	1-4
Netflix (HD)	5
Netflix (4K)	25
Xbox Live	3

Bandwidth Needs: Illustrative Household

Households require bandwidth for multiple simultaneous use cases during peak hours

Two children doing online schoolwork	25-50 Mbps
Netflix streaming on living room smart TV	5-25 Mbps
Parent attending Zoom meeting	1-4 Mbps
Total Bandwidth Required	**~30-80 Mbps**

Figure 4. FCC application-based accounting makes a case for 100 Mbps

In the recent massive federal Rural Digital Opportunity Fund (RDOF), the FCC conducted a reverse auction for broadband deployment subsidies at 25/3 Mbps (minimum), 50/10 Mbps (baseline), 100/20 Mbps (above baseline), and 1000/500 Mbps (gigabit tier). Less than 1% of winners nationwide won with less than the 100/20 Mbps tier; in Arkansas, 100% of awards went to 100/20 Mbps bids or higher (Figure 5) – another signal that 100 Mbps is the current mainstream minimum target. (RDOF 904 Auction Award winners can be found at https://www.fcc.gov/auction/904/round-results.)

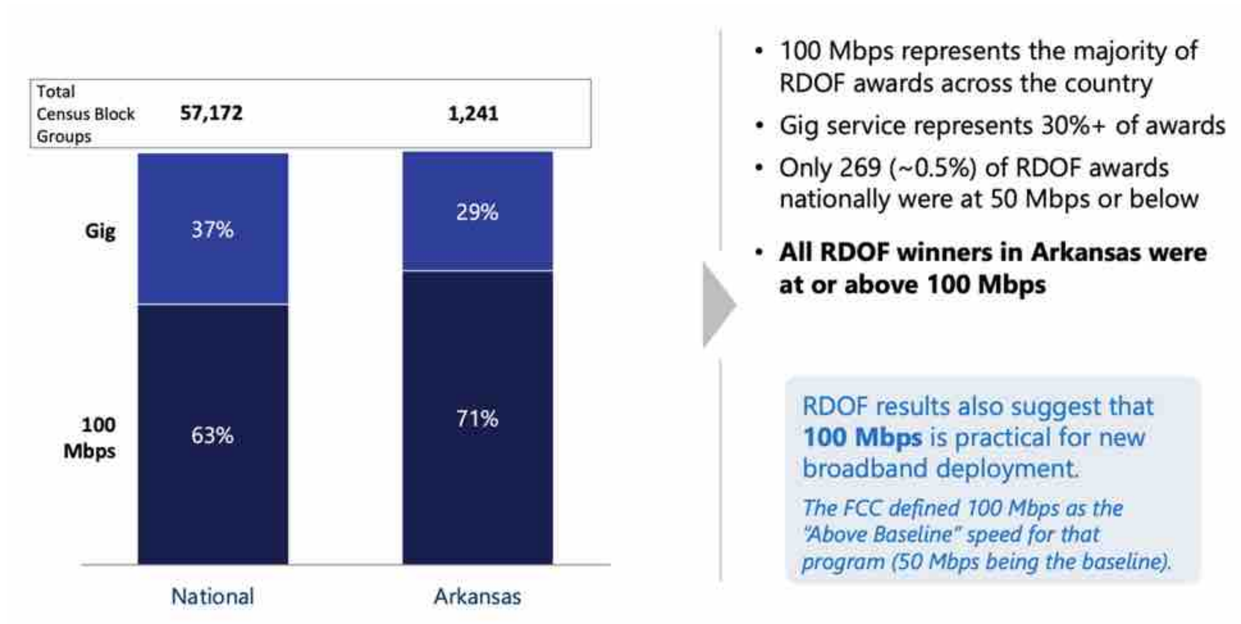


Figure 5. RDOF indicates 100 Mbps is the right target

We are also hearing national leadership (Figure 6) asserting 100 Mbps is the current acceptable minimum broadband speed.

Jessica Rosenworcel **(FCC Chairwoman)**	"It's **time for the FCC to adopt a standard of 100 megabits per second.** I regret we are so unambitious that we do not even consider this here. Moreover, we need to **revamp our thinking about upload speeds**. At present, our standard is 3 megabits per second. But **this asymmetrical approach is dated**. We need to recognize that with extraordinary changes in data processing and cloud storage, upload speeds should be rethought." *- Dissenting Statement to Fifteenth Broadband Deployment Report Notice Of Inquiry (10/23/2019)* "It seems crazy that we are going to sit here today and pronounce what service speeds are adequate ten years hence. But we do just that with the baseline speed of 25 megabits per second that we propose ... I don't think we can know exactly how we will use broadband capacity ten years hence. But I do think that right here and now we need to be more ambitious. **I think 100 megabits per second is table stakes and we are going to need more symmetrical upload and download speeds** as we move from an internet that is about consumption to one that is about creation. This is especially true in rural areas, where we anticipate whole new economies developing based on mass amounts of data from precision agriculture." *- Partially Dissenting Statement to RDOF Report and Order (2/7/2020)*
Bipartisan Group of Senators	"Going forward, **we should make every effort to spend limited federal dollars on broadband networks capable of providing sufficient download and upload speeds and quality**, including low latency, high reliability, and low network jitter, for modern and emerging uses... **Our goal for new deployment should be symmetrical speeds of 100 Mbps**, allowing for limited variation when dictated by geography, topography, or unreasonable cost" *– Broadband Speed Letter addressed to FCC Chairwoman, USDA Secretary, USDOC Secretary, NEC Directory (3/28/21)*

Figure 6. Washington leadership signaling that 100 Mbps is the current threshold speed for policy

Furthermore, all recent and forthcoming federal funds (Figure 7) have set the threshold speed to 100 Mbps, so we see a consistent **consensus view that the definition of the broadband gap threshold speed today is 100 Mbps**.

Recent Federal Programs Embrace 100 Mbps Target	
NTIA Infrastructure Fund	**100/20 Mbps**
ARPA SLFRP	**100/20 Mbps, path to 100/100**
ARPA Capital Projects Fund	**100/100 Mbps**
IIJA Bead	**100/20 Mbps, prefer fiber**

Figure 7. Recent federal broadband funding programs consistently require 100 Mbps download speed.

With 100 Mbps set as the definition of the threshold speed, we can analyze coverage to classify all Arkansas households as either served (covered) or unserved (in the broadband gap).

Current and Planned Broadband Coverage

An accurate view of current and planned broadband coverage is critical to enable the efficient use of funds to fill the coverage gap. The FCC collects coverage data semi-annually from broadband service providers who report the highest speed available in each census block where they offer service. The FCC compiles and presents this data in their national broadband map. This map has been used by state and federal agencies to determine census block eligibility for various broadband funding programs. The gray areas in Figure 8 are census blocks with households unserved by at least 100 Mbps service, according to FCC Form 477 data. There are 251,000 households in these gray areas, about 21% of all households in Arkansas.

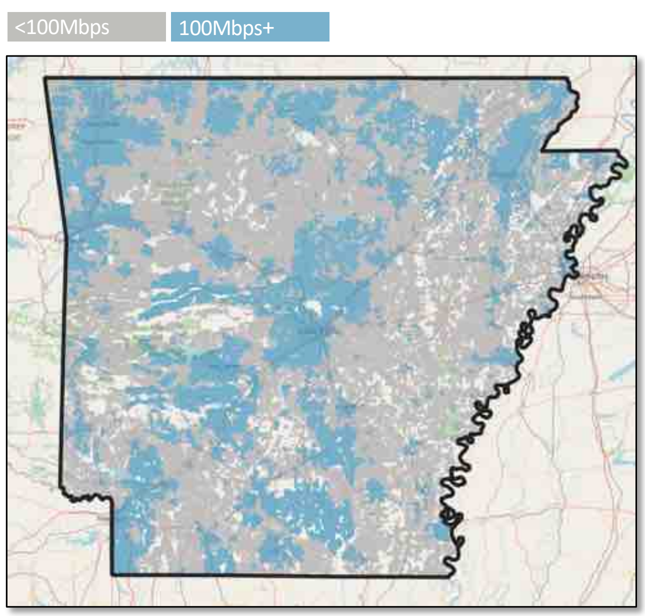


Figure 8. Baseline broadband gap per FCC Form 477

Problems with FCC Form 477 and the National Broadband Map

While FCC Form 477 data provides a useful baseline, the map has been widely criticized for underreporting the broadband gap. In a widely cited paper[1] based on an address-level sampling, broadband consultancy BroadbandNow concludes that the FCC undercounts the broadband gap by a factor of two. Microsoft's analysis based on the speed of software downloads from its servers estimates the gap is three times larger than reported by FCC Form 477. There are a number of potential flaws with the FCC data, including the following:

- Granularity Problem
  One of the chief criticisms stems from the fact that the methodology works on census block granularity rather than address-by-address. The methodology declares whole census blocks served if any one address is served. Census blocks have a small number of households, so the geographical coverage of any one census block is very small in urban areas, but larger in sparser populations. As such, the assumption that all households in a block are served if any one address is served is usually correct in denser areas, but less so in sparse areas where broadband coverage has more variability over larger areas.

- Technical Problem
  There is a related technology factor in sparse areas that impacts the accuracy of using any one household as a proxy for a whole census block. Speed for common rural broadband technologies like Fixed Wireless Access (FWA) and Digital Subscriber Line (DSL) is distance-dependent such that 100 Mbps service might be available within a few hundred feet of a service provider hub, dropping to a few Mbps a few miles, or feet farther on. Census blocks with these rural technologies are reported as covered by the highest speed available to any one household in the block, while more distant households in the census block may have only much lower speed service, or no service. In such cases, service providers are reporting coverage accurately as per the FCC's methodology, but the methodology itself is flawed.

- Time Lag Problem
  Another problem with FCC Form 477 is that the most recently published data is from reports filed by service providers at the end of Q3 2020, so that data is now more than two and a half years out-of-date. The FCC is in a quandary since huge funding programs like RDOF require a long period of time during which maps need to be frozen for program administration through a process of defining eligible areas, computing available subsidies, publishing rules, qualifying bidders, adjudicating challenges, executing auctions, dispersing funds and so forth. Meanwhile, networks are expanding, new locations are coming online, and the map data is getting stale.

  In Arkansas, rural electrical co-ops and others have deployed several new broadband service options over the past couple of years, yet these new areas are not represented in the current published version of the FCC map. While the criticism of FCC Form 477 has focused on *underreporting* the broadband gap, we found that **the overall size of the broadband gap in Arkansas is *overreported* by the FCC map,** primarily due to recent broadband expansion efforts.

- Compliance Problem
  We also found that service providers both underreported and overreported coverage in FCC 477 when we compared those filings with actual internal company broadband coverage data. Some underreported coverage is certainly expected since FCC reporting

lags the deployment of new broadband coverage. However, we found instances of overreported coverage for which there is no obvious explanation. We can speculate that some combination of lax compliance, erroneous reporting, misinterpretation of rules, or technical complications contributed to these situations. There is no process to audit or enforce accurate reporting and no penalty for inaccurate reporting, so providers may not be overly concerned with accuracy.

Accurate Broadband Coverage

Bridging the broadband gap is critical to all Arkansans, especially those lacking a broadband option today. Since solving this problem will be very expensive, it's critical to target funds efficiently – and that depends on having accurate broadband maps. To that end, we collected data that refines the federal map and provides a much more accurate picture of broadband coverage in Arkansas.

Methodology

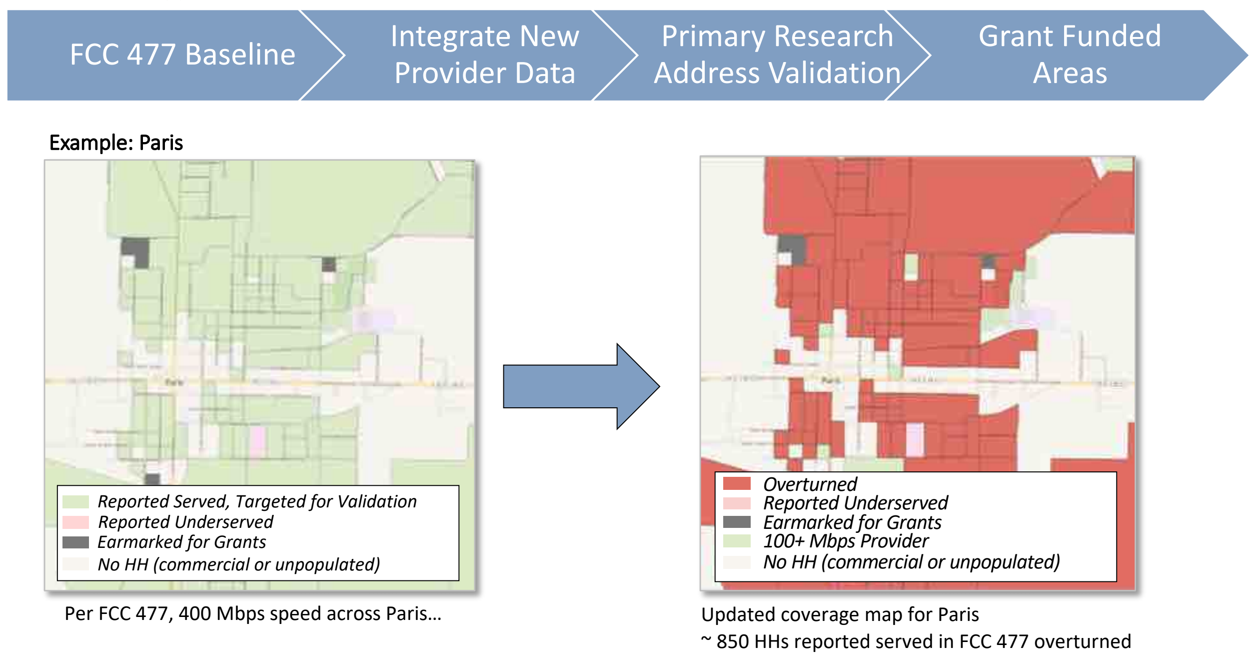


Figure 9. Process to create a more accurate broadband coverage map

Step 1: Baseline Map from FCC Form 477

FCC Form 477 data attempts to specify where there is *current* broadband coverage. With FCC Form 477 data as a starting point, we refined this baseline map with overriding data from our research.

Step 2: Directly Sourced Service Provider Coverage Data

We integrated specific network data from service providers who agreed to participate in our project. Operators provided data in various forms including address-by-address service coverage spreadsheets, GIS shapefile coverage maps, and/or detailed network infrastructure diagrams.

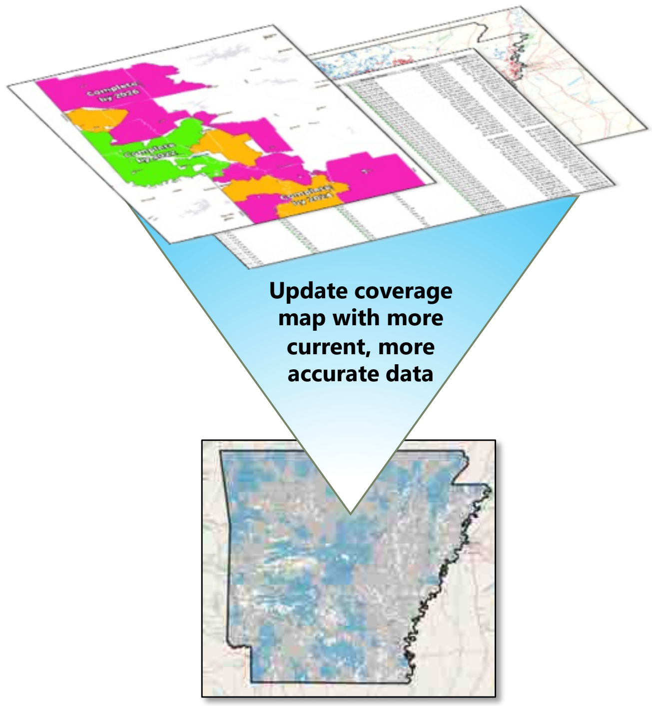


Figure 10. Integration of provider-sourced broadband coverage data

Step 3: Address-Specific Broadband Availability Checks at Service Provider Web Sites

In urban areas where broadband was widely available, we found anomalies where blocks were unexpectedly *unserved* by 100+ Mbps broadband. We checked broadband availability in these blocks and corrected these errors. For example, in Figure 11, the census block containing the Leverette Garden Apartments in Fayetteville is wrongly reported as unserved in FCC 477, though surrounded by multiple 100+ Mbps providers with a carrier "point-of-presence" in the apartment complex itself. Upon further verification, it was determined that Gigabit service is available at this location from Cox Cable.

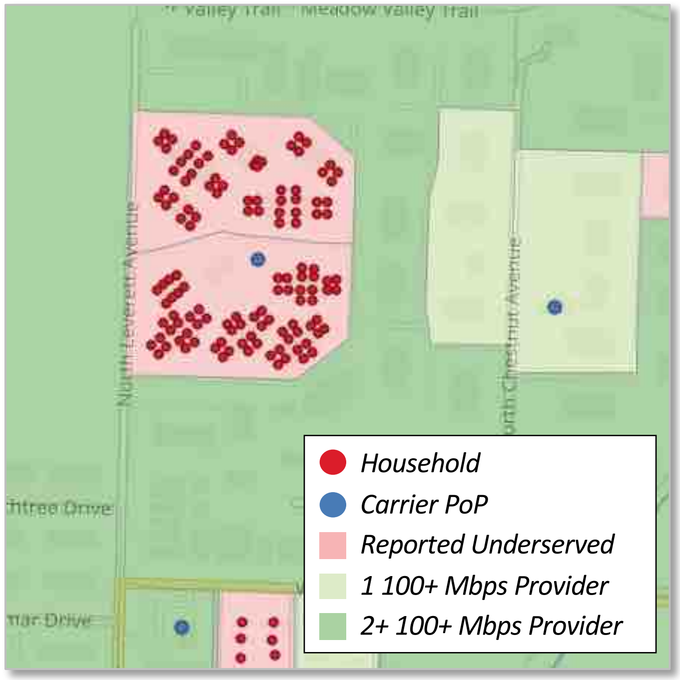


Figure 11. Example of underreported coverage in Fayetteville

For census blocks reported with a single 100+ Mbps provider and no plan for future coverage from a grant award, we performed address-specific website lookups at service provider websites to validate or invalidate the availability of 100+ Mbps service. Checking service availability by address at provider websites is a manual, tedious, and time-consuming process. To implement this program at a larger scale, we leveraged an Amazon AWS service to enlist a global network of "gig workers" to follow scripts and report findings. Trial runs were conducted to confirm accuracy before we scaled up to high volume. Every address was checked twice by two separate "master level" workers, and any conflicting results were re-evaluated. More than 125,000 address-specific web queries for Arkansas street addresses were performed for this study. To put that in perspective, BroadbandNow similarly sampled only 11,000 addresses nationwide to conclude that the FCC map underreports the broadband gap by a factor of two, in its widely cited paper [1].

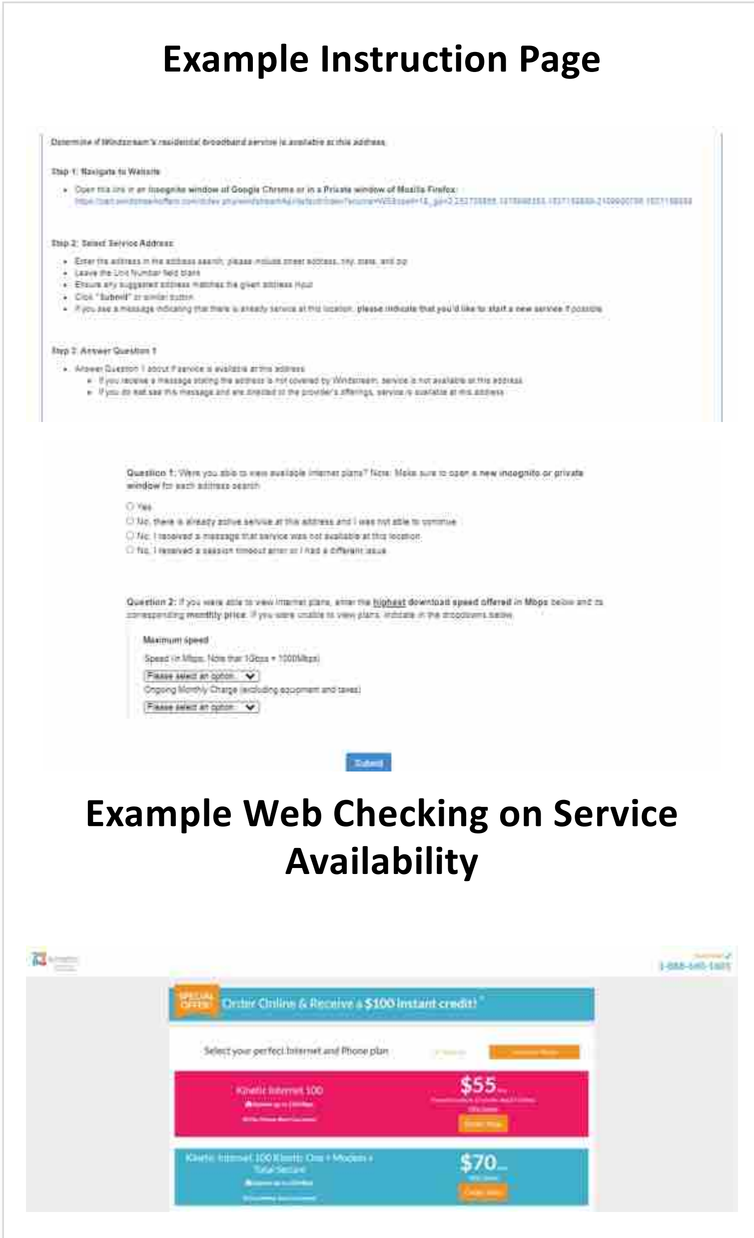


Figure 12. Example instruction page for address-specific service availability checks at provider web sites

Step 4: Integrated Data for Grant-Funded Areas

Awarded grants (CAFII, ACAM, RDOF, ARC, NTIA, USDA) define *planned* coverage from broadband grant awards. The set of households lacking both current 100+ Mbps coverage and planned coverage from awarded grants for 100+ Mbps comprise one key definition of the remaining broadband gap.

Findings

According to FCC 477 data, there are 251,000 HH lacking 100+ Mbps service in Arkansas. Through our methodology, **the status of 132,000 HH was corrected**.

- 45,000 HH reported as served by 100+ Mbps service were corrected to unserved status
- 87,000 HH reported as unserved by 100+ Mbps were corrected to served status

The net result of this process is an increase in coverage of 42,000 HH due primarily to new builds during the last few years that are not reflected in the published vintage of FCC Form 477 data. **The updated map of current broadband coverage shows the broadband gap is reduced from 251,000 HH (FCC) to 209,000 HH lacking 100 Mbps broadband service today**.

<100Mbps | 100Mbps+

Form 477 Reported Coverage Map

- **251K HHs (21%) reportedly underserved** with speeds < 100 Mbps
- Based on December 2020 FCC Form 477

Updated Current Coverage Map

- **Findings: 209K HHs (17%) are underserved**
- Net improvement primarily due to extensive new coverage by service providers

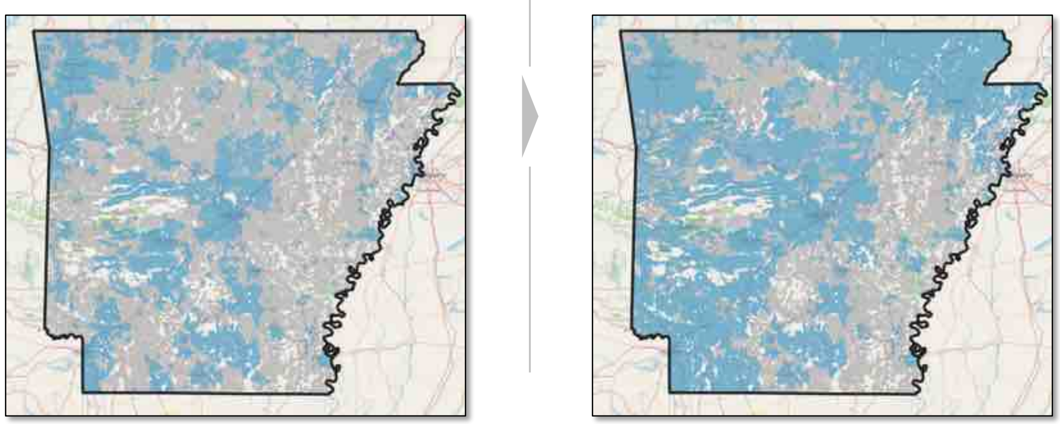


Figure 13. Coverage status corrected for 132,000 HH resulting in net reduction in gap by 42,000 HH

Of the 209,000 HH unserved by 100+ Mbps broadband today, **99,000 HH are planned for 100 Mbps coverage through one or more of the various grant programs**, primarily RDOF Phase 1, leaving **110,000 HH with no access to 100+ Mbps broadband today and no plan for 100+ Mbps broadband in the future**.

Most pending grants are from the federal RDOF program, which presents several risks that have been widely reported.

- **Weak bidder qualification:** Several large winners in the RDOF auction have questionable ability to execute on their commitments. Bidder defaults are possible, perhaps likely, with the result of leaving large areas unserved. Still, federal rules prohibit states from making awards to more highly-qualified applicants.
- **Protracted deployment timeframe:** RDOF requires only 40% of build-out after three years, measured on a statewide basis for each bidder, with completion only after six years plus an extra two years to cover added locations. Up to 20% of initial locations could wait up to six years for service in compliant deployments. Since accounting is done on a statewide basis, a provider could fulfill its obligations in some areas, while deploying nothing in other areas until the sixth year. Worse, they could default on those neglected

areas after six years, leaving some households without broadband. The protracted timeframe prevents early remediation of problems.

- **Wireless technology risk**
  - Of the Arkansas households covered by RDOF grants, 31,000 are likely planned for coverage by wireless technology – either FWA (Fixed Wireless Access) or LEO (Low Earth Orbit) satellite (Starlink). Wireless broadband raises the following concerns as compared to fiber (FTTH):
  - FWA offers less deterministic coverage and speed than FTTH with variable performance per HH depending on distance, obstructions (trees and hills), congestion, weather, and other wireless technicalities
  - Starlink coverage is also limited by tree cover, as customer satellite dishes require a wide clear view of the sky, which is very problematic for households in Arkansas's heavily forested neighborhoods.
  - There is a technical performance risk that LEO service will slow down as more users connect.
  - Starlink is also facing regulatory headwinds with protests from NASA about safety for future space launches and for asteroid detection if Starlink augments its planned 12,000 constellation (2,000 deployed so far) with 30,000 additional satellites. If Starlink is unable to fully deploy its planned constellation, system capacity will be reduced and the risk of performance problems will increase.
  - FWA technology vendor Tarana announced that ISP Resound plans to use its technology to meet 1,000/500 Mbps requirement in RDOF areas won by Resound in Arkansas. Since Tarana's technology is new and unproven with unprecedented performance claims, there is a technical risk as compared to well-known and proven FTTH technology.
  - FWA and LEO offer speeds lower than FTTH today and lack a roadmap to multi-gigabit speeds in decades ahead. Modern FWA is commonly touted as feasible for 100/20 Mbps service, but usually not for 100/100. No prior FWA technology has come close to the 1000/500 RDOF requirement claimed by Tarana. While 100/20 is feasible today and is expected to be viable for several years, there is no reason to believe that gigabit+ speeds will not be needed during the lifetime of this infrastructure investment.

Due to the near-term performance risk with FWA and LEO technologies, and the expectation that FTTH will be needed in the long run for gigabit+ speeds, it is useful to consider a scenario whereby RDOF grant areas planned for coverage only by wireless technology will also ultimately need subsidies for the deployment of FTTH. In this case, the broadband gap would increase by 31,000 HH to 141,000 HH.

It is impossible to know exactly where grant-supported future broadband deployments will not ultimately be successfully deployed, but 141,000 provides a good middle case (Scenario 3), while Scenarios 1 and 2 bracket the "ceiling" and "floor" cases, as shown in Figure 14.

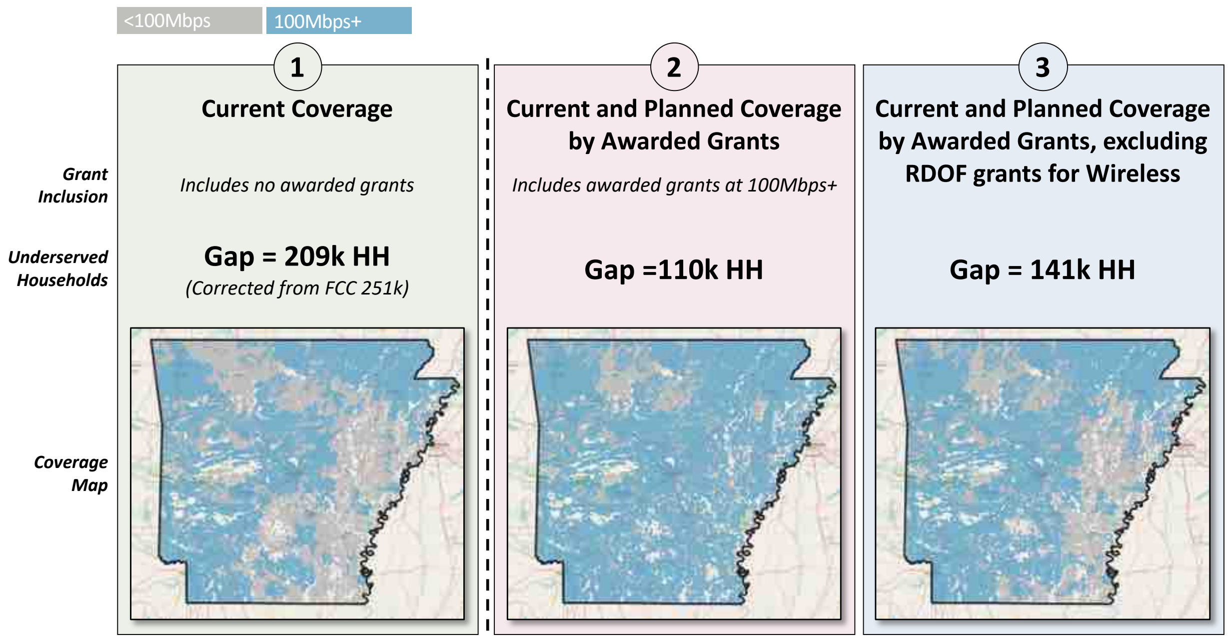


Figure 14. Top-level scenarios for budget guidance

Scenario 1 models a hypothetical worst-case scenario where no pending grants are assumed to succeed.

Scenario 2 models the best case where all pending grants are assumed to succeed, including RDOF awards for fixed wireless and satellite coverage. However, Scenario 2 is also recommended for near-term planning because federal rules prohibit the use of funds in areas already awarded grants. While the state may want to accelerate broadband availability in areas awarded RDOF grants, forthcoming federal funds are precluded from use for this purpose.

Map Maintenance

Broadband coverage maps are constantly changing as providers expand and upgrade their networks and new homes, neighborhoods, and multi-tenant buildings are constructed. With the status of 132,000 HH corrected from the published FCC map, **the coverage map resulting from this project is much more current and accurate**.

Challenge Process

Though the updated map is far more accurate, as part of the grant application process, we recommend a robust challenge process whereby providers can challenge the eligibility of census blocks for funding. This is important because:

- Coverage is always changing.
- Provider data may contain errors.
- Some smaller providers do not have online address validation.
- Providers may have undisclosed but firm plans to build out in new areas.

Providers with available services or firm deployment plans have a strong incentive to report coverage to prevent loss of market share to new subsidized competitors. While the motivation to report coverage already exists, the prospect of real near-term subsidies is likely to increase attention to accuracy. The challenge process should clear up any remaining “noise” in the coverage map.

New FCC Maps

Due to criticism of the national broadband map based on Form 447, the FCC has undertaken a new process to revamp their maps[2]. The new map will use a master location database called the Broadband Serviceable Location Fabric (BSLF), which is being compiled under contract presently. The BSLF is supposed to be ready by June 2022, after which ~2,500 providers will have three months to submit coverage data. The FCC expects to make new maps available shortly thereafter. Providers will be asked to submit updates bi-annually, and the platform will provide a feedback mechanism whereby the map can be challenged and corrected. The idea is to produce a dynamic map that is constantly under refinement to reflect true broadband coverage as accurately as possible. The new mapping project is visionary and ambitious, though the outcome is uncertain; some FCC staffers working on the project have privately expressed some doubt about achieving the intended goals. The IIJA BEAD program is supposed to rely on these new FCC maps, so the state will need to monitor progress on this initiative, and integrate any new FCC map data, when available.

Budget to Bridge the Gap

To assess the budget to bridge the broadband gap, it is first necessary to define the upgrade target speed and technology.

Considerations for defining target upgrade speed and technology

Initial Speed

There is broad consensus that 100 Mbps is the threshold for defining the broadband gap today. Accordingly, upgrades to at least that speed will narrow the gap, so **we can consider 100 Mbps acceptable for the initial upgraded speed**.

With the increasing use of two-way video for distance learning and work-from-home applications, there is a push for symmetrical 100 Mbps uplink speed, though our opinion is that 20 Mbps uplink is sufficient for nearly all consumers today. The Wireless Internet Service Provider Association (WISPA) formally protested the symmetric requirement, arguing that asymmetric 20 Mbps is sufficient. In doing so, they also signaled that their members will struggle to meet the more demanding 100 Mbps uplink speed with FWA technology. It is arguable that the 100/100 requirement is almost a proxy for requiring fiber and blocking FWA solutions but doing so under the guise of a technology-agnostic uplink speed requirement rather than stating the technology preference explicitly.

Future Speed

Since speed is a moving target and infrastructure is a multi-decade investment, it makes no sense to limit the consideration of speed to only the *initial* minimum requirement. We have seen how federal funding programs have advanced the minimum requirement from 10/1 Mbps to 25/3 Mbps and now 100/20 or 100/100 Mbps. **Why fund infrastructure for *today's* speed with a blind eye to inevitably higher speed that will be needed during the lifetime of the upgraded infrastructure?**

Quality

Solutions should also be evaluated in terms of coverage **consistency and completeness**. For example, Fiber-to-the-Home (FTTH) can provide the same consistent speed to every connected household, whereas Fixed Wireless Access (FWA) can provide faster service to homes closer to a tower. Furthermore, FWA and Low Earth Orbit (LEO) satellite technologies cannot provide 100% coverage in all situations due to signal obstruction by buildings, hills, and trees, while FTTH has no such limitation. Speed potential is one thing, but the ability to assure that speed is equally distributed to every customer in an area is a qualitative measure that also matters.

Time-to-Deploy

Time is of the essence. The need for broadband to support work-from-home, distance-learning, and telemedicine is critical *now*. Accordingly, solutions must be weighed not only by current/future speed and quality, but also by the amount of time required to get people connected. While rapid deployment is highly valuable, the state must **weigh the cost of expediency against the cost of meeting broadband connectivity requirements over decades**.

Risk

It is vital to assure funds go toward firms and technologies with a low risk of failure. Financial losses and setbacks due to failed execution, failed technology, or failed firms, are devastating. The state should **strongly prefer technologies and firms with solid credentials and proven track records**. Government infrastructure decisions should not be swayed by unproven vendor claims, as these funds are going toward large-scale production networks, not vendor R&D projects.

Cost

Of course, the wish list must always be balanced against finite financial resources.

Figure 15 shows the list of available broadband access technologies.

- **Fiber-to-the-Home (FTTH)** is the premium home broadband technology that offers complete, consistent high-speed coverage, and is "future-proof" to meet increased speed requirements over time. The downside to fiber, on average, is higher cost and longer time to deploy.
- **Digital Subscriber Line (DSL)** is the adaptation of telephone company phone lines to Internet access. DSL has reached the limit of its potential and is largely obsolete. No new DSL copper lines are being deployed.
- **Data-Over-Cable-Service-Interface-Specification (DOCSIS)** is the adaptation of Cable TV networks to broadband Internet access. As coaxial cable deployed for television has inherently more data capacity than phone lines, DOCSIS has become the workhorse for urban broadband in the U.S. DOCSIS version 3.0 (2006) can deliver up to 1 Gbps with a notoriously slow uplink while newer version 3.1 (2013) can deliver 5-10 Gbps and 1-2 Gbps uplink. The forthcoming version 4.0 (2019) can deliver 10 Gbps with fast 6 Gbps uplink speed. The cable TV plant was deployed with private capital without the need for subsidies, primarily in urban areas where sufficient household density makes for attractive financial returns. For greenfield deployment in rural areas, FTTH is superior. However, for infill in gaps near DOCSIS deployments, the state can consider upgrades to DOCSIS 3.1 or higher as functionally sufficient in comparison to fiber.
- **Fixed Wireless Access (FWA)** refers to terrestrial wireless from towers, akin to mobile cellular operation. Indeed, mobile cellular technology can and is used for "Fixed Wireless" where the endpoint device is deployed at a stationary location. The Wireless Service Provider Association (WISPA) has advocated 100/20 Mbps broadband speed, as this is generally considered achievable by current FWA systems. WISPA has opposed the 100/100 requirement, as this is difficult to achieve for most FWA systems. The fact of WISPA's opposition to 100/100 indicates the technology is near its current limit at that speed, which is a big concern since the minimum requirement for broadband speed will inevitably increase rapidly in the years ahead. While new vendors like Tarana may tout higher performance today, or have a roadmap to higher performance over time, such claims represent a higher risk as compared to FTTH (and DOCSIS) technologies that are deployed today in large-scale production networks.
- **Geosynchronous Equatorial Orbit (GEO)** satellite technology has been around for years. HughesNet and Viasat are the two current providers of this technology. The great thing

about satellite service is that no cables or towers or any infrastructure is required on the ground; only a customer dish is needed. The problem with GEO is that it's like a single base station serving the entire country. It has a broad swath of spectrum, but it still has a finite capacity that cannot be easily upgraded. Furthermore, it suffers from very high latency – that is, the round-trip time for a message to reach the satellite, return to earth to reach an Internet server, then forward a response via another trip through the satellite. The round-trip average time for Viasat is over 0.6 seconds (>10 times the typical latency of other technologies), which is too slow for interactive applications like voice and gaming. Finally, the customer dish antenna needs clear access to a stationary point in the southern sky, which is not always possible due to trees, hills, or other obstructions. Given all the limitations, GEO is a niche technology that cannot be a general solution to fill the broadband gap. At best, it's a niche infill technology for "better-than-nothing" service.

- **Low Earth Orbit (LEO) satellite** is the new and intriguing satellite service that aims to solve the limitations of GEO technology through a constellation of thousands of moving satellites at much lower altitudes. Starlink by SpaceX (Elon Musk) is the most ambitious project and the only such network in service today. Empirical data from Ookla shows that the average Starlink customer is getting over 100 Mbps currently, so the results are encouraging. The altitude for Starlink satellites is 5% of GEO, and latency is well under 0.1 seconds, making it viable for voice and interactive applications. However, since LEO satellites are not stationary in the sky, customer antennas must track satellites as they move across the sky, and must handoff connections between satellites, not unlike a mobile phone that hands off calls between base stations as it goes down a highway. Since satellites could appear anywhere, customer dish antennas need a 360-degree view of the sky down to about 25-degrees over the horizon, seriously limiting the addressable market for LEO since many Arkansas homes are in forested areas or are adjacent to hills. Beyond the line-of-sight requirement, there are technical risks as Starlink scales up to higher usage. Starlink has deployed 2,000 of the planned 4,400 satellites in its phase one, with ~8,000 more satellites planned for phase 2 and applications made to the FCC for 30,000 more. In addition to technical scaling risk, the deployment will take several more years to roll out, while the need for broadband is now.

Technology Options

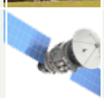
Wired (Aerial or Buried)	Fiber		**FTTH** Fiber-to-the-Home Fiber Optic Cables	• Fiber is the premier high-performance wired transmission technology • No other wired technology would be used for new infrastructure
	Copper		DSL Twisted pair copper Phone Lines	• Phone lines have been adapted for Internet access through dial-up and DSL • Retiring technology; nobody advocates copper phone lines for new infrastructure
			DOCSIS Coaxial copper Cable TV	• CableTV plant provides up to gigabit speeds with plant/electronics upgrades • Only attractive for upgrades to existing plant, which is mostly in urban areas
Wireless	Terrestrial (from towers)		**FWA** Fixed Wireless Access	• Terrestrial wireless delivered from tall towers, very much like mobile cellular • Indeed, cellular 4G/5G can be and is used for fixed wireless Internet access
	Satellite (from space)		GEO	• Space-based access from a stationary point in the sky 22,000 miles out • Viasat and Hughes are the two players • Slow speed and very high latency; GEO serves the "better than nothing" niche
			**LEO**	• Space-based access from a constellation of moving satellites < 1000 miles out • SpaceX is the primary player with their Starlink service

Figure 15. Wired and wireless broadband access technologies

All things considered, the three most promising technologies for bridging the broadband gap are FTTH, LEO, and FWA. These three technologies are compared in Figure 16 across six key dimensions.

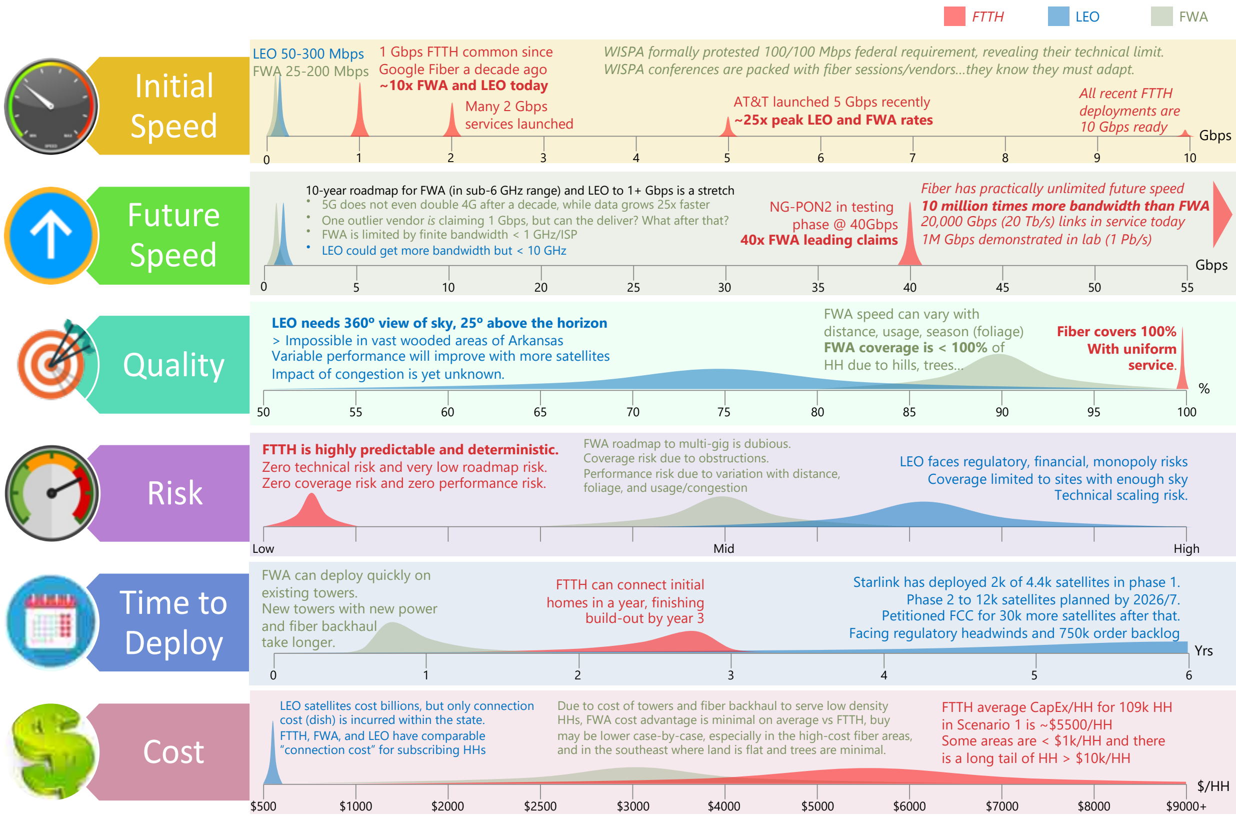


Figure 16. Comparison of FTTH, LEO, and FWA

FTTH is commonly deployed today with 10 Gbps technology that provides 100x growth for the ever-shifting broadband gap – enough to last 12 years without an upgrade according to Nielsen's Law – and 40 Gbps FTTH systems are in trials. Furthermore, fiber has known capacity to scale far beyond 40 Gbps as demonstrated in today's backbone links operating up to thousands of Gbps. Unlike wireless, physical obstructions and distance from the hub have no bearing on the ability to deliver uniform service to 100% of households. Consequently, **FTTH is by far the most future-proof, highest quality, and lowest risk technology.**

LEO is intriguing, but since there are likely years before the service is available to all, notwithstanding technical performance risks with scaling up, it really is not a solution that can meet time-to-deploy needs. Furthermore, trees and hills prevent LEO from being a solution for a large percentage of households, including multi-tenant buildings. Another concern with LEO is whether capacity can keep up with demand as the broadband gap threshold speed increases dramatically over time.

To the extent LEO is usable and available, consumers will be able to get this solution without infrastructure construction, though the $499 equipment cost, and $99 monthly service fee will be an impediment for many. The state might consider offering direct subsidies to customers for equipment, installation, and service in areas with no other broadband option in the future. The progress of Starlink and network buildout can be monitored over time to determine if there are situations where such an approach makes sense.

On average, FWA can be deployed more rapidly than FTTH, perhaps six to 18 months after funding is awarded versus two to three years for FTTH. Time to deploy is an important consideration; however, if one takes the long view (Figure 17), the risk is that investment in FWA to close the gap quickly could risk obsolescence in a few years, whereas generational broadband infrastructure investment is intended to serve for decades. If FWA were deployed at high scale to save 18 months versus FTTH, the risk is that coverage would need to be overbuilt with fiber in a few years anyway to keep up with ever-increasing demand.

FWA will offer lower cost in some places, but that will require case-by-case assessment. The cost of FWA coverage is largely a fixed cost for an area (tower, backhaul, and equipment), so the cost per household passed depends on the number of households covered and the fixed cost of the installation. Where towers and backhaul are in place, or where backhaul can be implemented with wireless links, coverage could be significantly lower than with fiber. In other locations, there might only be 50 homes in the coverage area of a tower that might cost $500,000 in total; at $10,000/HH passed, FWA may cost the same or more than FTTH. If the federal government provides sufficient funding to build out FTTH with funds that are not fungible for other uses, there is little to be gained by saving money with FWA.

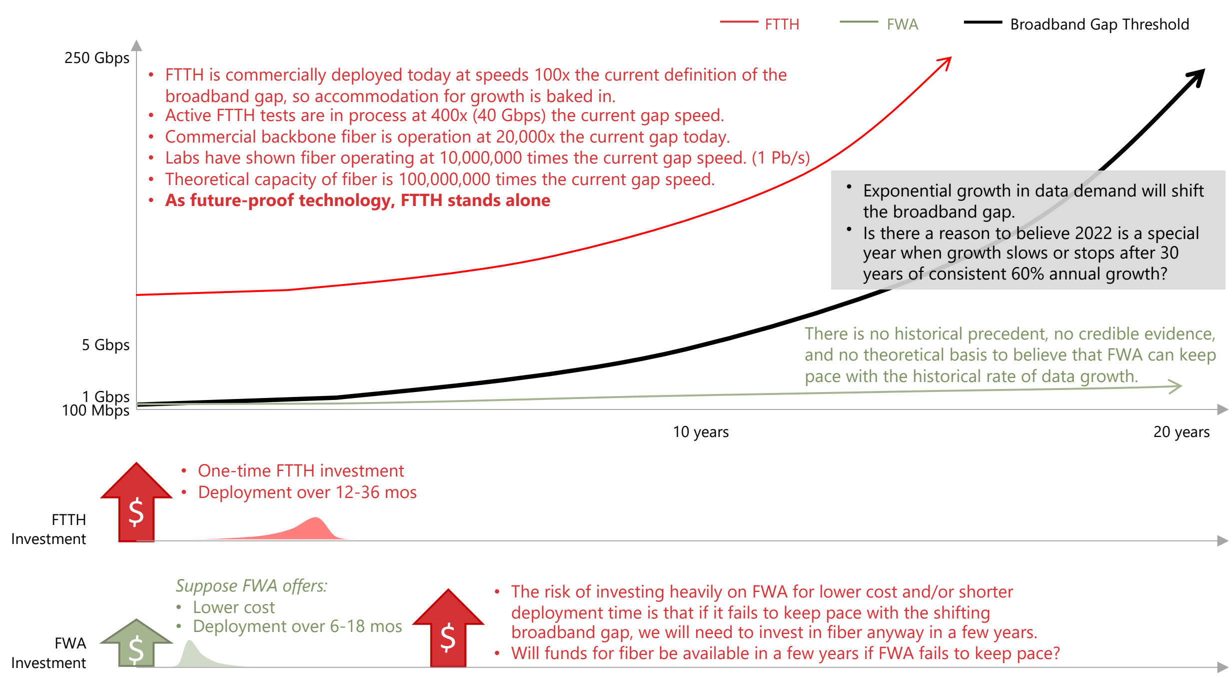


Figure 17. Taking the long view for generational infrastructure investment

Complementary Role of Fiber and Wireless Technologies

We need *two* complementary networks for the foreseeable future[3]:

1. Fiber for high performance at fixed locations
2. Wireless for basic connectivity over broad areas

Due to "future-proof" speed, uniform and comprehensive coverage, and low risk, FTTH is by far the technology-of-choice for fixed broadband to households. For home broadband applications, FWA and LEO are fallback options if FTTH is too costly or unavailable.

This work is focused on home broadband where fiber/FTTH offers unmatched high performance, but home broadband is not the whole Internet. We also need blanket Internet coverage at more modest speeds for:

- Mobile and portable devices (e.g., phones, tablets, laptops).
- Connected cars, tractors, drones, etc.
- Sensor networks, meters, and controls.

Wireless proponents may argue that fixed home broadband is simply a special case of mobile wireless where the endpoint is not moving. Certainly, with the current generation of 5G technology, mobile networks can be used for home broadband. Indeed, Verizon, AT&T, and T-Mobile all have fixed broadband offerings available in pockets around the country, including in parts of Arkansas. However, these services are marketed at < 100 Mbps, so they are only a stopgap solution that falls short of the current broadband gap threshold speed. Fixed wireless operators leveraging 5G technology optimized for *fixed* service, are stepping up to 100/20 Mbps. There is no reason to believe these platforms will keep pace as the broadband gap shifts to gigabit speed and beyond in the years ahead. Consider the mobile industry – by far the largest market for wireless services and devices, with billions spent annually on R&D. The decade-long journey from 4G to 5G yielded only ~25% higher speed for large cells as we see in rural areas using spectrum bands below 6 GHz that support long-range wireless coverage. The simple fact is that mobile wireless is bumping up against the physical limits of wireless transmission technology where operators typically have a fraction of 1 GHz of bandwidth for deployment. Compare this to the bandwidth in a strand of fiber, estimated to be 10 million times more. We see claims of 5G gigabit services in ads and articles, but these claims refer to 5G offered over a short-range millimeter wave spectrum from so-called "small cells." The range for these cells is measured in hundreds of yards, not miles, which is fine for urban neighborhoods, but worthless for vast rural areas in the digital divide.

Nonetheless, there may be an opportunity for a hybrid fiber/wireless approach, whereby tall towers with fixed/mobile coverage are deployed quickly to provide stopgap home Internet as quickly as possible, while FTTH networks are built out. Over time, households will shift to faster FTTH services, but the tower/wireless infrastructure investments will still have immense value in serving devices and applications that require ubiquitous coverage over large areas – mobile phones, agricultural drones, sensor networks, autonomous vehicles, and so forth.

A grant application scoring system that rewards both time-to-deploy and future-proof speed could garner high points in both categories with such a hybrid/transitional approach, though those advantages would be offset by higher cost. Still, if sufficient funds are available from federal subsidies, such proposals may fit the budget. Fiber links installed for tower sites could be leveraged for future FTTH, and future FTTH could be leveraged for smaller cells to improve wireless capacity and coverage, so there are interesting potential synergies.

Speed and Technology Recommendations

The minimum initial speed for new infrastructure should be at least 100/20 Mbps, with a preference for higher speed and symmetric uplink.

There is sufficient evidence and consensus around 100/20 Mbps as a threshold speed for the current broadband gap, and so any new infrastructure should meet or exceed this threshold. However, the grant evaluation system should reward any applications that provide higher speeds.

For multi-decade infrastructure, it is not sufficient for a solution to meet the *current* minimum speed only. The solution must provide a low-risk, low-cost upgrade to much faster speeds over time, *without* the need for major new infrastructure and associated public subsidies. The goal here is to make a one-time investment that pays dividends for more than 25 years.

Accordingly, there should be a **strong preference for "future-proof" technology**, implying that there is a smooth path to upgrade speed at 50% per year from the initial 100 Mbps minimum.

For FTTH, the case is quite simple, since 10 Gbps FTTH technology (XGS-PON) that supports 50% annual growth for 10 years is already in mass-scale commercial operation. Furthermore, 40 Gbps FTTH technology (NG-PON2) is in trials that will add 50% annual growth for another four years. Fiber supports much higher speeds as demonstrated in backbone transmission systems and in the theoretical bandwidth of the medium. Indeed, fiber sets the bar for "future-proof" technology, and any application to deploy FTTH should be accepted as fully "future-proof" without further explanation. Any other technology proposed should make the case for its upgradeability with high weight attributed to technology that is in large scale commercial operation, and minimal weight for laboratory demos or roadmap "slideware".

Estimation of Subsidies Needed to Spur Deployment

The broadband gap primarily exists because the cost of deployment in unserved areas is too high relative to the revenue that can be obtained; private firms would be unable to generate a viable return on their capital investment. Where population density is low, the cost of infrastructure per home passed is high, leaving households stuck in the broadband gap with no firms willing to invest the required capital.

Using new and more accurate broadband coverage maps and proprietary software, we simulated FTTH network buildouts for every unserved census block by Census Block Group (CBG). For each such fiber network design, we estimated the required CapEx for fiber, passive infrastructure, electronics, and labor required to fully install FTTH to every unserved HH and connect subscribing households to backbone fiber over time. For each CBG, we plugged the estimated CapEx into an ISP financial model to determine the amount of subsidy required for the ISP to achieve 15% IRR, a typical threshold service providers use to evaluate the financial feasibility of projects. The underlying assumptions in the simulation and the financial model are provided in *Appendix 3: ISP Financial Model*. We ran the network build simulation for each of the three top-level scenarios described in Figure 14, and we analyzed the financial model to study sensitivity to key variables. With financial data calculated for each CBG, we can add the data for summarization at the Census Tract, County, and statewide levels. The model methodology is summarized in Figure 18.

Methodology

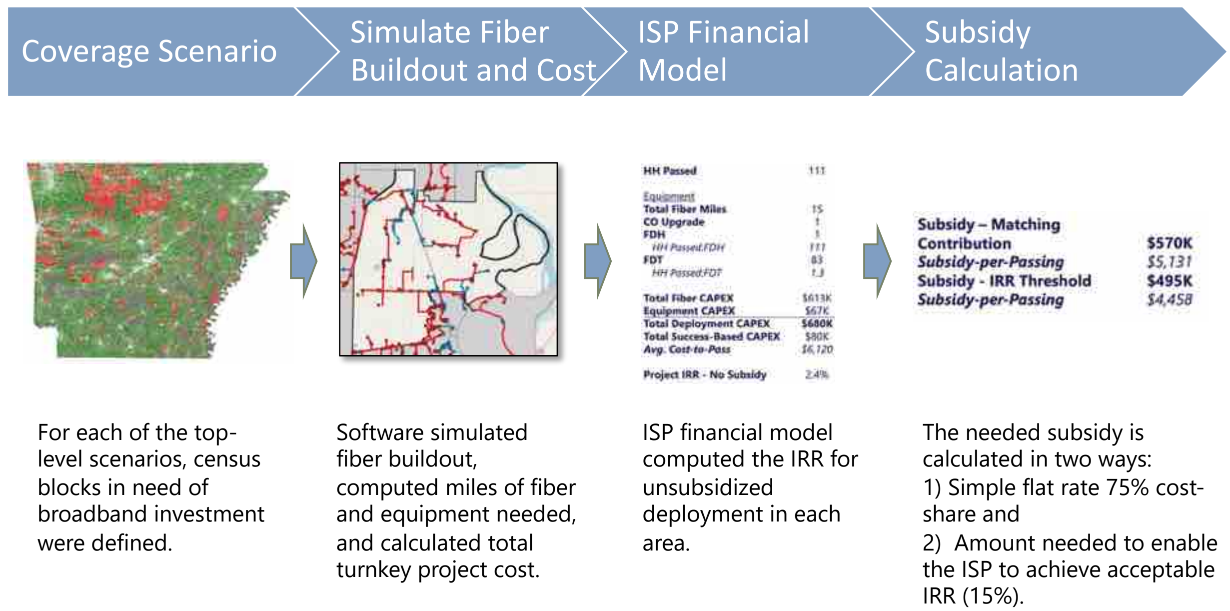


Figure 18. Process to estimate project capex and subsidy

CBG granularity fits well with existing service provider coverage areas, enabling incumbents to take full advantage of their existing assets to extend broadband cost-effectively. CBG areas are also small enough to enable smaller firms to compete. The choice of CBG granularity is validated by the FCC, which chose the same granularity for RDOF awards. For Scenario 2 (110,000 HH lacking 100 Mbps with no grant for future 100 Mbps service), there are about 1600 CBGs with unserved HHs. That's a lot of projects/subsidies to manage for Arkansas' lean broadband office, so it's important to have the budget for staff augmentation, a phasing plan to smooth out the peak administrative load, and an efficient application and decision-making process. Furthermore, CBGs in denser population areas are geographically small and can be consolidated to significantly reduce the number of projects to administer. The additional administrative cost will pay back in the efficient and effective allocation of funds.

Required subsidies were calculated by two methods as described in Figure 19.

Approach	Description	Considerations
Fixed Percent	State pays 75% of CAPEX ISP pays 25% of CAPEX	× Over-subsidizes low-cost areas where little or no subsidy may be needed for a viable ISP financial return ✓ Yet, low-cost areas have not been built out, so an incentive subsidy may be needed to spur deployment, whereas an IRR-based subsidy would provide none. ✓ In lower-cost areas, this can be viewed as a "ceiling" where a competitive process will drive the actual subsidy closer to the IRR-based subsidy amount. × Under-subsidizes high-cost areas where 75% isn't sufficient for a viable ISP return.
IRR Threshold	Using project finance concepts, estimates subsidy required for the ISP to achieve a 15% IRR	✓ More accurate estimation of the minimum funding required to entice providers to build. × May underestimate subsidy required to spur deployment in low-cost areas which should be feasible with no or low subsidy, but where ISPs have nevertheless declined to deploy. ✓ Accurately estimates the required subsidy for high-cost areas.

Figure 19. Two methods to estimate subsidy

This is best understood by looking at the resulting subsidies as a function of cost/HH passed in Figure 20. The lighter orange line shows the flat 75% subsidy, and the darker gray line shows the IRR-based subsidy. Looking at the first 20,000 or so least-cost households, the IRR-based subsidy is $0, implying that these are unserved areas that are financially viable for broadband deployment without subsidization, but where broadband remains undeployed, nonetheless. We think that there are a few reasons for this.

A single provider almost always serves such areas under no competitive pressure. While investment in broadband access would be sufficiently profitable, the provider may have other lines of business, like cellular, that offer higher returns or are more competitive and consequently draw available capital away from rural broadband projects. Furthermore, an exclusive provider may generate higher profits from existing legacy services without new investment for higher speed; in such a situation, the provider has an inherent financial incentive to defer new investment as long as possible.

Comparison of Subsidy Models

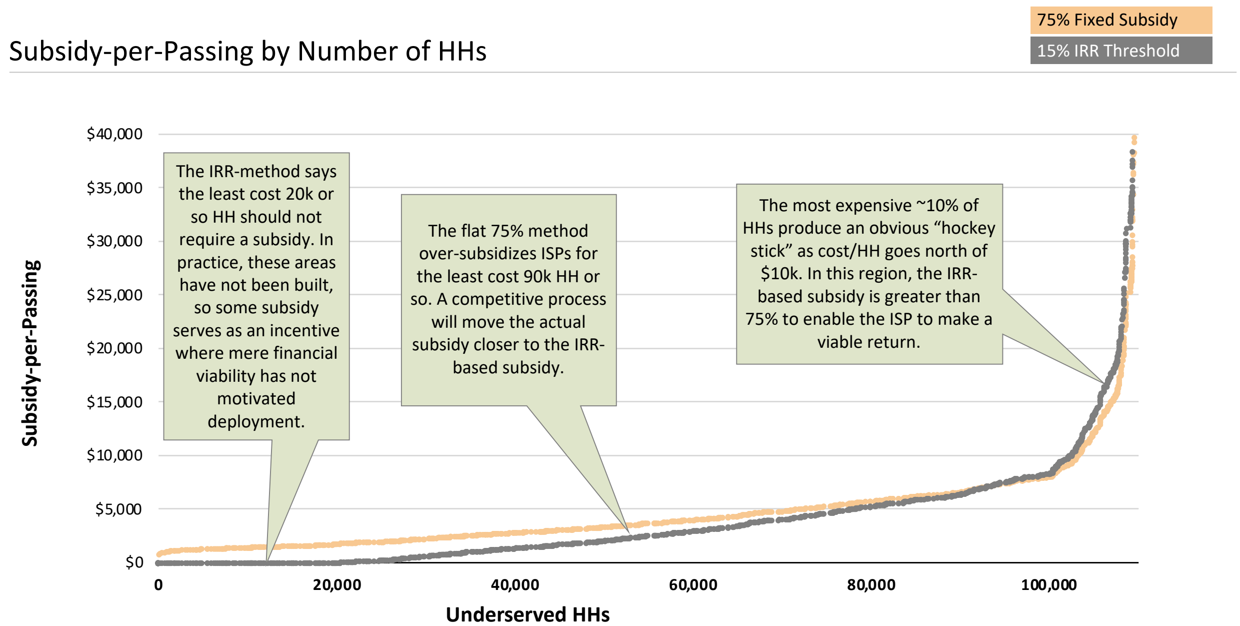


Figure 20. Comparison of subsidy models

Though broadband *could* be privately and profitably financed for these first ~20,000 HH without subsidies, the net result of market forces in these areas is that private capital *has not* been enticed to make that investment. While an IRR-based subsidy calculation would estimate a $0 subsidy for these areas, some subsidy is likely needed to spur investment either by the incumbent or by a new entrant. A flat 75% subsidy greatly over-subsidizes the provider and will create a high IRR; a competitive process will help find a market-driven subsidy between these two cases.

In the middle ~70,000 HH ranked by cost/HH, the story is similar; in this region of the curve, some non-zero subsidy is needed for the provider to achieve a minimal 15% IRR, but a flat 75% amount over-subsidizes the service provider; in other words, the IRR-based subsidy is just enough for the provider to make a 15% IRR, so if the state pays more than that amount (up to 75% of CapEx), the provider will make a return greater than 15%. In practice, 75% is the maximum award permitted by the IIJA BEAD program, but a competitive process will drive actual subsidies toward the lower "just enough" IRR-based amount.

In the highest cost 20,000 HH, a 75% subsidy is *not enough* for the operator to achieve a 15% IRR. In the high-cost region, the higher IRR-based subsidy provides more accurate estimates of the subsidy needed to enable a provider to build out in these areas with a minimal 15% IRR. The IIJA BEAD fund plans to have exception rules for "high-cost" households to enable subsidies > 75%, though details of those rules are yet to be released.

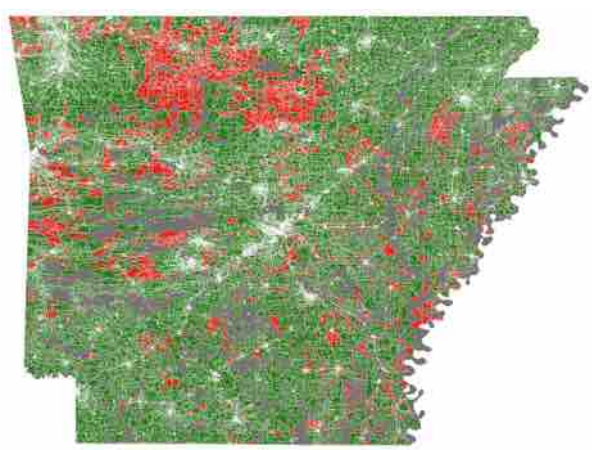
By calculating the subsidy with both methods, it sets an expected range of outcomes for the actual amount to be awarded in a competitive process. Figure 21 shows an example of the ISP financial model used in the analysis. Detailed model inputs are provided in *Appendix 3: ISP Financial Model*, and the spreadsheet is provided separately to test different assumptions.

Year	0	1	3	4	5	6	7	8	9	10	11	12	13	14
HH Passed		110,212	111,206	111,706	112,209	112,714	113,221	113,731	114,242	114,756	115,273	115,792	116,313	116,836
Total Subs		16,532	63,819	78,032	86,773	91,378	93,764	95,037	96,034	97,039	98,051	99,070	100,096	101,129
Uptake		*15%*	*57%*	*70%*	*77%*	*81%*	*83%*	*84%*	*84%*	*85%*	*85%*	*86%*	*86%*	*87%*
HH ARPU (Monthly)		$50.00	$52.02	$53.06	$54.12	$55.20	$56.31	$57.43	$58.58	$59.75	$60.95	$62.17	$63.41	$64.68
Total Revenue		$9.9M	$39.8M	$49.7M	$56.4M	$60.5M	$63.4M	$65.5M	$67.5M	$69.6M	$71.7M	$73.9M	$76.2M	$78.5M
EBITDA		-$1.1M	$24.5M	$33.0M	$39.3M	$43.0M	$45.5M	$47.2M	$48.7M	$50.2M	$51.7M	$53.3M	$54.9M	$56.6M
Margin		*-11%*	*62%*	*66%*	*70%*	*71%*	*72%*	*72%*	*72%*	*72%*	*72%*	*72%*	*72%*	*72%*
Deployment CapEx	**-$601M**													
Success-Based CapEx		-$20M	-$11M	-$8M	-$5M	-$3M	-$3M	-$2M	-$2M	-$2M	-$2M	-$2M	-$2M	-$2M
EBITDA - CapEx	-$601M	-$21M	$13M	$25M	$34M	$40M	$43M	$45M	$47M	$48M	$50M	$51M	$53M	$55M
Terminal Value														$442M
Cash Flow Proxy	-$601M	-$21M	$13M	$25M	$34M	$40M	$43M	$45M	$47M	$48M	$50M	$51M	$53M	$497M
IRR	3.8%													

Figure 21. ISP financial model to estimate IRR-based subsidy

Figure 22 shows the result of the simulation and financial modeling for a statewide build of "Scenario 2" covering 110,000 HH lacking 100+ Mbps broadband today and with no path to 100+ Mbps broadband by awarded grants. The model estimates that 13,200 miles of fiber are needed with total CapEx of $601 million, or $5,475/HH passed. An additional $79 million of CapEx will be needed over time to connect subscribing HHs to fiber at the street. Without subsidy, the resulting bid generates a mere 3.8% IRR, insufficient to attract private capital. The "just enough" IRR-based subsidy to support a 15% IRR is $429 million, or $3,907/HH passed. Alternatively, a flat 75% subsidy would cost $510 million, or $4,646/HH. A competitive process would be expected to fall within this range.

Example Scenario 2: Gap = Unserved with no grant



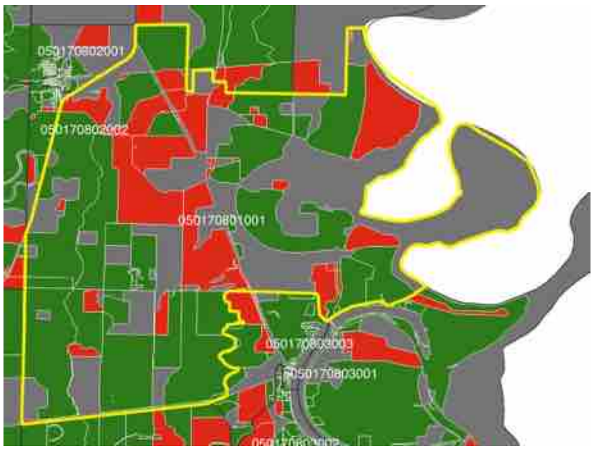
Network Build Analysis

Households Passed	**109.7K**
Total Fiber Miles	**13.2K**
Total Deployment CAPEX	**$601M**
CAPEX/HH Passed	*$5,475*
Success-based CAPEX	**$79M**
15% IRR Subsidy	**$429M**
IRR Subsidy/HH Passed	*$3,907*
75% Match Subsidy	**$510M**
Subsidy/HH Passed	*$4,646*

Figure 22. Scenario 2 example to expand broadband to 110k unserved HH

Within the model, we can drill down to the Census Block Group (CBG) level to see the local details, as shown in Figure 23 for a CBG in the Panther Forest area.

Case Study Build: Panther Forest, AR
Census Block Group 05 017 080100 1



HHs covered (now served or grants awarded)
Broadband gap
Uninhabited

Network Build Details

HH Passed in Unserved Blocks	**111**
Total Fiber Miles	**15**
Equipment	
CO Upgrade	1
Fiber Distribution Hub	1
Fiber Distribution Terminals	83
Total Fiber CAPEX	$613K
Equipment CAPEX	$67K
Total Deployment CAPEX	**$680K**
CAPEX/HH Passed	*$6,120*
Total Success-Based CAPEX	$80K
Project IRR - No Subsidy	2.4%
15% IRR Subsidy	**$495K**
Subsidy/HH Passed	*$4,458*
75% Matching Subsidy	**$570K**
Subsidy/HH Passed	*$5,131*

Figure 23. Example drill-down to census block group level

In this drill-down example, we see 111 unserved HHs in the red census blocks and that 15 miles of fiber would be needed to get these homes connected by FTTH. The total CapEx is $680,000 ($613,000 for fiber and $67,000 for equipment) plus $80,000 additional CapEx over time to connect subscribing HHs to the passing fiber. Without subsidy, the project returns only 2.4% IRR, insufficient to attract private investment. The estimated subsidy amount to spur deployment falls between $495,000 (IRR-based subsidy) and $570,000 (75% flat rate subsidy).

These drill-down figures are available for all CBGs and can thus be summed up to the census tract, county, or statewide level.

Scenarios

The fiber build simulation and financial models were run for the three top-level scenarios as shown in Figure 24.

	1. Current Gap	2. Current Gap - Awarded Grants	3. Current Gap - Awarded Grants + Wireless RDOF
Statewide Coverage %	**100%**	**100%**	**100%**
HHs Passed	**209.4K**	**109.7K**	**141.0K**
Fiber Miles	**34.5K**	**13.2K**	**20.0K**
Total CapEx	**$1,486M**	**$601M**	**$886M**
Subsidy Range	**$1,147 - $1,228M**	**$429 - $510M**	**$660 - $741M**
Subsidy-per-Passing	*$5,477 - $5,865*	*$3,907 - $4,646*	*$4,680 - $5,257*

Scenario 1

"Ceiling" case that estimates subsidies required to expand 100+ Mbps broadband to all 209k HHs not currently served.

Scenario 2

"Floor" subtracts grant awardees for 100+ Mbps from the first scenario. In other words, if all grants are successfully executed, Scenario 2 estimates the cost to bridge the remaining gap of 110k HH.

Scenario 3

"Middle case" that estimates the remaining gap if wireless RDOF winners from scenario 2 fail to deliver, or if future upgrades are required to future-proof these wireless-served households to fiber. (141k HH)

Figure 24. Top-level budget scenarios

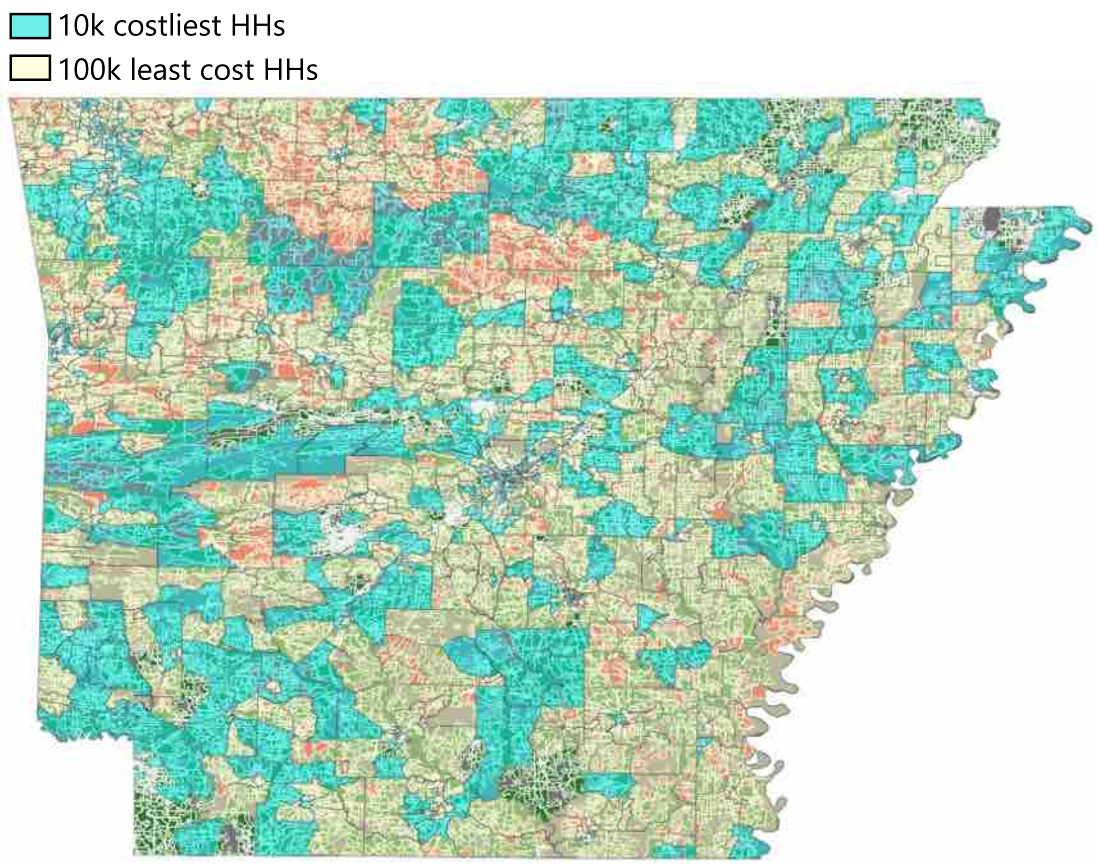
As per Scenario 1, 209,000 HH in Arkansas lack access to 100 Mbps broadband today. Nearly half of those HH are in areas that have received grants to build out 100+ Mbps, leaving 110,000 HH in Scenario 2 with no current 100+ Mbps access and no plan for 100+ Mbps access; Scenario 2, therefore, models the "floor" case with the least number of homes unserved under the assumption that all grants awarded to date are successful. Many RDOF grants have gone to traditionally wireless technology firms like SpaceX (Starlink) and Resound (Texas ISP). As wireless is unlikely to be "future-proof," HHs covered by wireless broadband initially are likely to fall back into the broadband gap eventually, as the threshold speed defining the gap increases over time. **As such, areas awarded to providers using wireless technology will likely need to be upgraded to fiber at some point in the future.** As a "middle case" between Scenario 1 ("worst case") and Scenario 2 ("best case"), we modeled Scenario 3 based on Scenario 2 *except* for those areas covered by wireless RDOF awards, resulting in new coverage for 141,000 HH.

For each scenario, we calculated the required subsidies with both the IRR-based method and the flat 75% method. **IIJA BEAD will prohibit subsidies for RDOF-awarded areas, so without additional funding sources, Scenario 2 provides the best estimate of what can be executed in the near term with total subsidies estimated to range between $429 million and $510 million to cover 110,000 HH.** Eventually, areas covered by wireless will need fiber upgrades to address variable performance, coverage holes, and to increase speed as the minimum acceptable threshold increases over time. Based on Scenario 3, an additional $231 million will be needed to cover these 31,000 HH.

Sensitivity Analysis

% Coverage

If funds are insufficient for 100% coverage, the maximum number of households can be covered by allocating funds in rank order from least to most expensive. In Figure 20, there is an obvious inflection point at about the 100,000th HH where the curve for cost/HH turns upward like a "hockey stick." We analyzed the cost of covering those 10,000 (9%) of the costliest homes in the "hockey stick" part of the curve. Figure 25 shows a color-coded map where the darker colored areas indicate CBGs where the most expensive 9% of HHs are located.



	HHs	CBGs	CapEx	CapEx/HH	% Gap	% AR HH
High Cost	**10k (9%)**	**639 (40%)**	**$178M (30%)**	**$17,800**	**9%**	**0.83%**
All Other	100k (91%)	970 (60%)	$423M (70%)	$4,230	91%	8.3%
Total	110k	1609	$601M	$5,464	100%	9.13%

Figure 25. CBGs (darker cyan areas) with the highest average cost/HH passed

The costliest 40% of the CBGs contain 9% of households and require 30% of total Capex to cover, with an average of $17,800/HH-passed, as compared to an average of $4,230/HH-passed for the other 90% of HH is the lower cost 60% of CBGs.

Regarding the implications for subsidies, we looked at the cumulative subsidy cost for CBGs in rank order from lowest to highest. For the flat 75% method, we found that the 10% costliest HH would consume 30% of the CAPEX, which makes sense, as that would be the same ratio as total CapEx shown in Figure 25.

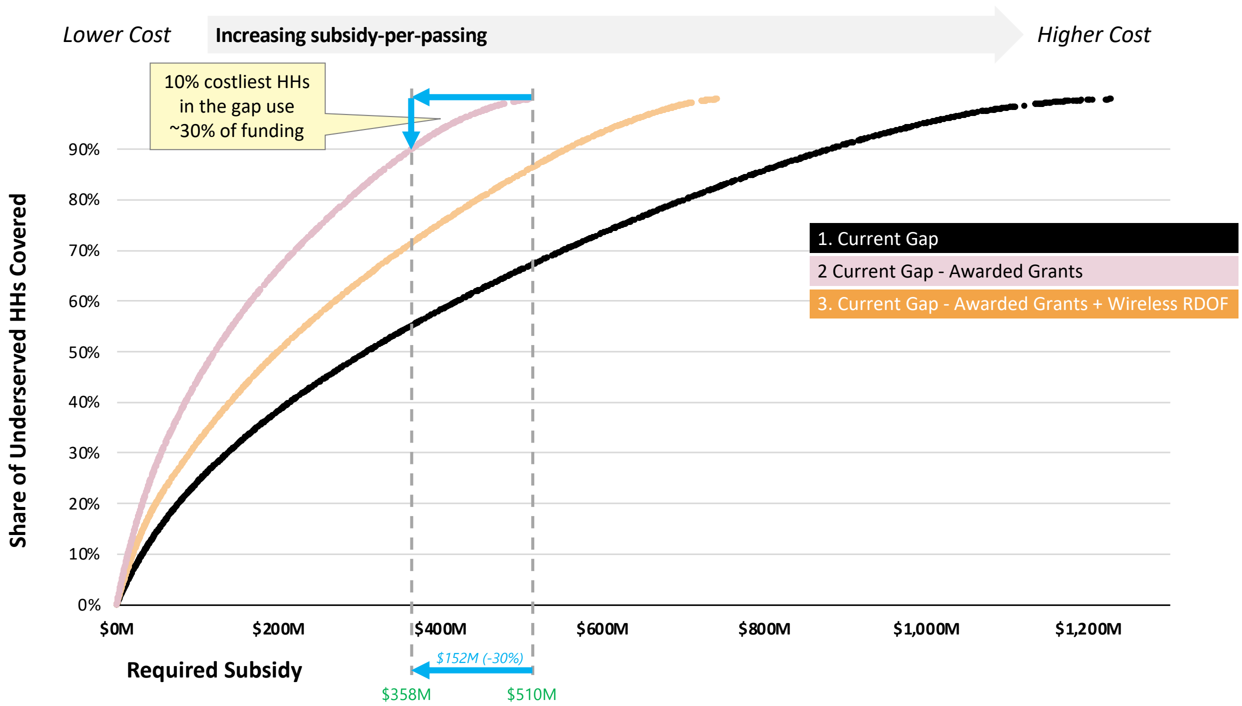


Figure 26. Budget consumed by costliest HH (75% flat rate subsidy)

However, we know that the flat 75% subsidy method over-subsidizes the first 100,000 households, where lower subsidies are needed for providers to achieve 15% IRR; furthermore, we know that 75% is an insufficient subsidy for the high-cost 10% or so of households. So, if we had a perfect allocation of funds enabling all providers to earn 15% IRR, we found that the high-cost households would consume 40% of subsidies, as shown in Figure 27.

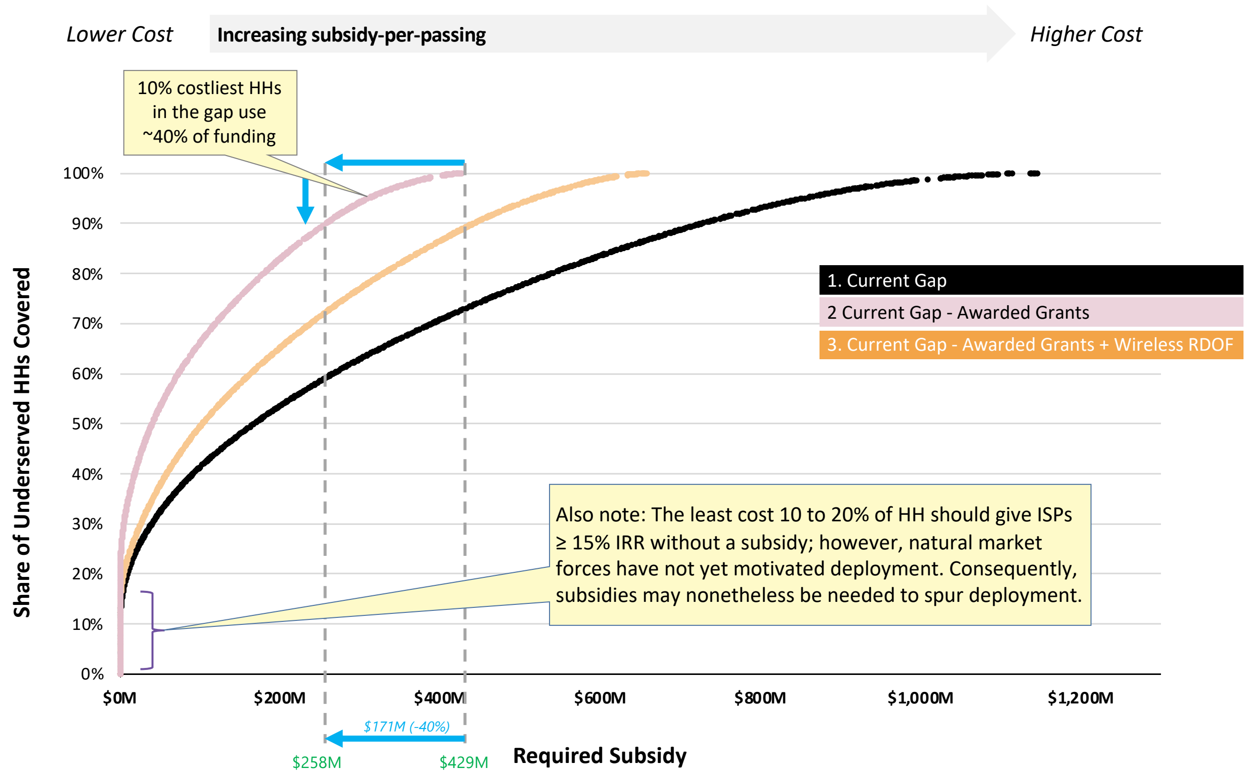


Figure 27. Budget consumed by costliest HH (15% IRR-based rate subsidy)

While this discussion has been based on "Scenario 2," similar results were obtained for the other two top-level scenarios, as summarized in Figure 28.

		1. Current Gap	2. Current Gap - Awarded Grants	3. Current Gap - Awarded Grants + Wireless RDOF
Exclude Costliest HH	Statewide Coverage %	98.2%	99.1%	98.8%
	HHs Passed	188.2K	98.2K	126.7K
	Fiber Miles	23.6K	8.8K	14.4K
	Total Deployment CapEx	$1,032M	$407M	$645M
	Subsidy Range	$727 - $876M	$254 - $358M	$442 - $552M
	Subsidy-per-Passing	*$3,863 - $4,652*	*$2,591 - $3,652*	*$3,488 - $4,359*
100% Coverage	Statewide Coverage %	100%	100%	100%
	HHs Passed	209.4K	109.7K	141.0K
	Fiber Miles	34.5K	13.2K	20.0K
	Total Deployment CapEx	$1,486M	$601M	$886M
	Subsidy Range	$1,147 - $1,228M	$429 - $510M	$660 - $741M
	Subsidy-per-Passing	*$5,477 - $5,865*	*$3,907 - $4,646*	*$4,680 - $5,257*

Figure 28. Summary of budget sensitivity to high-cost households

The key point is that if funds are insufficient to cover 100% of HH, it's possible to achieve near 100% statewide coverage with a substantial reduction in the budget by concentrating funds on the least cost ~90% of HHs in the broadband gap. Figure 28 shows, for example, that in Scenario 2, **reducing the statewide coverage goal from 100% to 99.1% reduces the required subsidy by 30% to 40%.**

The high budget estimates calculated for these census block groups are driven by the low density of underserved households. There are two impacts to the budget model resulting from low density.

The first impact is simply that more fiber route miles are required per household than in areas with higher density.

The second impact is that there are fewer households across which to spread the fixed cost of deployment, such as hub site equipment. The conservatively high financial model used in the analysis is based on the higher expense that would be incurred by new entrants, who would have higher fixed costs than incumbents. Incumbents should benefit from lower marginal costs to add these high-cost households. Accordingly, it's important to award grants through a competitive process that attracts incumbents to participate. While the model estimates 30-40% of the cost would be incurred in these areas, the actual cost could be materially less if incumbents broadly participate.

Small to Medium Business (SMB)

Our analysis focused on residential coverage, but we wanted to test the sensitivity to including the SMB segment. Qualitatively, we can anticipate the impacts:

- Initial fiber build cost is about the same since fiber designed to pass every HH will also pass nearly every SMB.
- Success-based fiber CapEx will increase due to the additional connections for SMB subscriptions.
- Revenue will increase with the addition of higher-priced SMB services.

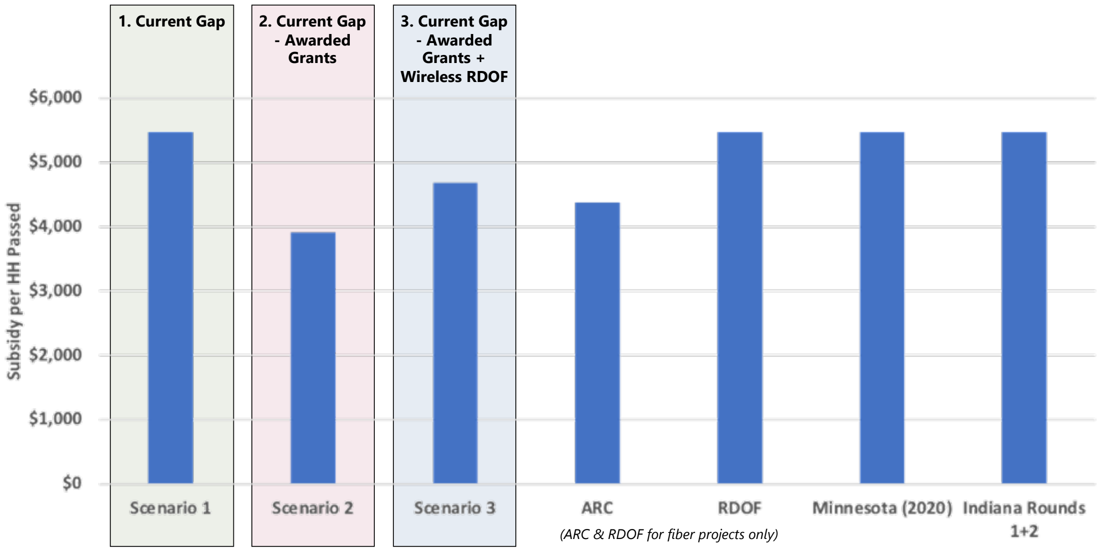
The quantitative impact to subsidies due to the inclusion of the SMB segment is summarized in Figure 29.

		1. Current Gap	2. Current Gap - Awarded Grants	3. Current Gap - Awarded Grants + Wireless RDOF
Residential + SMB	Statewide Coverage %	100%	100%	100%
	HHs Passed	209.4K	109.7K	141.0K
	SMBs Passed	8.3K	4.8K	5.8K
	Fiber Miles	34.5K	13.2K	20.0K
	Total Deployment CapEx	$1,486M	$601M	$886M
	Subsidy Range	$1,032 - $1,234M	$409 - $513M	$633 - $745M
	Net Change	-10% to + 0.4%	-4.7% to +0.6%	-4.1% to +0.5%
	Subsidy-per-Passing	*$3,863 - $4,652*	*$2,591 - $3,652*	*$3,488 - $4,359*
Residential Only	Statewide Coverage %	100%	100%	100%
	HHs Passed	209.4K	109.7K	141.0K
	Fiber Miles	34.5K	13.2K	20.0K
	Total Deployment CapEx	$1,486M	$601M	$886M
	Subsidy Range	$1,147 - $1,228M	$429 - $510M	$660 - $741M
	Subsidy-per-Passing	*$5,477 - $5,865*	*$3,907 - $4,646*	*$4,680 - $5,257*

Figure 29. Impact of including SMB segment in analysis

The net effect on subsidy estimates ranges from a decrease of 4% to 10% in IRR-based subsidies to an increase of about half a percent for flat rate 75% subsidies. The flat rate subsidy is independent of revenue, so the 0.5% increase reflects the additional CapEx required to connect SMBs to the network. With the IRR-based model, the subsidy reflects the impact of additional high-margin revenue from the SMB segment, so the required subsidy for the provider to achieve 15% IRR is reduced. In Scenario 2, which is most likely for near-term execution, the impact is less than 5%. Hence, we conclude that excluding the SMB segment from the model is largely inconsequential for budgetary purposes. In a competitive process, resulting *lower* subsidies will reflect upside revenue from the SMB segment as providers will factor SMB revenue into their internal financial models.

Comparison of Findings to Benchmarks



Households	209.4K	109.7K	141.0K	78.9K	145.0K	5.2K	21.9K
Grants	$1,147M	$429M	$660M	$346M	$319M	$21M	$79M

Source: FCC and Arkansas State Broadband Office
Note: RDOF based on HH coverage only

Figure 30. IRR-based subsidy aligns with grant program benchmarks

The subsidy budget per household is comparable to data from other broadband subsidy programs.

Leverage State-Owned Dark Assets

We spoke with state department heads to determine if there were state-owned assets that could be leveraged to help drive down the cost or reduce the time required to expand broadband coverage throughout the state.

- Regarding fiber routes, no state-owned dark fiber was found.
  - ARE-ON is a leased network with legal restrictions regarding its use.
  - ARDOT assets are purpose-built by providers to meet DOT needs specifically.
- State-owned tower sites *are* available.
  - 140 state tower locations are known and readily available.
    - All towers in the US are registered in an FCC database.
    - ISPs are welcome to contact state managers regarding use of these towers.
  - The usefulness of towers requires site-specific evaluation by ISPs.
    - Space, power, weight, wind, spectrum, height/coverage, rental cost, backhaul.
  - It's estimated that ten to twenty times as many towers are needed to cover the broadband gap fully. If perhaps half of the state-owned towers were useable in required locations, they would account for perhaps 5% of the sites needed.

Program Recommendations

Goals

Bridge the Gap, ASAP
- The over-arching goal is to expand broadband coverage to as many Arkansans as possible
- Slow Internet is an acute problem now for those in the gap, so time is of the essence.
- Coverage of the gap needs to be as complete as possible, ideally 100%

Future-proof
- The Broadband Gap is a moving target
- Infrastructure investment must be positioned to keep ahead of it

Eligible for federal funds
- IIJA BEAD is the 500-lb gorilla in federal funding with perhaps $1B coming to Arkansas
- The Program must target eligibility for massive generational BEAD fund

Cost-efficient
- The program design must stretch funds as far as possible for maximum benefit

Feasible
- The State has finite resources to administer the program
- The program must be designed for efficient administration at statewide scale

Figure 31. Program Goals

Program recommendations are shaped by goals and informed by best practices from other broadband grant programs, including RDOF and several state programs, such as Colorado, West Virginia, Tennessee, Wisconsin, Minnesota, and Indiana.

Goal 1: Bridge the Gap, ASAP

One criticism of RDOF is that the rules permit too much time for providers to build out coverage - 40% completion required only after the end of the third year, and 100% completion after six years. IIJA BEAD improves on that standard, requiring 100% completion within four years. Some state programs have required as little as two to three years for broadband projects. We recommend that awarded areas be completed within three years, especially considering current labor shortages and lingering supply chain problems.

Another problem with RDOF is that it requires coverage of designated census blocks within each awarded CBG, though the designated blocks are not the only underserved blocks within the CBG, leaving behind “swiss cheese” coverage holes. Furthermore, we do not recommend permitting operators to define polygons of their choosing – this leads to “cherry-picking” the most favorable areas while leaving some households in the broadband gap. We recommend that *all* remaining census blocks in the broadband gap must be built out for awarded CBGs in the new program.

Goal 2: Future-Proof

All new deployments should initially offer at least 100/20 Mbps, with higher speeds and symmetric uplink preferred. To accommodate the ever-increasing broadband gap threshold speed, the program should put a heavier weight on technologies that can credibly offer speeds up to 10 Gbps and beyond. For the past 30 years, home broadband speeds have grown by 50% annually; if that continues, we'll need 10 Gbps by the end of the decade and 40 Gbps within 14 years. All FTTH proposals can be accepted as "future-proof," as 10 Gbps FTTH is in commercial deployment today, and 40 Gbps products are in trials. All other technologies will be evaluated according to evidence for future-proof upgrades. Existing large-scale commercial deployments have high credibility, whereas lab demos and roadmap "slideware" have low credibility.

Goal 3: Eligible for Federal Funds

As IIJA BEAD is by far the largest forthcoming source of funds, its requirements are effectively requirements for any new state program.

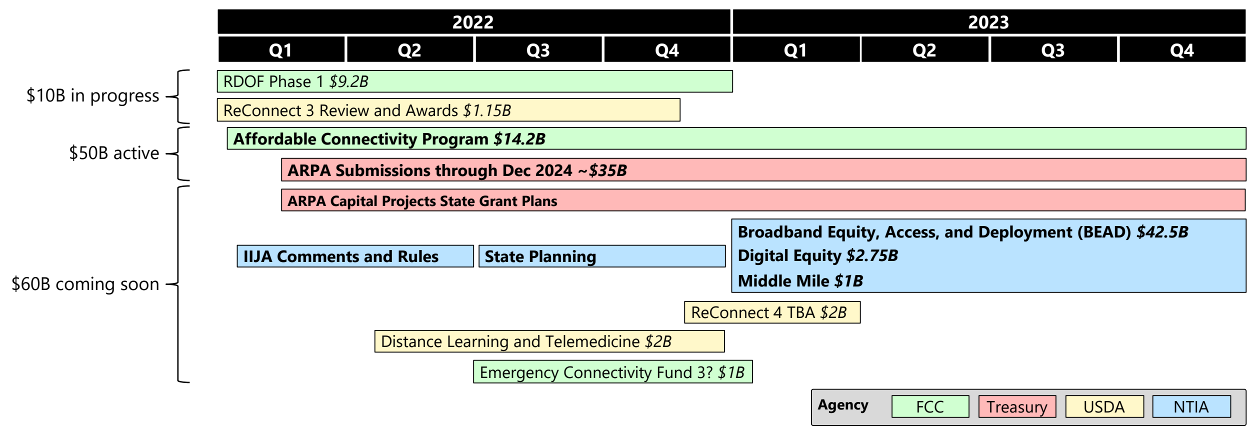
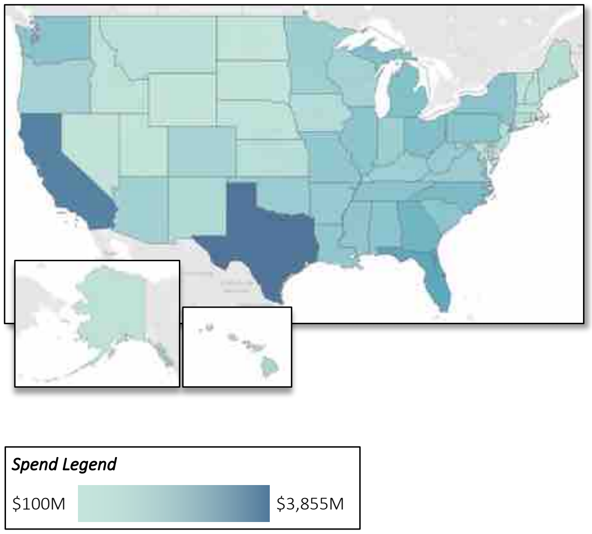


Figure 32. Most significant federal funding programs

As shown in Figure 33 we anticipate that Arkansas could receive up to $1 billion from BEAD, enough to deploy statewide FTTH.

IIJA will initially allocate $100M to all states, then the balance by need, with $1B estimated for Arkansas



State	Est. Funding ($M)	State	Est. Funding ($M)	State	Est. Funding ($M)
AL	$1,205	KY	$850	ND	$134
AK	$217	LA	$1,132	OH	$1,473
AZ	$773	ME	$324	OK	$913
AR	$1,017	MD	$214	OR	$687
CA	$3,366	MA	$179	PA	$1,260
CO	$655	MI	$1,365	RI	$100
CT	$391	MN	$895	SC	$1,169
DE	$100	MS	$1,145	SD	$146
DC	$100	MO	$1,095	TN	$1,271
FL	$2,249	MT	$267	TX	$3,855
GA	$1,722	NE	$191	UT	$173
HI	$542	NV	$129	VT	$199
ID	$235	NH	$253	VA	$908
IL	$1,232	NJ	$396	WA	$1,261
IN	$892	NM	$456	WV	$938
IA	$407	NY	$1,248	WI	$714
KS	$349	NC	$1,556	WY	$103

Total: $42.45 B

Allocation based on number of unserved locations, per BroadbandNow estimates

Sources: US Government, BroadbandNow

Figure 33. Based on BroadbandNow assessment of need, Arkansas could receive up to $1 billion from BEAD

NTIA full rules for BEAD are expected in June 2022. Current guidelines are summarized in Figure 34. Key points consistent with our recommendations are highlighted, including:

- Minimum speed of 100/20 Mbps.
- Ability to scale up speed over time – our recommendation requires proven upgradeability to 10 Gbps+, with the evidence required for any technology besides FTTH.
- An affordable service offering is required, leaving the definition of "affordable" to the states. **Most respondents in our community survey indicated that sub-$50/month is needed to be considered "affordable." Our 15% IRR-based subsidy estimates were based on $50/month average revenue, so it should be feasible for providers to offer sub-$50 rates for the affordable option.** The state should also have authority to adjust the affordable service speed and price, as both will change over time.
- BEAD will permit a four-year time to deploy; our more stringent recommendation for three years fits within the BEAD requirement.
- BEAD requires a 25% matching contribution from either the state or the provider, aligning with our flat-rate 75% subsidy budget calculation. As noted in our analysis, high-cost households will likely require more than 75% subsidization, and the BEAD program acknowledges that high-cost households will require an exception to this rule.
- BEAD requires an "evidence-based and expeditious challenge process" for funding eligibility, which we agree should be part of the state's program.
- BEAD requires prioritization of sub-25/3 areas over sub-100/25 areas. We suggest phasing awards accordingly; phasing has a side benefit of smoothing out the peak administrative workload.

- BEAD also prioritizes time-to-deploy, poverty level, and compliance to Davis-Beacon wages. An objective scoring system can accommodate these priorities and other state preferences, which we recommend for objective and efficient program administration.

Rules for Subgrantees

Speed: >100/20

Latency: Latency low enough for "reasonably foreseeable, real-time, interactive applications

Outages: No more than 48 hours of outages in any 365-day period (on average)

Availability: Provide access to all customers served by project awards

Security & Risk Mgmt.: Offer service compliant with NTIA cybersecurity and supply chain risk mgmt. practices (to be specified)

Low-Cost Broadband Service Option: Required to offer one low-cost plan option to subscribers (definition left up to states, with NTIA approval)

Time to deploy: Deploy network and offer service within **4 years** of receiving funds

Public Notice & Awareness: Provide public notice and conduct public awareness campaigns to areas where service is delivered

Fiber Optic Projects Any project involving fiber or conduit underground or along roadways must include interspersed conduit access points at "regular and short" intervals

Rules for States and Territories

Eligible Uses of Funds

- Unserved & underserved service projects
- Connecting eligible community anchor institutions
- Data collection, coverage mapping and planning
- Broadband adoption
- Installing internet/wi-fi infrastructure or providing reduced costs in MDUs
- Uses "determined necessary" by the Assistant Secretary of Commerce for Communications and information (Alan Davidson) to achieve program goals

Matching Requirement

States or the subgrantee (ISPs, partnerships, etc.) must provide at least **25% matching contribution of project funds**, except in high-cost areas (to be specified); Funding can come from existing government (e.g., CARES Act, American Rescue Plan)

Challenge Process

States must ensure a "transparent, evidence-based, and expeditious challenge process" for entities providing broadband can challenge the eligibility of a location or community for grant funding

Prioritization

1. **<25/3 areas first, then <100/20 areas**
2. **Projects that can scale up speed easily over time**
3. **Faster build time projects get priority**
4. **High poverty areas get priority**
5. **Davis-Beacon wage compliant projects get priority**

NTIA, IIJA Documentation, Fiber Broadband Association

Figure 34. IIJA/NTIA BEAD program guidelines

Potential Funding for Projects Excluded from Federal Programs

Rules for some federal programs prevent allocating funds into areas that already have an award from another program. This well-intentioned idea aims to prevent over-spending caused by redundant grants and ensure funds are available for areas lacking grants. However, the restriction may also hinder legitimate funding for projects that state and local leaders think are worthy.

Some RDOF awards may face insurmountable technical, regulatory, or commercial obstacles that won't be fully known for years. Some RDOF-funded areas may take up to six years for deployment and up to eight years for newly added households. Wireless grant awards may leave many houses unserved or poorly served and will not provide future-proof fiber. Some early grants were awarded for 10 or 25 Mbps, a level now considered below the broadband gap threshold. The risk to the state is relatively high that many residents will continue to suffer for years because of a promise that is slow to be, or may never be fulfilled. Federal rules are expected to prevent the use of new federal funds to remedy such problems.

Consequently, there is a need to identify ways to incentivize RDOF FTTH providers to accelerate their deployment timeframes and to incentivize wireless RDOF providers to abandon their awards so these areas can be eligible for fiber deployment with new federal funds. As the FCC is in rule formation phase for IIJA BEAD, perhaps the state could influence policy such that BEAD fund bidders can partner with wireless RDOF winners to deploy hybrid/transitional wireless/fiber networks or pay wireless RDOF winners to abandon their RDOF awards. Perhaps the FCC could be influenced to permit RDOF FTTH winners to receive BEAD funding priority in new areas if they commit to accelerating their RDOF deployments.

Goal 4: Cost-Efficient

An accurate map promotes cost-efficiency by assuring funds are targeted only to areas where needed. The updated map produced for this report corrected the coverage status for 132,000 households, resulting in the most accurate available coverage baseline, and the foundation for accurate budgetary estimates of network buildout.

To further narrow funding targets, we recommend a robust challenge process for areas planned for subsidies. Providers can challenge the eligibility of areas for grants by providing evidence of current broadband coverage or evidence of firm plans to deploy coverage within two years. Furthermore, a "transparent, evidence-based, and expeditious challenge process" is required by IIJA BEAD.

We recommend a competitive process to help drive down subsidies by leveraging market forces. The program must be designed to attract maximum participation, including incumbents and co-ops, who are advantaged with assets in place, and new entrants. We are recommending grants be awarded at CBG granularity to maximize competitive interest by aligning better with incumbent service boundaries to support lower-cost expansion by incumbents while fitting within the capital constraints of smaller firms. We also recommend combining small CBGs in denser areas to reduce the number of projects/awards to administer.

If funds are not sufficient for statewide coverage, the state may choose to prioritize lower-cost areas to maximize the number of households covered for a given budget. Our analysis estimates that the **costliest 1% of HH spans 40% of CBGs and requires 30% to 40% of the budget**.

Prioritizing future-proof technology like FTTH is also a capital efficiency strategy as it assures future subsidies will not be needed for upgrades when the broadband gap speed threshold increases.

Finally, to protect against fraud and waste, we recommend a reimbursement-based distribution to assure funds only go toward proper and incurred expenses.

Goal 5: Feasible

The state has finite administrative resources to run a grant program.

We recommend a comprehensive, evidence-based, and objective scoring process to enable efficient program administration.

With hundreds of grants to manage, some staff augmentation is recommended to help administer the program. If grants total $500 million, 1% overhead to administer them seems reasonable.

The state might also consider running the grant program in phases to reduce the number of applications to be processed simultaneously. Breaking the program into phases will reduce peak load. Rounds could be defined by groups ranked according to current speed, and/or by high-cost areas.

Program Characteristics

Recommended program characteristics are summarized in Figure 35.

Applicant Eligibility

Consistent with BEAD, we recommend that the program be open and attractive to the widest possible range of entities to maximize competition.

Household Eligibility

Households with <100 Mbps broadband today, and no plans for grant-funded 100 Mbps service in the future, are eligible for coverage under the new program.

Geographic Units

Since network simulation and financial analysis were done by independent census block groups (CBGs), *projects* can easily be defined by individual or multiple census block groups. A larger number of project areas will maximize competition, while a smaller number of project areas will be more efficient to administer, so the goal is to find the right balance. Definition and prioritization of project areas are implementation choices; however, in general, project areas of roughly equal size may be a good guide. In more densely populated areas, CBGs are smaller in area, so it makes sense to combine them into one project. In more rural areas, CBGs are larger, so projects may be defined for single CBGs. (We note that the FCC organized its rural RDOF program by single CBGs.) This general approach will best align project scope with incumbent service provider areas, enabling maximum leverage of their installed assets to minimize subsidies. While there are roughly 1,600 CBGs with underserved census blocks in "Scenario 2," we estimate that CBGs can be grouped into 300 to 500 projects by packaging CBGs in denser population areas together.

Upgrade Speed

The minimum initial upgrade speed should be 100/20 Mbps.

Future-proof Upgrades

Since infrastructure investment should endure for decades, strong preference will be given to technologies with a proven track record of scaling to 10+ Gbps.

Program Dimension	Recommendation	Rationale
Applicant Eligibility	ISPs, utilities, PPPs, municipalities…	• Diversifying the pool of applicants yields the greatest number of applications and generates greater competition • Scoring system should weigh qualifications of applicants such as financial strength, experience, D&B rating, Net Promoter Score, etc.
Household Eligibility	< 100 Mbps	• Industry concensus • Priority can be given to HHs with lowest speeds
Geographic Units	Census Block Group	• Best aligns with incumbent networks for least-cost • Enables smaller providers to compete for maximum market-based competition
Upgrade Speed	> 100/20 Mbps	• Prefer symmetric uplink and higher speeds
Future-proof Upgrades	50% annual increase to 10+ Gbps	• Strong preference will be given to technologies with proven path to 10+ Gbps • FTTH is accepted to meet this objective; other technologies will be evaluated based on credibility of the evidence such as large-scale commercial deployments
Completion Timeline	3 years	• Although past programs had a two-year timeline, some states are allowing longer terms because of supply chain concerns and labor shortages
Applicant Contribution	>= 25% (with flexibility for high-cost areas)	• Matching contribution ensures applicants share cost burden and are invested in success; flexibility ensures ability to cover most expensive HHs • Competitive process will increase % contribution in lower cost areas • 25% is the minimum requirement for BEAD
Maximum Grant Value	No	• Maximum grant values exclude some households from future coverage • Grants should be distributed based on and objective scoring system • The state may wish to set a reserve price per CBG to reject absurdly high bids in non-competitive situations.
Operation Requirements	10 years	• Applicants should guarantee service after the conclusion of the grant contract period in order to ensure households are actively being served by funded infrastructure
Success-Based CapEx	Yes	• The connection from the street to the house is a real part of the CapEx and should be included in the subsidy calculation to attract intended interest from ISPs
Fund Distribution Model	Reimbursement-based grant	• This is the standard system for U.S. states and assures funds only go toward proper and incurred expenses

Figure 35. Summary of recommended program characteristics

Completion Time

We recommend three years to complete projects; faster completion times can be rewarded in the scoring system. Some states have two-year completion targets, but three years is recommended considering labor shortages and supply chain issues, especially with increased broadband spending. This target is compliant with the BEAD four-year limit.

Applicant Contribution

Our recommendation is to contribute up to 75% but to use a competitive process to reduce subsidies toward the 15% IRR-based level. High-cost households will likely require more than 75% subsidies. Note that BEAD also requires a 25% match, with exceptions for high-cost households to be determined.

Maximum Grant Value

We are not recommending a fixed maximum value, but rather that the 75% threshold be used to gauge the maximum grant based on the CapEx cost estimates for each area. The state may want to set a "reserve price" for each area based on CapEx estimates to permit proposal rejection in the case of overly high bids in non-competitive situations while being open to evidence and retaining flexibility toward the goal of seeing broadband deployed everywhere.

Operation Requirements

We recommend that grant recipients guarantee service availability for at least ten years.

Success-Based CapEx

Providers spend additional capital dollars to connect households that subscribe to the service. We recommend this additional "success-based" CapEx be included in the subsidy calculation. It is an actual expense that providers must bear and include in their own financial analysis, which is why we included it in our subsidy calculations.

Funds Distribution

To protect against fraud and waste, we recommend a reimbursement-based distribution process to assure funds only go toward proper and incurred expenses. Reimbursement-based distribution was employed in all state programs that we reviewed.

Program Scorecard

We recommend a comprehensive, evidence-based, and objective scoring process to enable efficient program administration at the needed scale. An objective scorecard should be carefully designed to reward applications that best meet all the state's requirements and priorities while assuring that bidders cannot "game the system" to win awards counter to intentions. Key recommended criteria are summarized in Figure 36.

Criteria	Scoring Factors
Speed of service	• Additional points for speed above minimum 100 Mbps up to 1 Gbps; bonus points for uplink speed up to symmetrical
Future-proof	• Additional points for fiber
Quality of coverage	• Maximum score for 100% coverage; lower scores for solutions with < 100% coverage due to obstructions or other factors • Maximum score for uniform speed over time and distance for all customers; lower scores for speed variation across customers based on location or utilization.
Time to deploy	• Additional points for service availability ahead of maximum 3-year time frame
Qualifications	• Additional points for experience, financial strength, D&B credit rating, Net Promoter Score, Performance bond, etc. • The state should employ procurement best practices to qualify applicants and thereby minimize performance risk
Contribution	• Additional points for % contribution above minimum (25%)
Community Support	• Additional points for quality and quantity of partnerships, funding, or letters from community leaders
Community Impact	• Additional points for economic benefits such as job creation or job training
Affordability	• Additional points for participation in FCC Affordable Connectivity Program • Additional points for price tiers below required affordable price (an affordable option is required for IIJA fund grants)
Service Adoption Strategy	• Additional points for dedicated service adoption assistance and engagement plans outside of traditional marketing such as digital literacy training or outreach to seniors
Project Readiness	• Additional points for evidence of project readiness. Details on project schedule, budget, financial model, engineering plans, marketing strategy for packages with speed tiers and pricing will increase project readiness score.

Figure 36. Use of a program scorecard enables efficient and objective proposal evaluation

Speed of Service

The minimum initial speed is 100/20 Mbps. Higher points should be awarded for faster speeds and faster uplinks, up to symmetric speed.

Future-Proof Speed Upgrades

FTTH is acceptable without evidence. All other technologies will be scored based on the weight of evidence for a long-term path supporting 50% annual growth in home broadband speed.

Time-to-Deploy

Three years is the recommended maximum time, but higher scores can be awarded to proposals for faster deployment.

Qualifications

RDOF was criticized for awarding grants to underqualified bidders. We recommend that the state employ professional procurement best practices to qualify bidders and favor those who represent lower execution risk, demonstrable past success, and high customer satisfaction.

Contribution

While 25% is the minimum contribution, higher scores should be offered to providers who will make a higher percentage contribution. As noted, the least cost 20,000 homes or so should not require any subsidy for providers to make 15% IRR. A competitive process will help drive down the subsidy amount, which can be scored based on a percentage of the contribution.

Community Support

Support from community leaders reduces risk through collaboration. Bids with demonstrable local support should be rewarded with higher scores.

Community Impact

Proposals that provide workforce training or create local jobs should be recognized with higher scores.

Affordability

BEAD requires an affordable service option, though the definition of "affordable" is left to the state. Our community survey suggests that the "affordable" rate should be below $50, and our calculation of an IRR-based subsidy budget accommodates that price point. Bidders should be rewarded with extra credit for affordability beyond the minimum requirement.

Service Adoption Strategy

Applicants with plans for outreach to communities in need of assistance, such as seniors, to take advantage of broadband, should be rewarded. Applicants who demonstrate robust digital inclusion plans should receive higher scores.

Project Readiness

"Shovel-ready" projects deserve recognition over those merely on the drawing board. Evidence that material work has been done to prepare for deployment should positively and materially impact bid scores.

Program Grant Application Process

We recommend a six-step application process with competition in three rounds, as summarized in the guidelines shown in Figure 37. Details can certainly be tuned to fit with the state's preferences. The key ideas are to:

- Engage would-be providers to assure maximum interest and participation.
- Make the process as detailed as necessary, but as light as possible.
- Leverage competitive market forces to minimize subsidies and maximize capital efficiency.
- Make the process administratively feasible.

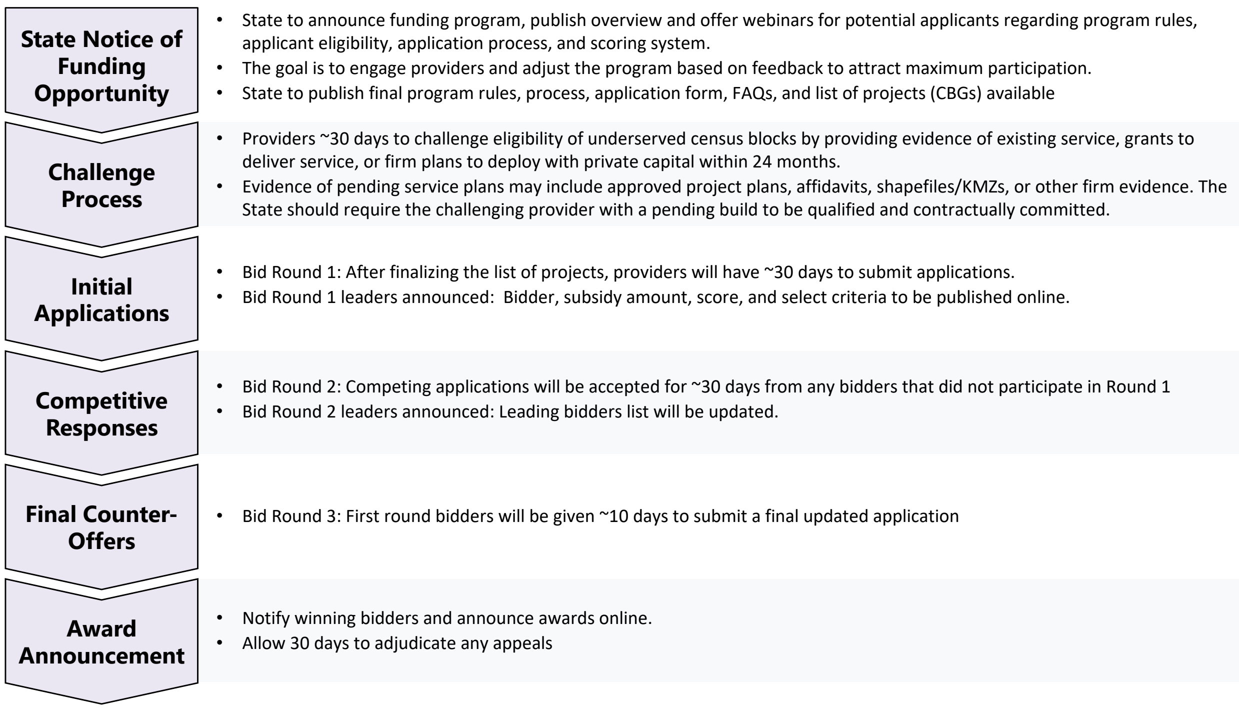


Figure 37. Grant application process

State Notice of Funding Opportunity

Publicize notice of funding opportunity for broadband expansion. Reach out to all service providers in the state, all electric utility companies, and local government entities. With hundreds of millions of dollars at stake, the program's goal should be to attract maximum participation.

Feedback, engagement, and published FAQs are recommended to engage potential bidders. Program rules can be tweaked based on feedback to maximize participation.

Challenge Process

Projects defined by Census Block Groups should be announced, with a list of eligible census blocks and an estimated number of households to be covered. Officials should allow 30 days for providers to dispute the eligibility of any census blocks covered by the proposed award. Evidence of existing services subscribed or available, or documentation on grants awarded, or firm plans to privately fund deployment must be provided to disqualify the block. Evidence of plans to deploy within two years may include detailed project plans, schedules, detailed budgets, or executive affidavits. Providers who block competitive bidding for subsidies through credible evidence of intent to build may be required to sign a commitment with penalties for failure to execute.

Initial Application

With a final list of eligible census blocks in each available project, a ~30-day window can be opened to accept initial applications. Applications will be scored according to published rules. The state should have the ability to reach out to applicants for clarification as needed. Leading bids after the first round will be posted.

Competitive Responses

After initial round bids are posted, firms are given 30 more days to submit competing bids, including firms that did not bid in the first round. The reason is to ensure awards are accessible to as many providers as possible. It is in the state's best interest to attract as much competition as possible to drive down required subsidies. After second-round bids are evaluated, the leading bidders' list should be posted online.

Final Counteroffers

Firms that submitted applications in Round 1 or Round 2 have ten days to submit best-and-final proposals in Round 3.

Award Announcement

After scoring the third round of bids, winners are announced and posted online. A 30-day window is permitted to adjudicate any protests.

Grant Applications in Multiple Phases

The state may want to run the process in multiple phases to prioritize areas to fund for BEAD compliance and to reduce peak administrative load. For example, Figure 38 shows census blocks color-coded by top available speed. The state could rank CBGs by the average speed of underserved HHs, and then group CBGs accordingly from lowest to highest as a method to break the granting process into phases. Rules could further require that providers make their best efforts to prioritize the most underserved blocks within awarded CBGs. As detailed BEAD rules have not been published, it's not yet clear what prioritization schemes will satisfy the requirements.

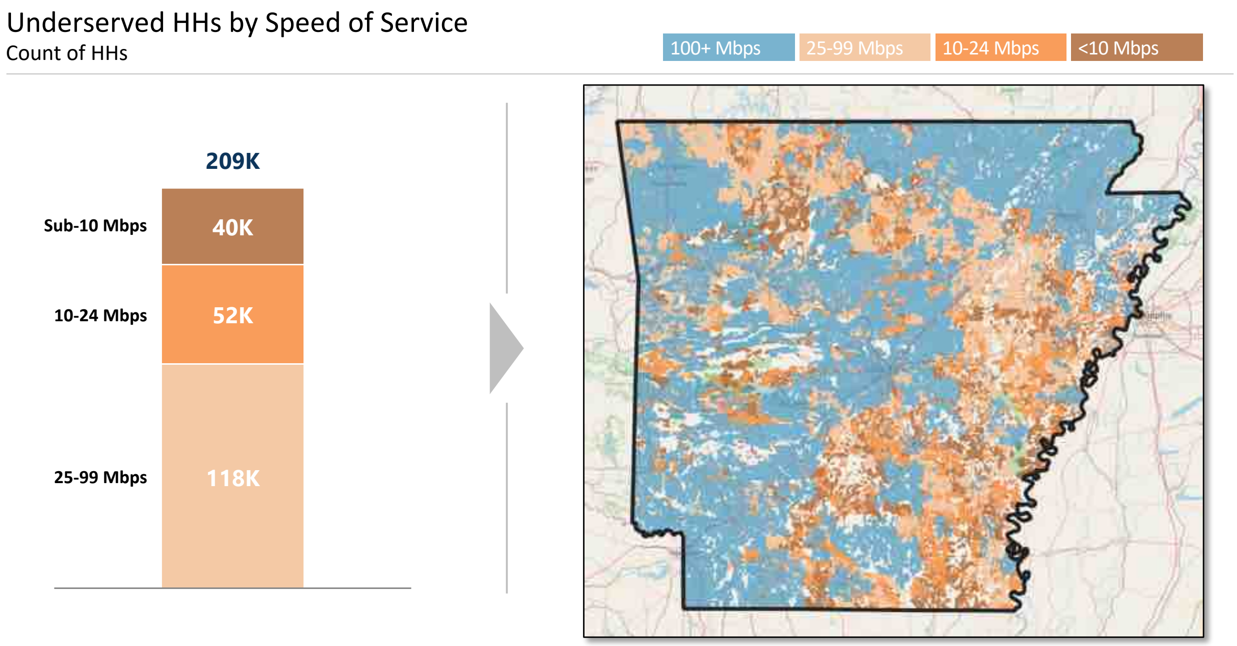


Figure 38. Coverage by speed could be the basis of prioritization

Figure 39 diagrams the breakdown of HH in each speed tier for the three top-level scenarios analyzed in this study. The stack on the left is for Scenario 2, with 110,000 homes lacking access to 100+ Mbps today, with no grants pending to provide 100+ Mbps service. Of those 110,000 HH, 25,000 have service under 10 Mbps, 22,000 HH have service between 10 and 25 Mbps, and the balance of 62,000 HH have service between 25 Mbps and 100 Mbps.

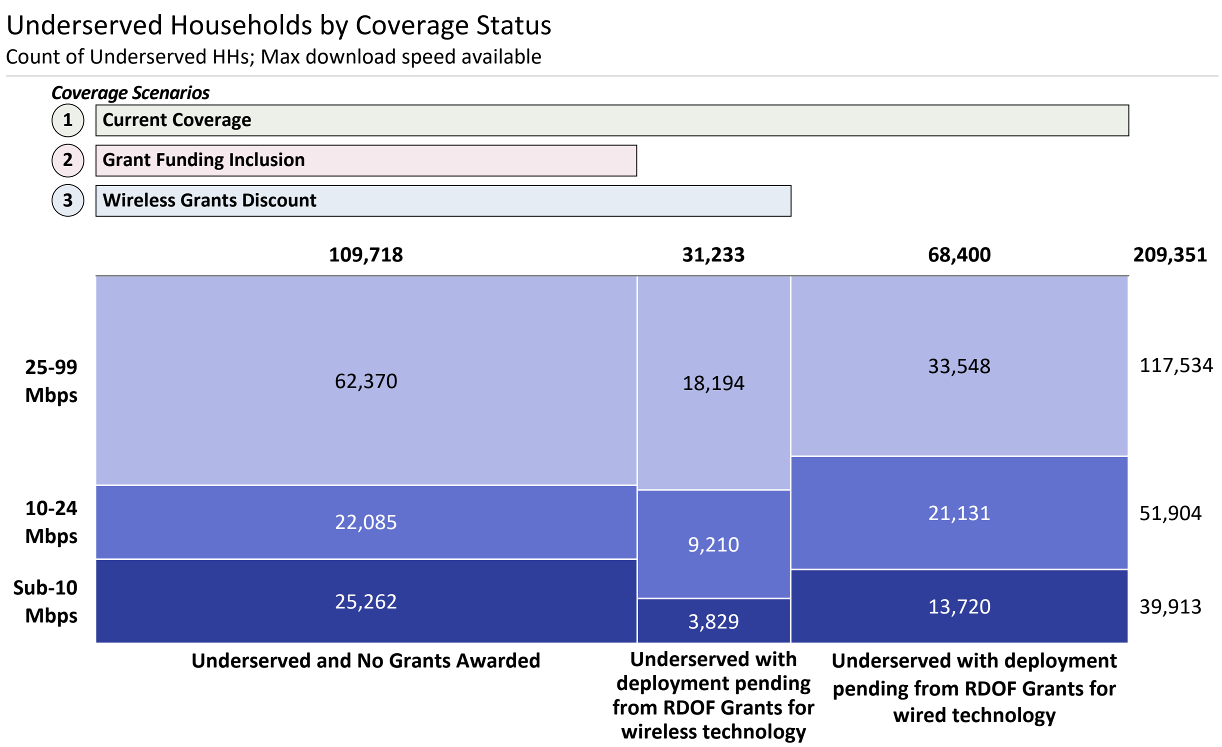


Figure 39. Breakdown of HH count by speed tier and top-level scenarios

CBGs could be ranked either by the quantity of HH at a given tier, or by the average speed, then partitioned into manageable chunks for grant administration.

Another dimension to consider is to separate out the high-cost CBGs (40% of CBGs) and administer the lower-cost CBGs (60% of CBGs) first.

For example, one possible ordering could be:

- Phase 1: CBGs with most blocks or HH under 10/1, excluding high-cost CBGs.
- Phase 2: Remaining CBGs with most blocks or HH under 25/3, excluding high-cost CBGs.
- Phase 3: Remaining CBGs, excluding high-cost CBGs.
- Phase 4: High-cost CBGs with most blocks under 10/1.
- Phase 5: Remaining High-cost CBGs with most blocks under 25/3.
- Phase 6: Remaining High-cost CBGs.

This would break down the program into six phases, with 268 CBGs per phase.

Affordability

While we normally refer to the "broadband gap" as areas lacking broadband availability at some particular speed, it's also important to address the "affordability gap." Broadband availability in a particular household is of no benefit if the service is unaffordable.

In our community survey, about one-third of respondents said they didn't have broadband due to *affordability*, not *availability*, so an affordable rate is a significant issue.

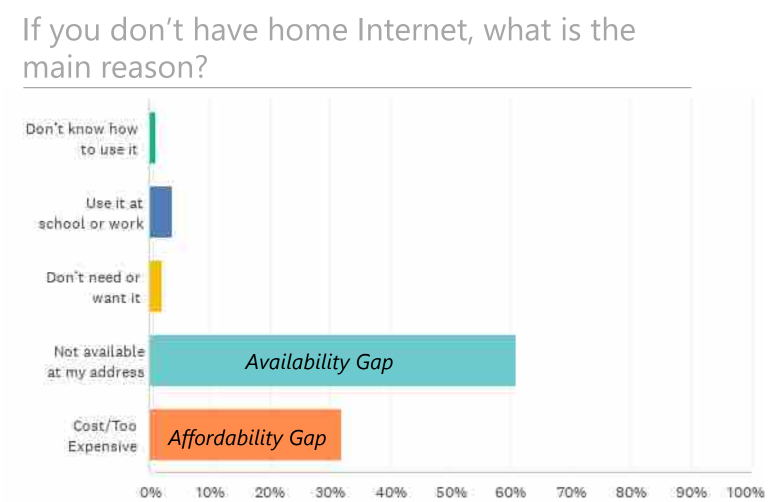
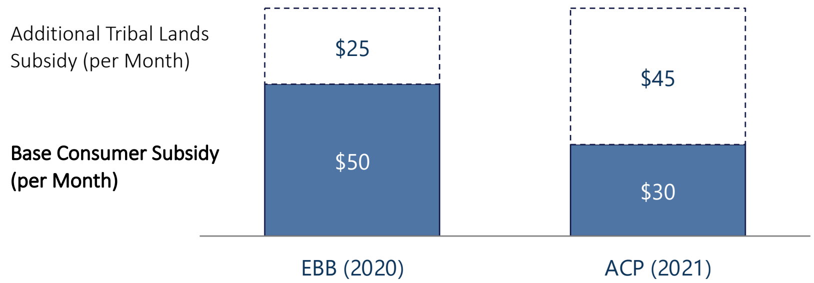


Figure 40. Availability Gap and Affordability Gap

Affordable Connectivity Program (ACP)

The IIJA includes $14.2 billion to subsidize consumer payments for broadband. Figure 41 summarizes the program and compares it to the predecessor Emergency Broadband Benefit (EBB) program.

Affordable Connectivity Program Comparison vs. Emergency Broadband Benefit



		EBB (2020)	ACP (2021)
	Total Funding	$3.2 B	**$14.2 B**
Consumer Qualifications *(1 household member must meet 1 criterion)*	**Income Level**	135% of poverty line	**200% of poverty line**
	Program Participation	• SNAP • Medicaid • Lifeline • Free/reduced school lunch	• SNAP • Medicaid • Lifeline • Free/reduced school lunch
	Pell Grant Status	Current Pell Grant recipient	Current Pell Grant recipient
	COVID Impact	Substantial income loss due to COVID (from <$99k prior year)	**No income loss provision**

4 Primary Updates

Sources: FCC, IIJA

Figure 41. Changes from EBB to ACP

The ACP provides a fixed $30/month subsidy but increases higher-income households' eligibility. Broadband is an ongoing monthly expense, while the IIJA provides a fixed fund for subsidies, which leads to the natural question: How long will the fund last?

One other consideration in understanding affordability is the subject of providers bundling other services with internet service to increase their revenue and create customer "stickiness." In several areas of the state, monopoly providers require consumers to purchase additional services (which the consumer may not want or need) to obtain internet access. The additional services required may be a telephone line or other ancillary service. So-called "naked internet" is not available from some providers, while in other cases, it is available, but at a price that is equivalent to a bundle of services. Affordability is partly driven by technology, but it is equally driven by public policy.

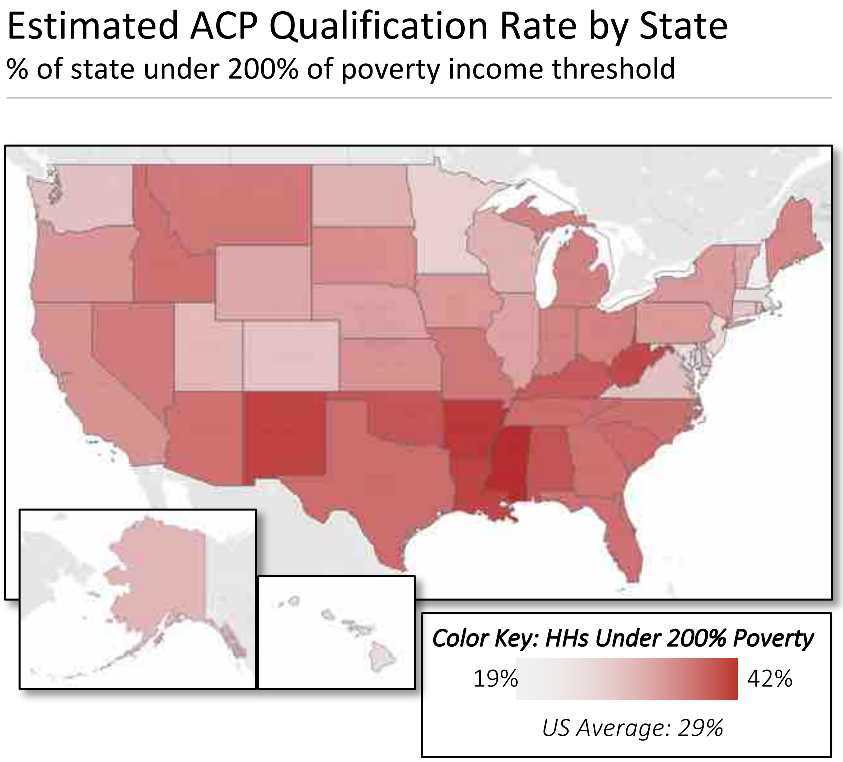


Figure 42. 39% of Arkansas HH will benefit from the ACP

Overall, 29% of U.S. households qualify for the ACP, though 39% of Arkansas households qualify. The duration of the ACP fund depends on shifts in eligibility and the uptake rate among the eligible. Figure 43 tabulates how many years the ACP will last as a function of these two variables. Terminal take rate may mirror other federal programs such as SNAP (~84% est. penetration), at which level the $14.2 billion fund would last only about 1.25 years. However, the ramp-up will likely take several years, so we can estimate that the program will likely last two to three years and perhaps longer.

Beyond that, the federal government may top up the fund or create a new system to subsidize rates for low-income households.

Total HHs under Program Income Threshold (%)

Take Rate of Eligible HHs (%)	26%	27%	28%	29%	30%	31%	32%
10%	11.5	11.1	10.7	10.3	10.0	9.7	9.4
20%	5.7	5.5	5.4	5.2	5.0	4.8	4.7
30%	3.8	3.7	3.6	3.4	3.3	3.2	3.1
40%	2.9	2.8	2.7	2.6	2.5	2.4	2.4
50%	2.3	2.2	2.1	2.1	2.0	1.9	1.9
60%	1.9	1.8	1.8	1.7	1.7	1.6	1.6
70%	1.6	1.6	1.5	1.5	1.4	1.4	1.3
80%	1.4	1.4	1.3	1.3	1.3	1.2	1.2
90%	1.3	1.2	1.2	1.1	1.1	1.1	1.0
100%	1.1	1.1	1.1	1.0	1.0	1.0	0.9

SNAP pen. rate

National avg. of 29% under 200% of poverty threshold

Figure 43. The number of years the ACP fund will last is based on %HH eligible and %uptake

Community Outreach

Digital inclusion addresses access to affordable broadband Internet services, Internet-enabled devices, access to digital literacy training, quality technical support, and applications and online content designed to enable and encourage self-sufficiency, participation, and collaboration. Including everyone in this process leads to digital equity – the idea that no one is systemically blocked from taking full advantage of publicly available benefits. Arkansas not only has a technology gap; we have a consumer awareness and resource gap. That is, we are short on digital inclusion. Many Arkansans cannot take full advantage of broadband internet access, even when available. More than once, we encountered someone who reportedly has "fiber-optic service from [*provider name*], but it just doesn't work." We mentioned the situation to the providers, who then investigated and found that the end-user often had a computer or other device too old to connect at the speed level they were paying for.

Our staff and associates conducted 325 in-person and 32 live video discussions and community meetings throughout the state, visiting all 75 counties. These meetings took place in various settings, including schools, libraries, civic clubs, healthcare facilities, Farm Bureau locations, county courthouses, and city halls. We met with city and county leaders, educators, law enforcement, farmers, small business owners, economic development staff, entrepreneurs, internet service providers, and ordinary residents, with more than 18,000 survey responses returned.

Individual charts below highlight the responses to each question.

About 18% of respondents reported having no internet service, having "other" internet service, or "don't know" what they have. Another 15% report having only cellular data, or a mobile hotspot, for internet access. A review sample of responses indicates that those without broadband internet service are significantly higher than the roughly 9% who responded to the question with "None."

Of those who reported having no internet service, about 60% responded that service was unavailable in their area, and 30% said it was too expensive. At the same time, about 70% of respondents said that having internet service is important to them.

One concern that arises when considering spending a large amount of taxpayer money on the broadband issue is whether people want or need it. Fewer than 1% of the respondents reported that they "Did Not Need/Want It." Communities statewide are energized around broadband internet access and are vocal about their needs.

In addition to the quantitative data gathered, our teams collected qualitative data – stories, comments, opinions, and thoughts from ordinary citizens around the state. Attendees were grateful for the attention and for the opportunity to be heard. A recurring theme in the meetings is that people in communities feel isolated and unheard. This project met with enthusiasm across the state as many people related their particular frustrations, needs, and anxieties about being excluded from the future.

Some notable conclusions can be drawn from the meetings and survey responses: the problem is statewide and not confined to a particular area; affordability is an important component of “availability”; attention needs to be paid to creating community awareness about how to access and use internet service effectively, and technology (through simply spending grant money) is not the only axis to be considered in closing the digital divide.

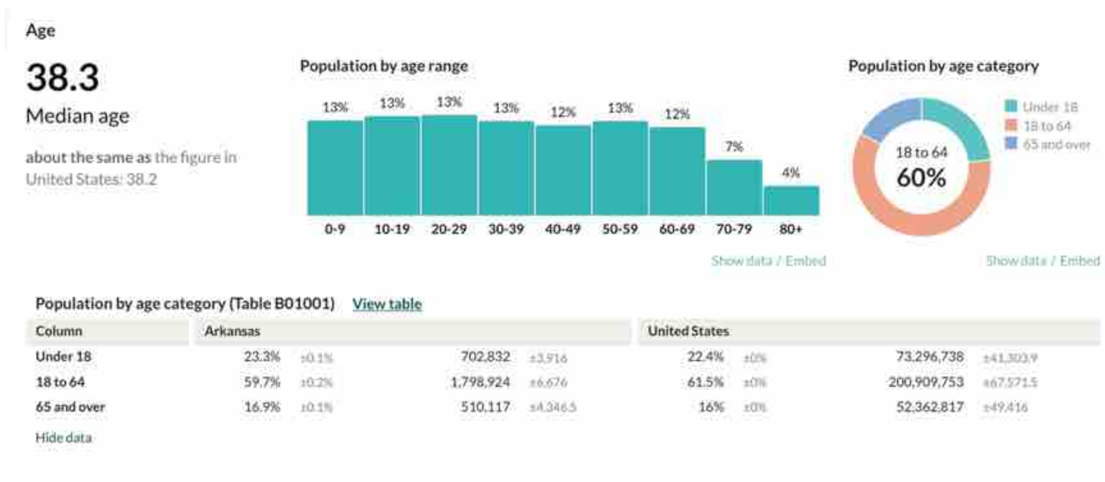
Census Data[4]

Households and Families

Many Arkansas demographics are similar to national averages. The average household size in Arkansas is 2.5 people compared to 2.6 nationally, for example. However, other statistics vary widely from national averages.

Figure 44 and Figure 45 below illustrate how closely Arkansas mirrors national demographics concerning age and household type. For example, married-couple households and households with non-family in Arkansas compare closely to the national averages in those categories. We have slightly more children and seniors by percentage and fewer people aged 18-64 than the national averages for those groups.

Even though the differences are small, these figures highlight the importance of broadband internet access in education, telemedicine, and economic development.



Column	Arkansas				United States			
Under 18	23.3%	±0.1%	702,832	±3,916	22.4%	±0%	73,296,738	±41,303.9
18 to 64	59.7%	±0.2%	1,798,924	±6,676	61.5%	±0%	200,909,753	±67,571.5
65 and over	16.9%	±0.1%	510,117	±4,346.5	16%	±0%	52,362,817	±49,416

Figure 44. Arkansas residents by age demographics

Households

1,170,544

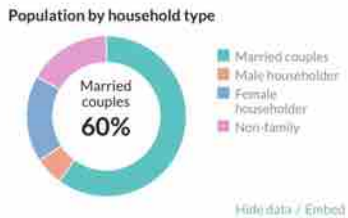
Number of households

United States: 122,354,219

2.5

Persons per household

a little less than the figure in United States: 2.6



Population by household type (Table B11002) View table

Column	Arkansas				United States			
Married couples	60%	±0.4%	1,757,954	±12,299	60.1%	±0.2%	191,385,584	±566,833
Male householder	5.7%	±0.2%	167,740	±5,994	6.4%	±0.1%	20,271,973	±191,631
Female householder	17.5%	±0.4%	511,351	±10,215	16.4%	±0.1%	52,246,320	±289,541
Non-family	16.8%	±0.2%	491,071	±6,230	17.1%	±0%	54,592,097	±123,973

Hide data

Marital status

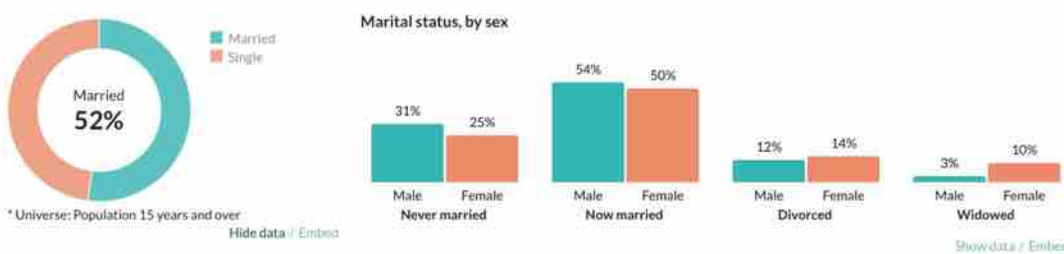


Table B12001 View table

Column	Arkansas				United States			
Married	52%	±0.3%	1,261,718	±7,180.9	50%	±0.1%	132,805,096	±277,877.3
Single	48.1%	±0.3%	1,167,088	±7,041.4	50%	±0.1%	133,027,071	±226,102.8

Hide data

Figure 45. Arkansas household demographics

Education and Training

While we have about the same percentage of high school graduates and those with some college, we have more with no degree and fewer with a bachelor's or post-grad. There may be several reasons for the differences between Arkansas and other states – poverty, lack of access to resources, shortage of facilities, etc. The point is that with adequate, reliable and affordable broadband access, more opportunities can be made available so that the education gap may also be closed, thus raising Arkansans' prospects for better employment and higher wages.

Due to the surge in demand for broadband infrastructure and network expansion across the country, industry groups and employers across Arkansas have raised concern that the supply of skilled, qualified workers will fall far short of what is needed to deploy new services on the scale and schedule contemplated. The IIJA makes funds available to invest in workforce development programs tailored to the broadband sector.

Whether the focus is on workforce development or increased post-secondary education, Arkansas stands to benefit from developing a robust broadband internet access program.

Educational attainment

87.2%

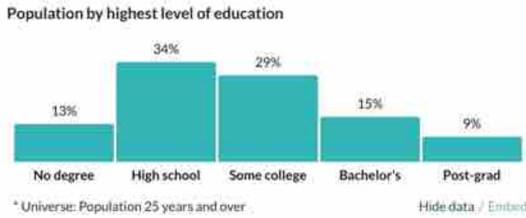
High school grad or higher

about the same as the rate in United States: 88.5%

23.8%

Bachelor's degree or higher

about three-quarters of the rate in United States: 32.9%



Population by highest level of education (Table B15002) View table

Column	Arkansas				United States			
No degree	12.9%	±0.2%	260,360	±4,182.6	11.5%	±0%	25,562,680	±66,530.2
High school	33.9%	±0.3%	686,812	±5,655.2	26.7%	±0.1%	59,421,419	±153,144.2
Some college	29.5%	±0.3%	596,855	±6,031.5	28.9%	±0.1%	64,496,416	±115,159.3
Bachelor's	15.2%	±0.3%	308,648	±5,053.4	20.2%	±0.1%	45,034,610	±110,632.9
Post-grad	8.6%	±0.2%	174,047	±3,243.2	12.7%	±0%	28,321,709	±97,773.2

Hide data

Figure 46. Educational attainment in Arkansas

Income

The median household income in Arkansas is about 75% of the figure in the United States. More than half of Arkansans live in a household with an income that is less than $50,000 per year, compared to 39.1% nationwide. This becomes an important figure as affordability is taken into consideration.

Income

$27,724

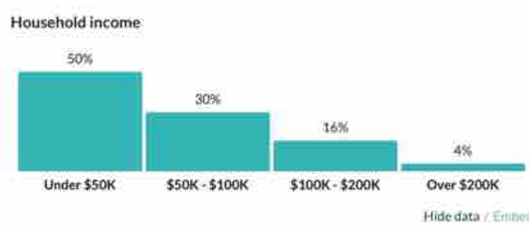
Per capita income

about 80 percent of the amount in United States: $35,384

$49,475

Median household income

about three-quarters of the amount in United States: $64,994



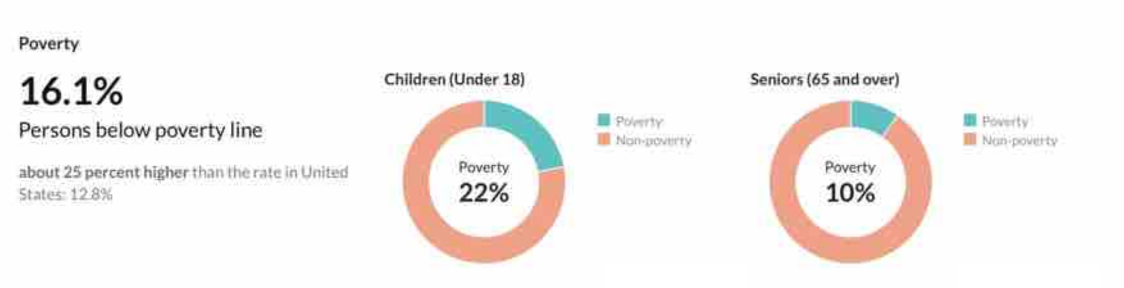
Household income (Table B19001) View table

Column	Arkansas				United States			
Under $50K	50.4%	±0.5%	590,261	±5,932.4	39.1%	±0.1%	47,785,414	±58,302.5
$50K - $100K	30%	±0.4%	350,561	±4,525.4	30%	±0.1%	36,648,022	±63,450.6
$100K - $200K	15.7%	±0.3%	183,378	±3,586.7	22.7%	±0.1%	27,817,092	±73,446.1
Over $200K	4%	±0.2%	46,344	±1,806	8.3%	±0%	10,103,691	±51,548

Hide data

Figure 47. Arkansas household income

We have more children living below the poverty line than the national average. Overall, we are about 25% higher than the national average of persons below the poverty line. By comparison, our seniors are about the same as the national average.



Children (Under 18) (Table B17001)

Column	Arkansas				United States			
Poverty	22%	±0.4%	151,653	±3,167.8	17.5%	±0.1%	12,598,699	±54,390.7
Non-poverty	78%	±0.2%	537,734	±4,616.3	82.5%	±0.1%	59,467,075	±64,344.3

Seniors (65 and over) (Table B17001)

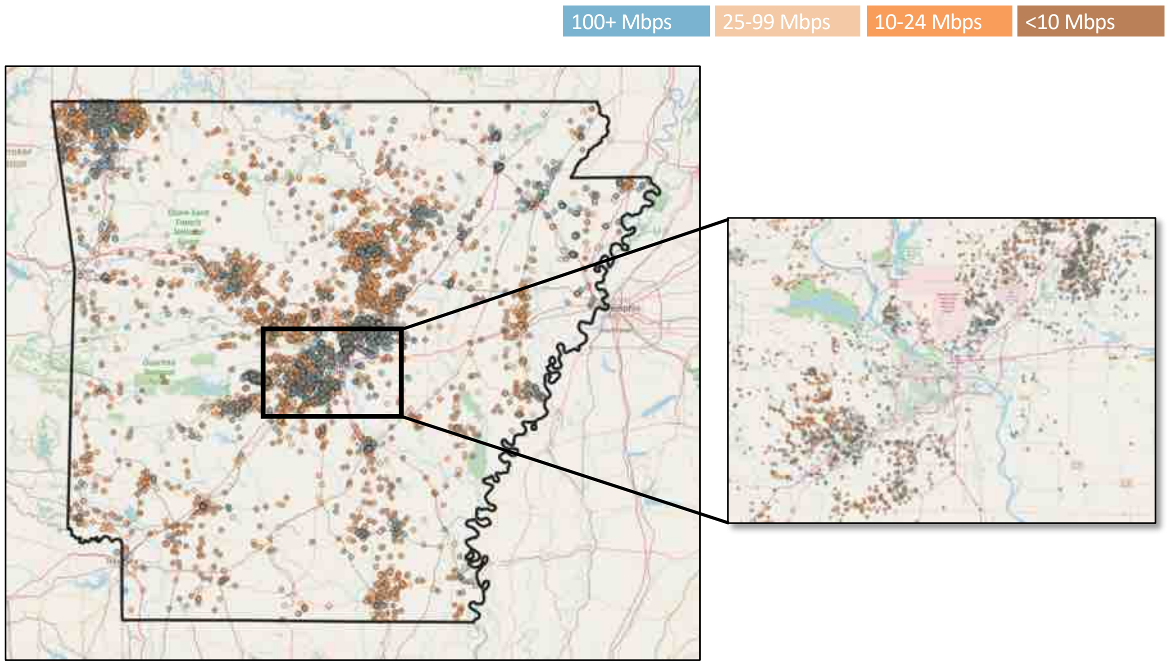
Column	Arkansas				United States			
Poverty	9.8%	±0.3%	48,358	±1,541.4	9.3%	±0%	4,756,707	±16,262.5
Non-poverty	90.2%	±0.6%	445,767	±1,770.4	90.7%	±0.1%	46,315,436	±17,287.6

Figure 48. Persons below the poverty line

The promise of ubiquitous, affordable, reliable broadband access statewide is that a population that closely resembles the rest of the nation in many ways can dramatically improve its economic, education, and business standing relative to those other states.

Map of Residential Households Surveyed

The map below shows the distribution of survey responses around the state and the speed test results. Of course, many of those surveyed could not complete this question because they have no internet access.



BDG Survey HHs by Speed Category

Speed Category	<10	10-24	25-99	100+	Total
Count	2,848	1,987	3,396	1,757	9,988
Share	29%	20%	34%	18%	100%

Figure 49. Speed test summary results

Community Survey

We conducted surveys of residents across the state. The surveys were distributed through several different statewide organizations, school districts, local community newspapers, Facebook, Twitter, mayors, county judges, legislators, civic groups, and our teams present in the communities. The goal was to reach as many households as quickly as possible.

A survey form was developed as an outreach tool, including a shareable QR code for the SurveyMonkey platform. The survey could be completed online with a phone, tablet, computer, or on paper.

Key observations about the respondents:

- About 75% have home WiFi networks.
- Nearly 44% consider their current Internet connection to be inadequate.
- 57.5% are willing to pay less than $50/month; another 32% would pay up to $100/month.
- All the following activities are considered to be Very Important by at least 20% of respondents: Distance Learning, Entertainment, Work-from-Home, Browsing, Gaming, and Security.
- Between 30%-40% considered reliable Internet service critical for work or school, respectively.
- Close to 50% of respondents think that their jobs or careers will be affected unless they get better internet access.

- About 26% say they will have to re-locate if they cannot get better internet access.
- About 23% of all respondents think better internet access is crucial for their children's education.

Survey responses indicate that multiple technologies are in use, but no technology is dominant. Cable modems and DSL are the most common Internet service access methods. Smaller numbers reported satellite/fixed wireless.

About 10% of respondents report no availability of any service.

Although respondents were not asked to disclose the current cost of their internet service, 32.24% indicated that they considered the Internet to be affordable if it costs less than \$100/month and 44.66% if it costs less than \$50/month. This indicates that most respondents would be willing to pay a competitive price for internet service. About 11% indicated that less than \$25/month is considered affordable.

Some providers require subscribers to purchase services that are unwanted or unnecessary to them to get broadband Internet service. Providers must consider many factors in establishing consumer prices for broadband service, including the cost of backhaul or "middle-mile" services in areas where the ISP may not have cost-effective choices from Tier 1 or 2 providers. That said, this is an area where policymakers may decide to focus attention to assure fairness to consumers and profitability for providers.

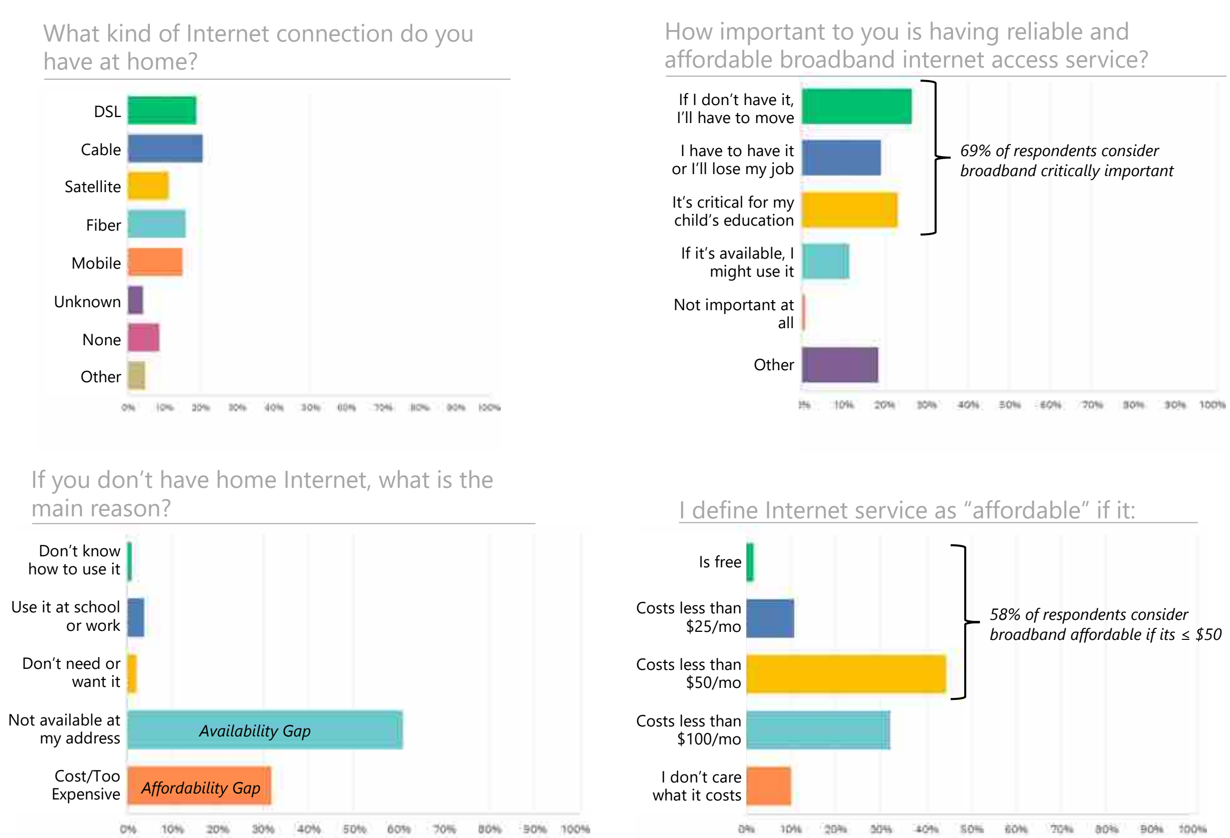


Figure 50. Survey results on home broadband

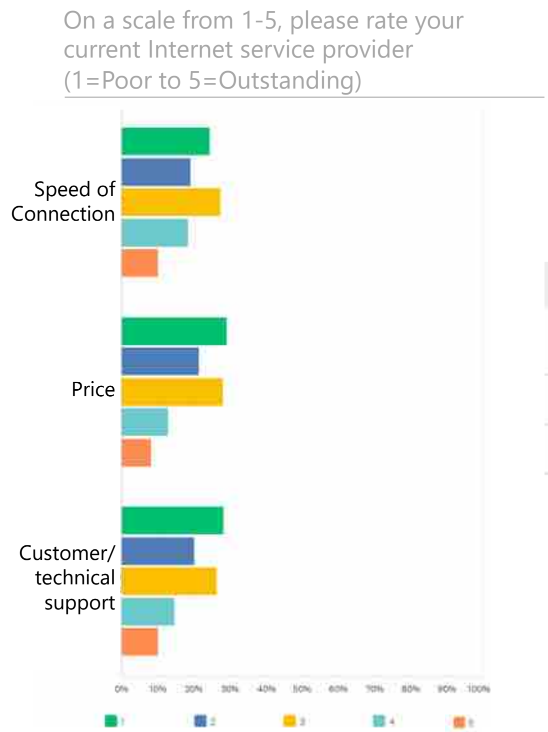
Satisfaction was also assessed as a function of cost, speed, and customer service.

About one in four respondents reported that they are Very Dissatisfied with the Speed of Connection. This is expected, given that almost 50% have service from DSL-enabled phone lines, a GEO satellite service, or a mobile hotspot. A majority report Satisfied to Very Satisfied with speed, reflecting service from fiber-optic or cable networks (56%).

Interestingly, Very Dissatisfied (with Price) is 29.25%, while Somewhat Satisfied and Very Satisfied (with Price) combine for only 21.1%.

A comment we heard repeatedly with respect to pricing was that subscribers are required to purchase a bundle of services (phone line, for example) to get internet service. Several companies require the subscriber to either purchase a bundle of services or the internet service is priced so that buying it as a standalone service is too expensive. Services such as Internet and landline telephone are apparently cross-subsidized. This seems especially prevalent in local telephone companies and appears in cable TV companies.

Customer/Technical Support splits about evenly between Very Dissatisfied/Somewhat Dissatisfied and Satisfied/Somewhat Satisfied/Very Satisfied (48.58% to 51.42%). However, Very Dissatisfied comes in at 28.27% compared to Very Satisfied at 10.19%. Only about one in four customers rate Customer/Technical Support as either Somewhat Satisfied or Very Satisfied.



	1	2	3	4	5	TOTAL	WEIGHTED AVERAGE
Speed of connection (bandwidth)	24.56% 4,139	19.19% 3,234	27.44% 4,625	18.53% 3,122	10.28% 1,732	16,852	2.71
Price	29.25% 4,865	21.48% 3,573	28.13% 4,679	12.90% 2,146	8.24% 1,370	16,633	2.49
Customer/technical support	28.27% 4,669	20.31% 3,353	26.45% 4,368	14.78% 2,441	10.19% 1,682	16,513	2.58

Figure 51. Customer satisfaction with current home broadband service

All Internet activities listed in Figure 52 are Very Important to respondents or someone in their household. While Gaming was the lowest-rated activity, it still has a 20% Very Important rating.

Entertainment, followed closely by Education and Work, has the highest proportion of Very Important ratings. This is significant because internet access is a disruptive technology relative to traditional entertainment distribution such as cable TV. According to "The Sustainable Future of Video Entertainment" from Interdigital.com (November 2020), video streaming will account for 82% of internet traffic in 2022.

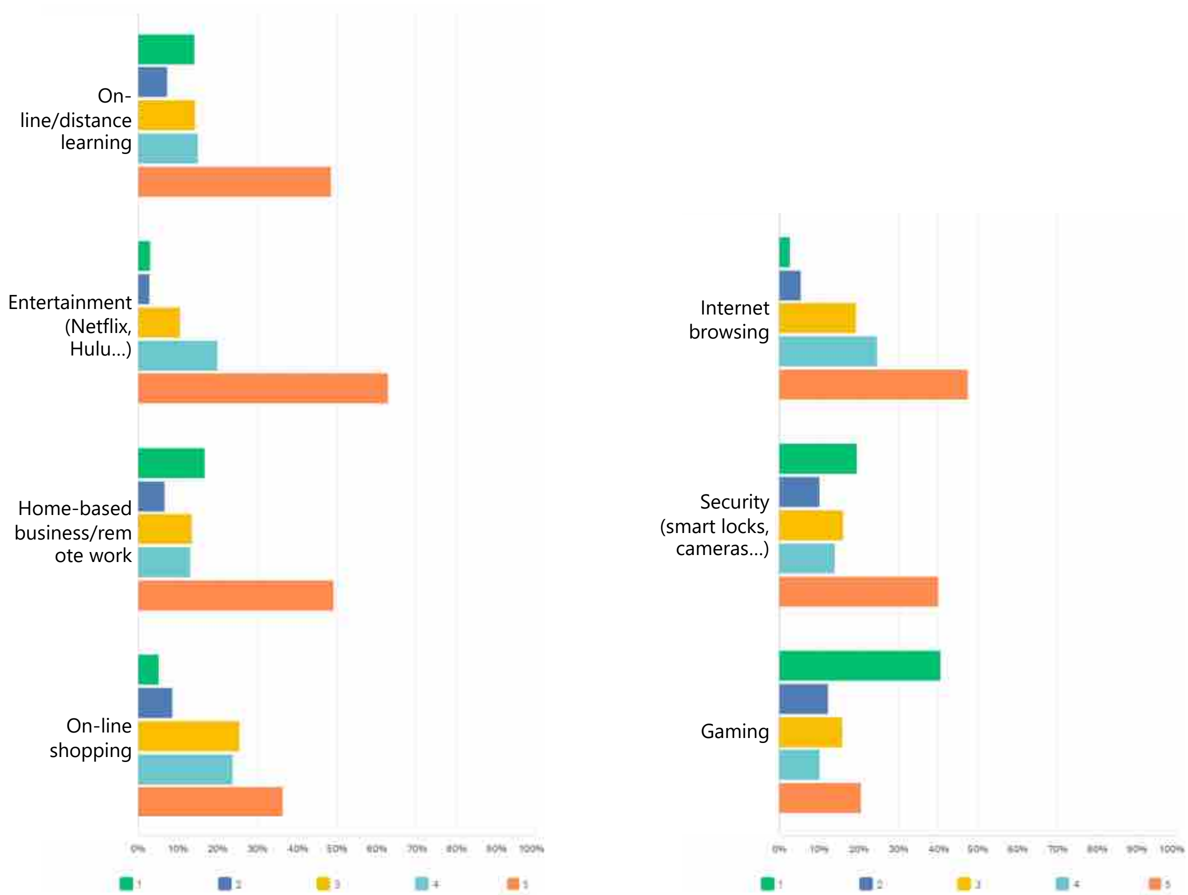


Figure 52. Internet activities

Internet usage is an important factor in identifying the Internet needs of residents and how they can be best served. Internet usage was assessed based on the rated importance of several Internet activities and the reported number of devices requiring Internet connection per household. Additionally, usage was assessed based on needs residents might have for training to learn how to use the Internet better.

Overwhelmingly, respondents indicate the need to connect wireless devices, including smart TVs. This indicates that, in addition to great broadband internet service, households also require high-quality WiFi. Based on interviews in communities, there is a significant educational opportunity to help consumers understand how internet access and WiFi work together and converge.

A large majority of respondents reported using a home WiFi network. This is to be expected given the near ubiquity of smartphones as access devices. That phenomenon contributes to the confusion for many consumers between what "internet access" is versus what "WiFi" is. For the average consumer, the terms are interchangeable. A common plea is, "I need better WiFi," when what is meant is, "I need better internet service for my WiFi-enabled device to connect to."

Further complicating the issue for consumers is that their smartphones also connect to cellular data through their mobile service providers. The average consumer does not know the difference between the sometimes complementary, sometimes competing, technologies. Unfortunately, many providers exploit this consumer confusion. Consumers are left vulnerable to marketing scams, predatory pricing, and bogus claims from some service providers.

About half of the respondents indicated that video training would be useful. Based on our observations in communities, there is a significant need to create more awareness among users concerning the devices they use for access; what they can/should expect from a provider; how the internet can be used to help in daily life; and, how to make informed decisions about selecting a provider (if more than one provider is available in their area). The subject of digital equity is of crucial importance. Getting affordable internet access to all households will be far more useful and valuable by helping consumers understand how to use the associated technologies. The subject of digital equity is of crucial importance. Getting affordable internet access to all households will be far more useful and valuable by helping consumers understand how to use the associated technologies.

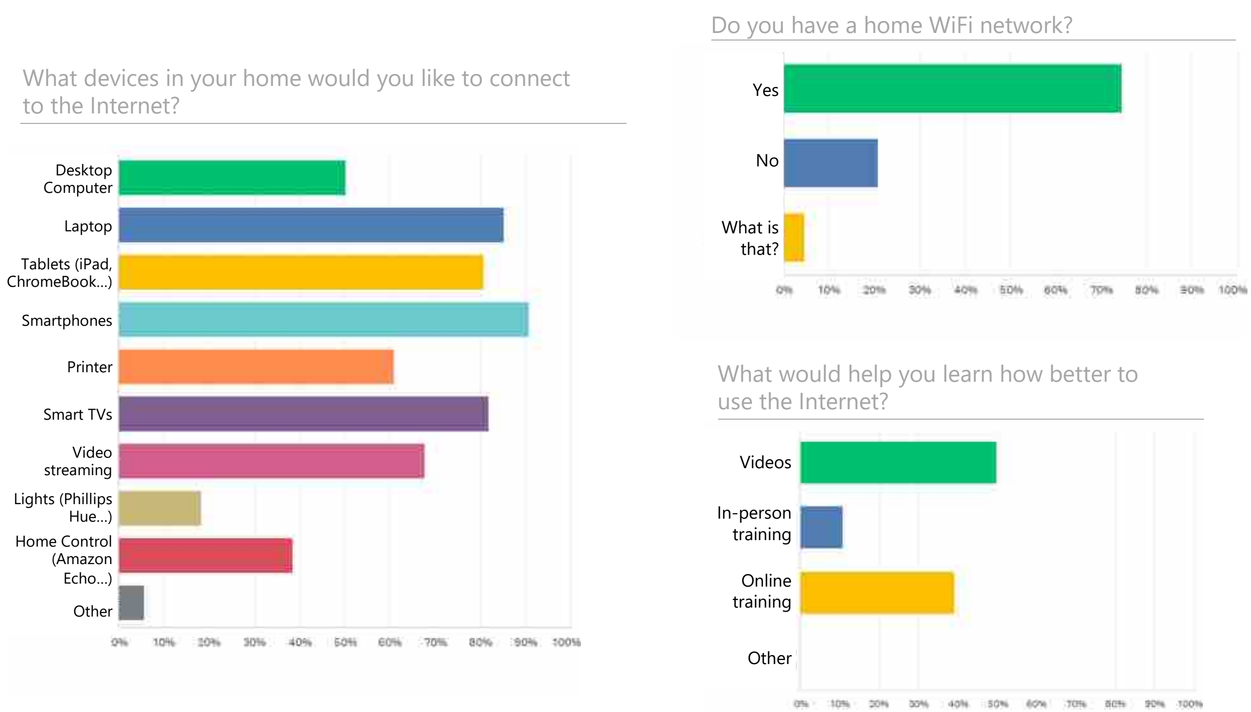
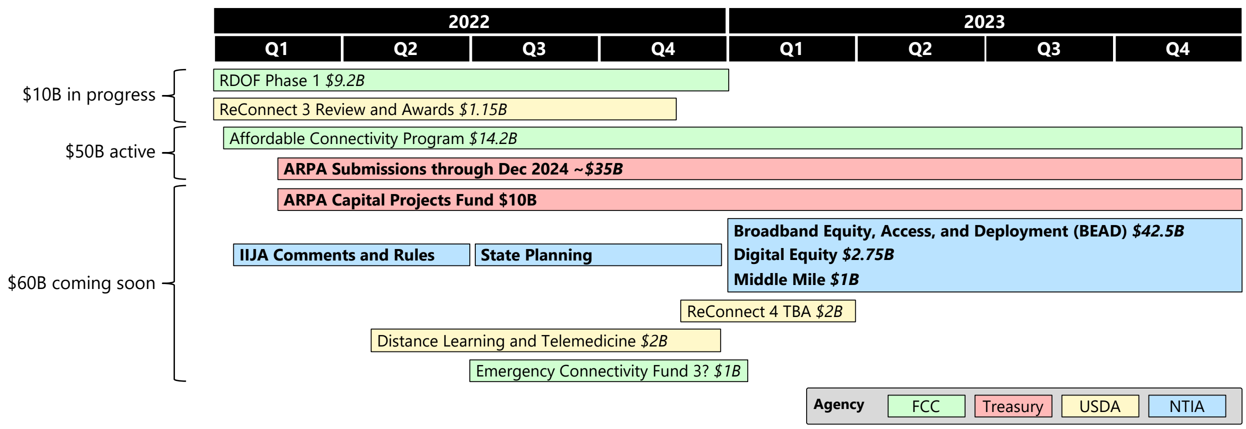


Figure 53. Home network

Appendix 1: Funding Sources



ARPA = America Rescue Plan Act, IIJA = Infrastructure Investment and Jobs Act, BEAD = Broadband Equity, Access, and Deployment SLFRP = State and Local Fiscal Recovery Plan

Figure 54. Federal funding programs

IIJA/NTIA BEAD is the primary new fund for states – the largest and 100% for broadband

The other large state funds are the more general ARPA (SLFRP and Capital Projects Fund)

Niche state funds available through IIJA/NTIA are the Middle Mile and Digital Equity funds.

Broadband Grant Funding Overview

	Total Federal Funding	
Rural Digital Opportunity Fund (RDOF)	~$20B	**Direct federal funding to providers** to build broadband service in **rural areas** • **Distributed $9.2B** in December 2020 auction, with **~$11.2B remaining**
American Rescue Plan Act (ARPA) *Coronavirus State and Local Fiscal Recovery Funds (SLFR)*	$195B Not exclusively broadband	**Arkansas received $1.57B** for responding to Covid-19, infrastructure improvements (broadband, water, sewers), paying essential workers, and addressing negative economic impacts caused by the pandemic – funds must be spent by 2026 • 25/3 unserved definition and priority for projects delivering 100 Mbps symmetrical
ARPA Capital Projects Fund	$10B	**Arkansas received $157.8M** • **Broadband deployment is a primary objective**, but States have wide discretion in their use of funds to build infrastructure • Rules prioritize symmetrical 100 Mbps service
Infrastructure Investment and Jobs Act (IIJA) **Broadband Equity, Access and Deployment (BEAD) Program**	~$42B Broadband Equity, Access and Deployment (BEAD) Program	**Each state receives min. of $100M**, with additional funding allocated via formula • All service providers, incl. municipal, cooperative, and private are eligible – **legislation does not prioritize non-profits** • Unserved areas with reliable service of less than 25/3 Mbps eligible and prioritized • **Minimum 100/20 Mbps service**; fiber required to be prioritized
Affordable Connectivity Program (ACP)	~$14B	**Consumers may apply directly** for subsidies to reduce monthly broadband cost • Households are eligible if any member has income below 200% of the poverty line or participates in other federal programs such as SNAP or Medicaid

Sources: US Government, Council of State and Local Governments, FierceTelecom

Figure 55. Current federal fund details

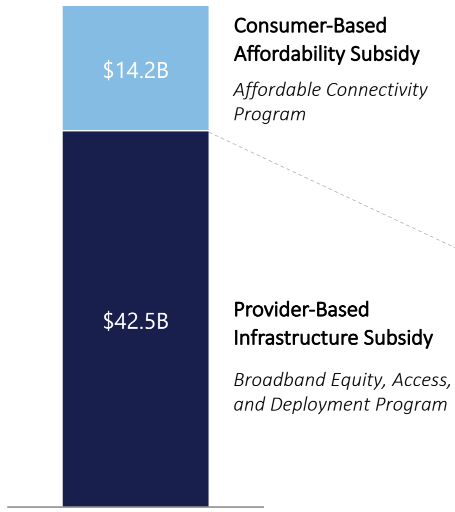
Program	Overview	Timeline	Eligibility	Upgrade Requirements	Coverage Targets
RDOF	▪ FCC program aimed at **increasing investment in rural broadband networks** ▪ Must offer one voice and one broadband service ▪ The exact **deployment schedule is determined by the carriers themselves** ▪ Funds distributed through reverse-auction ▪ Round 1: 180 bidders won **$9.2 billion** over 10 years targeting **5.2M locations**	▪ Phase I began in **2020** ▪ Phase II scheduled for **2023**	▪ Eligible areas defined as having less than **25/3 Mbps** and **no planned builds**	▪ Minimum **25/3**; Baseline **50/5**; Above Baseline **100/20**; Gigabit	▪ **40%** of the required number of locations in a state by the **end of third year** of support and an additional **20%** by the end of the fourth and fifth years of support
CAF II	▪ FCC program aimed at **increasing access to voice and broadband** services ▪ Awards **$1.5B** in annual support to winning carriers ▪ Focus on **larger providers**	▪ **2015-2021**	▪ Unserved of underserved areas	▪ Targets **10/1** Mbps	▪ **6 years** to plan and offer broadband to consumers. Price cap carriers that accepted CAF Phase II support must complete their deployment by the end of 2020.
A-CAM	▪ FCC program targeting **small rate-of-return carriers** ▪ **$4.9B** authorized over 10 years to target **455k homes and businesses** ▪ Provides $200 monthly subsidy ▪ Arkansas awarded **$62M** to cover **6,888 locations**	▪ **2017 -2028**	-	▪ Target mix of **10/1 and 25/3 Mbps**	▪ Target speeds of at least 25/3 Mbps to 80% of locations

Figure 56. Summary of recent federal programs now in deployment phase (part 1)

Program	Overview	Timeline	Eligibility	Upgrade Requirements	Coverage Targets
NTIA Broadband Infra.	▪ Department of Commerce program directed to **partnership between state and local government and providers of fixed broadband** ▪ $**288M** funded by the Consolidated Appropriations Act ▪ **172** census blocks in AR applied for funding	▪ Application closed **Aug. 2021**	▪ Areas under **25/3** Mbps are prioritized followed by areas under **100/20** Mbps	▪ **100/20** Mbps.	-
Broadband ReConnect	▪ USDA program to furnish loans and grants for broadband service in eligible rural areas ▪ **$700M** in pure grant funding, **$250M** in loan-grant combo ▪ Max award of **$25-35M** with **20% required match**	▪ Round I & II in **2019-2020** ▪ Round III Nov. 2021	▪ >90% under **100 Mbps** and not located or adjacent to an area greater than 20k	▪ Targets **100/100** Mbps; excludes satellite and mobile wireless	-
Arkansas Rural Connect (ARC)	▪ Grant program designed to expand the broadband footprint ▪ Projects reviewed and funded via legislative authorization ▪ Total of **$118M** of funding in Round I sourced from state funds and CARES Act	▪ Ongoing	▪ No more than 80% of total population served with **25/3 Mbps** speeds	▪ **25/3** Mbps	-

Figure 57. Summary of recent federal programs now in deployment phase (part 2)

2021 IIJA Broadband Funding ($B)



Implementation Details

- **$30/mo.** per HH, (or $75/mo. per HH in tribal areas)
- **Providers** must seek approval to participate via the Wireline Competition Bureau
- **Consumers must apply** and prove either**:**
    - Income at/below 200% of state poverty guidelines, or
    - Participation in specific housing, tribal or educational programs (e.g., SNAP, Lifeline, etc.)
- Intended to provide **long-term assistance** beyond $3B Emergency Broadband Benefit passed in Dec 2020

- **Funds released to states** after FCC **broadband access mapping exercise** to be finished by ~Q3 2022
    - **Minimum of $100M per state** with additional funding per state based on number of unserved (priority) and underserved locations
- **Grants administered by state broadband offices** which define grant programs (26 states with centralized broadband offices today)

US Government, FCC,

Figure 58. IIJA BEAD for states/infrastructure and ACP for consumers

State	Form 477	*Mix %*	BB Now	*Mix %*	MSFT	*Mix %*
AL	$1,803	4.2%	$1,205	2.8%	$983	2.3%
AK	$302	0.7%	$217	0.5%	$111	0.3%
AZ	$1,017	2.4%	$773	1.8%	$744	1.8%
AR	$1,709	4.0%	$1,017	2.4%	$681	1.6%
CA	$1,519	3.6%	$3,366	7.9%	$3,497	8.2%
CO	$480	1.1%	$655	1.5%	$559	1.3%
CT	$100	0.2%	$391	0.9%	$430	1.0%
DE	$100	0.2%	$100	0.2%	$100	0.2%
DC	$100	0.2%	$100	0.2%	$100	0.2%
FL	$2,290	5.4%	$2,249	5.3%	$2,070	4.9%
GA	$1,816	4.3%	$1,722	4.1%	$1,246	2.9%
HI	$100	0.2%	$542	1.3%	$107	0.3%
ID	$239	0.6%	$235	0.6%	$228	0.5%
IL	$754	1.8%	$1,232	2.9%	$1,796	4.2%
IN	$779	1.8%	$892	2.1%	$1,221	2.9%
IA	$403	0.9%	$407	1.0%	$611	1.4%
KS	$378	0.9%	$349	0.8%	$491	1.2%

State	Form 477	*Mix %*	BB Now	*Mix %*	MSFT	*Mix %*
KY	$837	2.0%	$850	2.0%	$919	2.2%
LA	$1,568	3.7%	$1,132	2.7%	$940	2.2%
ME	$174	0.4%	$324	0.8%	$259	0.6%
MD	$429	1.0%	$214	0.5%	$490	1.2%
MA	$427	1.0%	$179	0.4%	$670	1.6%
MI	$1,286	3.0%	$1,365	3.2%	$1,544	3.6%
MN	$425	1.0%	$895	2.1%	$815	1.9%
MS	$1,690	4.0%	$1,145	2.7%	$735	1.7%
MO	$1,297	3.1%	$1,095	2.6%	$1,140	2.7%
MT	$450	1.1%	$267	0.6%	$188	0.4%
NE	$219	0.5%	$191	0.4%	$320	0.8%
NV	$246	0.6%	$129	0.3%	$268	0.6%
NH	$136	0.3%	$253	0.6%	$122	0.3%
NJ	$377	0.9%	$396	0.9%	$711	1.7%
NM	$763	1.8%	$456	1.1%	$402	0.9%
NY	$743	1.7%	$1,248	2.9%	$2,471	5.8%
NC	$1,419	3.3%	$1,556	3.7%	$1,483	3.5%

State	Form 477	*Mix %*	BB Now	*Mix %*	MSFT	*Mix %*
ND	$100	0.2%	$134	0.3%	$121	0.3%
OH	$1,016	2.4%	$1,473	3.5%	$1,914	4.5%
OK	$1,399	3.3%	$913	2.2%	$729	1.7%
OR	$650	1.5%	$687	1.6%	$453	1.1%
PA	$1,599	3.8%	$1,260	3.0%	$1,853	4.4%
RI	$100	0.2%	$100	0.2%	$104	0.2%
SC	$1,300	3.1%	$1,169	2.8%	$834	2.0%
SD	$136	0.3%	$146	0.3%	$146	0.3%
TN	$1,315	3.1%	$1,271	3.0%	$1,137	2.7%
TX	$3,236	7.6%	$3,855	9.1%	$3,199	7.5%
UT	$320	0.8%	$173	0.4%	$172	0.4%
VT	$139	0.3%	$199	0.5%	$120	0.3%
VA	$1,472	3.5%	$908	2.1%	$893	2.1%
WA	$841	2.0%	$1,261	3.0%	$797	1.9%
WV	$1,073	2.5%	$938	2.2%	$437	1.0%
WI	$1,248	2.9%	$714	1.7%	$983	2.3%
WY	$129	0.3%	$103	0.2%	$105	0.2%

Figure 59. Estimate for Arkansas share of Bead: $1 billion

Estimated ACP Qualification Rate and Annual Funding by State

HHs (and % of total) under 200% of poverty income threshold, implied annual funding at $30/mo for all eligible HHs

State	Total HHs (M)	Eligible HHs (M)	% of HH Eligible	Est. ACP Subsidy ($M)	Mix %	State	Total HHs (M)	Eligible HHs (M)	% of HH Eligible	Est. ACP Subsidy ($M)	Mix %	State	Total HHs (M)	Eligible HHs (M)	% of HH Eligible	Est. ACP Subsidy ($M)	Mix %
AL	1.9	0.7	*36%*	$244	*1.8%*	**KY**	1.7	0.6	*35%*	$216	*1.6%*	**ND**	0.3	0.1	*25%*	$26	*0.2%*
AK	0.3	0.1	*24%*	$25	*0.2%*	**LA**	1.8	0.7	*38%*	$244	*1.8%*	**OH**	4.5	1.4	*30%*	$489	*3.7%*
AZ	2.8	0.9	*32%*	$326	*2.4%*	**ME**	0.5	0.2	*29%*	$54	*0.4%*	**OK**	1.5	0.5	*35%*	$195	*1.5%*
AR	1.2	0.5	*39%*	$166	*1.2%*	**MD**	2.4	0.5	*21%*	$180	*1.3%*	**OR**	1.7	0.5	*28%*	$164	*1.2%*
CA	15.5	4.3	*28%*	$1,557	*11.7%*	**MA**	2.7	0.6	*21%*	$200	*1.5%*	**PA**	5.0	1.4	*27%*	$486	*3.7%*
CO	2.2	0.5	*23%*	$188	*1.4%*	**MI**	3.9	1.2	*30%*	$419	*3.1%*	**RI**	0.4	0.1	*24%*	$35	*0.3%*
CT	1.4	0.3	*23%*	$113	*0.9%*	**MN**	2.2	0.5	*22%*	$175	*1.3%*	**SC**	2.0	0.7	*33%*	$235	*1.8%*
DE	0.4	0.1	*25%*	$33	*0.3%*	**MS**	1.1	0.5	*41%*	$170	*1.3%*	**SD**	0.3	0.1	*29%*	$35	*0.3%*
DC	0.3	0.1	*25%*	$25	*0.2%*	**MO**	2.4	0.7	*31%*	$266	*2.0%*	**TN**	2.7	0.9	*33%*	$312	*2.3%*
FL	8.4	2.7	*32%*	$968	*7.3%*	**MT**	0.4	0.1	*31%*	$46	*0.3%*	**TX**	11.3	3.7	*33%*	$1,328	*10.0%*
GA	4.1	1.3	*32%*	$473	*3.6%*	**NE**	0.7	0.2	*26%*	$71	*0.5%*	**UT**	1.3	0.3	*24%*	$110	*0.8%*
HI	0.5	0.1	*21%*	$41	*0.3%*	**NV**	1.2	0.4	*31%*	$133	*1.0%*	**VT**	0.2	0.1	*26%*	$22	*0.2%*
ID	0.7	0.2	*32%*	$80	*0.6%*	**NH**	0.5	0.1	*19%*	$36	*0.3%*	**VA**	3.3	0.8	*23%*	$276	*2.1%*
IL	4.9	1.3	*26%*	$471	*3.5%*	**NJ**	3.5	0.7	*21%*	$266	*2.0%*	**WA**	3.0	0.7	*23%*	$250	*1.9%*
IN	2.6	0.8	*30%*	$280	*2.1%*	**NM**	0.8	0.3	*38%*	$111	*0.8%*	**WV**	0.7	0.3	*37%*	$92	*0.7%*
IA	1.2	0.3	*27%*	$121	*0.9%*	**NY**	7.6	2.1	*27%*	$746	*5.6%*	**WI**	2.3	0.6	*25%*	$202	*1.5%*
KS	1.1	0.3	*28%*	$114	*0.9%*	**NC**	4.1	1.3	*32%*	$469	*3.5%*	**WY**	0.2	0.1	*26%*	$21	*0.2%*

***~37M eligible HHs** (29%), **$13.3B annually** (at 100% take rate)*

Figure 60. Estimate 39% of Arkansas HH eligible for ACP subsidy

Appendix 2: State Broadband Programs

	Wisconsin Broadband Expansion Program *Started in 2013*	**Colorado Broadband Fund** *Started in 2014*	**Minnesota Border to Border Grant Program** *Started in 2014*	**Indiana Next Level Connections Program** *Started in 2019*	**West Virginia State Broadband Initiative[1]** *Started in 2022*	**Tennessee Emergency Broadband Fund** *Started in 2022*	**Arkansas Rural Connect Program (ARC)** *Started in 2019*
State Population	*~5.9M*	*~5.8M*	~5.7M	~6.8M	~1.8M	~7.0M	~3.0M
Applicant Eligibility	Telcos, utilities, municipalities in partnerships w/ operator	Telcos, Utilities	Telcos, partnerships, non-profits, municipalities	Businesses, cooperatives	Telcos, non-profits, municipalities, partnerships	Telcos	Communities *in partnerships* with ISPs
Household Eligibility	<25	<25	<100	<25	<25	<100	<25/3
Geographic Units	Addresses	Addresses	Addresses	Addresses	State defined areas	Census Blocks *(unclear)*	Community-level[3]
Upgrade Minimum	*Not explicitly stated*	>25	>100	>50	>100	>100	>25/3
Completion Timeline	2 years					3 years	~2 years
Applicant Matching Contribution	None	25%	50%	20%	25% or $500 per address	30%	*Not explicitly stated*
Maximum Grant Value	None	None	$5M[2] per application	$5M per application	$20M	None	$3,000 per passing (flexible)
Operation Requirements	*Not explicitly stated*	5 years	5 years	*Not explicitly stated*	*Not explicitly stated*	3 years highly encouraged	~10 years from grant
Success-Based CapEx Inclusion	*Not explicitly stated*	Customer drop costs	Customer drop costs	*Not explicitly stated*	Up to demarcation point (ONT)	Service and installation costs	Installation and testing costs
Fund Distribution Model	Reimbursement-based grant used by all state programs						

[1] Criteria focuses on Major Broadband Project Strategies (MBPS) program
[2] 2021 maximum size, 2022 max to be determined
[3] 95% of locations must be covered

Sources: Grant program webinars and websites, U.S. Census Bureau

Figure 61. Summary of state program characteristics

Formalized Scoring (MN, IN, WV, TN, AR)

	Description	WI	CO	MN	IN	WV	TN	AR
Speed of service	Preference for higher speeds above minimum threshold	X	X	X	X	X	X	
Matching	Preference toward higher share of total project cost above minimum match	X	X	X	X	X	X	X *Grant amount per HH passed*
Community Support	Preference toward quality and volume of partnerships, local funding, and letters from community			X	X	X	X	
Economic & Community Impact	Deployment to anchor institutions, businesses, and farms	X	X	X	X	X	X	
Affordability	Preference for affordability measures outside of FCC Affordable Connectivity Program such as low-cost price tiers			X	X	X	X	
Adoption Strategy	Preference for focused adoption assistance and engagement plan outside of traditional marketing			X			X	
Project Readiness	Realistic and complete project plan, cost-effective financial model, certified engineering plan, and demonstrated ability to deliver service			X	X	X	X	
Priority Places/HHs	Preference toward greater number of priority households (<25/3) and economically distressed areas	X	X	X		X	X	X *<10/1; poorer areas*

Figure 62. State program application evaluation criteria

Background & Program Rules

- Biannual **last-mile** (can include middle mile if necessary) rural broadband grants
- Application to board prepared by applicants
- 2020 had 37 applications across the two cycles, and 13 projects won grants
- **Reimbursement-based** grant program
- Example Grantees:

	Rule
Applicant Eligibility	Telco, Utilities
Household Eligibility	**<25/3 is unserved**, <10/1 is priority; must **lack at least one satellite provider *and* one non-satellite provider;** must be **outside municipal areas** or in **cities with <7,500 inhabitants**
Geographic Units	Address – providers submit **list of address locations**
Upgrade Minimum	**>25/3**
Completion Timeline	Construction must be completed within **24 months** after application
Applicant Cost Match	**25%** of total cost of project
Challenge Process	60-day public comment period, **ISPs can prove areas are served**; applicants **can appeal**
Max Grant Value	Overall cycle has **total grant pool size**, no defined maximum on an individual grant level
Operation Requirements	Commit to minimum **5 years of network operation** after completion of the project
Success-Based CapEx	Yes - Example grants cover CPEs and other customer drop costs

Award Selection Process

- **No use of formal scoring** system
- Applicants need to meet "minimum requirements" as first bar to cross
  - Majority of applicants **are excluded because proposed areas are served** or will be served within 12 months
- Broadband Deployment Board **chooses grant winners based on factors** such as enhancing economic development, matching funds, latency and speed, cost-effectiveness, and if households are "critically" unserved (<10/1)
- The Deployment Board is **not limited by their outlined criteria**, as they can decide based on "any other information that Board deems pertinent"

Figure 63. Colorado: $46 million in grants since 2014 through a reimbursement-based grant program

Background & Program Rules

- Three programs:
  - $45M toward Major Broadband Project Strategies Program (MBPS)
  - $25M toward Line Extension Advancement and Development (LEAD)
  - $40M for GigReady Program
- Application to board prepared by applicants
- **Reimbursement-based** grant program
- Programs are generally similar, with different conditions regarding the type of project (extensions vs. new projects) and timeline of completion
- MBPS is most similar to a target program in Arkansas

For MBPS Program only

	Rule
Applicant Eligibility	Telco, non-profits, municipalities and governments, partnerships
Household Eligibility	**No provider offering 25/3**, satellite and mobile wireless do not count; Targeted addresses must fall within "Eligible Service Areas" defined by the state
Geographic Units	"Eligible Service Areas" (defined by state); applicants can also propose "Additional Service Areas"; Areas do not have to be contiguous
Upgrade Minimum	**>100/20 scalable to 100/100; 1000/500 encouraged**
Completion Timeline	Construction must be completed within **24 months** after award; 6 month delays allowed for issues not caused by applicant
Applicant Cost Match	**Lesser of 25%** of total cost of project or $500 per passed address
Challenge Process	**ISPs can prove areas are served**; applicants can **re-submit proposals**
Max Grant Value	$20M grant funding cap per project; maximum of 5,000 targeted addresses
Operation Requirements	Not stated
Success-Based CapEx	Funding covers until the network demarcation point (e.g., NID or ONT)

Award Selection Process

- **Formal scoring** system
- For MBPS program, providers are scored across three areas**: technical**, **financial**, and broadband development **impact**, each worth 100 points
- Technical includes **project readiness** (30 points), **operational readiness** (30 points), and **speed** of service (40 points)
- Financial includes **cost-efficiency** (40 points), **matching funds** (20 points), **financial resiliency** (30 points), and **commitment** of proposed **matching** (10 points)
- Broadband Development Impact includes **affordability** (20 points), **community impact** (50 points), and level of **demonstrated community support** (30 points)

Figure 64. West Virginia has three programs for deployment

Background & Program Rules

- Two programs:
  - Tennessee Broadband Accessibility Grant – awarded $60M since 2017
  - Tennessee Emergency Broadband Fund – new $400M fund
- Application prepared by applicants
- **Reimbursement-based** grant program
  - Last 15% of grant is withheld until project closeout
- Can serve areas that were auctioned through RDOF

	Rule
Applicant Eligibility	Telcos
Household Eligibility	Eligible areas are geographic **areas** in which **at least 80% of households and businesses lack a fixed, terrestrial provider offering 100/20; <25/3 given priority**
Geographic Units	Believed to be Census blocks in which 80% of households and businesses lack 100/20
Upgrade Minimum	**>100/20 scalable to 100/100; technology agnostic**
Completion Timeline	**3 years**
Applicant Cost Match	**30% minimum**
Challenge Process	**ISPs can prove areas are served after public notice period;** grant finalists are given three weeks to respond to comments
Max Grant Value	No maximum
Operation Requirements	Highly encouraged to serve area for **at least 3 years** after contract completion
Success-based CapEx	Yes, covers expenses related to test of service and installation

Award Selection Process

- **Formal scoring** system
- For Emergency Broadband Fund, applicants are scored out of **210 points across 9 categories**
- Funding: **Need for grant** funding (50 points), leveraged and **match funds** (15 points)
- Quality: **Speed**, **scalability**, and **affordability** (25 points), **sustainability** and **implementation readiness** (30 points)
- Community: **Economic** and **community impact** (30 points), **community support** (20 points)
- Other characteristics: **adoption strategy** (20 points), **Broadband Ready Community**[1] (10 points), **County Designation**[2] (10 points)

[1] Political subdivisions apply for Broadband Ready Community designation which the Tennessee Department of Economic & Community Development evaluates

[2] Federally designated as "distressed" or "at-risk" county

: Tennessee Broadband Website

Figure 65. Tennessee: Emergency Broadband Fund will distribute $400 million for broadband

Background & Program Rules

- State Broadband Expansion Grant Program has given $74.2M across 268 projects since 2013
    - 2022 round has $100M available
- Both last-mile and middle-mile
- Application prepared by applicants
- **Reimbursement-based** grant program
- Example Grantees:

	Rule
Applicant Eligibility	For-profits and non-profits, utilities, and municipalities *in partnerships*
Household Eligibility	Areas with **fewer than 2 providers offering 25/3** service; areas with no fixed offering of 5/0.6 given priority
Geographic Units	Addresses
Upgrade Minimum	Not stated
Completion Timeline	**24 months**
Applicant Cost Match	**None,** but a priority factor
Challenge Process	**ISPs can prove areas are served during public notice period;** grant finalists are given one week to respond to objections; no appeal process otherwise
Max Grant Value	No maximum
Operation Requirements	Not stated
Success-based CapEx	Unclear

Award Selection Process

Figure 66. Wisconsin: Broadband Expansion Grant Program since 2013, with $100 million for FY2022

Background & Program Rules

- Border to Border Grant Program was established in 2014
    - FY2021 had $20M available
    - FY2022 has $70M available
- 2020 had 64 applications, 39 projects were recommended for funding
- >$100M total has been awarded
- Both last-mile and middle-mile
- Application prepared by applicants
- **Reimbursement-based** grant program
- Example Grantees:

	Rule
Applicant Eligibility	Businesses, partnerships, political divisions, tribes, nonprofits
Household Eligibility	Both underserved and unserved areas: <100/20 wireline speed underserved, <25/3 is unserved
Geographic Units	Addresses
Upgrade Minimum	100/20 scalable to 100/100
Completion Timeline	For FY2021 (early 2021 award decision), **completion by June 2023**
Applicant Cost Match	**50%**
Challenge Process	**ISPs have 30 days to prove areas are served or will be served within 18 months**
Max Grant Value	$5M for FY2021
Operation Requirements	5-year service commitment
Success-based CapEx	Encouraged to incorporate customer drop prices into grant budget

Award Selection Process

- **Formal scoring** system
- Scored out of 120 points
- **Anticipated Broadband Improvements** (20 points), **Grant Funding Request Amount** (10 points)
- **Critical Need/Community Participation** (15 points), **Project Readiness** (25 points), **Project Sustainability** (25 points)
- **Economic Development & Community Impact** (15 points), **Broadband Adoption Assistance** (10 points)

Figure 67. Minnesota: Border to Border Program to fund last and middle-mile projects since 2014

Background & Program Rules

- ~$79M awarded in Rounds 1 and 2, ~22k total passings (19.5k residential)
- Third round (Spring 2022) received **>250 LOIs requesting $606M in funding**
- Last-mile (including middle-mile that is necessary for last-mile)
- After initial applications, applicants can submit **"competitive applications"** if they can provide **same service level** to same area at a **lower cost to the state**
- **Reimbursement-based** grant program
- Example Grantees:

	Rule
Applicant Eligibility	Businesses, cooperatives
Household Eligibility	<25/3
Geographic Units	Addresses
Upgrade Minimum	**50/5**, 100/100 given priority
Completion Timeline	**24 months**
Applicant Cost Match	**20%**
Challenge Process	**ISPs have 30 days to prove areas are served or will be served within 18 months**
Max Grant Value	**$5M**
Operation Requirements	**5-year** service commitment
Success-based CapEx	N/A

Award Selection Process

- **Formal scoring** system
- Scored out of 250 points
- **Project Description and Readiness** (65 points)
- **Project Impact** (20 points), **Community Support and Engagement** (15 points)
- **Technical Qualifications and Re** (10 points)
- Economically Disadvantaged **Student Household Service Packages** (15 points)
- Objective Scoring (125 points) split into **# of passings and speed** (60 points), and **matching** (65 points)

Figure 68. Indiana Next Level Connections Program: ~$79 million in the last two years to pass 22,000 HH

Background & Program Rules

Arkansas Department of Commerce Broadband Office

- Awarded >$300M since 2019
- Communities or municipalities applying must have at least 500 people with at least 200 lacking 25/3
- Claws back fund distribution if <95% of footprint is covered by end of 10-year period
- **Reimbursement-based** grant program
- Example Grantees:

	Rule
Applicant Eligibility	Subdivisions (Municipalities, counties, communities) *in partnership* with an ISP
Household Eligibility	<25/3
Geographic Units	Community-level; <80% must have <25/3; 95% of locations must end up being covered
Upgrade Minimum	>25/3
Completion Timeline	~2 years
Applicant Cost Match	*Not explicitly stated*
Challenge Process	Not explicitly outlined, but known to exist
Max Grant Value	$3,000 Per Passing or $2,000,000 (whichever is lower)
Operation Requirements	~10 years
Success-based CapEx	Includes installation and testing costs

The $3,000 max. per passing was stated "flexible" in a supplemental rule from Mike Preston (Dec. 28, 2020)

Award Selection Process

- **Formal scoring** system
- Scored out of 100 points
- **Grant request per household connected** (60 points)
- **Current service deficiency** (25 points)
  - 25 points if 90% of project footprint is unserved by 10/1; else 0
- **Poverty** (15 points)
  - 15 × (100-percentile of income per capita)

Figure 69. Arkansas Rural Connect (ARC) Program has distributed >$300 million since its inception

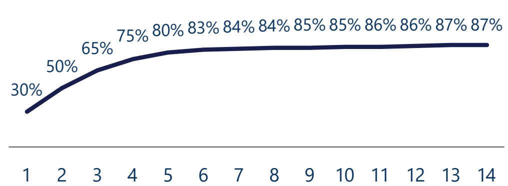
Appendix 3: ISP Financial Model

	Driver		Description	Benchmarks Range	Model Assumption
Build Assumptions (CapEx)	Fiber Deployment Cost		• Cost of deploying aerial fiber (including equipment & installation) • Based on estimates from contractors for fiber build projects	*$27K* ↔ *$91K*	$40k per mile
	Network Equipment	Central Office / Headend	• Cost of upgrading an existing CO • Highly dependent on type of provider		$14K per CBG *Modeled as expected cost at CBG level*
		Fiber Distribution Hub	• Cost of equipment and establishing Fiber Distribution Hub	*$8K* ↔ *$15K*	$11.5K per Unit
		Fiber Distribution Terminal	• Cost of equipment and establishing Fiber Distribution Terminal	*$300* ↔ *$500*	$500 per unit
		Connection Cost	• Cost of connecting premises to the fiber route incl. equipment & labor	*$470* ↔ *$990*	$600 per premises
Operation Assumptions	COGs/Operation Expenses		• % of revenue allocated to OPEX	*15%* ↔ *40%*	25%
	Maintenance CapEx		• % of revenue allocated to maintenance	*2%* ↔ *10%*	4%
	Residential ARPU		• High Speed Data ARPU per HH	*$40* ↔ *$115*	$50 monthly
	SMB ARPU		• High Speed Data ARPU per SMB	*$140* ↔ *$225*	$150 monthly
	S&M Cost		• Sales & Marketing Costs based on gross adds revenue	*300%* ↔ *500%*	500% of GA ARPU
Terminal Value Assumptions	Growth Rate		• Assumed growth of cash flow		3%
	Discount Rate		• Cost of capital for ISP		15%

Figure 70. Benchmarks and provider data for revenue and cost assumptions

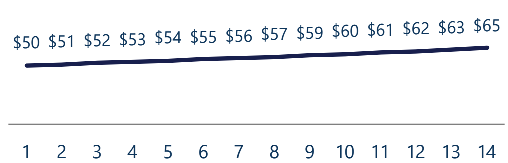
Key Driver Summary

Subscriber Uptake
(% of Passings)



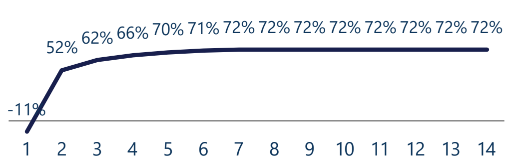
- Given limited competition, provider expected to capture a large majority of the market
- Benchmarks suggest potential for an even more aggressive ramp

Data ARPU
(Monthly)



- Conservative ARPU estimate given economic constraints of target markets and accessibility objectives of subsidy program
- Grown at 2% CAGR

EBITDA Margin



- Driven by 25% COGs assumption and S&M costs associated with gross adds
- Initial ramp a function of front-loaded S&M costs

Figure 71. Benchmarks used for key operating assumptions

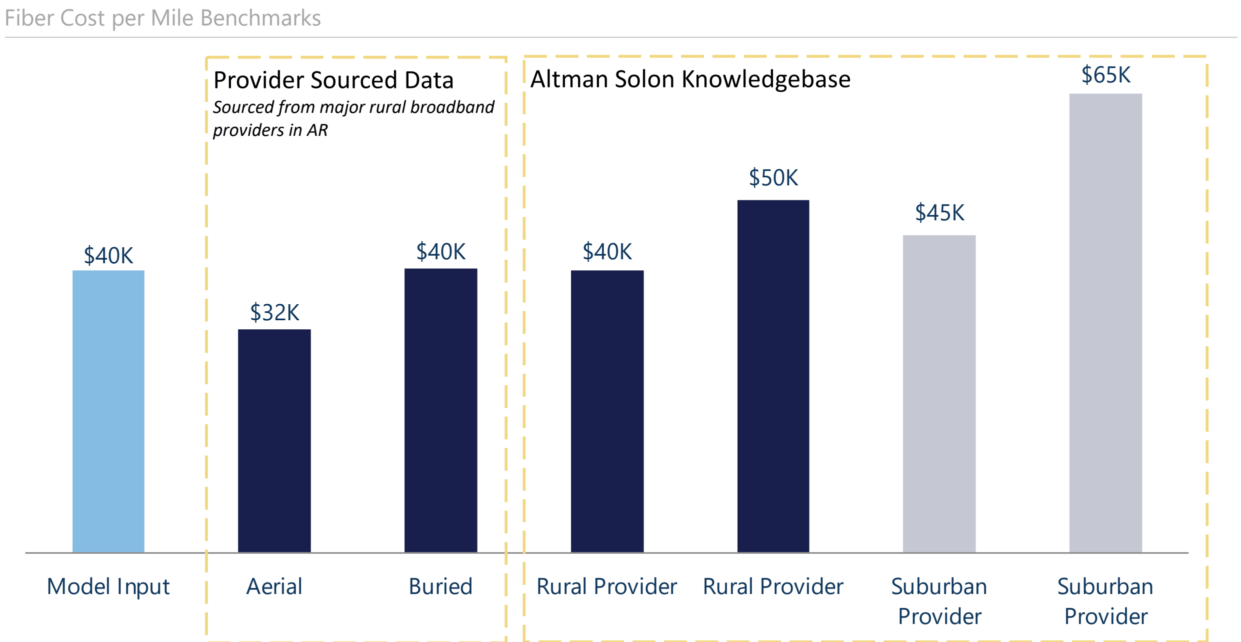


Figure 72. Model uses a $40,000 per mile cost assumption, in line with benchmarks from rural providers

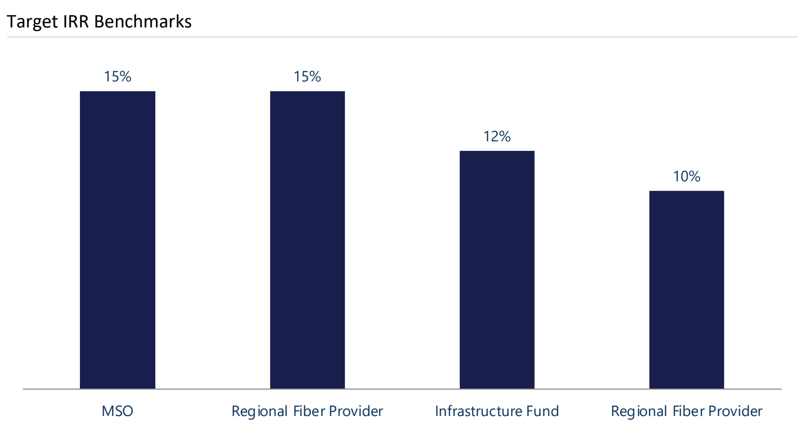


Figure 73. 15% IRR target is within a range of benchmarks from fiber providers

Example: Full state model for Scenario 2 (109k HH)

Year	0	1	3	4	5	6	7	8	9	10	11	12	13	14
HH Passed		110,212	111,206	111,706	112,209	112,714	113,221	113,731	114,242	114,756	115,273	115,792	116,313	116,836
Total Subs		16,532	63,819	78,032	86,773	91,378	93,764	95,037	96,034	97,039	98,051	99,070	100,096	101,129
Uptake		*15%*	*57%*	*70%*	*77%*	*81%*	*83%*	*84%*	*84%*	*85%*	*85%*	*86%*	*86%*	*87%*
HH ARPU (Monthly)		*$50.00*	*$52.02*	*$53.06*	*$54.12*	*$55.20*	*$56.31*	*$57.43*	*$58.58*	*$59.75*	*$60.95*	*$62.17*	*$63.41*	*$64.68*
Total Revenue		$9.9M	$39.8M	$49.7M	$56.4M	$60.5M	$63.4M	$65.5M	$67.5M	$69.6M	$71.7M	$73.9M	$76.2M	$78.5M
EBITDA		-$1.1M	$24.5M	$33.0M	$39.3M	$43.0M	$45.5M	$47.2M	$48.7M	$50.2M	$51.7M	$53.3M	$54.9M	$56.6M
Margin		*-11%*	*62%*	*66%*	*70%*	*71%*	*72%*	*72%*	*72%*	*72%*	*72%*	*72%*	*72%*	*72%*
Deployment CAPEX	**-$601M**													
Success-Based CAPEX		-$20M	-$11M	-$8M	-$5M	-$3M	-$3M	-$2M	-$2M	-$2M	-$2M	-$2M	-$2M	-$2M
EBITDA - CAPEX	-$601M	-$21M	$13M	$25M	$34M	$40M	$43M	$45M	$47M	$48M	$50M	$51M	$53M	$55M
Terminal Value														$442M
Cash Flow Proxy	-$601M	-$21M	$13M	$25M	$34M	$40M	$43M	$45M	$47M	$48M	$50M	$51M	$53M	$497M
IRR	3.8%													

Note: Source spreadsheet is available to test different assumptions.
Note: Source spreadsheet is available to test different assumptions.

Figure 74. ISP financial model used to compute subsidy needed for the project to yield target IRR

Appendix 4: Technology

Overview of Broadband Access Subsystems

The Internet is a massive "network of networks where thousands of autonomous networks are interconnected through standard protocols to enable global connectivity. Rural broadband access networks distribute data at the edge of the Internet, analogous to distribution systems for water, electricity, packages, and traffic. High-capacity "trunks" carry bulk traffic to the core of the Internet, and from there, traffic branches out through lower-capacity tributaries, ultimately reaching devices in individual homes. As with all distribution networks, the cost/home is low in the shared high-capacity backbone portion of the network and increases as the network extends toward the endpoints, where cost is born by fewer and fewer users, ultimately reaching individual households. We'll use the following terms to describe the distribution tiers comprising broadband networks:

- **Core**: Central site to consolidate all traffic where it is exchanged with backbone providers.
- **Backhaul**: high-speed transmission from the core to regional "hubs', aka "middle mile."
- **Access**: subsystem linking regional hubs to individual households, aka "last mile."
- **Home Network:** subsystem to connect multiple devices via a shared Internet connection.

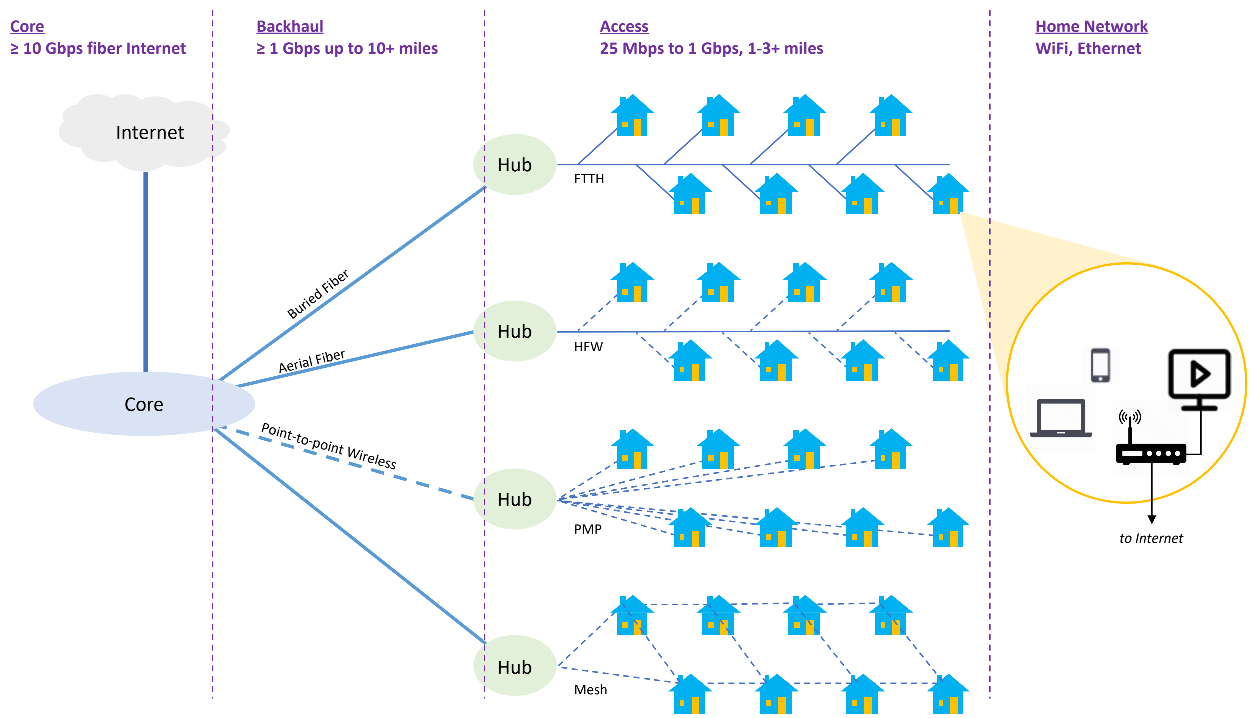


Figure 75. Broadband Distribution Tiers

Traffic from home networks is concentrated through a gateway device onto an access network and transmitted via hubs over backhaul lines to a core site where all traffic is routed to one or more backbone Internet Service Providers (ISPs). These major subsystems are present in all technologies. Hubs could be switches, routers, or passive splitters in a fiber network or base stations in a terrestrial wireless network. Mesh access systems can look odd as they may relay traffic between peer households before reaching the hub. While orbital satellite systems also have these tiers, only the wireless access connection from each house toward a satellite (hub) in space is visible on the ground.

Hubs concentrate traffic onto high-speed trunks to save cost by eliminating the need to run cables from each household to the core. Furthermore, fiber-to-the-home technology (Gigabit Passive Optical Network, or GPON) is generally designed around the idea of a 12-mile maximum cable length while splitting signal power across 32 homes. For wireless technology, typical tower-based wireless access hubs can typically serve from a one to five-mile radius, depending on frequency band and tree coverage (3 to 25 square mile area) when "coverage limited." In higher density areas, wireless technology could be "capacity-limited," driving the design to smaller cell sites to keep the total served households below some limit required to deliver good service quality – typically in the hundreds-of-households range per tower.

Core

Overview

All traffic from a broadband access network converges into a core site where one or more high-capacity transmission lines, or "trunks," carry aggregate traffic to one or more backbone Internet Service Providers (ISPs). Based on the latest empirical data, trunks need to be sized with about 3 Mbps of capacity per subscriber served downstream in the access network.

Finally, note that the core-site itself is a single point of failure. It hosts network and computer equipment to support connectivity and various operational and management functions.[5] Therefore, for high availability, the core site should have backup batteries or a generator to assure continued operation in the event of a commercial power outage at the core-site.

Infrastructure Assets

Utility Poles

In theory, the capital cost for aerial fiber deployment is about half that of buried fiber, assuming utility poles are present. Utility poles can also be used for wireless coverage via the deployment of pole-mounted "small cells." In some places, electric utilities are actively leveraging their pole assets to help bring broadband to the communities they serve. Some are becoming full-fledged broadband service providers, while others are cooperating with the logistical support and reasonable cost to support third-party deployment on their poles. Even if the pole owner is helpful and cooperative, pole usage requires pole attachment fees, engineering drawings, project planning and coordination, make-ready work by the pole owner, safety compliance and insurance, record-keeping, auditing, and accounting. So, while pole usage is advantageous to avoid the higher cost and longer timeframes associated with buried fiber, the advantages are reduced by complications and expenses associated with the coordinated use of shared poles.

To estimate the cost of fiber deployment, we can draw on authoritative work done by industry and the FCC in building a cost model for the Connect America Fund (CAF), also used by the Rural Digital Opportunity Fund (RDOF).[6] The FCC (via CostQuest Associates), designed national scale fiber coverage using detail GIS-based simulations with least-cost routes, terrain and other local data as well as detailed cost data on fiber, conduit, labor, poles, and structural elements.

The resulting average cost for fully installed rural aerial fiber on existing poles came to $2.52/ft. In comparison, rural buried fiber ranged from $4.61/ft to $6.99/ft, depending on soil and rock characteristics. To this, the cost of "make-ready" fees must be added, which can double the total cost. Benchmarks from rural providers, including providers in Arkansas, put the cost at about $40,000/mile.

To estimate pole attachment cost, we referred to a large-scale study by Penn Law, who analyzed 577 agreements for cable pole attachments around the country in its 2018 report to the FCC.[7] Key variables considered were the type of utility (municipal, investor-owned, co-op, other) and whether the FCC or the state regulated the utility. Arkansas is one of 20 states certified by the FCC to regulate pole attachments; however, investor-owned utilities (IOUs) still fall under the purview of the FCC. As Entergy is an IOU, we can use the average rate for FCC-regulated IOUs from this study, based on 114 contracts, of $16.20/year ($1.35/month) per attachment. In the case of wireless device attachment, the figure is $105.07/year ($8.76/month), based on 85 contracts.

There is a wide variance in fees, and the real cost in the study area can only be fully known after successful contract negotiation with the pole owner(s).

Vertical Real Estate

For deploying wireless technology, any natural sites or manmade infrastructure above the trees with line-of-sight to potential customers is a candidate for deploying wireless base station equipment. Wireless internet firms have deployed from tall buildings, cell towers, electrical transmission line towers, water towers, grain elevators, and hilltops. Using available vertical real estate can speed time to deploy by avoiding the time and cost associated with finding sites and constructing towers.

Where existing vertical sites do not have space available, are not high enough, are not available where needed, or otherwise don't satisfy requirements, new tower sites can be constructed. Tower construction involves a long-term land lease, permitting, fencing, grounding, lightning protection, lighting, concrete foundation, structural steel, equipment hut, power feed, construction, and installation cost. Based on empirical data, new tower sites range in cost from $125,000 to $450,000 depending on height, type, and location. To achieve the desired coverage, tower height requirements can be determined from running radio frequency (RF) propagation models. Note that renting space on an existing tower could easily cost $300-500/month – about the same as the payment on a 5% 30-year note for the construction of a new tower, so assuming financing is available, the cash flow may not differ much between renting space on existing towers vs. constructing new towers; of course, renting tower space reduces the amount of up-front capital and time required for deployment.

Backhaul

Network Model

For either fixed wireless or fiber-to-the-home access, it makes sense to establish regional concentration points in areas with the highest population density. This way, traffic can be consolidated onto high-speed transmission to minimize total cable cost. Furthermore, wireless towers have a practical coverage limit, generally a few miles, depending on the technology employed, terrain, height, foliage, and such topographical factors. While a single fiber can operate over many tens of miles, typical cost-effective FTTH systems are standardized around a maximum 12-mile distance. Optical splitters are commonly deployed with 32:1 concentration to save money on cable costs. Fixed wireless tower site locations are more constrained than fiber since good locations must have radio signal propagation paths that reach target customers and because fixed wireless generally has a shorter service range than fiber. To choose reasonable tower sites for regional hubs, the starting point is to look for locations with high elevation amid population centers. Coverage models can be engineered for each area by starting with this strategy and iterating with trial-and-error based on propagation simulations, site availability and cost.

Fiber

Fiber optic cable offers practically unlimited capacity, with speed limited only by the capability of the electronics, not by the fiber medium itself; thus, electronics can be upgraded in the future to higher speeds when needed, while the fiber cable plant itself can meet the demand for decades to come. The overall cost of a fiber backhaul network is dominated by the cost per mile of installing the fiber, with electronics and ancillary equipment comprising 8-15% of the total cost.

Buried Fiber

Buried fiber is the premium connectivity option - most expensive and slowest to deploy. Still, it provides the highest speed, longest range, unlimited upgrades, multi-decade lifespan, high immunity to an outage, power efficiency, low-cost electronics, and no fees for renting space on poles or towers.

Figure 76. Trenching to Bury Fiber Optic Cable

Due to inclement weather and fire, buried fiber is protected from outages but is subject to cable cuts due to digging and drilling. While outages are less frequent than other technologies, repairs can take much longer due to the time required to mobilize excavation and fiber equipment/technicians and the time needed to dig, replace, and repair fiber.

Another advantage of buried fiber over aerial fiber is that there are no ongoing and recurring pole attachment fees and no delays or costs associated with coordinating the shared use of poles. When comparing the cost of buried and aerial fiber, it's, therefore, necessary to consider the initial capex for construction and the lifetime cost of pole attachment fees as part of that comparison.

Speed		Practically unlimited capacity. Speed is determined by the attached electronics. 10 to 400 Gbps trunks are commonly deployed today. With Wave Division Multiplexing (WDM), multiple 400 Gbps signals can share fiber. 20 Tb/s trunks are in commercial service. Furthermore, high-capacity trunks are deployed with numerous fiber strands, with 144 and 288 fibers commonly used, so trunk capacity is unfathomably large.
Range		Practically unlimited for statewide applications. In practice, system components are engineered to cover transmission losses due to connectors, distance, and margin for future extensions and repairs.
Time to Deploy		Most time-consuming option. Two to three years would be typical for surveys, permits, engineering drawings, excavation, and fiber placement.
Dependencies		Requires permission to trench in easements.
Risks	Outage	Subject to daylong outages to repair cables cut or damaged by digging; however, ring topologies can instantly reroute around any single fiber cut to avoid service disruption.
	Technology	Very mature, proven technology. No technical risk.
	Scaling	Practically unlimited scaling with electronics upgrades.
	Quality	Very low risk; service speed and reliability is highly deterministic.
Cost	Infrastructure	$50,000 to $200,000 per mile depending on technique (shallow trench, conduit, depth) and soil type.
	Equipment	Small percentage of the link cost, in the tens of thousands of dollars per end.
	Recurring	Electricity, insignificant.

Figure 77. Buried Fiber Backhaul Attributes

Aerial Fiber

Aerial fiber is strung on utility poles like telephones, cable TV, and electrical power cables. Where utility pole access is available at no/low cost, aerial fiber is faster and lower cost to deploy than buried fiber.

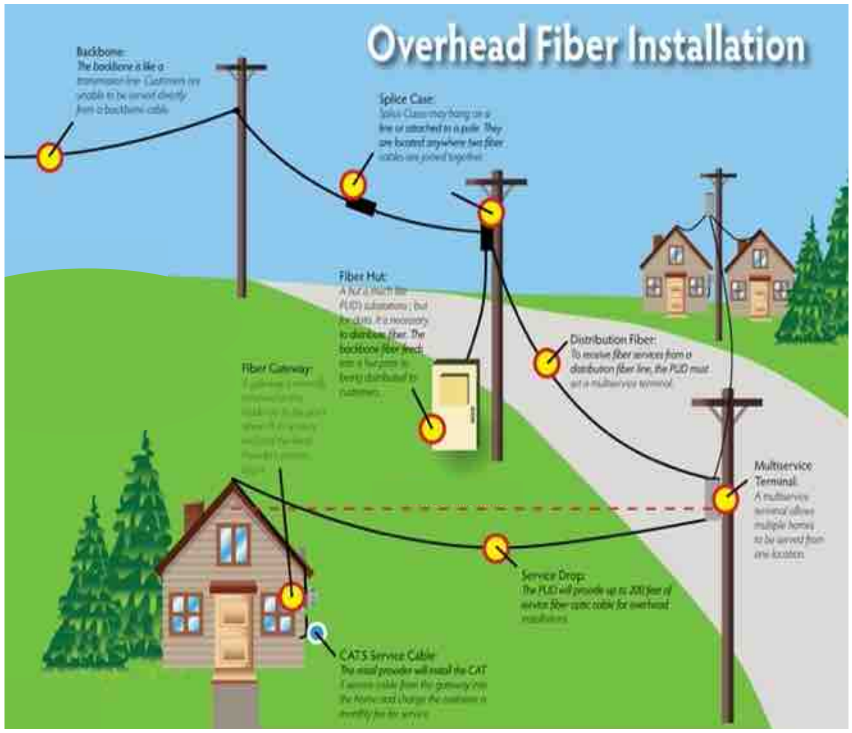


Figure 78. Depiction of Aerial Fiber from Mason County PUD of Shelton, WA

Aerial fiber is subject to the same sort of outages that impact other aerial utility cables, including hazards such as lightning, ice, rodents, fire, vandalism, and vehicles. Since aerial fiber is above ground, repairs can usually be made more quickly than buried fiber.

The feasibility of aerial fiber depends on the availability of utility poles, pole attachment rights, and attachment fees. In 2018, Penn Law's Center for Technology, Innovation and Competition surveyed 577 wired pole attachment agreements. The FCC referenced their published study, Survey of Rates for Pole Attachments and Access to Rights of Way, []. The average rate for an FCC-regulated Investor-Owned Utility (IOU), such as Entergy, was $16.20/year ($1.35/month) based on a review of 114 such contracts.

Speed		Practically unlimited capacity. The attached electronics determine speed. 10 to 400 Gbps trunks are commonly deployed today. With Wave Division Multiplexing (WDM), multiple 400 Gbps signals can share fiber. 20 Tb/s trunks are in commercial service. Furthermore, high-capacity trunks are deployed with numerous fiber strands, with 144 and 288 fibers commonly used, so trunk capacity is unfathomably large.
Range		Practically unlimited for statewide applications. In practice, system components are engineered to cover transmission losses due to connectors, distance, and margin for future extensions and repairs.
Time to Deploy		Faster than buried cable, much slower than wireless. 18-24 months would be typical for pole inspections, make-ready work, design, and fiber placement.
Dependencies		Requires permission to attach to utility poles.
Risks	Outage	Subject to daylong outages to repair cables cut or damaged by weather or other physical damage; however, ring topologies can instantly reroute around any single fiber cut to avoid service disruption.
	Technology	Very mature, proven technology. No technical risk.
	Scaling	Practically unlimited scaling with electronics upgrades.
	Quality	Very low risk with fiber optic cables.
Cost	Infrastructure	$2.52/ft. ($13,306/mile) installation cost based on FCC ACAM model. Rural ISP empirical data ranges from $25,000 to $75,000 per mile after inclusion of make-ready fees.
	Equipment	Small percentage of the link cost, in the tens of thousands of dollars per end.
	Recurring	Average $16.20/pole/year attachment fee [7]. Based on US average pole spacing of 172 ft., or ~30 poles/mile – that's about $500/mile/year ($41/mile/month). Note that this monthly payment per mile is equivalent to monthly payments to finance ~$8,200/mile ($1.55/ft.) of capex (based on a 30-year 5% fixed monthly note), which offsets a material amount of the savings expected from aerial fiber over buried fiber.

Figure 79. Aerial Fiber Backhaul Attributes

Diamond State Network

The IIJA middle mile fund is small compared to BEAD, only $1 billion; however, the state should be open to middle mile proposals that could leverage this or other federal infrastructure funds. We were impressed with the proposed middle-mile project from Diamond State. The middle mile network would provide enhanced resiliency for these "last mile" networks, lower-cost backbone connections and could serve other regional "last mile" providers in the state. We would encourage serious consideration of this proposal to align well with other infrastructure funds besides BEAD.

A coalition of 14 Arkansas electric co-ops wants to extend a fiber backbone network to serve their members and other regional Arkansas service providers[8]. Diamond State has a compelling vision and proven ability to execute. We recommend that their proposal be given serious consideration; their proposal may be a perfect fit for the IIJA $1-billion Middle Mile fund.

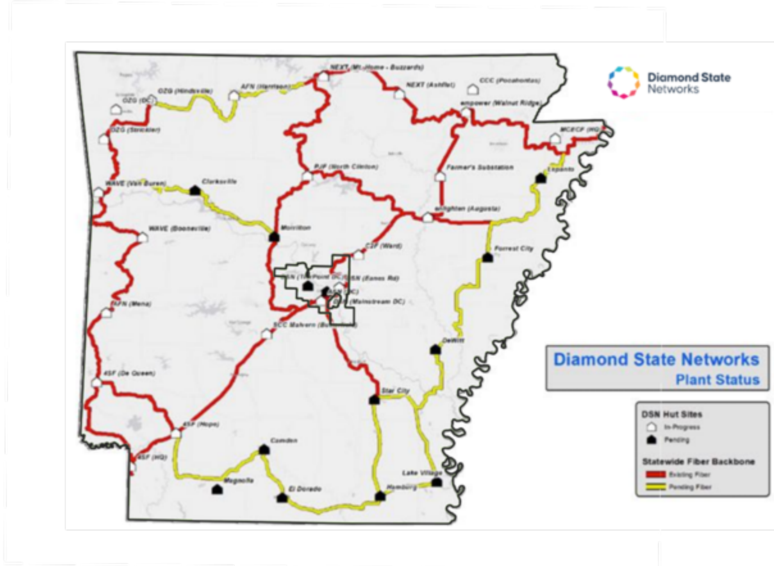


Figure 80. Diamond State Networks Plan

Wireless

Where fiber-optic cables are not affordable or not feasible or take too long to install, an alternative is point-to-point wireless. The biggest challenge with wireless links is the requirement for a clear line-of-site between points along the path, including clearance for the Fresnel zone.[9] This requirement is met by mounting wireless transceivers on vertical infrastructure above buildings, hills, and trees along the path – on cell towers, water towers, or other tall structures or geographic features.

Figure 81. Wireless Transmission Over Trees and Hills

Where existing structures are not available, new towers can be constructed. Wireless links don't have the virtually unlimited capacity of fiber optic cables, though multigigabit systems are available for multi-mile links.

An advantage of wireless links over fiber is that they are immune from cable cuts. However, depending on the operating frequency of wireless links, they are subject to occasional short-term outages during heavy rain, fog, or snow. Furthermore, electronics mounted outside on towers are subject to weather-related hazards such as high wind and lightning. Tower-top repairs require daylight, safe conditions, and trained climbers, so outages due to damaged antennas or electronics can take many hours to arrange repairs. Despite these challenges, wireless transmission links have been employed for decades and are a mature and generally reliable technology.

The primary capital expense is for towers on which to mount wireless equipment. Tower space (and cost) can be shared with other applications such as mobile cellular. Furthermore, towers could be employed not only for backhaul transmission lines but can also be used for last-mile fixed wireless access systems that connect directly to surrounding homes. Indeed, the quickest path to broadband is to use wireless for both last-mile access and backhaul transmission. Wireless backhaul links can be deployed with either "Licensed" or "Unlicensed" technologies.

Licensed Point-to-Point (PtP) wireless

Licensed microwave bands assure exclusive use of wireless channels, so the primary benefit is high quality and reliability by eliminating the possibility of interference or noise from external sources that could disrupt or degrade communications. The downside is that licensed wireless links require extra time and extra cost to obtain and maintain licenses. Higher power and lower noise permit higher speed and/or longer range per MHz of licensed spectrum as compared to unlicensed spectrum. There are attractive licensed bands in the 6 GHz and 11 GHz range that can operate over 20+ miles with multigigabit speed. The 6 GHz range (5,925 to 6,425 MHz) has over 500 MHz of spectrum available with licenses available up to 160 MHz wide, while the 11 GHz range (10.7 to 11.7 GHz) has 1,000 MHz of spectrum available with licenses up to 80 MHz wide.

Unlicensed PtP Wireless

Unlicensed links have no licensing cost or overheads and can be deployed in a day. There is a lot of spectrum available for unlicensed bands that can be harnessed for point-to-point data links. Unlicensed spectrum bands suitable for gigabit-class links include:

- 5 GHz band: about 200 MHz of the band is available for relatively high-power PtP links.
- 6 GHz band: 1,200 MHz (the new "WiFi 6E" band; 850 MHz can be used outdoors[10]).
- 60 GHz band: 14,000 MHz ("V band" millimeter wave; also used for WiFi 802.11ad/ay).
- 70/80 GHz band: 10,000 MHz ("E band" millimeter wave).
- Free Space Optical (FSO) employs fiber optic lasers without the fiber.

5 GHz is commonly used for point-to-point transmission because it features long range, a lot of channel space for high speeds at high power, immunity to rain fade, low-cost equipment, and can operate up to 1 Gbps at several miles.

6 GHz (WiFi 6e expansion band) solutions for long-range point-to-point links are not yet available and it's not known if high-power operation for PtP links will be permitted. The 6 GHz band is already used for licensed operation, so it will be interesting to see if perhaps the band will shift to a "license-by-rule" system for PtP links with a centralized spectrum access controller, giving priority to incumbents, similar to CBRS and TVWS systems, or perhaps shift to a "light-licensed" system such that governing E-band systems today. For now, this a possible *future* technology only.

60 GHz V-band systems can offer multigigabit speed but are very limited in range because atmospheric water absorbs energy in that frequency range, resulting in link outages during heavy rain. Still, these links are viable for short distances up to a mile or more, and some systems support fallback operation to a slower speed in the 5 GHz range in the event of rain fade.

70/80 GHz E-band is very similar to V-band. If the deployment employs links under a couple of miles, E band links in the 70/80 MHz range can provide capacity in the 1 to 10 Gbps range. E-band offers high speed over short range and is subject to rain fade outages during heavy downpours, though has better immunity to weather than V-band. It is, however, immune to fading from fog and snow. Links can be engineered for acceptable reliability based on weather statistics.

FSO also operates up to the 10 Gbps range but is generally more expensive than E-band and suffers from fading in fog and snow and is also sensitive to movement such as structural sway due to wind. Currently, price/performance, supply diversity, and maturity lag behind E-band links so FSO is limited to niche applications where E-band spectrum is unavailable or where line-of-sight clearance is extremely tight. There is a recent entrant to the space called X-Lumin,[11] with credentials from the defense industry for land-to-space communications. They claim to support up to 4 Tb/s by leveraging the same technology used for fiber – DWDM (dense wave division multiplexing) with single-mode lasers, whereas past FSO systems have used lower power multimode lasers. It's unclear how they are achieving this while meeting power levels for safety standards. Perhaps they have a protective safety "sleeve" beam that cuts power when the beam is interrupted, similar to the technology demonstration recently announced by Ericsson for using lasers as "wireless power" for 5G base stations.[12] In any case, these systems are unproven and *very* expensive, and might only be viable as a substitute for burying fiber in dense urban areas where digging streets is exorbitantly expensive; if they are successful serving such applications, we would expect the technology to come down in price over time so that it becomes viable in a greater range of applications. For now, this technology is on the long-term "watch list," rather than the near-term planning horizon.

<table>
<tr><td colspan="2">Speed</td><td>1 to 5 Gbps.</td></tr>
<tr><td colspan="2">Range</td><td>Two to 20+ miles.</td></tr>
<tr><td colspan="2">Time to Deploy</td><td>If towers are present, three to six weeks lead time are needed for design, equipment acquisition, licensing, and scheduling climbers. Additional time may be required if the tower owner is slow to respond with an agreement to use space. Actual installation is a one-day activity. Where new tower sites are needed, permitting, site acquisition and tower construction can lead to six to 18 months for full project completion.</td></tr>
<tr><td rowspan="4">Risks</td><td>Outage</td><td>Immune from cable cuts and weather degradation/outage, but outdoor electronics are subject to lightning and wind damage resulting in multi-hour outages to make repairs.</td></tr>
<tr><td>Technology</td><td>Very mature, proven technology. Low technical risk.</td></tr>
<tr><td>Scaling</td><td>Limited by spectrum, power regulations, physics. Incremental upgrades may be possible, but large increases for long-term usage growth will probably require migration to higher capacity fiber.</td></tr>
<tr><td>Quality</td><td>Licensed spectrum is protected from interference. Largely immune to weather-based fading. No material concerns.</td></tr>
<tr><td colspan="2">Dependencies</td><td>Requires access to towers or other vertical assets with line-of-sight clearance including allowance for Fresnel zone; if towers must be constructed, access to land is needed.</td></tr>
<tr><td rowspan="3">Cost</td><td>Infrastructure</td><td>$150,000 to $450,000 if new tower site is needed.</td></tr>
<tr><td>Equipment</td><td>Licensed links cost $8,000-$12,000 while unlicensed links cost $2,000 to $6,000.</td></tr>
<tr><td>Recurring</td><td>~$1000/year for license maintenance, and $250-$500/month for tower land lease. The model assumes towers are owned as a capex expenditure, though the financing and depreciation from that approach could be substituted with a roughly equal amount of monthly expense for tower space rental where existing structures are available.</td></tr>
</table>

Figure 82. Licensed PtP Wireless Backhaul Attributes

Hybrid/Transitional

Backhaul technologies can be mixed to achieve the most economical deployment. Where utility poles are available, aerial fiber may be preferred. Where easements are reasonable to access, but poles are not, buried fiber may be the right choice. Where transmission is needed to remote areas that are not economically reachable by fiber, or where access is needed sooner than can be achieved with fiber, wireless technology may be the best solution. Different technologies can be used over different segments comprising the overall network. For each leg in the backhaul network, engineers can select the best option based on technical, financial, and timing objectives. Furthermore, backhaul can be transitioned; for example, both wireless microwave backhaul and fixed wireless access may be employed for rapid broadband coverage, and then both technologies may be transitioned to fiber for higher speed in the long run.

Access Technologies

Broadband access systems extend broadband connectivity from regional hubs to each subscriber's household. Transmission to the home is done either with "wired" or "wireless" technology.

Wired Access

Fiber-to-the-Home (FTTH)

Fiber-to-the-Home (FTTH) is the premium "last mile" access solution with gigabit speed common today, and virtually unlimited capacity to support speed upgrades for decades to come.

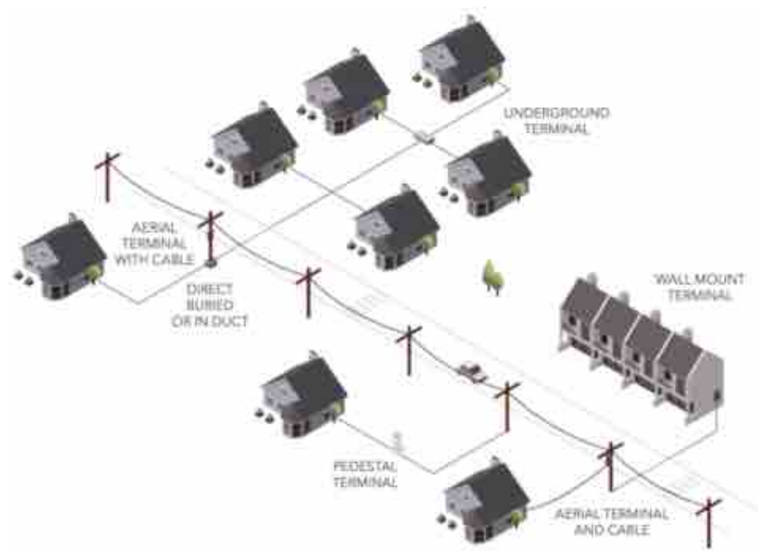


Figure 83. Fiber-to-the-Home (FTTH) Last Mile Access

FTTH is the most expensive last-mile technology and the slowest to deploy due to time-consuming planning/permitting, trenching/tunneling, splicing, testing, and installation of physical plant and equipment, especially conduit and cables. While FTTH takes the longest time and is the most expensive option, it meets or exceeds the performance of all other options and has the most capacity to support long-term speed upgrades. FTTH can be delivered by an aerial cable strung on utility poles or by buried cable, or both.

The cost of fiber is driven by the cost per foot of cable/conduit and labor to place it, while electronics are a minor additional cost. For buried fiber, there are no significant recurring costs; for aerial fiber, the one significant recurring cost is pole attachment fees paid to the owner of the utility poles. While the cost of pole attachment varies and could only be known after negotiation with pole owner(s), our budgetary model is based on the authoritative large-scale Penn Law study [7] conducted for the FCC in 2018. For an FCC-regulated Investor-Owned Utility (IOU) like Entergy, that study found an average cost of $1.35/pole/month based on review of 114 commercial contracts.

Speed		Speed is determined by electronics, with 10 Gbps XGS-PON routinely deployed currently. 1 Gbps is the most common service rate, though speed is trending up. Google Fiber[13] and others have announced service offerings up to 2 Gbps; AT&T has launched 5 Gbps and some municipal networks[14] are offering 10 Gbps. Altice just announced plans for 10 Gbps offerings by the end of 2022.[15] 40 Gbps NG-PON2 equipment is in the testing phase with multiple operators.
Range		Practically unlimited. Range depends on optical transceivers driving the signal and engineering to accommodate losses due to connections, distance, and splitters. 20 km distance with 32:1 passive splitters is a very common FTTH specification.
Time to Deploy		Typically, two to three years are needed for the design, approval, and installation process including surveys, engineering drawings, government permits, surveys, trenching, boring, conduit and fiber installation.
Dependencies		Requires permission to bury in easements and/or attach to utility poles.
Risks	Outage	FTTH is subject to cable cuts due to physical damage, not unlike cable cuts that disrupt electrical power. Weather, mobilization of excavation or elevating equipment, specialized fiber technicians and fiber splicing equipment, and such factors can significantly impact time-to-repair. Buried fiber is more immune to damage than aerial fiber but is also more expensive to install and takes longer to repair, on average. Day-long outages impacting large areas are possible with FTTH technology.
	Technology	Very mature, proven technology. No technical risk.
	Scaling	Practically unlimited scaling with electronics upgrades. 10 Gbps is routinely deployed today; 40 Gbps NG-PON2 is in testing stage.
	Quality	Very low risk. Speed may vary in shared GPON architectures. Future congestion can be resolved by reducing spitter ratios and/or upgrading electronics.
Coverage Cost	Infrastructure	$25-$200,000/mile. In AR statewide simulation for 109,000 HH gap, costs came to $601 million or about $5,500/HH passed based on average $40,000/mile based on rural benchmarks. "Make-ready" costs to prepare poles for deployment could be a third of the cost; these fees pay for creating space on poles and upgrading poles that are not suitable. The "make-ready" work can take six to nine months.
	Equipment	8-15% of total CapEx.
	Recurring	No significant recurring cost for buried fiber. For aerial fiber, there is ~$16.20/pole/year attachment fee [7]. Based on US average pole spacing of 172 ft., that's about 30 poles/mi, or $500/mile/year ($41/mile/month). Note that this monthly payment per mile is equivalent to monthly payments $8,200/mile ($1.55/ft.) of capex (based on a 30-year 5% note) for buried fiber, which negates a significant amount of the savings expected from aerial fiber over buried fiber.
Connection Cost	Infrastructure	Industry estimates range from $500 to $700 to add customers.
	Equipment	Optical Network Units (ONU) for GPON are quite low cost - $40 to $65. Additional cost is often incurred to include a home wireless router.
	Recurring	None.

Figure 84. FTTH Attributes

Legacy Wired Technologies

DSL

Digital Subscriber Line (DSL) technology was and is employed by telephone companies to enable "high speed" internet service over phone lines via "twisted pair" wires starting in the late 90's. Unfortunately, "twisted pair" was designed a century ago to carry voice calls, and its adaption to data is limited by distance. DSL was an interim technology in the evolution of the internet that is now largely obsolete. AT&T recently announced that DSL offerings will be discontinued, and while DSL is still offered by many rural telephone companies, it rarely meets the FCC definition of minimum broadband speed (25 Mbps in the downlink and 3 Mbps in the uplink). Over short distances, newer DSL technology like VDSL2 or G.Fast can offer 100+ Mbps services over distances up to 1,000 ft. or more. While DSL may be a niche opportunity for incumbent local exchange telephone companies, it would never be used in new network builds.

Cable/Coax

Coaxial cable and Hybrid Fiber Coax (HFC) is the current workhorse for broadband delivery in the United States. CATV companies who deployed coaxial cable to provide hundreds of paid TV channels decades ago were able to repurpose that cable plant with two-way transmission supporting internet access speeds up to hundreds of Mbps with low-cost cable modem technology. Designed for carrying hundreds of video channels, CATV systems were inherently designed to carry much more bandwidth than telephone company voice-centric twisted pair cable, and so CATV firms have been able to take advantage of that lucky accident to dominate broadband access. While HFC upgrades have been very successful where CATV was deployed decades ago for television, it's of no consequence for greenfield applications lacking legacy CATV cable plant. For new broadband access systems, where the investment will be made to install new cables all the way into the home, there is no good reason to consider anything other than fiber.

Wireless Access

Whereas fiber is the only real option for *wired* access, there are many technologies and topologies for *wireless* access, which are organized herein as follows:

- Wireless Broadband from Towers.
  - Mobile Cellular (Do-It-Yourself and Home Broadband Service).
  - Citizens Band Radio Service (CBRS).
  - Television White Spaces (TVWS).
  - Unlicensed FWA.
- Wireless Broadband from the Neighborhood ("Small Cells" and Mesh networks).
  - Terragraph– Neighborhood Area Networks (NANs).
  - Hybrid Fiber Wireless (HFW).
- Wireless Broadband from Space.
  - Geosynchronous Equatorial Orbit (GEO) Satellite.
  - Low Earth Orbit (LEO) Satellite.

Spectrum for Fixed Wireless Access (FWA)

The available spectrum for Point-to-Multipoint (PtMP) FWA deployment (without a cellular license) is summarized in the following table:

	Band (GHz)	Width (MHz)	Power (W)	Tree Loss	Subs/ Cell	Range (mi)	Speed (Mbps)
TVWS	0.6	24*	4*	0.1 dB/m	50	5-10+	25-50
ISM 900 MHz	0.9	26	4	0.2 dB/m	50	5+	25-50
ISM 2.4 GHz	2.4	83.5	4	0.5 dB/m	100	3-5	25-100
CBRS	3.6	80**	100***	0.7 dB/m	500	3-5	25-200
UNII 5 GHz	5	580	4	1 dB/m	250	3-5	25-200

* Varies by region based on TV broadcast signals present. In some places, no channels are available at any power level. In very rural areas, power is permitted up to 16W. 4 channels at only 40mW is typical best available in study area at max 98'.

** Varies. 150 MHz total in band on priority basis. No highest priority incumbents in study area, but 70 MHz of priority licenses were acquired, and those owners get priority if/when they deploy. 80 MHz is up for grabs by anyone. Sharing will be centrally managed if/when there is more than one deployment using available spectrum.

*** 100W per 20 MHz. An active AT&T proposal in front of the FCC is requesting an increase to 3,200W/20MHz channel, equivalent to cellular system power level.

Figure 85. Spectrum Available for Rural Broadband without a Costly Cellular License

From this summary, we can make the following points:

- FWA in the TVWS band is potentially interesting because of its low frequency that easily penetrates trees; however, spectrum availability varies from place to place depending on protections in place for existing television broadcast signals, so it may not be possible to use it uniformly across the study area. Some areas do not have sufficient spectrum available to offer viable speed and capacity. With few commercial systems available, equipment prices are relatively high. A new entrant, called WiFrost[16] hopes to substantially reduce equipment pricing.
- FWA in 900 MHz is also interesting because of the ability to penetrate trees very well – though half as well as TVWS; however, it does not suffer from limitations of avoiding TV interference; 900 MHz spectrum is uniformly and freely available. TVWS *potentially* has much more available spectrum, but only in extremely rural areas. 900 MHz is a narrow band but could prove useful to fill in coverage where trees block access by other bands. There are not a lot of 900 MHz products available, so prices are above average for the best systems, though lower than current TVWS offerings.
- FWA in 2.4 GHz offers three times as much spectrum as 900 MHz but does not penetrate trees well. Since 2.4 GHz basically requires line-of-site but offers much less spectrum than the similarly positioned 5 GHz band, it has only niche applications for incremental capacity. Low-cost equipment is available from several suppliers.
- FWA in the CBRS band is quite new and potentially a game-changer for fixed wireless service, as it is the first low-cost spectrum band permitted for exclusive use at high power. Furthermore, 3.6 GHz offers favorable propagation and penetration characteristics as compared to 5 GHz technology, which is most widely used by WISPs today. Furthermore, many products for the CBRS band have been developed based on state-of-the-art mobile LTE and 5G standards, supporting the most advanced modem and antenna processing

techniques to yield the highest user density and aggregate capacity. On the downside, spectrum availability varies from place-to-place and could vary from time-to-time; furthermore, high-power 4G/5G equipment is more expensive than equipment for unlicensed bands.

- FWA in 5 GHz is the most common band used by Wireless Internet Service Providers (WISPs) because of the large amount of spectrum and availability of low-cost products, owing to high competition and global volume, but it requires strict line-of-sight, limiting the addressable market in heavily wooded areas. A new entrant, Tarana Wireless,[17] claims to offer superb non-line-of-site access in 5 GHz with 100+ Mbps speed uniformly at 1-mile radius; this may be useful in small towns with good population density over a short range but may not be so helpful covering the vast rural countryside. Tarana and Resound, a Texas ISP that won significant RDOF awards in SE Arkansas, have announced plans to use the Tarana wireless solution to fulfill RDOF obligations to deliver 1,000/500 Mbps service. This level of service from wireless access systems is unprecedented and will need to be monitored with scrutiny. Tarana has spent over a decade developing their solution, and they have DNA from smart antenna technology going back a decade before that. They have developed custom silicon and they have a lot of traction among wireless ISPs desperately in need of faster technology. Tarana has made extraordinary claims, and so extraordinary evidence will be needed; if they have succeeded in creating a quantum leap in FWA performance, and if they can execute at scale, then their solution will certainly warrant further evaluation. A true 1,000/500 FWA solution could provide a 10-year bridge to multi-gigabit fiber deployment in the long run.

Technologies in different bands have varying strengths and weaknesses, so they are often complementary, working together to provide more complete solutions.

Wireless Access from Towers

Mobile Cellular – Do It Yourself (DIY)

Everyone is familiar with wireless data on mobile phones. Mobile wireless is optimized for sustained connections over broad coverage areas, with small low-power devices (cell phones), even while moving at vehicular speeds. While cellular service is fantastic for mobile handheld access, speed varies a lot by location and few people consider their mobile phone to be a viable substitute for home broadband, though some people may be familiar with mobile phone "tethering", or the use of a mobile hotspots (MiFi, Nomad) as means to share a mobile connection to computers on a local WiFi network.

Some residents may be able to employ a standard cellular connection for home broadband. While not widely promoted, there are devices technically like hotspot routers or tethered cell phones but with some important differences:

- No mainstream consumer brands.
- Enterprise brands like Cradlepoint and Peplink tend to be high-priced and not well-suited to individual consumers.
- New entrants from popular WISP vendors, Mikrotek and Ubiquiti, are well-priced and the Ubiquiti unit probably brings needed ease-of-use to consumer applications.

- Outdoor mounting permits elevation and avoids wall penetration loss to increase speed relative to mobile wireless devices.
- Outdoor devices have large antennas and high transmit power to increase speed relative to mobile wireless devices.
- Outdoor devices connect to an indoor network to support multiple user devices.
- Power is supplied from an indoor power supply with Power-over-Ethernet (PoE).
- Installation and configuration requires significant effort.

Example devices for consumers can be found like this unit from Yeacom[18] on Amazon, or the Outdoor Router[19] shown in Figure 86. A cellular subscription is required with a SIM card provided by the carrier. The SIM card goes into the device which looks like any other cellphone to the provider's network.

Figure 86. DIY Cellular Fixed Wireless Access Device

Another device that is lower cost just became available in June 2021; this device is made by MikroTik and is available on Amazon for $142 or on specialty equipment e-commerce site Streakwave for $114. MikroTik is a popular supplier of equipment for Wireless Internet Service Providers (WISPs), and so this could be a well-supported product from a local service provider or IT company that might provide installation, configuration, and support. This product has been certified to work on the AT&T cellular network.

Figure 87. New Mikrotik STX Fixed Cellular Access Device ($114)

Similarly, an even newer product has become available from Ubiquiti, who is also a popular WISP supplier and has consumer WiFi offerings. Ubiquiti has one new device that is available today and a longer-range dish that is in "early access" status. Both devices have an MSRP of

$199. Ubiquiti tends to emphasize ease-of-use, so these products may be the best consumer options based on the combination of ease-of-use and low cost. Ubiquiti's products only support AT&T currently.

Figure 88. New Cellular Internet Access Devices from Ubiquiti ($199)

The monthly cost of service would be the cost of the cellular plan; users will want to subscribe to a data service with no data volume caps. Also, since this system uses a mobile network that is optimized for cell phones, the network might not provide the volume of data desired by most users employing this technology for home broadband. Due to complexity, service performance risk and cost, this technology cannot be recommended for general use, though it could be an immediate solution for the most desperate and technically inclined users willing to experiment with a DIY solution. At best, this is a niche solution for a relatively small number of users.

Speed		25 to 75 Mbps.
Range		3+ miles from serving cell tower.
Time to Deploy		A cellular network is only deployable by major cellular firms. Self-installation of a fixed access device would be a 1-day project, with lead time to acquire equipment.
Dependencies		Requires decent signal power from serving cell tower. Requires sufficient capacity on normal cellular network to support broadband service.
Risks	Outage	Service availability would be equivalent to availability of mobile service from the serving tower.
	Technology	Niche equipment makers with interoperability, performance, and hardware failure risks.
	Scaling	Only a limited number of users as existing cellular networks are likely lacking in both wireless capacity and backhaul capacity to support many home broadband users.
	Quality	Service is subject to cellular network performance which may vary significantly from place to place and from time to time. There would be no service assurance from the service provider.
Coverage Cost	Infrastructure	N/A It would not be possible to deploy a cellular network; availability would be subject to cellular coverage by existing mobile operators.
	Equipment	
	Recurring	
Connection Cost	Infrastructure	N/A.
	Equipment	$150 - $450 per location.
	Recurring	$50-100+/month for standard cellular data plan with unlimited usage.

Figure 89. DIY Mobile Cellular for Home Broadband Attributes

Mobile Cellular – Home Broadband Service

The use of cellular networks for home broadband is far more accessible and feasible where cellular firms officially offer such services and supply/install wireless broadband routers. In this case, users can obtain turnkey installation and can hold service providers accountable for performance.

AT&T, T-Mobile, Verizon, US Cellular, and other carriers are marketing fixed wireless services over 4G and 5G cellular networks in many areas. This technology could deliver 25/3 Mbps broadband services where available but will generally fall short of the 100/20 Mbps target. Performance of the service will vary based on distance from the cell tower, obstructions, traffic congestion and other factors.

The three largest national mobile operators (Verizon, AT&T, and T-Mobile) all have home broadband service offerings from their mobile networks. The problems with mobile wireless broadband include:

- Performance varies greatly by geographical location due to varying distance and obstructions between the mobile device and the nearest cell site.
- Performance varies greatly over time due to network usage and congestion.
- Mobile service can be expensive or inadequate for the volume of data consumed in-home broadband applications and high-speed data volume is often capped.

For these reasons, mobile wireless is generally not an acceptable solution for home broadband; however mobile operators are now offering fixed wireless services specifically designed for stationary home broadband consumers. These fixed wireless services feature:

- Cell sites upgraded for increased wireless and fiber backhaul capacity.
- Coverage targeting rural areas in need of good broadband alternatives.
- Devices optimized for home broadband.
- Reasonable price points for unlimited high-speed data.

T-Mobile promised regulators that it would make fixed wireless service available to 90% of the U.S. population within six years of its merger with Sprint – thus by April of 2026. As part of this condition, the FCC said that two-thirds of the rural population would need access to 100 Mbps within that time frame. T-Mobile recently reduced the price of home Internet service to $50/month with no contract and no data cap, while setting an expectation of 50 Mbps downloads, without any guarantee.[20] T-Mobile's service employs a self-installable home gateway as shown in Figure 90. Optimizing performance will likely require that the device be placed in a window that receives the best signal.

Figure 90. T-Mobile Home Wireless Internet Gateway

T-Mobile is rich with spectrum and has announced aggressive build-out of new base stations following its merger with Sprint. In October 2020, T-Mobile announced expansion of their home broadband service to 450 cities and towns including the following locations in Arkansas: Camden, Paragould, Jonesboro, Pine Bluff, Fayetteville-Springdale-Rogers, Batesville, Hot Springs, Helena-West Helena, Arkadelphia, El Dorado, Magnolia, Hope, Little Rock-North Little

Rock-Conway, Russellville, Searcy, Blytheville, Forrest City, Malvern, and Fort Smith. In August of 2020, T-Mobile announced plans to upgrade 50,000 cell sites to support fixed wireless over a 2.5-year period.[21]

In March of 2021, Verizon announced[22] that its rural wireless home internet service is now available in 48 states (excludes Alaska and Vermont); however only in 189 "markets." Verizon positions its offering at 25 Mbps and charges $60/month with a reduced rate of $40/month for mobile subscribers, with no data caps. Verizon's consumer equipment costs $240 (or $10/month for 24 months) and is self-installed like T-Mobile's:

Figure 91. Verizon Home Wireless Internet Gateway

Verizon claims to have nearly complete 4G LTE coverage in the study area with significant pockets of 5G coverage. T-Mobile and Verizon claim nearly complete 5G coverage, with pockets of 4G. For large area coverage like this, there is very little difference in 4G and 5G performance. The very high speeds touted for 5G use millimeter wave spectrum at higher frequencies over very short distances – so it's deployed in stadiums and some dense urban neighborhoods; there is little speed benefit for 5G over 4G in rural deployments.

AT&T is also marketing Fixed Wireless Internet service for $60/month with a $99-installation fee, though they position the speed as minimum 10 Mbps with typical experience of 25 Mbps. AT&T has a 350 GB data cap, with additional fees for overages; this could be a risk for some users as the national monthly volume average is trending toward 650 GB. AT&T's fixed wireless service requires professional installation of an outdoor antenna. In 2015, AT&T announced a commitment to offer high-speed internet to more than 1.1 million rural locations by the end of 2020 as part of its participation in the FCC Connect America Fund (CAF) program. Arkansas was among 18 states announced to be part of this coverage plan.

Figure 92. AT&T Fixed Wireless Device Mounted on Subscriber's Home

The three relevant URLs to check availability based on address from the three major mobile operators are as follows:

Verizon: https://www.verizon.com/home/lte-home-internet/#check-availability

T-Mobile: https://www.t-mobile.com/isp/eligibility

AT&T: https://www.att.com/internet/fixed-wireless/

Speed		25 to 100 Mbps.
Range		3+ miles from serving cell tower.
Time to Deploy		A cellular network is only deployable by major cellular firms. Installation of a fixed access device would require a couple of hours from a cellular technician, or just a few minutes for self-installable indoor equipment.
Dependencies		Requires decent signal power from serving cell tower, which depends on distance and obstructions.
Risks	Outage	Service availability would be equivalent to availability of mobile service from the serving tower.
	Technology	Fixed wireless services from cell sites are relatively new, but the technologies involved are mature and represent no significant risk.
	Scaling	Variable performance through peaks and valleys of usage through the day can be expected; however, carriers should engineer sufficient capacity to meet minimum service levels most of the time. Cellular network technology upgrades about once per decade; it's not expected that technology will get much faster for rural tower-based networks. For example, 5G is only about 25% faster than 4G. Touted 1+ Gbps cellular 5G speeds are being offered only over "small cells" in densely populated areas using high-frequency millimeter wave spectrum which is suitable only for small range and does not penetrate trees; it is not a rural broadband technology.
	Quality	Service is subject to cellular signal strength, which depends on distance and obstacles (trees, hills, structures) between the home and the tower.
Coverage Cost	Infrastructure	N/A It would not be possible to deploy a cellular network; availability would be subject to cellular coverage by mobile operators.
	Equipment	
	Recurring	
Connection Cost	Infrastructure	N/A.
	Equipment	$0 - $240 per sub.
	Recurring	$50-70/month for a cellular home broadband plan.

Figure 93. Mobile Cellular Home Broadband Service Attributes

Citizens Band Radio Service (CBRS)

CBRS employs 150 MHz in the 3,550-3,700 MHz range. Despite the similar sounding name, CBRS is unrelated to "CB radio" used by truckers.

Prior to the development of CBRS, only big cellular companies could deploy high-power 4G/5G technology, due to the tens or hundreds of millions of dollars required to purchase spectrum rights in government auctions. Besides high cost, the problem with exclusively and uniformly licensed spectrum over broad areas is that spectrum capacity sufficient to serve urban areas is underutilized in rural areas; that underutilized capacity is one reason mobile cellular companies are now able to offer home broadband service from their rural cell towers – but they need to upgrade equipment and backhaul to employ spare spectrum for these new services.

About a decade ago, an initiative called Citizens Band Radio Service (CBRS) was launched to enable deployment of high-power 4G and 5G systems in the 3.6 GHz band *without* high-cost licensed spectrum. Rather, a centralized Spectrum Access System (SAS) has been developed to centrally manage spectrum transmission rights in near real time. Base stations are in constant contact with a SAS that grants transmission rights and orchestrates spectrum sharing. The resulting system is a hybrid between traditional licensed systems and unlicensed systems that aim to offer the benefits of both: 1.) high-power, interference-free transmission as with licensed spectrum, and 2.) zero up-front license fees as with unlicensed spectrum. The trade-off is the complexity of dealing with a dynamic licensing system and the requirement to share spectrum with other parties; rural broadband is one of the primary applications targeted by CBRS. Furthermore, while the spectrum does not require a massive up-front capital expenditure, SAS providers charge for spectrum coordination; for example, Google, a CBRS advocate, offers SAS for $2.25 per user per month – that's similar to the cost per user for internet bandwidth from the backbone provider. Though not free, SAS fees are an affordable "tax" on subscriptions (5% on a $50/month subscription, e.g.) enabling small deployments by smaller firms without the need for large-scale multi-million-dollar spectrum acquisitions. Note that the SAS fee is comparable to the amortized cost of the spectrum. For example, recent 10-year CBRS PAL licenses sold for an average cost of $0.22/MHz-Pop – that's 22 cents for each person per MHz, so for three million people in Arkansas and 60 MHz total spectrum, the value would be ~$40 million. If 10% of 1.4 million locations pay $2.25/month for an SAS fee, that's also nearly $40 million over 10 years.

Through a process initiated 10 years ago, CBRS spectrum just became available in 2022, while CBRS equipment had only recently started shipping from multiple vendors such as Airspan, Baicells, Blinq, BEC, Ericsson, Radwin, and Tarana Wireless. Industry enthusiasm for this novel technology has been very high due to its unique first-of-a-kind approach to provide the benefits of both licensed (high performance) and unlicensed (low cost) bands. Several 4G/5G systems are now available for deployment in CBRS spectrum. With low-cost access to CBRS spectrum, and with high transmission power limits permitted, it is now technically and financially feasible to deploy a community-scale mobile cellular 4G/5G network; indeed, some devices like the iPhone 12 and 13 natively support the CBRS band. With that said, one of the target markets for this technology is rural *fixed* wireless broadband, and most systems are optimized for that purpose – with fixed rooftop devices and antenna technologies optimized for fixed operation. As such, CBRS technology can essentially be considered equivalent to home broadband services offered by the big three cellular firms.

Figure 94. Examples of CBRS Base Stations and Customer Rooftop Devices (Blinq Networks)

3.6 GHz signals operating at high power, like mobile cellular systems, are often described as a "near-line-of-site" technology. As with all wireless services, data rates will vary due to distance, obstructions, and utilization; however, with proper design, CBRS can meet the 100/20 Mbps performance standard.

Of the 150 MHz total CBRS spectrum, incumbents (mostly the US Navy on the coast) have the highest priority. The FCC auctioned 10-year 10 MHz licenses (up to seven in any area) on a county-wide basis, with a maximum of four channels going to any single firm. These Priority Access Licenses (PALs), have second priority behind incumbents. Any spectrum not in use by incumbents or PAL licensees is available for free use under a General Authorized Access (GAA) basis, as permitted by an authorized (Spectrum Access System) SAS. Google and Federated are two firms recognized as SAS providers by the FCC.

No incumbent federal government usage is present in Arkansas – most incumbent usage is on the coastline. The FCC auction for 70 MHz (of 150 MHz total) of CBRS spectrum through county-based 10 MHz PALs concluded in August of 2020.

To assess feasibility of deploying CBRS, we ran simulations using the Google Network Planner (GNP) application. Google, one of two FCC-approved SAS providers, offers GNP to service providers to plan and promote CBRS deployment. The simulation is configured with location and technical specifications for base stations and addresses for households. GNP evaluates the signal path from hundreds of points throughout a defined radius around each household address to surrounding base stations to determine what portion of the area can meet a designated performance threshold.

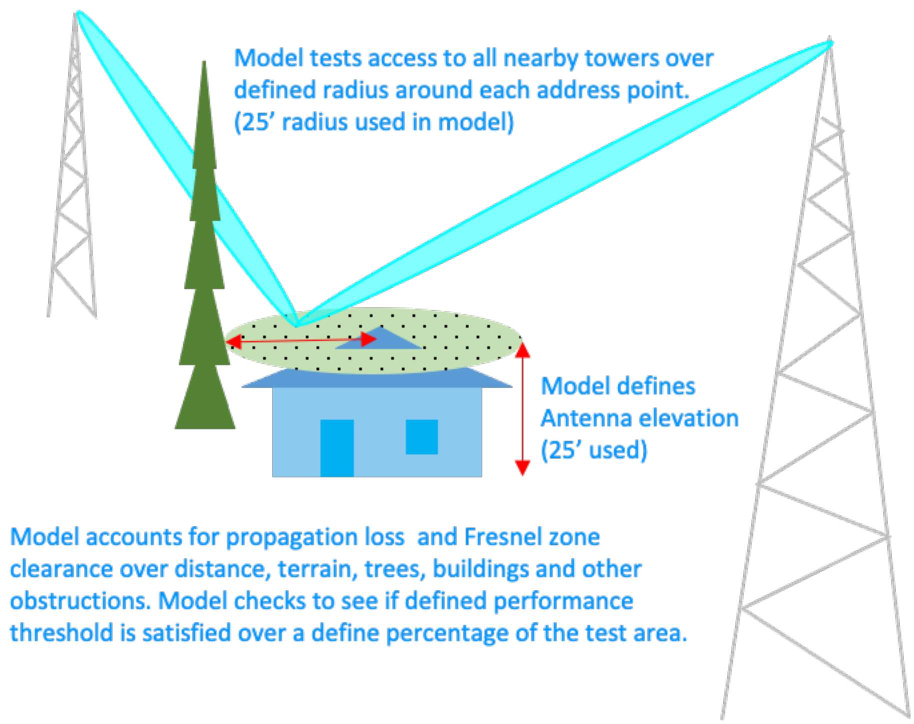


Figure 95. Propagation Path Simulation

As an example, below is a simulation for census tract 4007 with six 250' towers:

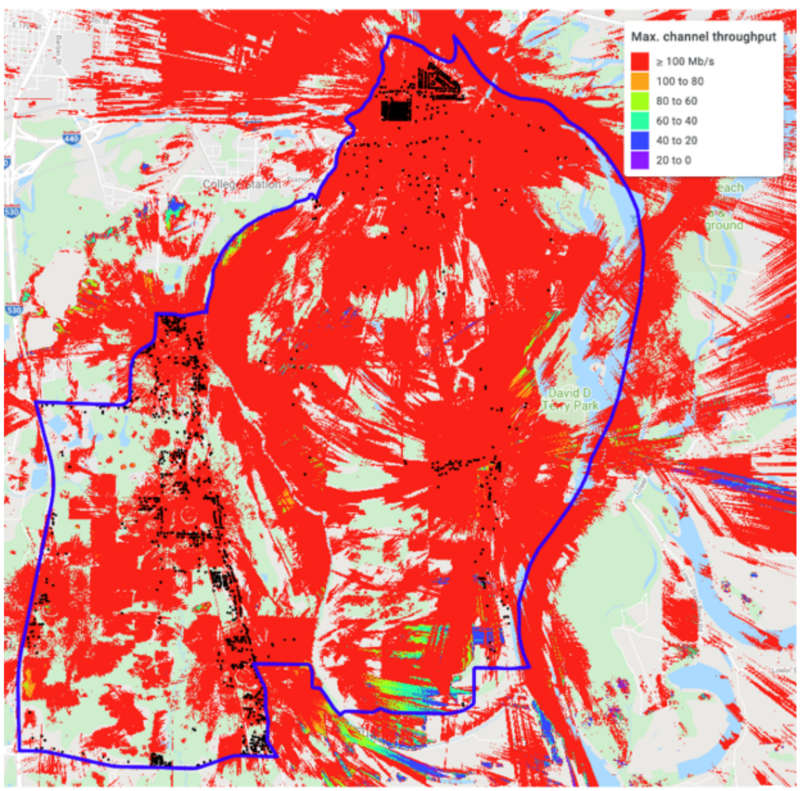


Figure 96: Predicted Coverage from 6 Towers at 250'

This looks pretty good, with most address points in red areas where speed is predicted to be over 100 Mbps. All address points were evaluated for at least federal minimum 25/3 Mbps coverage, resulting in the following plot:

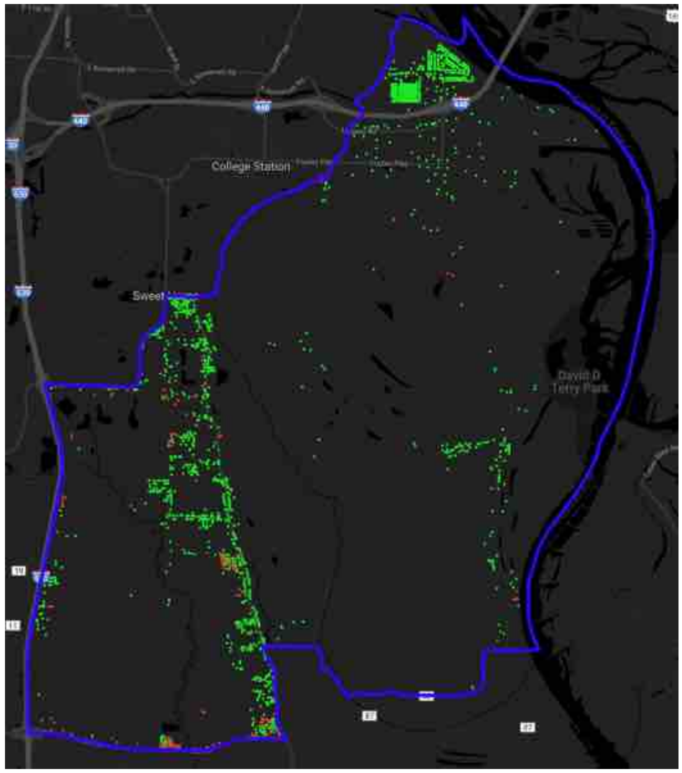


Figure 97: 89% Coverage > 25 Mbps from 6 Macrocells at 250’

The model predicts that 89% of households could get at least 25/3 Mbps service with the proposed 6-cell network (most would get significantly higher speeds). By augmenting CBRS coverage with some lower frequency TVWS or 900 MHz technology, or by adding more microcells to fill coverage gaps, it should be feasible to achieve over 95% coverage. While this simulation was based on 25/3 Mbps service, it’s clear from Figure 96 that 100 Mbps is available to most locations.

It may look strange to see some red dots and green dots so close together. Why can one home get service while the home next door cannot? Drilling down into any household shows the traced paths to provide an explanation. For example, Figure 98 shows propagation analysis of neighbors on E. Dixon Road in Pulaski County. The elevation profile on the left shows a house that cannot achieve the minimum 25 Mbps service threshold from any of the surrounding base stations due to signal loss through trees, while the neighbor shown on the right is able to get 100 Mbps service because it has a stronger signal with fewer obstructing trees.

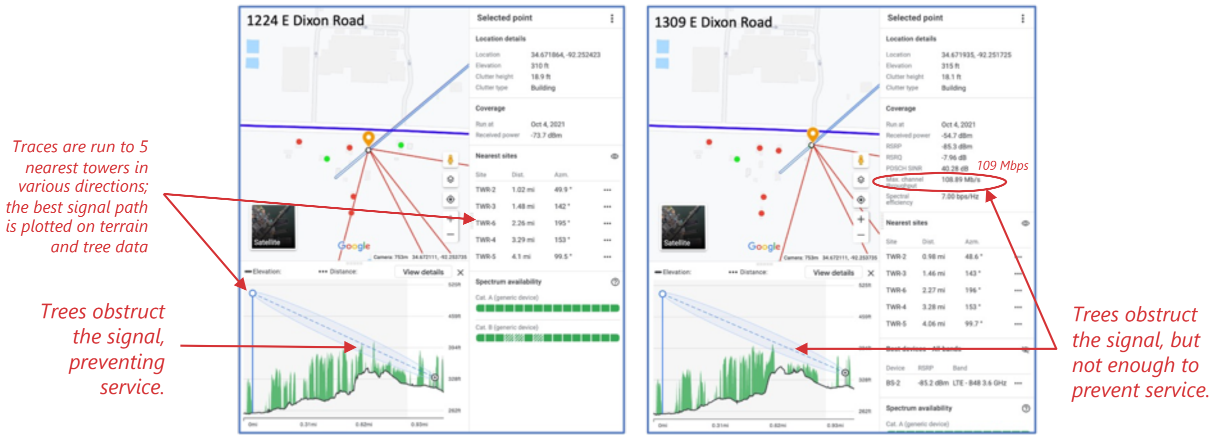


Figure 98. Side-by-Side Path Profiles of Neighboring Households with Different Outcomes

Would a CBRS network provide enough capacity for all subscribers? With six modeled sites, each base station would need to support an average of 200 locations if 75% of all locations subscribe, so perhaps the heaviest cell would need to serve twice the average, or 400 subscribers, which is easily within reach of current technology. Consider these CBRS deployment models from one of the base station vendors modeling over *1000* locations per cell with average speed in the 100 to 150 Mbps range (BLiNQ):[23]

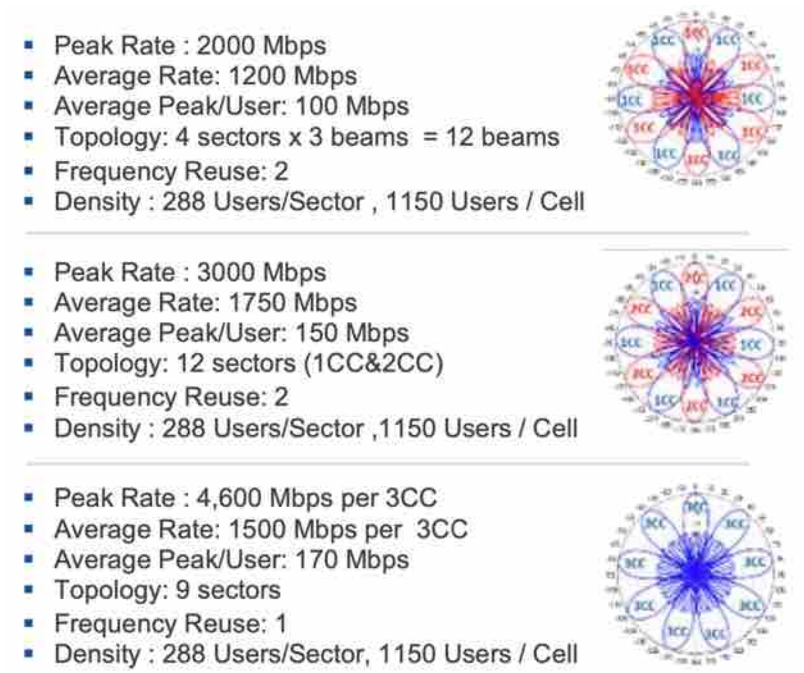


Figure 99. BLiNQ Networks CBRS Base Station Capacity Models

These models each use 60 MHz of spectrum; if one assumes only 30 MHz is available, capacity figures in this chart would drop by half but would still surpass the conservatively high estimate of maximum subscribers per cell site in this model.

We ran RF coverage simulations in five market areas with 68 cell sites in a range of terrain resulting in an average 1.7-mile cell radius (nine square miles). The challenge with the economics is the fixed cost of new towers and possibly fiber backhaul relative to the number of households covered in low-density areas. Since FWA is essentially a fixed cost per area covered, the economic feasibility becomes a function of household density. In some areas, there were less than a hundred households and so the cost per HH/passed was comparable to the cost of deploying fiber-to-the-home.

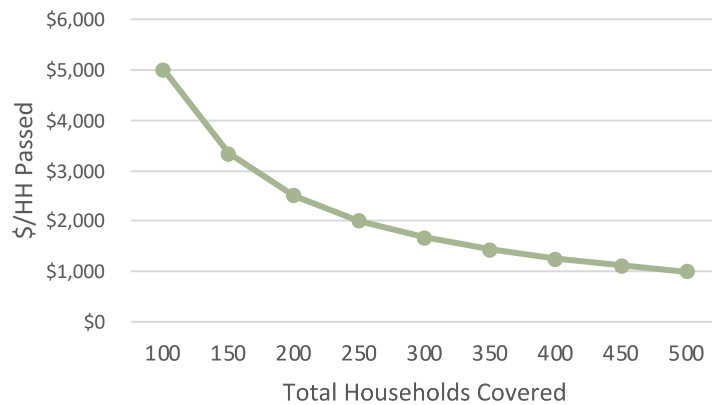


Figure 100. FWA cost per HH/passed depends on household density

Some technology vendors have touted 4G/5G mobile technology in the CBRS band or other bands as a potential solution for fixed wireless access to the Internet. For example, Sempre[24] manufactures a hardened tower with integrated edge data center capability. Intriguingly, Sempre has said its backers can provide capital for deployment of their technology and can also bring licensed spectrum. Providers might want to partner with Sempre to propose rapid time-to-deploy coverage at low cost (financed by Sempre) while long-term FTTH broadband is constructed for future-proof speed. As households adopt FTTH, Sempre towers can be leveraged for mobile coverage to connect smartphones, agricultural drones, and sensors, for example. Sempre's solution is also positioned as military grade with hardening features such as Electro Magnetic Pulse (EMP) resistance.

Figure 101. Sempre EMP-resistant tower and integrated edge data center

Another manufacturer, Tekniam,[25] touts its rapidly deployable mobile base stations with integrated mesh wireless backhaul capability. Providers may choose to use these technologies in their deployment plans.

Figure 102. Tekniam wireless equipment

Speed		25-200+ Mbps. Varies by location due to distance, obstructions, devices, and cell site equipment. Varies over time due to utilization. Typical max offering is 100/20.
Range		1-5 miles.
Time to Deploy		Tower equipment can be deployed and optimized in a matter of days; however, four to eight weeks are typically needed for design, equipment acquisition, and resource scheduling. Where new tower sites are needed, permitting, site acquisition and tower construction can lead to six to 18 months for full project completion.
Dependencies		Deployment requires tower sites and available CBRS spectrum. While strict line-of-site to customers is not needed, obstacles (trees, hills, structures) will degrade or block the signal to some homes that would otherwise be within the coverage radius.
Risks	Outage	Tower-based equipment is subject to weather-caused damage, such as from lightning or high wind.
	Technology	CBRS is new technology. While the 4G/5G technology on which it is based is mature, the use of a Spectrum Access System (SAS) to coordinate spectrum usage is new. Real-world experience with actual deployment is in early days, so there is some risk in predicting real-world coverage and capacity. Nonetheless, the principles of 4G/5G coverage are well-known, and signal propagation modeling tools for the 3.6 GHz are mature.
	Scaling	As wireless technology is a shared medium with finite spectrum, the technology has limits on the number of users and amount of traffic that can be carried. Depending on specifics, it may be possible to upgrade equipment, add base station sectors, or add towers to add more capacity. Through these methods, it's possible to reuse the same spectrum in smaller and smaller areas to increase overall network capacity; accordingly, the technology does scale but some methods (cell splitting) require significant *additional CapEx*. Since fixed wireless antennas are directional, adding towers may require re-aiming some household antennas to take full advantage, so such moves can be somewhat costly and time-consuming. Furthermore, finite spectrum limits peak speed, and there is no clear long-term path to achieve gigabit-class speed.
	Quality	Service quality is subject to cellular signal strength, which depends on distance and obstacles (trees, hills, structures) between the home and the tower. CBRS spectrum is subject to sharing and contention with other operators in the same area, but with ample spectrum and low likelihood of more than a couple of operators, the risk may be tolerable. A secondary market has emerged for dedicated Priority Access Licenses (PALs) that would eliminate the risk of spectrum contention but would require significant CapEx for PAL licenses.
Coverage Cost	Infrastructure	\$150,000 to \$450,000 where new tower sites are needed. \$40,000 to \$120,000 more if new power and fiber backhaul is needed.
	Equipment	\$15,000/sector; 2 to 4 sectors/tower (\$30,000 to \$60,000/tower)
	Recurring	High power base stations will consume over \$100/month in electrical energy. Leased space for existing towers is \$250 to \$500/month. Land leases for owned towers could be a few hundred dollars per month.
Connection Cost	Infrastructure	N/A.
	Equipment	\$350 for high-performance rooftop transceiver + indoor wireless router and installation. Total estimate is about \$500 per connection.
	Recurring	\$2.25/month/subscriber for SAS fee.

Figure 103. CBRS Attributes

Television White Space (TVWS)

TV White Space refers to the unused TV channels between the active ones in VHF and UHF spectrum (470-698 MHz range in the U.S.). These are typically referred to as the "buffer" channels. In the past, these buffers were placed between active TV channels to protect stations from mutual broadcasting interference. It has since been researched and proven that this unused spectrum can be used to provide broadband internet access while operating harmoniously with surrounding TV channels.

In 2010, the FCC made this highly effective yet underutilized spectrum available for unlicensed public use. With the use of a centralized controller to coordinate usage by "White Space" radios, these unused channels can be employed for broadband internet access. The technology was standardized as "802.11af" by the WiFi working group of the IEEE where it was given the nickname "Super WiFi" due to its long coverage range as compared to standard WiFi.

Large technology firms, including Microsoft, Google, Dell, HP, Intel, Philips, and Samsung formed the White Spaces Coalition to promote development and deployment of broadband services in television broadcast spectrum gaps. This led to the development of so-called "cognitive radios" with transmission frequencies coordinated through a network of sensors and a centralized Spectrum Access System (SAS) – concepts subsequently employed for CBRS technology. Microsoft was particularly active under its AirBand[26] program in promoting development of the TVWS market.

Despite strong initial backing and enthusiasm, the TVWS industry has been slow to progress; nonetheless, there are still signs of life. Recently, in October 2020, the FCC updated rules[27] to enable higher power and taller towers in remote areas, increasing viability; in April 2021, Radwin announced the availability of new TVWS products. Another new startup called WiFrost,[28] founded by former staff from TVWS equipment pioneer Adaptrum, is conducting field trials with a modern approach leveraging cloud-based management and open mobile 4G technology (like CBRS vendors). 4G technology permits higher spatial reuse of limited spectrum to effectively multiply cell site user capacity.

Figure 104. Examples of TVWS Base Stations and Household Devices from Radwin

The unique appeal of TVWS technology is the low frequency of operation in the 600 MHz range where signals easily propagate through trees and even over hills – which is why television broadcast signals are in this band.

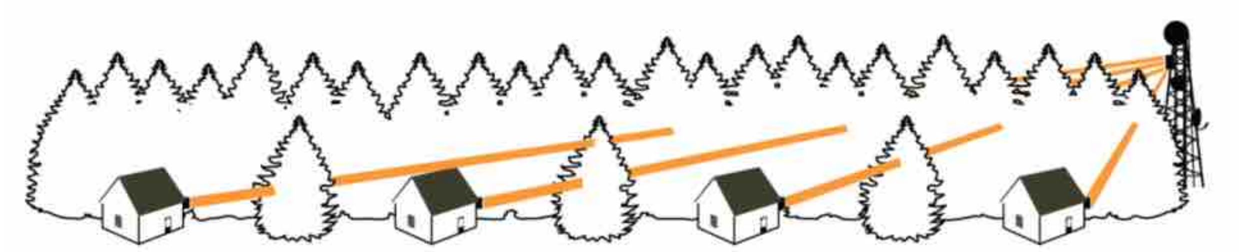


Figure 105. Non-Line-of-Sight (NLOS) Technology Enables Connections Through Foliage

Peak speeds depend on the ability to use contiguous channels, as no suppliers currently support carrier aggregation across separated channels. Currently, all suppliers support up to four contiguous 6 MHz channels for a total channel size of 24 MHz; wider channels provide higher speed and greater capacity. The Radwin equipment provides dual 150 Mbps sectors with 24 MHz of spectrum per sector (four contiguous channels per sector) with 50-150 Mbps speed per user, serving up to 64 users. The technology should be able to offer 25/3 Mbps service, but it will fall short of the 100/20 Mbps target.

Unfortunately, there are a few other problems with TVWS deployments:

- Because signals propagate so easily, there are strict limitations on power and tower height to protect TV broadcast signals.
- Allowed height and power levels vary based on distance from protected television broadcast zones, with 98′ being the maximum height allowed.
- Because TV signals are intentionally spaced with gaps to limit interference, the number of contiguous channels available for broadband are very limited in rural areas near population centers where multiple TV broadcasters operate.
- With varying allowances for power and height, it may be impossible to design uniform coverage across a given target area.
- TVWS has not been highly adopted and so there are few vendors producing modest volume, and equipment cost is consequently relatively high.

Additionally, TVWS is complicated by the requirement that equipment connect to a spectrum access system (SAS) to coordinate permission to broadcast on specified channels with specified power – adding uncertainty to the technology. The SAS database administrator presently commissioned by the FCC to coordinate spectrum access in the U.S. is Red Technologies.[29] In many areas, only a single 4-channel group was available.

Speed		25+ Mbps. Varies by location due to distance, obstructions, devices, and cell site equipment. Varies over time due to utilization.
Range		5 to 10+ miles.
Time to Deploy		Tower equipment can be deployed and optimized in a matter of days; however, four to eight weeks are typically needed for design, equipment acquisition, and resource scheduling. Where new tower sites are needed, permitting, site acquisition and tower construction can lead to six to 18 months for full project completion.
Dependencies		Deployment requires tower sites and useable TVWS spectrum.
Risks	Outage	Tower-based equipment subject to weather-caused damage such as from lightning or high winds.
	Technology	TVWS is relatively new technology. Real-world experience with actual deployment is limited, so there is some risk in predicting real-world coverage and capacity.
	Scaling	A 4-channel group enables shared 150 Mbps capacity per cell site. In theory, additional cells could be added for more capacity, but this technology should be viewed primarily as complementary to serve a relatively small number of hard-to-reach locations. TVWS will probably never scale past 25 to 50 Mbps class speed, so it is only an interim technology on the path toward gigabit class speed.
	Quality	Service quality is subject to signal strength, which depends on distance and obstacles (trees, hills, structures) between the home and the tower.
Coverage Cost	Infrastructure	$150,000 to $450,000 where new tower sites are needed. $40,000 to $120,000 more if new power and fiber backhaul is needed.
	Equipment	$4,500 per base station (WiFrost intends to halve that figure.)
	Recurring	Leased space for existing towers is $250 to $500/month. Land leases for owned towers could be a few hundred dollars per month.
Connection Cost	Infrastructure	N/A.
	Equipment	$500 per user for the TVWS rooftop device, plus the cost of an indoor wireless router and installation. Total could be in the $700 range.
	Recurring	Spectrum Access System fees would be paid on recurring basis to Red Technologies. For CBRS, Google charges $2.25/HH, and we can expect TVWS fees will be similar, though probably a bit higher due to the lower volume of sales and monopoly provider of SAS service (Red Technologies).

Figure 106. TVWS Attributes

Unlicensed FWA

While CBRS and TVWS employ spectrum access systems (SAS) to orchestrate exclusive "license by rule" transmission, unlicensed FWA systems are free to use without any coordination or cost. Unlicensed FWA systems are commonly deployed by Wireless Internet Service Providers (WISPs) in rural markets. These systems are very similar to cellular mobile systems in that wireless base stations are installed on tall towers covering up to a few miles in radius but connecting to stationary roof-mounted devices on subscriber homes with low-power unlicensed spectrum rather than to handheld mobile devices using high-power licensed spectrum.

Figure 107. Fixed Wireless Rooftop Antenna and Base Station Tower

The great attraction of unlicensed spectrum is that there is a lot of bandwidth available at no cost; the downside is that unlicensed bands are subject to uncontrolled interference from other users and equipment and is required to operate at lower power than equipment in licensed bands. However, interference is not a significant concern in rural deployments where there are few interfering signals and ample unused spectrum available. The disadvantage of lower power as compared to mobile cellular systems or CBRS systems is that there is less power budget available to overcome degradation from propagation loss through trees and other obstructions. Therefore, some cellular home broadband systems can offer indoor devices, while unlicensed FWA systems always require large outdoor antennas. CBRS is in the middle, with lower power than cellular but much higher than FWA; indeed, there are some indoor CBRS devices available. With outdoor, roof-mounted, high-gain antennas, CBRS can be very competitive with cellular mobile performance, though the CBRS frequency band in the 3.6 GHz range does not penetrate trees and walls as effectively as cellular bands in lower frequencies.

Frequency bands available for unlicensed FWA deployment include:

- 900 MHz band: 26 MHz (niche, low-capacity applications lacking line-of-site).
- 2.4 GHz band: 83.5 MHz (used for WiFi, Bluetooth, and other applications).
- 5 GHz band: 580 MHz (used for WiFi).
- 6 GHz band: 1,200 MHz (new WiFi 6E standard; future 850 MHz useable outdoors).

The 6 GHz band is also used for point-to-point microwave and has only just been opened for new unlicensed applications. A spectrum sharing system (like the SAS in CBRS and TVWS) will be needed to enable sharing for outdoor applications while protecting incumbent and priority traffic. Regulations for outdoor deployment in 6 GHz are still in development and systems are not yet available, so this is a band to keep an eye on for the future but is not something that can be deployed or even put into a plan yet.

Among unlicensed bands, the 5 GHz range (with 580 MHz of bandwidth) has much more capacity for broadband services and is the workhorse band for most FWA deployments today.

Lower frequencies are much better at penetrating trees, however, so they can be considered as complementary systems to serve a small number of users that are otherwise unreachable. The challenge with 5 GHz is that it is essentially a pure line-of-sight technology, so the question is what fraction of households would have line-of-sight to a base station among the trees and hills in the study area. An example Line-of-Sight (Los) was simulated from six 250′ towers in census tract 4007 shown in Figure 108 where only 37% of locations have line-of-sight access with the 6-site model.

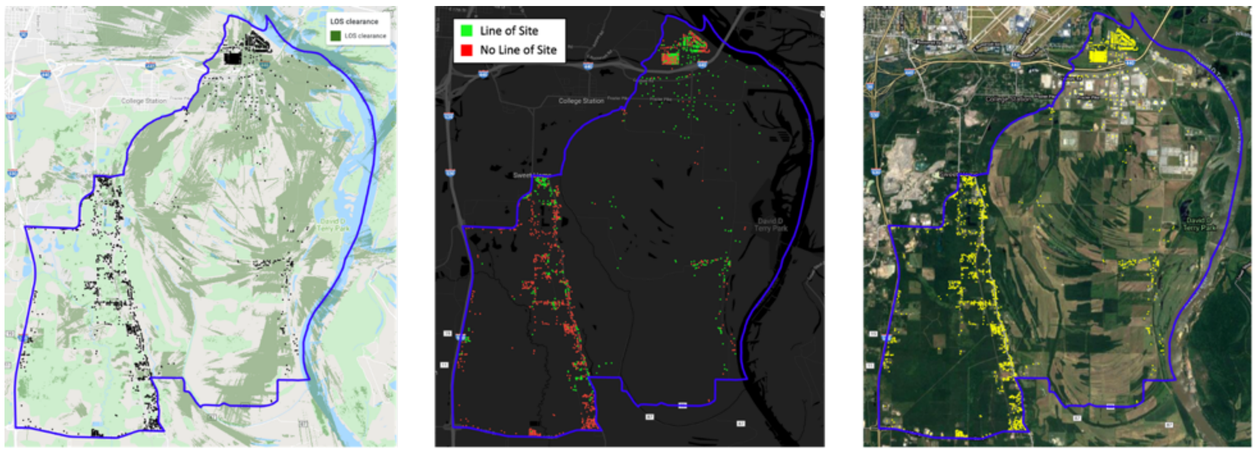


Figure 108. 5 GHz coverage with 6x250′ towers predicted by LoS (37%)

The dark green areas in the leftmost diagram show line-of-sight (LoS) coverage, which appears sparse. The center diagram color-codes individual sites with green for sites that have LoS coverage, and red for sites lacking LoS. Visually, we can see that a strong majority of locations in the southwestern area along state highway 365 lack LoS coverage. Overlaying the satellite image in the rightmost diagram reveals the reason – this area is densely forested. While LoS systems could play a role in the large, unforested and sparsely populated areas in the southeast, it's clear that households in forested areas cannot generally be served by LoS technology.

The 2.4 GHz unlicensed band offers a similar amount of spectrum as CBRS, and while this lower frequency band penetrates trees better than 3.6 GHz, power is limited to only 4% of CBRS power and usage is not exclusive, offsetting its propagation advantage. Furthermore, higher speed and capacity in CBRS depends not only on lower interference and higher power, but also on advanced technologies like channel-bonding, beamforming and null-steering which are available with 4G/5G mobile-class equipment, but not with low-cost 2.4 GHz gear that is often WiFi-based.

The 900 MHz band is narrow with lower speed and capacity than the other bands; however, its advantage is that signals can propagate through trees. Accordingly, 900 MHz may be a low-cost and attractive complementary technology to deploy in addition to CBRS to serve some incremental households where higher frequency signals cannot reach.

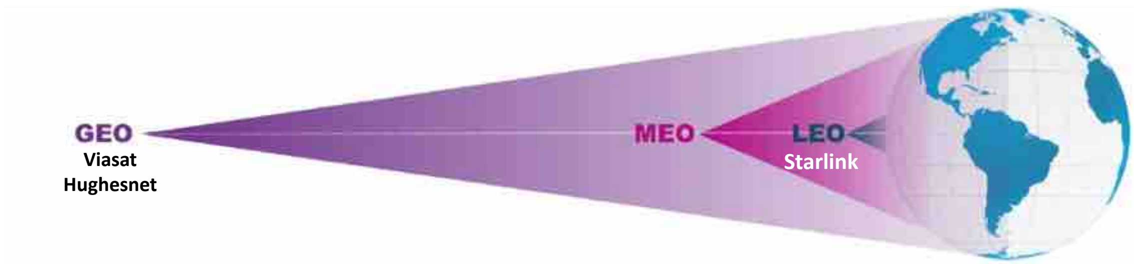
Speed		25-200+ Mbps. Varies by location due to distance, obstructions, devices, and cell site equipment. Varies over time due to utilization.
Range		0.25 to 5+ miles.
Time to Deploy		Tower equipment can be deployed and optimized in a matter of days; however, four to eight weeks are typically needed for design, equipment acquisition, and resource scheduling. Where new tower sites are needed, permitting, site acquisition and tower construction can lead to six to 18 months for full project completion.
Dependencies		Deployment requires tower sites and available spectrum. 5 GHz band requires line-of-site to nearly all households; while 2.4 GHz has some limited range with tree penetration loss, it can largely be considered a line-of-sight technology as well. The narrower (lower capacity) 900 MHz band can serve homes obscured by trees as a complementary technology for a smaller number of homes.
Risks	Outage	Tower-based equipment is subject to weather-caused damage, such as from lightning or high winds.
	Technology	FWA wireless technology is widely deployed. Technology risk is low. Risk of outside interference is relatively low in rural areas. Risk of incomplete coverage and variable performance with distance, obstructions and usage is high.
	Scaling	As wireless technology is a shared medium with finite spectrum, the technology has limits on the number of users and amount of traffic that can be carried. Depending on specifics, it may be possible to add base station sectors to existing cells or additional towers to add more capacity. Through these methods, it's possible to reuse the same spectrum in smaller and smaller areas to increase network capacity. Accordingly, FWA technology does scale up in capacity *with additional infrastructure investment*; however, adding towers will generally require re-aiming household antennas to take full advantage, so such growth can be fairly costly and time-consuming. Furthermore, finite spectrum limits peak speed, and there is no clear long-term path to achieve gigabit-class speed with unlicensed FWA.
	Quality	Service quality is subject to signal strength, which depends on distance and obstacles (trees, hills, structures) between the home and the tower. Unlicensed FWA spectrum is subject to interference from other operators or other signal sources in the same area. With ample spectrum in the 5 GHz range, there is likely to be plenty of spectrum available to find clean channels, especially in rural areas. In the narrower 900 MHz and 2.4 GHz ranges, there is more risk since there is little spare capacity to support multiple providers. Nonetheless, these bands are commonly used for rural broadband applications. Services can degrade when antennas shift due to vibration and wind, so occasional tuning is needed to sustain quality.
Coverage Cost	Infrastructure	$150,000 to $450,000 if a new tower site is needed. $40,000 to $120,000 if new fiber backhaul is needed.
	Equipment	$5,000-$50,000/tower.
	Recurring	Leased space for existing towers is $250 to $500/month. Land leases for owned towers could be a few hundred dollars per month.
Connection Cost	Infrastructure	$0.
	Equipment	$300-$400 per household.
	Recurring	$0.

Figure 109. Unlicensed band Fixed Wireless Access (FWA) attributes

Wireless Access from Space

Geosynchronous Equatorial Orbit (GEO) Satellite

The older generation of satellite technology is based on satellites in geosynchronous equatorial orbit (GEO), enabling household satellite dishes to be aimed at a fixed point in the sky. GEO satellite-based internet access is available from two operators in the United States: HughesNet and Viasat. To achieve a stationary orbit relative to the earth, satellites must be placed about 22,000 miles above the earth; at that distance, signals take about 250 milliseconds (ms) to make the round trip from a user to the satellite and back to the earth station where data is forwarded to some destination on the internet, from where the process repeats on the reply. Therefore, the round-trip time between a user and web server is at least 500 ms (half a second) – unacceptable for interactive applications like voice and online gaming.



	GEO (~36,000 km)	MEO (~8,000 km)	LEO (~1,000 km)
Latency	Medium (~700 m/s)	Low (~150 m/s)	Very low (~50 m/s)
Network size for global services	3 satellites (99% coverage)	6 satellites (96% coverage)	Thousands of satellites (100% coverage)
Data gateways required	Few, fixed	Several, flexible	Numerous, local

Figure 110. GEO vs. LEO Orbit

In practice, Viasat publicly states average latency is around 638 ms whereas average cable broadband latency is 30 ms or less.[30] The FCC established 100 ms as the "low latency" threshold for broadband connections in the RDOF auction, relegating GEO satellite providers to the "high latency" category permitting latency up to 750 ms, with an associated weighting penalty in the auction rules.[31]

Viasat has announced deployment of three new satellites starting mid-2022 offering 8x increase in capacity; it's expected that the user experience will materially improve, but the latency issue is bound by the speed of light and cannot be overcome from GEO orbit.

Figure 111. Viasat Dishes Installed at Customer Locations

It is difficult to see how Viasat can compete directly against Starlink which will offer thousands of times more capacity and 1/20th of the latency. It's even more difficult to recommend current GEO satellite technology due to empirical data and anecdotal evidence implying the service frequently cannot meet the 25/3 Mbps standard, and only meets the very accommodative "high-latency" specification for broadband. With planned tripling of capacity, Viasat might provide passable speed by late 2022, and that might create a near-term but short-duration window. In the absence of any other options, GEO satellite services provide a last resort option that is expensive for its performance, but still better than nothing.

Obviously, satellites are not an option to build and control locally. It makes sense to monitor availability, price, and performance of new offerings if and when they become available from the new generation of Viasat satellites.

Speed		Often <25 Mbps today; 25-100+ Mbps w/ 3rd-gen satellites starting in 2023.
Range		Ubiquitous coverage from space.
Time to Deploy		N/A.
Dependencies		Home antenna requires line-of-sight to satellite in the southern sky.
Risks	Outage	Wind or storm damage to customer equipment.
	Technology	Many years of commercial service. Speed from upgraded satellites is expected to be better, but proof will come only after deployment. There is risk that Viacom will not try to compete for consumer broadband and will instead target services to government and industrial applications. Satellite deployment could fail resulting in significant delay to services from 3rd generation systems.
	Scaling	The total capacity of a GEO satellite is fixed, so as more users are added or as data/user increases, congestion and lower performance results. Such congestion is clear with the current generation of technology based on empirical reports. The upgrade to a third-generation satellite is a massive and expensive undertaking but is supposed to bring an 8x capacity increase. Nonetheless, that capacity will eventually be consumed by insatiable demand for bandwidth, and congestion will resume.
	Quality	Speed degradation or brief outages during very heavy rain or snow.
Coverage Cost	Infrastructure	N/A. Can only be deployed by specialized space satellite firms.
	Equipment	
	Recurring	
Connection Cost	Infrastructure	N/A.
	Equipment	$0 to $250 depending on contract terms for installed equipment.
	Recurring	$50/month for 25 Mbps; $100/month for 50 Mbps; $150/month for 100 Mbps based on current offerings. Future pricing with next-generation technology is TBD.

Figure 112. GEO Satellite Attributes

Low Earth Orbit (LEO) Satellite

LEO satellite technology is significantly different from GEO technology:

- LEO satellites orbit 500 to 1000 miles above earth rather than 22,000 miles as with GEO.
- Due to much lower orbit, LEO can meet the FCC "low-latency" (<100ms) specification.
- Satellites are not stationary relative to the ground, so ground stations track multiple satellites in their field-of-view, changing satellites as they fly by; the system works like mobile phones that switch base stations as they go down the highway, except with LEO, the base stations (satellites) are moving while the users are stationary.
- At low orbit, the coverage area of any one satellite is limited, so rather than three satellites to cover the Earth as with GEO technology, LEO systems rely on constellations of hundreds to thousands of satellites.
- Smaller satellites and the innovation of reusable rockets have greatly reduced the cost of satellite deployment, enabling this new generation of LEO technology.
- With thousands of satellites, total data capacity and individual speeds are much higher.
- Unlike GEO technology that requires a clear view to the southern sky, LEO satellites are in all directions; servos on the dish automatically steer it around in search for signals and then automatically steers to track satellites as they pass overhead. Future devices will likely use electronic beam-steering to track antennas for increased reliability.
- A broad view of the sky is needed in 360-degrees since overhead satellites can appear anywhere. As the constellation is "densified," the field of view can be narrowed. Currently, 25-degree elevation clearance off the horizon is recommended in all directions – whereas the GEO satellite requires about the same, but only toward a stationary spot in the southern sky. Per Starlink's FAQ page: "Users who live in areas with lots of tall trees, buildings, etc., may not be good candidates for early use of Starlink."[32] It's unclear how much this requirement will relax as the full constellation is deployed. However, information suggests the angle may increase to about 35-degrees above the horizon, which will remain an insurmountable challenge in forested areas.

LEO technology has the potential to be a game-changer for rural broadband with ubiquitous coverage (except where impeded by trees), 100+ Mbps speed, and low latency, with global coverage over the next few years; however, technological and execution risks remain.

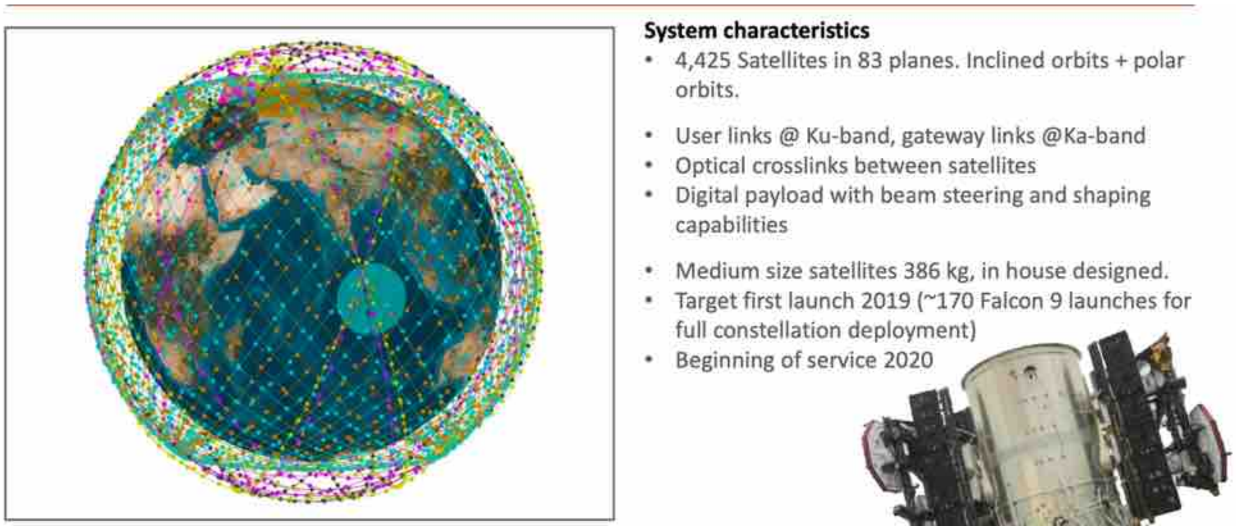


Figure 113. SpaceX Starlink Low Earth Orbit (LEO) System Overview

LEO is specifically noted in the ASBO State Broadband Managers Report for its potential to bridge the rural broadband gap.

Figure 114. Starlink $499 Self-installation Kit

Speed		100-300 Mbps.
Range		Ubiquitous coverage from space.
Time to Deploy		Starlink is now in commercial service; coverage and speed increasing over initial roll-out phase through 2024.
Dependencies		Clear line-of-sight to the sky 25º off the horizon across 360º arc. When constellation fills out, vertical clearance requirement could improve to 35º.
Risks	Outage	Speed degradation or brief outages during very heavy rain or snow. Wind or storm damage to customer equipment.
	Technology	This is new technology, so actual performance will only be known over time. Empirical data from early users is encouraging with the average now over 100 Mbps. There are still technical, regulatory, execution and financial risks in play that could prevent or delay full deployment.
	Scaling	LEO capacity can be increased with the addition of satellites. The initial phase calls for 4,000 satellites by 2024. Starlink has been approved to deploy ~12,000 satellites through 2026 and has petitioned to deploy 30,000 more satellites after that.
	Quality	Speed degradation or brief outages during very heavy rain or snow.
Coverage Cost	Infrastructure	N/A. Can only be deployed by specialized space satellite firms.
	Equipment	
	Recurring	
Connection Cost	Infrastructure	N/A.
	Equipment	$499 with self-installation kit.
	Recurring	$99/month.

Figure 115. LEO Satellite Attributes

If and when viable services are available, there may be a need for subsidies to assure affordable access, as $499 self-install kits and $99/month will be a barrier for most people. Spreading $500 equipment costs over a 24-month service contract adds about $21/month to the monthly bill. With the federal ACP benefit at $30/month, we could imagine $70/month for a 100+ Mbps service for eligible households. Infrastructure funds could go toward the cost of customer dishes and installation. Line-of-sight clearance will materially limit the addressable market in forested terrain, though improving over time as more satellites are deployed. Equipment prices should go down with volume and design improvements over time, but Musk has stated that the current dish costs $1,000 to produce. If Starlink's business plan enables them to continue to subsidize $500 per subscriber, the cost would need to drop by half to allow for no-cost equipment; in practice, we expect the benefit of future cost reductions will be split between reduced subsidies by Starlink and lower retail price for the customer.

Starlink currently has a backlog of 750k orders and a build-out schedule that extends to 2026 and beyond. It's unknown when there will be enough capacity and consumer equipment to clear the backlog, nor how performance will be impacted as the number of users increases. These issues present considerable risk; however, Starlink is a technology to track and may have applicability to some locations, especially very remote and sparse households where FTTH cost is highest.

LAN Technologies

The broadband access problem does not end when the internet reaches the home; internet distribution throughout the home is an often-overlooked problem that can add hundreds of dollars and hours of labor to achieve desired coverage.

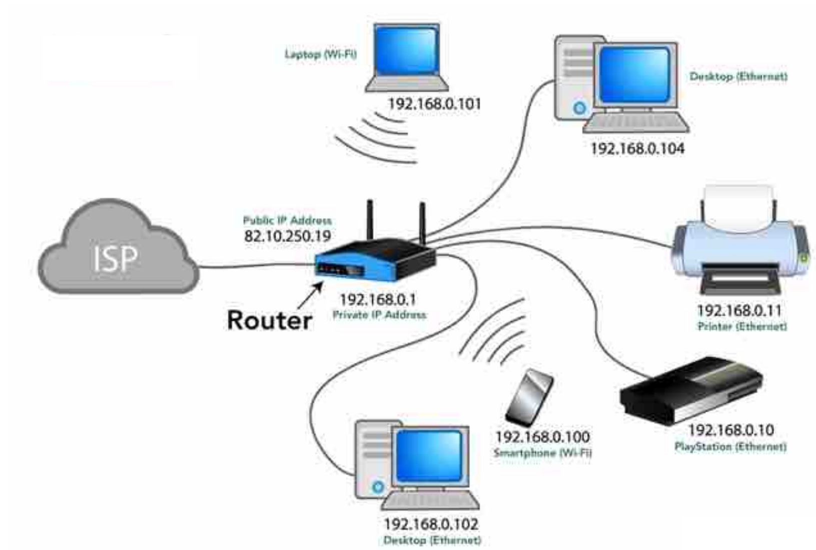


Figure 116. Home network or LAN to link devices to each other and the Internet

Beyond the initial installation of the "Local Area Network" (LAN), users are often frustrated with technical or performance problems with their applications. Since most consumers lack a basic understanding of networking technology, many can't determine if a problem is caused by a device, home network, or internet service. Any complete solution to broadband access should contemplate how users will be better able to resolve connectivity issues themselves and how they will get cost-effective help from outside sources. Improvement in digital literacy and the availability of resources to resolve technical issues are important for users to have a positive experience with internet-based services and applications.

WiFi

WiFi has become the preferred technology for distributing the internet throughout a home and for connecting to devices. The convenience of untethered connections is compelling, especially with portable devices like smartphones, tablets, and laptops. WiFi requires one or more WiFi access points to be deployed in the home; usually, one WiFi access point is integrated with a home router with multiple wired ports and connects to the internet service. Most broadband service providers now bundle a home wireless router with their service. This is sufficient for many users, but for larger homes, a single WiFi signal does not extend throughout the home in all places where the user would like internet access. WiFi signals vary in strength based on distance, obstacles, interference, device characteristics, frequency band, operating mode, and other factors. Such factors result in performance that varies from time to time, place to place, and device to device. Variable performance and dead zones frustrate many users.

WiFi Extenders

Consumers can purchase WiFi extenders to help remediate WiFi coverage problems. WiFi extenders plug into power outlets somewhere between the target slow/dead zone and the main WiFi Access point. Devices can then connect to the WiFi signal emitted from the extender, which relays data to and from the main access point. These WiFi extenders must be configured, which can be confusing to non-technical users. Extenders can fail to function when they become disconnected due to configuration changes on the main WiFi Access Point or get into a bad operational state. User devices sometimes fail to connect to the best signal, especially when moving around. These kinds of issues are frustrating for users.

WiFi Mesh

Newer WiFi mesh systems resolve many problems with traditional extenders. Mesh systems are centrally configured from one place (usually a smartphone application) to keep everything in sync and working smoothly together, with a user interface designed to be comprehendible. Mesh nodes link together wirelessly (like extenders) but automatically and can also manage connection hand-offs between nodes to be sure devices always connect to the best signal. Mesh systems solve many of the problems with WiFi extenders but at a price – systems can cost hundreds of dollars depending on the brand and number of nodes.

HomePlug

HomePlug, also known as powerline networking, is a convenient technology that uses power lines to extend connectivity around the home. A hub device connects to the main internet connection and plugs into a power outlet. The hub then connects to remote HomePlug devices that are plugged into power outlets in other rooms where connectivity is needed. Remote devices may have wired data jacks and integrated WiFi access points to provide wired and wireless connectivity. This technology eliminates the challenge of connecting nodes through walls with wireless links since connections are wired over the power lines. While HomePlug technology has some advantages over WiFi and Ethernet LANs, it seems the least well-known and least deployed. Device prices are in the $40 to $100 range depending on brand and features such as speed and WiFi support, so the total cost for multiple rooms can be significant. Device configuration is also required, which can be overwhelming for some users, though the ease of configuration improves as manufacturers leverage ubiquitous smartphone applications to set up devices.

Ethernet

Where feasible, some customers may prefer to run wired data connections to data jacks around the house, connected with a switch. By adding phone jacks, or cable jacks, technicians can usually fish wires into walls from under the house or the attic, or else they can install an external raceway in which to run cables. Installing data cables is usually an expensive option for existing construction, though it offers high performance and eliminates electronics and wireless propagation/interference issues that complicate WiFi-based LANs. Often WiFi needs to be added to wired jacks anyway since many new devices are WiFi-only or because users prefer the convenience of untethered devices.

Point-to-Point Wireless Bridge

What about rural customers with outbuildings like barns and workshops or guesthouses? In these cases, the LAN may need to be extended outdoors over some distance between buildings. In such cases, there are low-cost point-to-point wireless bridges that can extend LAN connectivity. Many non-technical users don't know about these solutions, and few want to mount and configure their own systems. Such users may value cost-effective options to extend connectivity to multiple buildings. Gigabit speed point-to-point wireless links are available for as little as $160, but installation and configuration may be technically prohibitive for many consumers.

Acknowledgments

The Broadband Development Group (BDG) is pleased to present the 2022 Arkansas Broadband Master Plan. To prepare this report, BDG strived to receive and solicited input from many entities and citizens across the state – at all levels of government, including stakeholders, broadband providers, interest groups, state government commissions, coalitions, associations, and, most importantly, Arkansas residents.

First and foremost, BDG appreciates Governor Asa Hutchinson and the Arkansas Department of Commerce leadership, namely Secretary Mike Preston, State Broadband Manager Steven Porch, and Chief of Staff Jim Hudson, for the opportunity to present this report and be valued partners in this endeavor.

Second, members of the Arkansas General Assembly played a key role in developing this report. Not only did the General Assembly properly vet and weigh in during the advent of this effort, but members assisted in scheduling and advertising **357 community meetings** held in all **75 counties** of the state from October 2021 through March 2022. Legislators attended and participated in community meetings and ensured a wide variety of voices were heard in the community fact-finding portion of this task, which was a key portion of the inquiry. **More than 18,000 broadband surveys** emanating from every county in the state shaped the findings of this report. Legislators disseminated these surveys electronically through social media and email and physically to many of their constituents. Without this assistance, there is no doubt that the breadth of this report would have been limited because it would not have reflected an accurate measure of the community concern.

At least 59 members of the Arkansas General Assembly personally contributed to the preparation of this report.

- **State Senators** included Senators Bob Ballinger, Charles Beckham, Ron Caldwell, Breanne Davis, Jonathan Dismang, Jane English, Ben Gilmore, Kim Hammer, President Pro Tempore Jimmy Hickey, Ricky Hill, Keith Ingram, Missy Thomas Irvin, Blake Johnson, Mat Pitsch, Bill Sample, and James Sturch.
- **House of Representatives included** Representatives Fred Allen, Howard Beaty, Rick Beck, Mary Bentley, Ken Bragg, Harlan Breaux, Karilyn Brown, Joshua Bryant, John Carr, Carol Dalby, Les Eaves, Denise Ennett, Deborah Ferguson, David Fielding, Charlene Fite, Lanny Fite, Jack Fortner, Denise Garner, Delia Haak, Spencer Hawks, Monte Hodges, Mike Holcomb, Joe Jett, Fred Love, John Maddox, Julie Mayberry, Austin McCollum, Gayla Hendren McKenzie, Stephen Meeks, Reginald Murdock, Mark Perry, Aaron Pilkington, David Ray, Marcus Richmond, Johnny Rye, Speaker of the House Matthew Shepherd, Dwight Tosh, Kendon Underwood, Jeff Wardlaw, Les Warren, Danny Watson, Jim Wooten, and Carlton Wing.

Many members of the executive branch assisted and met with BDG teams, including Arkansas State Library Director Jennifer Chilcoat, Arkansas State Library ERate Director Amber Gregory, Arkansas Department of Transportation Director Lorie Tudor, Arkansas State Police Colonel Bill Bryant, Arkansas State Police representative on Arkansas Interoperable Communications Executive Committee Doug Cash, Assistant Commissioner of Research and Technology at the

Arkansas Department of Education Don Benton, the University of Arkansas for Medical Sciences Director of Institute for Digital Health and Innovation Dr. Joseph A. Sanford, Director of Rural Services at the Arkansas Economic Development Commission Becca Caldwell, Director and Program Manager of the Arkansas Wireless Information Network Penny Rubow, and Arkansas Economic Development Commission Regional Director Amy Williams. Arkansas Public Broadcasting Service officials Marty Ryall, Ed Leon, Andrew Bicknell, and Dr. Ron Rainey of the Division of Agriculture assisted.

The Arkansas State Library alerted local libraries and facilitated meetings with several anchor institutions, including Arkansas River Valley Library System Regional Director Misty Hawkins, and Elkins Public Library Director Audra Ball, among others.

County officials played an important role in facilitating meetings and serving as sounding boards related to broadband needs in their areas. They also advertised meetings in the media, attended, distributed, and elicited responses from hundreds of broadcast broadband surveys. We met with county judges, their staffs, and quorum court members. The Association of Counties and its staff, namely Chris Villines, Mark Whitmore, and Josh Curtis, attended meetings and assisted with establishing meetings. County officials who were key to the effort include Saline County Judge Jeff Arey, Craighead County Judge Marvin Day, Jackson County Judge Jeff Phillips, Pulaski County Judge Barry Hyde, Woodruff County Judge Larry Key, Izard County Judge Eric Smith, White County Judge Michael Lincoln, Benton County Judge Barry Moehring, Director of Information Technology of Benton County James Turner, Stone County Judge Stacey Avey, Crawford County Judge Dennis Gilstrap and Brad Thomas, Director of Crawford County Office of Emergency Management, Ashley County Judge Jim Hudson, Baxter County Judge Mickey D. Pendergrass, Clay County Judge Mike Patterson, Conway County Judge Jimmy Hart, Faulkner County Judge Jim Baker, Grant County Judge Randy Pruitt, Lonoke County Judge Doug Erwin, Miller County Judge Cathy Hardin Harrison, Office of the Carroll County Judge Rhonda Griffin, Hot Spring County Judge Dennis Thornton, Poinsett County Judge Randy Milles, Scott County Judge James Forbes, Lafayette County Judge Danny Ormand, and Columbia County Judge Denny Foster. Additionally, we met with Bradley County Economic Development Official Dr. Bob Smalling and the Bradley County Economic Development Council.

The Arkansas Municipal League and mayors throughout the state assisted in scheduling and holding community meetings. Blake A. Gary of the Arkansas Municipal League staff assisted. BDG also conducted broadband discussions at formal city council meetings. Additionally, there were informal gatherings. Special thanks to Jacksonville Mayor Bob Johnson, Bella Vista Mayor Peter A. Christie, Forrest City Mayor Cedric Williams, Cherokee Village Mayor Russell Stokes, Jr., Hot Springs City Manager Bill Burrough, Ward Mayor Charles Gastineau, Dermott Municipal Official Anthony L. Scott, Walnut Ridge Mayor Charles Snapp, Berryville City Director Dean Lee, Mountain Home Mayor Hillrey Adams, West Memphis Communications Director Nick Coulter, Bluff City Mayor Pamela Purifoy, Prescott Director of Economic Development Mary Godwin, Gentry Mayor Kevin D. Johnston, Little Rock Digital Equity Coordinator Maddie Long, Dr. Jay Barth, Greers Ferry Mayor Daryl Birdsong, Cabot Mayor Ken Kincaid, Jonesboro Mayor Harold Copenhaver, Osceola Mayor Sally Longo Wilson, West Memphis Mayor Marco McClendon, Crawfordsville Mayor Joe Marotti, Tyronza Mayor Charles Glover, Cabot Director of Special Projects Bryan Boroughs, Alma Mayor Jerry Martin, West Memphis Utilities Assistant General

Manager Ward Wimbish, Gould Mayor Matthew Smith, Eureka Springs Economic Developer Sandy Martin, Eureka Springs Mayor Robert Berry, Pine Bluff Special Projects Coordinator William Fells, Pocahontas Mayor Keith Sutton, Strong Mayor Daryell Howell, Keo Mayor Stephanie White, Eudora Mayor Tomeka Butler, Huttig Mayor Tony Cole, Hamburg Mayor David Streeter, Waldron Mayor Randy Butler, Hot Springs Mayor Pat McCabe, Greenbrier Mayor Sammy Hartwick, Fayetteville Chief of Staff Susan Norton, Mountain View Mayor Roger Gardner, Yellville Mayor Shawn Lane, Assistant to the Osceola Mayor Stacey Travis, Siloam Springs City Administrator Phillip Patterson, Montrose Mayor Joseph Carlton, Walnut Ridge Mayor Charles Snap, Smithville Mayor Mitch Whitmire, Warren Mayor Denisa Pennington, Texarkana Mayor Allen Brown, Vilonia Mayor Preston Scroggin, Magnolia Mayor Parnell Vann, amongst numerous city council members.

Discussions with stakeholders were key to this effort. Special thanks to the Arkansas State Chamber of Commerce's Randy Zook, Vice President of Programs and Partnerships Shelley Short and staff. The state chamber contacted all their member organizations and helped kick off the planning for local and community meetings at the beginning of the study. Other chambers of commerce leaders assisted because of this outreach, including Texarkana Chamber of Commerce President and CEO Mike Malone and Dean Barry, Batesville Area Chamber of Commerce CEO Crystal Johnson and COO Jamie Rayford, Greater Searcy County Chamber of Commerce Executive Director Darryl Treat, El Dorado-Union County Chamber of Commerce President and CEO Bill Luther, and Nevada County Chamber of Commerce Director Jamie Hillary.

Additionally, economic developers, health care institutions, federal organizations, churches, civic clubs, interest groups, coalitions, associations, and law enforcement groups around the state have a great interest in broadband to their areas. Thanks to Arkansas Rural Health Partnership CEO Mellie Bogani Bridewell, Ashley County Medical Center CEO Dr. Phillip K. Gilmore, Heartland Forward's Angie Cooper, Delta Regional Authority's Aury Kangelos, Tusk Strategies' Meg Pisarczyk, Newton County Baptist Church Pastor Andrew Campbell, The Generator Executive Director Mildred Franco, AR-TX Economic Development Commission President and CEO Rob Sitterly, Robin Hickerson, Huntsville Kiwanis Club's Tamra Long, Arkansas Martin Luther King, Jr. Commission Executive Director DuShun Scarbrough, and Arkansas Sheriff's Association's Scott Bradley.

Broadband providers were key to our findings, **so we met with 29 providers**. Special thanks for the facilitation of these meetings go to Arkansas Cable and Telecommunications Association Executive Director Joe Molinaro, Four States Fiber General Manager Marty Allen, Electric Cooperatives of Arkansas's Kirkley Thomas, Kinetic by Windstream's President Jeff Small and Director of Governmental Affairs David Avery, First Electric Cooperative Corporation CEO Don Crabbe and VP of Marketing and Development Tonya Sexton, OzarksGo! General Manager Steven Bandy, Leverage Broadband Strategies Chief Strategy Officer Doug Maglothin, Carroll Electric Cooperative Corporation CEO Rob Boaz, and Cox Communication Manager of Government and Regulatory Affairs Angela DeLille.

Broadband access is key to the education of our children and young adults. Many thanks to the Arkansas Association of Education Administrators for alerting their superintendents and school districts about this project. Particularly, we want to thank Dr. Mike Hernandez for his organization's assistance. We met with school officials all over the state with a special nod to Searcy County School District Superintendent Alan Yarbrough and Melbourne School District Superintendent Danny Brackett. Additionally, we met with Bret Cooper of Williams Baptist College in Lawrence County.

The Arkansas Farm Bureau and its staff provided access to all its county board meetings, and we attended and had 30 broadband discussions in 30 different counties across the state. The Arkansas Farm Bureau and its staff, including Vice President for Public Affairs and Government Relations Stanley Hill, Director of State Affairs Jeff Pitchford, and Assistant Director of Local Affairs and Rural Development Phillip Powell, who is tasked with the following broadband on the state and national level, provided countless hours of assistance in establishing the community meetings at the advent of the project. Thanks to Arkansas Farm Bureau regional directors Jason Kaufman, Steven Stroh, and Jeremy Miller. District Directors Austin Lester, Tanner Riggin, and Dustin Hill also provided valuable assistance. Justin Reynolds, Vice President of Organization and Member Programs was instrumental in facilitating meetings throughout the state. Under the leadership of Rich Hillman, the Arkansas Farm Bureau adopted affordable and accessible high-speed broadband as a primary policy objective. Public broadband discussion meetings were held in Independence, Fulton, Washington, Stone, Franklin, Crawford, Cleburne, Clark, Saline, Pope, Benton, Columbia, Cross, Boone, Pulaski, Union, Johnson, Perry, Grant, Yell, Hot Spring, Howard, Conway, Faulkner, Madison, Phillips, Woodruff, Desha, Drew and Ashley counties. The Farm Bureau's commitment to the issue and the further development of rural Arkansas is unsurpassed. Without the jump start of meetings organized by the Farm Bureau's staff, this project would not have met its goal of four to five in-person community meetings in all 75 counties within five months.

Special Thanks

BDG wishes to thank the following service providers who graciously provided additional support to the project by making detailed network and service data available. Their strictly voluntary contributions helped us create the maps and build plan estimates, making our analysis more accurate.

- Arkansas Valley Electric Cooperative Corporation
- Clay County Connect, Inc.
- Cox Communications, Inc.
- Craighead Electric Cooperative Corporation
- E. Ritter Communications Holdings, Inc.
- MCEC Fiber, Inc.
- North Arkansas Electric Cooperative, Inc.
- Ozarks Electric Cooperative, Inc.
- South Central Arkansas Electric Cooperative
- Windstream Holdings, Inc.

Table of Figures

Community Meetings (2021-2022)

Oct. 12 - Independence County Farm Bureau
Oct. 12 - Windstream Provider
Oct. 14 - White County Judge's Office
Independence County Courthouse
Ash Flat County Courthouse
Salem Farm Bureau
North East Arkansas Elec. Co-op Provider
Oct. 18 - Washington County Farm Bureau
Oct. 19 - Jonesboro City
Oct. 19 - Searcy City
Oct. 20 - AT&T Provider
Oct. 29 - Little Rock City Staff
Oct. 29 - Heartland Forward
Nov. 1 - Stone County Judge's Office
Mountain View Newspaper
Mountain View Businesses
Stone County Courthouse
Stone County Farm Bureau
Yelcot Communications Provider
Franklin County Farm Bureau
Nov. 2 - Crawford County Judge's Office
Crawford County Office of Emergency Management
Crawford County Farm Bureau
Cleburne County Farm Bureau
Nov. 4 - Jacksonville City Council
Clark County Farm Bureau
South Central Electric Co-op Provider
Zoom Meeting with Librarians Statewide
Nov. 8 - Saline County Farm Bureau
Pope County Farm Bureau
Springdale Rotary Club
Arkansas River Valley Regional Library System
Nov. 9 - Hot Spring County Farm Bureau
White County Farm Bureau
Saline County Meeting
Nov. 11 - Benton County Farm Bureau
Columbia County Farm Bureau

Arkansas Connectivity Coalition
Nov. 13 - Cross County Farm Bureau
Nov. 15 - Boone County Farm Bureau
Saline County Judge's Office
Saline County Sheriff's Dept.
Saline County Assessor's Office
Saline County Revenue Office
Baxter County Farm Bureau
Yellville Mayor
Mountain Home Provider
Baxter County Judge's Office
Nov. 16 - Pulaski County Farm Bureau
Nov. 17 - Benton County Leadership
Nov. 18 - Johnson County Farm Bureau
Union County Farm Bureau
Arkansas Assoc. of Black Mayors
Nov. 19 - Pulaski County
Nov. 22 - Perry County Farm Bureau
Nov. 29 - Woodruff County Staff
Wynne Economic Development
Nov. 30 Eureka Springs City
Carroll County Broadband Provider
Marshall Public Library
Marshall Chamber of Commerce
Grant County Farm Bureau
Dec. 1 - Little Rock City Staff
No. Pulaski Republican Women
Dec. 2 - Farm Bureau State Convention
Dec. 3 - Gravette Kiwanis
Provider Interview
Dec. 6 - City of Cabot Mayor's Office
Dec. 8 - Sebastian County Judge
Yell County Farm Bureau
Dec. 9 - Cabot City
Ward City
Hot Spring County Farm Bureau
Lafayette County Quorum Court
Nevada County Library
Columbia County Schools

Arkansas Legislature Black Caucus
Dec. 10 - ARTELCO Provider
North Little Rock Chamber of Commerce
Dec. 13 - Arkansas State Police
Dec. 14 - FIrst Elec. Co-op Provider
City of Camden
Dec. 15 - Trumann Lions Club
Craighead Elec. Provider
Melbourne Public School
Conway Housing Authority
Dec. 16 - Batesville Chamber of Commerce
Cave City Provider
Spring River Area Chamber of Commerce
Dec. 17 - E Ritter Provider
MLK Commission Food Pantry
Dec. 20 - Alma City
Comcast Provider
Dec. 21 - Cox Communications Provider
Dec. 28 - Little Rock Port Authority
Dec. 29 - Diamond State Networks
Jan. 5 - ZOOM Town Hall Meeting
Jan. 6 - Fidelity Provider
Jan. 10 - Malvern City
Hot Spring County Judge’s Office
Texarkana Economic Development
Hot Spring Chamber of Commerce
Four States Co-op Provider
Hot Springs Resort Cable Provider
Malvern Library
Jan. 11 - Columbia County Farm Bureau
ZOOM Town Hall Meeting
ZOOM Town Hall Meeting
ZOOM Town Hall Meeting
Gould City Council
Jan. 12 - ZOOM Town Hall Meeting
ZOOM Town Hall Meeting
ZOOM Town Hall Meeting
Pike County Delight Library
Delight Local Business

Pike County Judge's Office
Pike County Library
Barnum Library Glenwood
Jan. 13 - Cross County Farm Bureau
Polk County Judge's Office
Polk County Chamber of Commerce
Polk County Library
ZOOM Town Hall Meeting
ZOOM Town Hall Meeting
ZOOM Town Hall Meeting
Jonesboro City Staff
Jonesboro Library
Wynne City
SATCO Provider
Woodruff Co-op Provider
Montgomery County Judge's Office
Montgomery County Clerk's Office
Montgomery County Assessor's Office
Montgomery County Library
Jan. 14 - Pine Bluff City
Aristotle Provider
Jan. 18 - Union County Farm Bureau
Jan. 19 - Drew County Farm Bureau
Desha County Farm Bureau
ZOOM Town Hall Meeting
Ashley County Farm Bureau
Benton County Staff
Dallas County Judge's Office
Dallas County OEM
Dallas County Library
Dallas County Chamber of Commerce
Cleveland County Judge's Office
Cleveland County Library
State Revenue Office Rison
Jan. 20 - East Poinsett County School Dist.
Lawrence County Judge's Office
Lawrence County Clerk's Office
State Revenue Office / Walnut Ridge
Lawrence County Library

Jan. 21 - Little River County
Jan. 24 - Hazen Public Library
Hazen Newspaper
Hazen Local Business
Faulkner County
Forrest City
West Memphis Mayor
West Memphis Electric
Crawfordsville City
Jan. 25 - Jackson County Farm Bureau
Tyronza City
Wilson - Business
Wilson City Office
Osceola Mayor
Osceola Public Library
Osceola Potential New Company
Blytheville Public Library
Blytheville Southern Bancorp
Jan. 27 - Howard County Farm Bureau
Craighead County Farm Bureau
Menifee City Council
Little River County Judge's Office
Little River County Assessor's Office
Little River County Clerk's Office
Ashdown Public Library
Sevier County Judge's Office
Sevier County Clerk's Office
Sevier County Collector's Office
Sevier County Assessor's Office
Sevier County Library
Jan. 28 - Woodruff County Judge's Office
Woodruff County Clerk's Office
Woodruff County Assessor's Office
Woodruff County Library
Arkansas Revenue Office - Augusta
Jackson County Judge's Office
Jackson County Clerk's Office
Jackson County Treasurer's Office
Jackson County Collector's Office

Jackson County Circuit Clerk’s Office
Jackson County Library
Jan. 31 - Greene County Judge‘s Office
Greene County Assessor’s Office
Greene County Collector’s Office
Greene County Clerk’s Office
Greene County Circuit Clerk
Greene County Library
Paragould Chamber of Commerce
Randolph County Judge’s Office
Randolph County Clerk’s Office
Randolph County Assessor’s Office
Randolph County Collector’s Office
Randolph County Library
Clay County Judge’s Office
Clay County Assessor’s Office
Clay County Collector’s Office
Clay County Library
Rector Library
Newton County Piercetown
Jasper - Business
Mountain Home
Feb. 1 - Lonoke FB
Monroe County Judge’s Office
Monroe County Clerk’s Office
Monroe County Assessor’s Office
Monroe County Circuit Clerk Office
Monroe County Library
Lee County Judge’s Office
Lee County Assessor’s Office
Lee County Circuit Clerk’s Office
Lee County Clerk’s Office
Lee County Collector’s Office
County Judges’ Annual Meeting
Feb. 2 - ZOOM Town Hall Meeting
Siloam Springs Kiwanis
ZOOM Town Hall Meeting
Feb. 7 - Eureka Springs City
Gentry City

Scott County Judge
Waldron Mayor
Scott County Sheriff's Office
Feb. 8 - ZOOM Town Hall Meeting
Elaine City
Feb. 9 - ZOOM Town Hall Meeting
ZOOM Town Hall Meeting
Feb. 10 - ZOOM Town Hall Meeting
ZOOM Town Hall Meeting
Wilmot City
Greenbrier City
Feb. 15 - Conway County Judge
ZOOM Town Hall Meeting
Vilonia City
Morrilton Library
Hot Springs City Council
Feb. 16 - Jackson County Farm Bureau
Dardanelle Chamber of Commerce
ZOOM Town Hall Meeting
ZOOM Town Hall Meeting
Garfield City
Feb. 17 - Madison County Farm Bureau
Madison County Herald
Madison County School Admin
Madison County Hardware
Madison County Businesses
Faulkner County Farm Bureau
Phillips County Farm Bureau
Dermott City
ZOOM Town Hall Meeting
ZOOM Town Hall Meeting
Feb. 18 - Woodruff County Farm Bureau
Feb. 21 - Lake Village City
Hamburg City
Ashley-Chicot Provider
Crossett Hospital
Montrose City
ZOOM Town Hall Meeting
Feb. 22 - Howard County

Arkadelphia City
ZOOM Town Hall Meeting
Feb. 24 - Warren City
ZOOM Town Hall Meeting
Feb. 28 - Strong City
Huttig City
El Dorado Library
ZOOM Town Hall Meeting
March 1 - Paron City
March 2 - Pocahontas Rotary Club
Clay County
Traskwood
ZOOM Town Hall Meeting
Clay County Provider
Paragould Provider
March 3 - Conway County Farm Bureau
Hoxie City
Walnut Ridge City
Smithville City
Columbia County Extension Service
ZOOM Town Hall Meeting
March 7 - Cox Provider
March 8 - Keo City
ZOOM Town Hall Meeting
March 9 - De Queen City
Mineral Springs City
ZOOM Town Hall Meeting
March 10 - Huntsville Kiwanis
Pine Bluff City
Elkins Library
ZOOM Town Hall Meeting
March 14 - Garland County Quorum Court
March 15 - Sebastian County Economic Development
Ozark City
Carroll Electric Co-op
March 17 - Suddenlink Provider
March 25 - Bradley County Economic Development

Endnotes

[1] https://broadbandnow.com/research/fcc-broadband-overreporting-by-state

[2] https://www.fiercetelecom.com/broadband/fcc-expects-its-revamped-broadband-maps-be-ready-fall

[3] https://www.fiercetelecom.com/broadband/fcc-expects-its-revamped-broadband-maps-be-ready-fall

[4] Census data from ACS 2020 5-year unless noted

[5] Depending on the specific design, the core site would likely require a couple of standard data center equipment racks to hold a router, switches, firewall, content cache, network management, DHCP, and DNS servers.

[6] Alternative Connect America Cost Model https://transition.fcc.gov/wcb/ACAM040115.pdf

[7] https://www.fcc.gov/sites/default/files/ad-hoc-commitee-survey-04242018.pdf

[8] http://diamondstatenetworks.com/

[9] https://en.wikipedia.org/wiki/Fresnel_zone

[10] UNII-5 (500 MHz in 5925-6425 MHz range) and UNII-7 (350 MHz in 6526-6875 MHz range) bands will permit outdoor transmission at typical unlicensed power levels (36 dBm); however due to incumbent usage (such as licensed PtP microwave in the 5925-6425 MHz band), permission to transmit will be governed by some to-be-determined automatic frequency coordination system.

[11] https://x-lumin.com/

[12] https://www.ericsson.com/en/news/2021/10/ericsson-and-powerlight-achieve-base-station-wireless-charging-breakthrough

[13] https://fiber.google.com/2gig/

[14] Pushing the residential home broadband envelope to 10 Gbps. Examples include Fairlawn OH, https://www.fairlawngig.net/residential/, Salisbury NC https://www.fairlawngig.net/residential/, Cedar Falls IA https://www.cfu.net/tv-internet/internet-service-info/10-gig-internet, Chatanooga TN https://www.lightwaveonline.com/fttx/ftth-b/article/16651481/epb-brings-10gbps-ftth-to-chattanooga

[15] https://www.fiercetelecom.com/operators/altice-usa-targets-10-gig-rollout-2022

[16] https://www.wifrost.com/

[17] https://www.taranawireless.com/

[18] https://www.amazon.com/dp/B079K6WFYQ/ref=cm_sw_em_r_mt_dp_DG35J19JF5E2FKX3F1DF

[19] https://www.outdoorrouter.com/product-category/outdoor-4g-router-mimo-wifi-300mbps/america-4g-outdoor-router/

[20] https://www.fiercewireless.com/operators/t-mobile-cuts-fwa-home-internet-cost-by-10-verizon-expands-5g-home

[21] https://www.fiercewireless.com/operators/t-mobile-says-it-will-have-thousands-2-5-ghz-sites-live-year

[22] https://www.fiercewireless.com/operators/at-t-starts-offering-5g-fixed-wireless-for-business-customers

[23] BLiNQ products presented at WISP America in Ft. Worth April 26-28, 2021

[24] https://www.sempre.ai/rural

[25] https://www.tekniam.com/solutions

[26] https://www.microsoft.com/en-us/corporate-responsibility/airband/technology

[27] https://advanced-television.com/2020/10/28/fcc-tvws-boost-for-rural-broadband/

[28] https://www.wifrost.com/

[29] https://usa.wavedb.com/channelsearch/tvws

[30] Viacom statement regarding satellite service latency. https://testmy.net/hoststats/viasat?source=content_type%3Areact%7Cfirst_level_url%3Article%7Csection%3Amain_content%7Cbutton%3Abody_link

[31] FCC RDOF Fact Sheet https://www.fcc.gov/auction/904/factsheet

[32] https://www.starlink.com/faq