Can Unlicensed Wireless Solve the Rural Digital Divide?

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Table of Contents

Executive Overview 3

Capabilities Needed to Meet the Broadband Need 4

How Much Broadband Does an Unlicensed Wireless Need to Deliver? 4

How Many Lack High Speed Broadband and Where are They? 5

Can Unlicensed Wireless Meet Rural Broadband Needs? 6

Technical Limits on Offered Speed 6

Lack of Adequate Spectrum – Especially Unlicensed 7

Summary/Conclusions 9

APPENDIX A Understanding the Fantastic Wireless Claims 11

Author Biography 12

Executive Overview

There are a variety of landline or wireless technologies that can deliver broadband. Many factors must be considered when selecting the best technology for delivering broadband. Some of the factors when determining the suitability of a broadband network include the speed, quality (latency, jitter, and capacity), the capital cost (both short-term and long-term), operational expense, mobility, transferability, scalability, sustainability, and reliability.[1] In most instances, wireless solutions have an advantage with respect to mobility and transferability (ability to move broadband investment from one subscriber location to another). When considering fixed broadband, few would argue that fiber is the undisputed king when considering broadband speed, quality, scalability, sustainability, reliability, and total cost of ownership.[2] This should be obvious from the fact that both landline and wireless providers have been replacing much of their networks with fiber over the last 15 years.

Much has already been written on the fact that the initial capital investment is often lower for a wireless network, but this advantage often disappears (and sometimes flips) when considering the increased operational expenses of wireless and the ongoing capital investment required.[3] We will not consider licensed spectrum because it is a limited valuable commodity should be reserved for mobility applications, and in fact we should discourage deployment of BEAD funded networks using licensed spectrum for that reason. Our intention herein is not to rehash those issues, but to focus on the suitability of unlicensed wireless to provide fixed broadband service in rural areas and under what circumstances should public funds be used to deploy such networks.

The Broadband, Equity, Access, and Deployment (BEAD) program is a once in a generation opportunity to close the broadband gap in the United States.[4] It is not only important to close this gap, but also to keep it closed. Deploying highly reliable networks that have fast speeds (both upload and download) will help close that gap today, but these networks must also be scalable and sustainable to keep this gap closed in the future. Congress also recognized this in the Infrastructure, Investment, and Jobs Act (IIJA) defined "Reliable Broadband Service" as ". . . broadband service that meets performance criteria for service availability, adaptability to changing end-user requirements, length of serviceable life."[5] The IIJA also required that Administrator to ". . . ensure that the network built by the project can easily scale speeds over time."[6] As discussed later, the Federal Communications Commission's (FCC) restrictions on the use of spectrum and the laws of physics make it difficult, if not impossible, for unlicensed wireless networks to meet these requirements of the IIJA.

Much of the BEAD funding will be focused on rural areas, since it is the rural customers that have been on the wrong side of the digital divide.[7] These areas have unique challenges when deploying broadband. Solutions that may be reliable and cost-effective in an urban environment may not always be a smart choice for rural areas. All wireless has the unfortunate characteristic that the radio signal degrades as the distance between the customer

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[1] Broadband Speed Characteristics, Larry Thompson, PE, Nathan Weber, PE, Brian Enga, PE, June 2018.

[2] Comparing Wired and Wireless Broadband, Broadband Communities Magazine, Larry Thompson, PE, Brian Bell, PE, Brian Enga, PE, and Warren Vande Stadt, June 2015.

[3] Future Proof: Economics of Rural Broadband, Comparing Terrestrial Technologies & Investment Considerations to Meet Increasing Consumer Broadband Demands, Foundation for Rural Service, Larry Thompson, PE, Brian Enga, PE, and Brian Bell, PE, March 2021 (https://www.ntca.org/sites/default/files/documents/2021-05/Future%20Proof%20--%20Economics%20of%20Rural%20Broadband%20FINAL_0.pdf)

[4] Global speed indexes don't have the United States in the top ten countries with respect to broadband speeds.

[5] Infrastructure, Investment, and Jobs Act (IIJA), SEC. 60102 (2) (L)

[6] IIJA, SEC. 60102 (2) (I) (ii)

[7] FCC Broadband Map (https://broadbandmap.fcc.gov/)

and the tower increases. This characteristic is exacerbated at higher frequencies. In general, more spectrum is available at higher frequencies, which make them capable of faster broadband speeds, but these frequencies are also plagued by lack of penetration of obstacles and extreme weather effects and require a dense grid of fiber connected cell sites which generally results in a higher initial capital expense than what is required for Fiber to the Premises (FTTP).

As we will see, rural wireless solutions that are practical for rural broadband are left only with mid-band (1-6 GHz range) or low-band (less than 1 GHz). The only spectrum available for use by most broadband providers in these bands are in an unlicensed band or lightly licensed band, since the scarce licensed frequencies are "owned" by a small number of wireless carriers that use this spectrum primarily for mobile voice and small-screen broadband. The amount of spectrum determines the broadband speed and capacity. There is only 26 MHz of unlicensed spectrum in the low-band and 1,760 MHz of unlicensed spectrum in the mid-band (when including the 6GHz spectrum that is not yet available for use). All the spectrum on a fiber is available to the provider – from 1,260 nm to 1,680 nm (in common use with today's technologies). This would mean that a single fiber has 59 million MHz of spectrum available – 33,000 times more than a wireless provider.

Although the Infrastructure, Investment, and Jobs Act (IIJA) and the NTIA BEAD program require networks with speeds of 100/20Mbps, it would be short-sighted to use public funds on networks that are unable to scale to meet a customer's broadband needs in the next few years. Today, the average broadband speed according to OOKLA is over 250Mbps[8] and we will need to be preparing for gigabit speeds in the next few years. There is no spectrum available that would allow a fixed wireless network to practically and economically deliver these speeds in a rural environment – and no wireless technology advances on the horizon will change that. This is likely why fiber continues to be the preferred technology in the IIJA and NTIA's BEAD program.

For fixed broadband deployments, fiber will continue to be the most future proof of all technologies. Some have argued that fiber can in some applications be more expensive than a wireless network when designing a network that is capable of only 100/20Mbps. A fiber-based broadband network is not only a network for today, but also for the next generation. Making the wrong technology choice now will result in much more investment required in the coming years just to meet increasing customer demands and will likely doom many to be on the wrong side of the digital divide forever.

Capabilities Needed to Meet the Broadband Need

How Much Broadband Does an Unlicensed Wireless Need to Deliver?

During the recent pandemic, we realized the profound impact that the Internet has on nearly every area of our lives, including education, retail, healthcare, public safety, and entertainment. The Internet has fundamentally changed how we communicate, the size and scope of our global economy, and even our political system. The Internet has also evolved to meet the rapidly increasing customer demand. Customers continue to demand faster speeds and higher capacities as telehealth becomes more commonplace as a means of medical care, as education increasingly migrates online, as Ultra High-Definition television (UHDTV) becomes commonplace, and with the dramatic growth of connected devices of all kinds needing Internet access.

[8] https://www.speedtest.net/global-index/united-states#:

Less than 10 years ago, the Federal Communications Commission's (FCC) definition of broadband was 4 Mbps download and 1 Mbps upload (4/1Mbps). The Twelfth Measuring Broadband America (MBA) Report[9] recently released by the FCC shows that in October 2021 the average fixed broadband speed was 307.7 Mbps for download and the average of 58.4 Mbps for upload. Both download and upload speeds have been increasing by an average of over 38% annually since the FCC started publishing the MBA reports. If the broadband speeds continue at this rate – and we have no reason to believe that they will not – the average broadband download speed will be nearly 6 Gbps by 2030 as shown in Figure 1.

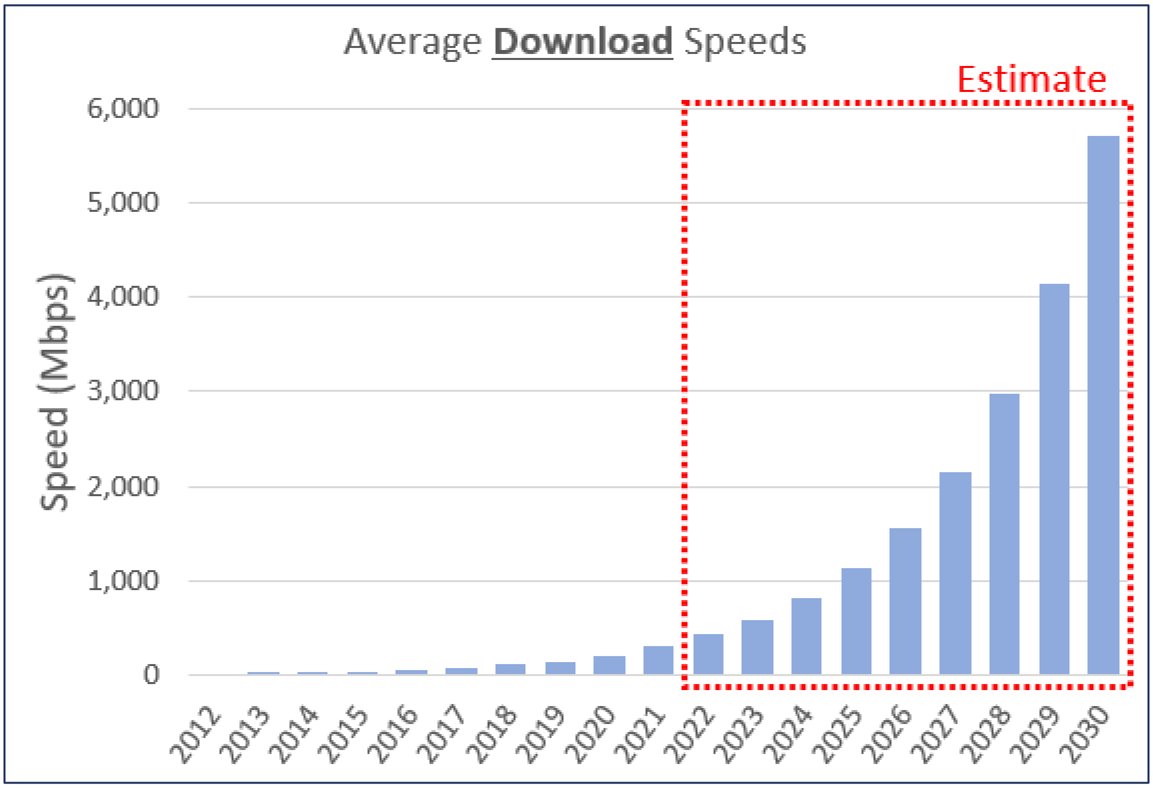

FIGURE 1. AVERAGE DOWNLOAD SPEEDS – BASED ON FCC MBA REPORTS

How Many Lack High Speed Broadband and Where are They?

Millions in the United States are on the wrong side of the digital divide. Choosing the wrong technology solution to bridge this divide could only solve the problem for a short time and be only a broadband "band aid." The FCC's recent Broadband Data Collection (BDC) efforts have shown there are approximately 7.8 million locations that cannot receive the FCC's currently defined minimum broadband standard of 25/3Mbps and another 6 million that cannot receive 100/20 Mbps.[10]

Most Americans that lack broadband are in rural areas with low population density. According to the FCC, 22.3 percent of Americans in rural areas lack broadband of at least 25/3 Mbps, as compared to only 1.5 percent of

[9] FCC's Tenth Measuring Broadband America (MBA), Fixed Broadband Report, January 6, 2023.
[10] FCC's Broadband Map found at https://broadbandmap.fcc.gov/home

Americans in urban areas.[11] Because of this, these rural areas have been the focus of recent government funding, including the Connect America Fund Phase II, the Rural Digital Opportunity Fund, and the upcoming Broadband Equity, Access, and Deployment. Many of these areas have less than 10 locations per square mile and many of the areas are less than 5 locations per square mile.

There are many wireless and wireline technologies that can effectively and economically provide broadband to densely populated urban areas. However, low density is one of the largest barriers to broadband. To solve the problem of the digital divide, the technology must not only be able to deliver high quality broadband that meets the customers need – both today and in the future – and able to do it cost-effectively in these rural areas.

Can Unlicensed Wireless Meet Rural Broadband Needs?

Wireless equipment vendor claims can easily lead one to believe that their broadband performance is much better than it is in reality. Some of these claims are misleading because they often quote broadband speeds by combining both the download and upload speeds, refer to total line rate instead of the actual speed available to the customer, assume an unrealistic amount of spectrum, and assume unrealistically short distances. These factors combined often result in fantastic wireless performance claims.[12] The laws of physics still apply to wireless networks – the amount of broadband delivered to a customer over a wireless network is ultimately determined by the spectral efficiency, number of customers served by each wireless antenna or sector (oversubscription), and by the frequency spectrum (both the quantity and location in the frequency band).

Technical Limits on Offered Speed

Spectral efficiency is a measure of how much information in “bits per second” (or broadband speed) per Hz of frequency spectrum used. Advances in wireless technology over recent years have resulted in improved spectral efficiency. Modern wireless networks can achieve an average of 2 to 4 bps/Hz across their coverage areas. Newer technologies such as Multiple-Input and Multiple-Output (MIMO) where multiple transmitters and receivers are used simultaneously to deliver the wireless signal have been largely responsible for improving spectral efficiency. For example, if a wireless system could achieve a spectral efficiency of 5 bps/Hz when using 40 MHz of spectrum, the antenna (or “beam”) would have a total capacity of 200Mbps which would be shared by all customers (both upload and download) served by that antenna or beam.

Most wireless providers oversell their network capacity of each antenna (or sector or beam) many times over. This is referred to as oversubscription and helps wireless carriers spread their investment over more customers to reduce their cost per customer. Oversubscription is defined in terms of the ratio of the total bandwidth sold to the total bandwidth available. For example, if the wireless provider has sold a 100Mbps download service to 8 customers (800Mbps sold capacity) and has 200Mbps of available download capacity, this would be an oversubscription of 4:1. These 8 customers would each believe they have the 100Mbps of capacity they purchased but would actually have much less, since only 2 of the 8 customers could operate at full speed at any given time. Too much oversubscription can result in poor network performance as too many customers are attempting to use

[11] FCC’s 2020 Broadband Deployment Report, https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2020-broadband-deployment-report

[12] Refer to Appendix A for a better description of the terminology used in the wireless industry and how their performance claims can often be misunderstood so one believes their performance is actually better than reality.

the same frequency band. As the wireless carrier increases their offered broadband speed as users continue to demand more, the oversubscription ratio increases and the broadband performance for each customer degrades.

Lack of Adequate Spectrum – Especially Unlicensed

A wireless network's speed and distance is also limited by the spectrum being used. Unlike fiber where the operator has an almost unlimited amount of spectrum available, wireless spectrum is a scarce commodity and heavily regulated by the FCC. There are very few frequency bands with enough capacity to meet a broadband demand of urban customers and few, if any, that can meet the demands of rural customers where they may live several miles from the tower. As broadband demand continues to grow, the available spectrum will be unable to meet most user's fixed broadband needs.

By today's standards, a broadband network must deliver at least 100/20Mbps.[13] Assuming a spectral efficiency of 5 bps/Hz, one would need 24MHz of spectrum to deliver 100/20Mbps service to a single user. If there were 15 customers served by this sector, 90MHz of spectrum would be required if a 4:1 oversubscription ratio was needed. As stated earlier, the average broadband speed is growing at a rate of 38% per year. Therefore, a broadband network installed today with a life expectancy of 5 years would need be capable of offering 500/100Mbps to these customers. To achieve this, the wireless operator will need 450 MHz of spectrum. Even if technical advances resulted in doubling the spectral efficiency, 225MHz of spectrum would still be needed for these 15 same customers.

We also have the challenge that a wireless signal degrades the farther it travels. Just as flashlight's intensity is much less when pointed as a distant object as compared to pointing at a close object. So, it is with wireless networks. As the distance increases, the power decreases. This is especially true with higher frequencies. This also limits the spectrum that can be used by wireless networks when serving rural customers.

There are three basic spectral bands, which are low-band, mid-band, and high-band (often referred to as millimeter wave or mmW). These three spectral bands can be seen in Figure 2. Each of these spectral bands have their own unique properties which we will discuss as it relates to broadband use.

Wireless signals using low-band spectrum can propagate for many miles – sometimes up to 15 or 20 miles when the terrain is flat. At these low frequencies, obstacles such as trees and walls do not have a significant impact on the wireless signal. When using low-band in rural areas, a single tower would have the ability to reach many miles and potentially serve a thousand or more customers (although the broadband speed would be likely be slow with this many customers sharing the same spectrum). However, nearly all the bands in the low-band spectrum are licensed and are mostly only 5MHz or 6MHz blocks. Many rural broadband providers do not own any of this spectrum and if they did, it would be difficult to achieve more than 25/3Mbps to a single user. The only unlicensed band is 900 MHz and is rarely used by broadband because of noise and congestion from other devices in the band. Because of the broadband limitations, this spectrum is not practical to be used meet today's broadband needs in rural areas and will not be considered any further.

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[13] NTIA Broadband, Equity, Access, and Deployment Notice of Funding Opportunity, Section IV (C), Program Requirements, Page 67 and the IIJA under the Deployment and Provision of Service Requirements, required that an entity who receives a subgrant for the deployment of a broadband network shall provide broadband service at a speed of not less than 100 megabits per second for downloads and 20 megabits per second for uploads.

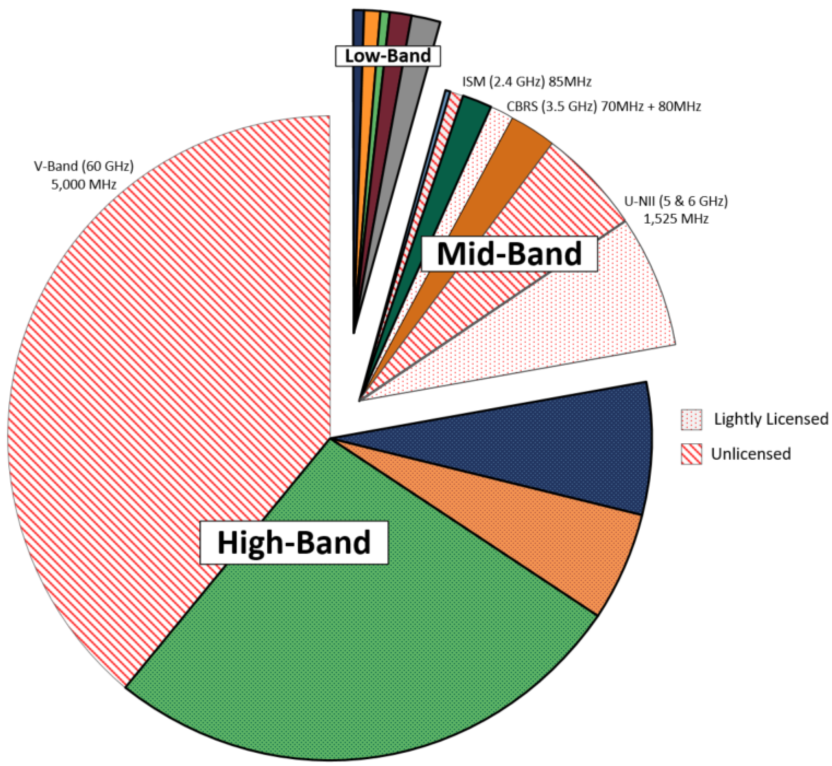

Figure 2. Broadband Spectrum

There is enough spectrum in the high-band to accommodate gigabit broadband speeds (almost 90 GHz when considering licensed and unlicensed). However, the distance these high frequency signals can travel are measured in hundreds of feet – not miles. In addition, any obstacle between the tower and customer will effectively block the signal. Rain, snow, and fog can also have adverse effects on these signals which can result in outages. In many rural areas, each customer would require their own fiber-fed tower since these towers need to be within a few hundred feet of the customer. This is not a practical nor cost effective solution for a rural deployment. A design like this would require nearly as much fiber as a FTTP design and would be more expensive than FTTP to deploy and maintain. Because of this, we will not consider the high-band spectrum a practical solution for rural broadband any further.

That leaves us with the mid-band spectrum. There are three areas of the mid-band spectrum that have been the focus of wireless broadband deployments. These are:

- **BRS/EBS Band** – The Broadband Radio Service/Education Broadband Service (BRS/EBS) band has 190 MHz of spectrum which could accommodate 100/20Mbps service while allowing for reasonable oversubscription. Unfortunately, this is a licensed band and a single carrier (T-Mobile) has most of the BRS/EBS licenses nationwide. This is likely not an option for most wireless broadband providers.
- **CBRS Band** – The Citizens Broadband Radio Service (CBRS) band has 70MHz of licensed spectrum and 80MHz of "lightly licensed" spectrum referred to as General Authorized Access (GAA). Any wireless operator is allowed to use the GAA portion (provided it is not at capacity). In theory, the first user of the spectrum could access all 80MHz. However, when the second user requests access they would each be limited to 40MHz. The spectrum continues to be subdivided as more wireless broadband providers request access. Each time the spectral band is divided in half, the broadband speed available to the

wireless customer is also divided in half. A provider with only 20MHz of CBRS spectrum could likely provide 25/3Mbps service to a small number of customers within 5 miles of the tower but would not be able to deliver 100/20Mbps service to these same customers unless they were unrealistically close to the tower (where higher spectral efficiency is possible).

- **5&6GHz U-NII Band** – The 5GHz Unlicensed National Information Infrastructure (U-NII) band is used by most home Wi-Fi access points. The FCC recently expanded this band to include another 850MHz of spectrum in the 6GHz band for outdoor use. However, this spectrum will be managed like CBRS (GAA) so the amount of spectrum each provider is allocated is based on the number of providers that request spectrum in this band. Also, there are already other users in this frequency band such as fixed terrestrial microwave systems, earth-to-space satellite service, and television broadcast services who take priority over new users of the spectrum. This band is already crowded with other users (which increases the noise and interference in the band) and will likely become more crowded. Even if the initial wireless deployments show promising broadband results, it is likely they will degrade as more devices and wireless operators begin using the spectrum.

Providing broadband to rural areas over a wireless network presents both technical and economic challenges. From a technical perspective, there is barely enough spectrum to meet rural customer's broadband needs today, much less in the future. From an economic perspective, limiting the number of customers per tower or moving towers close enough to the customer to achieve the needed broadband may not make financial sense. For unlicensed bands, there is also no guarantee that the speeds achievable today can be achieved tomorrow as more devices and other providers begin operation in the same band. The unpredictable nature of these bands make it difficult for the provider to commit to a broadband speed except at very low rates.

A fiber network, such as FTTP does not suffer from these limitations. All the "spectrum" on a fiber is available to the provider for delivering broadband to their customers. Not only is the capacity on fiber predictable, but there is also a lot of it. Most FTTP networks today relay on XGS-PON which is capable of 10Gbps download. Not only can XGS-PON meet the most demanding broadband customers' needs today, but it will also be able to meet their ever-growing demands for many years to come and can easily deliver faster broadband with inexpensive equipment upgrades.

Summary/Conclusions

Today, wireless networks are used to provide broadband to customers that have no better solution available. As broadband demands continue to increase, it will become increasingly difficult for a wireless provider (especially those relying on unlicensed spectrum) to meet the fixed broadband needs of their customers – largely due to the scarcity of spectrum that is suitable for rural broadband applications. When building a broadband network using public funds, it is important to take a realistic view of the future capabilities and limitations of the network to understand the future network investments needed to continue to meet their customer's broadband needs. The broadband speeds claimed by wireless technologies may sound promising, but a rigorous and disciplined technical analysis of what such networks can and cannot deliver in needed – not marketing claims.

There is simply not enough low-band spectrum to meet the growing needs of broadband customers. Mid-band spectrum may be reasonably well-suited for use for the long distances in rural areas, but there is not enough of it to provide future broadband speed demands. Using the unlicensed frequency spectrum in the mmW band presents different challenges – especially when attempting to deliver broadband to rural areas. The mmW band has adequate spectrum to deliver very fast broadband services, but the spectral characteristics are not well suited to provide rural broadband as is the subject of the BEAD program. In most areas, using mmW would require each rural resident to have his or her own wireless tower. Most of these towers would be required to have fiber connections to deliver the needed broadband capacity to the network connection point.

It is difficult for rural wireless networks using unlicensed frequency bands to deliver world-class broadband service today. This will become harder in the future not easier. Apart from some very limited circumstances presenting ideal conditions as summarized herein, the technical and related economic hurdles will be substantial, if not insurmountable. The NTIA NOFO was correct by not allowing unlicensed wireless network access to BEAD funds. Using crowded unlicensed bands, should be rejected due to reliability issues associated with unlicensed frequencies. These bands certainly don't meet the IIJA requirements of being able to "scale speeds over time."[14]

[14] IIJA, SEC. 60102 (2) (I) (ii)

APPENDIX A

Understanding the Fantastic Wireless Claims

The performance claims of wireless networks can often be misleading. Because of this, it is easy to be misled into thinking that the performance of a wireless network is much better than it is in reality. There are several ways that wireless equipment manufacturers or wireless providers "overstate" their performance. These include:

- **Quoting Total Capacity Rather than Download Speed** – Wireless network speeds are often characterized by summing both the upload speed and the download speed. For example, a wireless network claiming 100Mbps capability may only have 85/15Mbps capability or one claiming to 1 Gbps service may in reality on be able to provide 500/500Mbps. However, landline providers refer only to their download speed. A FTTP provider would refer to the 500/500Mbps service as 500Mbps rather than 1Gbps. This alone can lead someone to believe that the wireless performance is twice what it actually is.
- **Stating Performance in Unrealistic Scenarios** – Performance for wireless network is often specified as "best case" using very short distances, a single customer, and unrealistic amounts of spectrum.
    - **Short Distances** – Similar to how a flashlight is bright when pointing at a close object and dim when pointed at a distant object, the wireless signal power is weaker when farther from the antenna. This results in a slower speed connection or no connection at all. Quoting performance for a user near the tower is not representative of all customers in the wireless coverage area.
    - **Single Customer** – Wireless networks transmit their signals over airwaves that have a fixed and finite amount of network capacity which is shared by many users. Quoting performance for a single user is unrealistic since the capacity used by each user (in the same antenna or beam) reduces the amount of capacity available to the others.
    - **Unrealistic Amounts of Spectrum** – The performance of a wireless system is often quoted using more bandwidth than is realistically available to a typical provider, which also results in overstating the broadband performance.
- **Confusing PtP and PtMP** – Wireless networks used to deliver broadband to end user customers are Point-to-Multipoint (PtMP) systems. With a PtMP system, a single antenna or tower serves many customers. Backhaul networks are Point-to-Point (PtP) systems where an antenna (or dish) on one tower is communicating with an antenna (or dish) on another tower. Wireless network equipment can often operate in a PtMP or PtP configuration. A PtP system can generally reach farther distances and have faster speeds because of better gain antennas, higher radiated power, and higher performance electronics. However, the PtP performance is often quoted and can be misinterpreted as the performance that can be expected at an end user location in a PtMP configuration.
- **Network Speed vs Customer Capacity** – In addition to end user data, a wireless network must also carry signaling information, error correction coding, address information, network control codes, and other information. When quoting the network speed, it is not uncommon for a wireless equipment manufacturer to quote the total line speed which includes the overhead information rather than what is actually available to the end user. In some instances, line speed can be twice the speed that is available to the end user.

Author Biography

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Larry Thompson is a licensed professional engineer and has been designing satellite, wireless, and broadband wireline networks for more than 35 years. Larry received his bachelor's degree in physics from William Jewell College and his bachelor's and master's degrees in Electrical Engineering from the University of Kansas. Prior to founding Vantage Point Solutions in 2002, Larry held several engineering and management positions with TRW's Space and Defense sector, CyberLink Corporation, and Martin Group. Larry is currently the CEO of Vantage Point Solutions, which has over 400 employees and is a national provider of engineering and consulting services. Over the years, he has assisted many wireless and wireline companies successfully manage their technical, regulatory, and financial challenges.

Larry was a two-term member of the FCC's Broadband Deployment Advisory Committee (BDAC), is a frequent speaker at state and national conferences, and a frequent expert witness at utility commission and legal proceedings relating to telecommunication technology and regulatory matters.

About Vantage Point Solutions

Better Broadband means Better Lives. Vantage Point Solutions, Inc. helps providers bring this promise to life through comprehensive engineering and consulting solutions tailored to the unique needs of the companies, Cooperatives, and communities we serve.

Vantage Point works with broadband and telecom providers in more than 40 states. Our nearly 500 employees include ten licensed professional engineers, three attorneys, and industry leaders in technology and advocacy. With professional engineers and regulatory experts under the same roof, we understand the big picture for any individual company decision or broader industry policy.

As an employee-owned company, we hold ourselves to a high standard for both service delivery and business ethics. These high standards extend to our industry involvement, where we are staunch advocates for the broadband deployment everywhere tied to the responsible use of broadband investment.

About Fiber Broadband Association

The Fiber Broadband Association is the voice of fiber. It is the premier association that focuses solely on fiber, providing the advocacy, education and resources to companies, organizations and communities who want to deploy the best networks through fiber to the home, fiber to the business and fiber everywhere. Fiber everywhere ensures digital equity and enables every community to leverage economic and societal benefits that only fiber can deliver.

Fiber Broadband ASSOCIATION

VantagePoint EMPLOYEE OWNED