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Comparison: Fixed Wireless Access vs. All-Fiber Networks

for Broadband Access

a **Whitepaper** by the
Fiber Broadband Association

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Executive Summary

Fixed wireless access technologies are currently being promoted as an alternative to all-fiber access to provide high performance broadband service. While fixed wireless technologies offer some access to broadband service, the user experience as defined by the Broadband Experience Index[1] (reliability, speed, latency, quality of service) will be far short of what fiber technology can provide. A fixed wireless-based service may often be limited by spectrum holdings and resulting propagation limitations of the technology. For the most part, this statement applies regardless of population density. Spectrum is very expensive in urban areas and is best used for mobile applications. In suburban and rural areas, wireless signal range limitations increase costs and reduce viability as a long-term solution to meet increasing bandwidth needs.

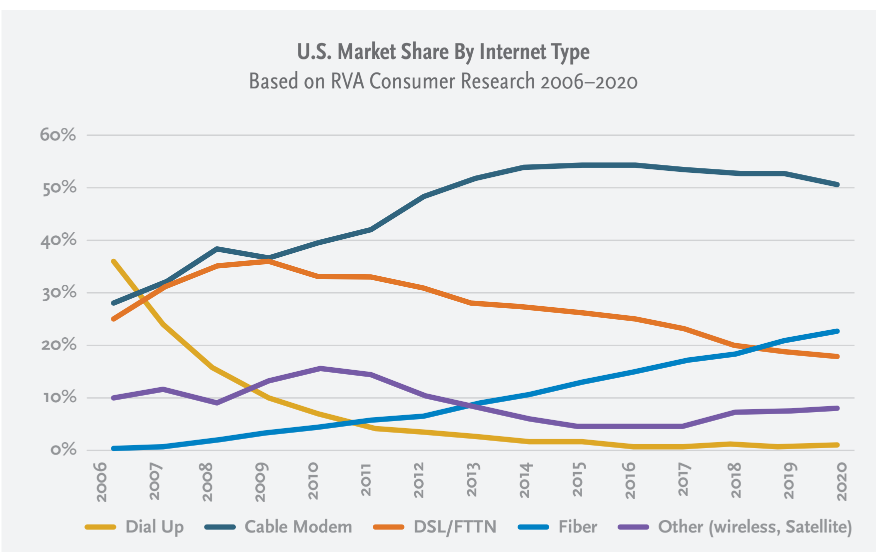
Today's high bandwidth, low latency applications require fiber's far higher bi-directional capacity, longer range, and lower total cost of ownership. Fixed wireless can be deployed more quickly than fiber to provide temporary, lower performance service in certain instances. Fixed wireless service may address the needs of users today by achieving a minimum service commitment but will likely not be able to keep pace with increased customer bandwidth demand in the future. In addition to its inferior service, the total lifecycle cost for fixed wireless is much higher than that for fiber to the home.

Fiber comprises a large and increasing share of total broadband internet connections in America. In contrast, fixed wireless networks are best positioned to serve low bandwidth applications with a limited user base. Fiber and fixed wireless technologies have been used for years in a complementary way.[2] At best, fixed wireless broadband service should be viewed as a "stepping stone to fiber". For this reason, as the "do it once, do it right" option, fiber continues to be the answer to meet long-term residential and business bandwidth requirements.

Background

Consumers and communities increasingly understand the value of high performance, FTTH networks and are demanding that service providers provide such access. By contrast, fixed wireless service serves a limited market. As the demand for bandwidth continues to rise, future deployments will increasingly favor fiber over fixed wireless networks. This paper will compare the two technologies to highlight the many reasons why this is the case.

According to the year-end 2018 Federal Communications Commission (FCC) "Internet Access Services" report published in 2020[3] based on form 477 data, fixed wireless subscribers were only 0.2% of the connections with 25 Mbps downstream, and 0.1% of the 100 Mbps connections.



According to data collected by RVA LLC for the Fiber Broadband Association, the number of homes passed by all-fiber networks now exceeds 50.6 million; more than 22.5 million homes are connected to all-fiber networks for at least one service (Internet, television, or telephone).

1 https://www.fiberbroadband.org/blog/fiber-broadband-association-releases-broadband-experience-index

2 "The road to 5G is paved with fiber", Fiber Broadband Association, December 2017

3 https://docs.fcc.gov/public/attachments/DOC-366980A1.pdf

Comparing Fixed Wireless Networks and All-Fiber Networks

This paper evaluates all-fiber and fixed wireless networks[4] based on their respective capabilities to deliver broadband service to end users in various locations: commercial properties, single family homes, and multi-family dwelling units (apartments, condominiums, etc.). The metrics used to evaluate these technologies, technical and operational, include broadband data speed, latency, resiliency, deployment speed, cost, and lifecycle.

Fixed Wireless network architectures are typically either Point-to-Point or Point-to-Multipoint. Point-to-Point networks are normally designed using high-gain directional antennas or microwave dishes that focus signals from one location to the other. These networks are not typically used to offer broadband service directly to many locations and, in the context of this evaluation will not be considered a broadband access technology. Alternatively, Point-to-Multipoint applications have a single location with a wide beamwidth antenna broadcasting one signal to multiple locations with high-gain, small beamwidth antennas in the return path. With Point-to-Multipoint designs, the bandwidth at the distributing location is shared amongst the remote locations (i.e. end users).

In the United States, the FCC is responsible for allocating and coordinating commercial Fixed Wireless spectrum. Traditional licensed spectrum allocations (aka bands) include 700 MHz, 850 MHz, 900 MHz, 1900-2100 MHz, CBRS (3.6 GHz), 4.9 GHz, 6 GHz, and the 5G millimeter wave spectrum of 24-28 GHz to 60 GHz. Each of these FCC spectrum windows has its own characteristics that make it a preferred choice for different Fixed Wireless applications. However, when compared to fiber, these technologies are limited by frequency allocations with relatively narrow bandwidths that limit broadband speed, or for millimeter wave technology, by distance limitations.

Although there have been some proof of concept experiments in the industry for use of mmWave reported in long range applications, it should be considered that those references are not universally achievable in every situation as is fiber. Cited distances of up to 6.5km with mmWave require line of sight, professional installation of roof top antennas and are significantly impaired by weather events like rain depending on the rain zone of the location where deployed.

Fiber networks can have similar system layouts in that Point-to-Point and Point-to-Multipoint systems (implemented in the form of Passive Optical Networks (PON)) are often used in a complementary way to provide Fiber-to-the-Premise (FTTP) service.

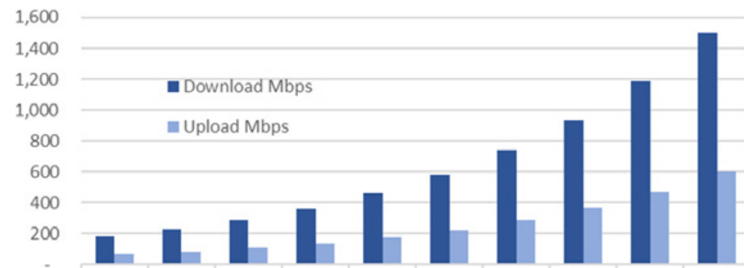
Broadband Data Speed[5]

Downstream and upstream data speeds are vital considerations in determining how best to meet consumers' demands. Broadband service fills an increasingly large role in everyday life, facilitating work, learning, health, security, and entertainment at home. Applications such as ultra-high-definition video including 4K and 8K resolutions, cloud-based artificial intelligence, augmented and virtual reality, and gaming are being adopted by consumers at a very rapid rate, driving increased demand both upstream

A single optical fiber with bandwidth of 50 THz , has 100,000 to 5,000,000 times more capacity than the limited chunks of electromagnetic spectrum available for fixed wireless systems.

4 When the word "fiber" is used in this paper, it is in the context of "all fiber access networks" used to provide broadband service to commercial properties, single family homes, multi-family dwelling units (apartments, condominiums, etc.),

5 Per their 2018 Broadband Deployment Report, the FCC defines the broadband data speed benchmark of 25 Mbps download/3 Mbps upload (25 Mbps/3 Mbps) for fixed services.



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Download Mbps	179	227	287	364	461	583	739	935	1,185	1,500
Upload Mbps	65	83	106	136	174	223	285	365	468	599

and downstream[6,7]. Historical applications have driven internet access bandwidth requirements doubling every 3 years.[8] As observed in 2020, the emergence of the Covid 19 pandemic has profoundly impacted bandwidth usage and growth patterns. Research by the Fiber Broadband Association suggests that bandwidth demand may accelerate even faster to exceed 1 Gbps by 2030 as shown in the graph to the right. These impacts are described in the FBA paper, **"Fiber Broadband Can Eliminate The North American Rural Digital Divide"**.[9] FTTH (Fiber-to-the-Premise) networks today are more than capable of allowing access to these applications by providing symmetrical 1 Gig (1Gbps) to 10 Gig (10Gps) service. Further, the same fiber pipe installed day one is capable supporting increased speeds to 25, 50, 100 Gig and much higher as future market demands require. Fiber-based access speed limits are currently not constrained by technology. In other words, we do not foresee a limitation in the broadband data speeds of fiber — either download or upload — for many decades due to the characteristics of fiber alone.

The basic nature of fixed wireless technologies is that they are limited in broadband data speeds by the availability of frequency spectrum bands at any given time and location.

Spectrum is such a precious resource because it is used in so many applications from communications to broadcasting to astronomy and everywhere in between. An example of the rarity of spectrum was in the recent FCC Auction 107 for 5G spectrum in the 3.7 GHz band. This auction of 280 MHz of spectrum across the country brought in almost $81 Billion.[10] Excellent references to illustrate the shortage of spectrum, and why it is so valuable, are the NTIA US Frequency Allocation Map and FCC online table of frequency allocations.[11,12] One glance at the higher frequency lines on the map (the frequencies that can deliver the most bandwidth) show the complexity in carving out significant chunks of spectrum to deliver high speed wireless services. This topic will also be addressed later in the **Implementation section** of this paper.

6 Comments of the Fiber Broadband Association to FCC Docket GN Docket No. 20-269, "Inquiry Concerning Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion"

7 https://www.bondcap.com/report/itr19/#view/53

8 https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.html#_Toc532256802

9 FBA paper, "Fiber broadband can eliminate the North American rural digital divide

10 Auction 107 - 3.7 GHz

11 https://www.ntia.doc.gov/page/2011/united-states-frequency-allocation-chart

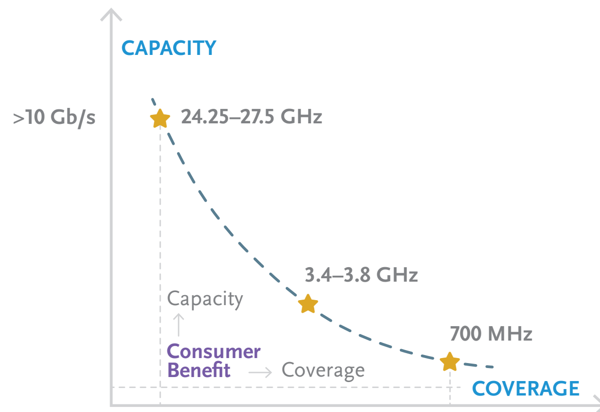
12 fcctable.pdf

Fixed Wireless Networks Have Speed Limitations and Are Cost Prohibitive

There is a limit to the speeds that can be provided over a given block of spectrum, and the financial value proposition of accumulating blocks of spectrum in rural areas is typically not viable to provide higher levels of service. The wireless industry has done a fantastic job of increasing spectral efficiency, defined as bits per second per Hz of spectrum.[13] 5G networks and beyond with small cells can increase spectrum efficiency but does not solve the fundamental physics and economic problem posed above.

In addition, wireless speeds available from a single tower/cell site can vary significantly, depending on the distance of the user from the site, as well as additional factors, such as weather, terrain, and other absorber/reflectors in the signal path. The relationship between distance and bandwidth is shown in the graph below, with speeds decreasing significantly as distance from the tower/site increase. Fiber on the other hand supports both long distances (across oceans for example) together with the highest bandwidth available in any medium.

Wireless Coverage and Capactiy by Frequency Used



One of the limiting factors for 5G High-Band (whether used for mobile or residential use) is limited coverage. The Higher the 5G frequency, the higher the capacity for bandwidth (speed), but signal coverage is reduced dramatically–typically down to about an area about 650 feet in diameter.

Source:

Considering Real World Data Speeds, Fiber is the Better Medium

Since 2014, fiber has provided ubiquitous, consistent, and symmetrical 1Gbps to subscribers and 10Gbps to the consumer is becoming more widespread today. As of the publishing date of this paper, Q2 2021, fixed wireless providers have not provided anything close to 1Gbps in widespread commercial service[14]. To the contrary, more than 1100 rural fiber broadband providers operate networks of various sizes in some of the most remote parts of America, and hundreds of those providers offer symmetrical gigabit speeds. Service offerings greater than 1 Gbps are now being offered and used by end customers.[15]

Since fiber optic networks are essentially closed systems, they are capable of providing far more bandwidth with near zero susceptibility to outside interference. The symmetric speeds offered by fiber is critical as consumers depend on applications such as video conferencing for business, virtual classrooms, and telemedicine. As closed systems, fiber networks far surpass fixed wireless systems in their ability to deliver broadband today, and even more so in their ability to keep pace with growing bandwidth demands for decades to come.

13 https://mma.prnewswire.com/media/944546/CTIA_Spectrum_Efficiency.pdf?p=pdf

14 The Fiber Broadband Association does not dispute the ability of fixed wireless equipment to provide Gigabit broadband speeds in laboratory settings with large bandwidths of spectrum. We are simply highlighting that with current FCC spectrum allocations, it is difficult for Fixed Wireless Service Providers to deliver Gigabit broadband in a symmetrical fashion, ubiquitously, at scale.

15 https://www.utopiafiber.com/10g-info/

Latency

Another technical consideration with broadband service is latency. Latency is defined as the amount of delay, typically measured in milliseconds, that occurs in a round-trip data transmission. Latency is unavoidable in any internet connection and can only be reduced by the design and management of a network. Latency is a critical factor in newly released and anticipated technologies such as 5G wireless, two-way video, augmented and virtual reality, autonomous vehicles, telemedicine, smart city applications, video conferencing, controls, etc. For example, the technology enabling the features offered by “smart vehicles” will need access to data in near real time to effectively work with traffic lights and traffic cameras to avoid collisions.

All-fiber networks have significantly lower latency compared to fixed wireless networks. Since fixed wireless networks are fundamentally extensions of fiber or copper-based systems, there is inherently more delay in these systems – the delay of the fiber or copper wireline systems, plus additional delay required to convert the wireline signal to wireless. In addition, latency for fixed wireless networks is further increased by distance, terrain, line-of-sight barriers, weather, and other environmental factors which simply have no impact on fiber networks.

A recent random study of broadband users by RVA, LLC focused on real world speed and latency tests. In comparison with all fiber networks, the study found that Cable has 37% poorer real world latency performance and DSL/FTTN was 54% poorer. Wireless and traditional Satellite systems have even worse latency performance with over 5x and 70x more network delay than fiber.

While we anticipate wireless latency performance to improve with 5G networks and beyond, there will likely continue to be significant advantages for all fiber networks compared to fixed wireless or 5G networks.

Reliability and Resiliency

For this discussion, reliability is focused on design and routine day-to-day availability. The term resiliency is focused on the ability to address a fault and restore service.

Where high-availability of service is a requirement, both fiber networks and fixed wireless networks should be designed with geographically redundant paths or in ring configurations.

Fixed Wireless – More Threats to Performance

Fixed wireless signals travel through the air, an ever-changing medium subject to fluctuations and interference caused by a wide range of both environmental and manmade factors. Some of these factors include temperature, humidity, rain, fog, wind, tree growth, building construction, and even large trucks or buses blocking line of sight to an antenna. Lightning is an additional risk factor for fixed wireless networks. Fixed Wireless communications paths also must overcome such temporary obstructions as airplanes, helicopters, and drones. In addition to these physical barriers, wireless networks may also be impacted by frequency interference caused by other electromagnetic spectrum users on the same or adjacent frequencies, machinery, or power transmission lines.[16] Wireless networks operating in higher spectrum bands suffer even greater impairments from environmental variations and physical barriers that increase with distance. These networks may be range-limited to hundreds of meters. Finally, as speeds go up, the number of wireless access points must increase to reduce the distance from the end user, resulting in many more access points. Each of these access points are powered and serve as a potential point of failure in the network.

16 https://www.bbc.com/news/uk-wales-54239180

Fiber is Safe From Threats Affecting Fixed Wireless

Fiber has a proven track record as a more consistent and stable platform than fixed wireless networks for high bandwidth delivery of data. Because fiber systems are closed and not subject to environmental factors fiber systems are able to maintain a consistently available path between the network and customer.

Fiber has far fewer points of failure compared to fixed wireless. Completely passive fiber optic access networks have a reliable operating range of 20 km, with some versions having significantly longer range. Based on these considerations, fiber networks are more reliable than fixed wireless for broadband access.

From a resiliency perspective, all fiber access networks clearly have an advantage in restoration time. Fixed wireless network radios destroyed by a lightning strike may require one or more truck rolls to install a new radio (which must be in stock), restoration or splicing of the fiber connection to the radio, and restoration of the electrical power connection. Physical cuts are one of the most significant concerns that threaten a fiber system, but restoring a cut fiber can be completed with a single truck roll to perform a single function.

Implementation – Deployment Speed

While fiber may be future-proof, constructing a fiber network can be time-consuming. In contrast, a wireless network may be faster to install, even in instances where a fixed wireless network requires fiber to connect back to the main network. However, wireless construction timelines can also depend on the status of a tower or other antenna structure. The need for new towers or poles, and the new electrical power connections required for each can significantly delay wireless network deployment. However where power and towers already exist or can be built quickly, fixed wireless may be deployed to serve as a temporary alternative to fiber broadband or niche service. This could apply in very low density rural areas where subscription rates for fiber do not yet justify the investment required to bring fiber service.

Regardless of the type of network being used, government regulations impact construction. For fiber, routes can be aerial, buried, or a combination of both. Prior to construction of aerial cable, permission may be required for pole access. Make-ready relocations on existing poles must also be completed. For buried cable, permits must be obtained to use right-of-way or land acquired for private access. Make-ready and permitting are both time and resource consuming tasks for the construction of a fiber network. In a similar fashion, when constructing a Fixed Wireless network, there are numerous regulatory issues associated with frequency use and tower sites. This includes regulations from the FAA, the FCC, environmental and historic reviews, and local government zoning regulations. In addition, an electrical power connection must be secured from the local power utility and installed to the wireless radio site. All of these consume time and resources during a fixed wireless deployment. While both fiber and wireless technologies are forced to contend with regulatory concerns, from strictly an implementation standpoint, fixed wireless can be faster than a fiber cable installation.

Curb Appeal

One additional factor that is difficult to quantify in a comparison of fixed wireless versus fiber is the public's aversion to the large towers required in many instances for wireless technology. To address this, the wireless industry is deploying more systems using distributed antenna systems (DAS) and small cells on power/telephone poles. In contrast, constructed buried fiber has limited visual impact on the environment. Aerial fiber offers similar aesthetic benefits as it typically takes advantage of existing poles or structures.

Infrastructure Costs – Capital and Operational Expenses

In a recent survey of NRTC members, the CAPEX cost of fiber in rural areas was reported as "Cost per mile generally $20K - $30K; variability driven by factors such as the percent of aerial vs. underground miles and make ready requirements.[17] While there are many variables to these capital costs, we will focus on these estimates for the purposes of this discussion. Using these estimates and a conservative estimate of the number of cable miles required to service an area, one can calculate a budgetary estimate of initial infrastructure cost for a community. Overall, the construction and operational costs of FTTH broadband networks provide higher speeds and have proven to be less expensive than fixed wireless solutions in the long term.

In contrast, the capital cost to construct and fully install a single antenna site with multi-sectored equipment on an existing structure in a fixed wireless system requires a capital investment in the range of $50K - $300K[18]. It is important to note that these fixed wireless cost estimates may not include the cost of constructing the towers or antenna structures themselves. That process can add significant cost to a fixed wireless project. The ability to provide broadband to a specific area using wireless technology is dependent upon the bandwidth of the frequency, the location of the antenna site, the data speed desired, and the distance and terrain between the antenna and the CPE. These factors are inputs to a propagation model with the quantity of antenna sites required as the output. The cost per antenna is multiplied by the quantity of antenna sites to get the cost to serve the community. Additional costs include licensed spectrum, powering, metering and backhaul.

Fixed wireless service with small cells has been proposed as a potential alternative to the final fiber to the home drop. As discussed earlier in the paper, due to lack of spectrum, fiber is needed to feed small cells to deliver any significant amount of bandwidth beyond subsistence levels. Therefore, the main question in comparing fiber and wireless networks is the cost of the final drop. In most "apples to apples" comparisons, to provide bandwidth to scale for future demand, the cost of small cells is similar or potentially more expensive versus a fiber drop. There will be outliers to the scenario above, but the conclusion holds generally.

"the total cost of operations of FTTP over a 10-year period would be approximately half that of fixed wireless in the same unserved areas"

Illustrating this point, CTC Technology and Energy recently compared the cost to serve a community using FTTP and Fixed Wireless. The results were summarized with the following statement: *"Overall, a fiber investment would have higher capital costs than wireless but much lower operating costs—and would be a better investment over time. Based on engineering and cost-estimation of both a wired (fiber-to-the-premises) and a fixed wireless solution for unserved King County, we conclude that overall, FTTP represents a better broadband solution than fixed wireless for most unserved areas of King County. While FTTP has a higher initial capital cost per passing than a fixed wireless solution, the total cost of operations of FTTP over a 10-year period would be approximately half that of fixed wireless in the same unserved areas—primarily because of the need to replace wireless equipment at relatively short intervals and the cost of leasing space on commercial towers."*[19] Other analyses of other situations often yield similar results.

In the telecom industry today, fiber is considered to have significantly lower operational expenses and to be more "future-proof" than other technologies.[20] The report referenced in the footnote (13) focused primarily on wireline technologies, and including DSL and cable, but the trends likely extend to fixed wireless and or satellite-based solutions, given some of the inherent challenges posed by these networks highlighted earlier in this paper.

Although the initial cost of a fiber network may be more expensive driven primarily by installation labor costs, operational and upgrade expenses are dramatically lower, making fiber the clear long term lower cost alternative. Factoring in cost per bit, fiber is an incredible bargain, which is why it continues to be deployed heavily in networks around the world.

17 Rural Electric Cooperative Broadband Benchmarking Report, PowerPoint Presentation (nrtc.coop)

18 Unpublished data from FBA member feedback

19 CTC Telecom and Energy Broadband Access Study Prepared for King County, Washington, in Response to the Proviso of Ordinance 18835, Section 118 December 2019

20 Operational Expenses for All-Fiber Networks are Far Lower Than for Other Access Networks, Fiber Broadband Association, June 2020

Comparison

Lifecycle and Upgrade Paths

If properly installed and maintained, fiber will last for decades.[21] The network electronics and light sources have a shorter useful lifespan, typically in the range of 10-15 years, and are replaced as technology improves and bandwidth requirements change. In contrast, the life expectancy of fixed wireless systems is reduced by the unavoidable exposure to elements and its limited capacity to meet growing consumer demands. Due to these considerations along with historical trends, wireless networks have an estimated useful lifespan in the 5-8-year range, with equipment upgrades needed to provide ever-growing performance and technology features, and legacy systems are often continued to support legacy handsets. Historically, fixed wireless networks require component replacement to avoid obsolescence. Fixed Wireless Networks will struggle to keep pace with consumer demand for increased broadband speed and sustainable performance. This makes system replacements and upgrades necessary to meet future customer demands.

Wireless technologies are often identified by the generation of technology being deployed, and new generations are introduced frequently. Examples in cellular are 4G, 5G, or, for Wi-Fi, 802.11"XX", where "XX" refers the standards reference. Wi-Fi is also rebranding to Wi-Fi 4, 5, and 6, etc.

To deliver higher reliability or higher speed service, wireless service providers will typically acquire dedicated spectrum, adding to the cost of the network. Spectrum availability in a specific band or location may impact ability to evolve those offerings. An alternative method is to deploy service on unallocated spectrum on a "best effort" basis, but as previously noted, interference may be a problem.

Although the majority of existing fiber networks currently operate on GPON technology (2.4 Gbps downstream, 1.2 Gbps upstream), symmetric 10 Gbps XGS-PON access technology is becoming widely available, allowing for delivery of end subscriber services in the multi-gigabit range at low latency, and can coexist with past and future transmission protocols. Higher speed versions such as 25, 50, and 100 Gbps are in development, and in some cases already commercially deployed.

While there have been significant improvements in the quality of single-mode fiber deployed in access networks over the past 30+ years, the fundamental design has remained constant for decades. Due to the long-term reliability and scalability of fiber, we cannot foresee the time when the fiber deployed in access networks today will need to be upgraded to a different design, earning fiber its "future proof" reputation.

21 ITU-T Series Supplement 59 SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS, Guidance on optical fibre and cable reliability, 02/2018

Summary

Fiber and fixed wireless technologies of various types have coexisted for years in a complementary way. We expect that relationship to continue as bandwidth demands increase and the number of fiber connected wireless nodes increases. Wireless technology is most valued and needed to provide mobility, and the bandwidth, latency, reach, and reliability of fiber will be increasingly essential to connect more wireless radios to the network. Fixed wireless technologies can also be used as a temporary solution to provide service to specific areas until subscription rates support taking fiber to the end point, but are not an acceptable substitute for all-fiber access networks.

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If It's Not Fiber, It's Not Broadband