Microsoft

Overview of Internet service provider technology considerations for rural broadband deployments

TV white space technology pioneers achieve almost a 10x increase in deliverable radio throughput in a span of only 18 months

Prepared by Paul Garnett & Sid Roberts
Microsoft Airband Initiative
November 2019

Below, we provide an explanation of the different technologies our Internet service provider partners are using to deploy broadband networks in rural areas and the role TV white space technology is playing. The most cost-effective approach to closing the digital divide for the 16.8 million people in rural areas in the United States lacking broadband access is to rely on a mixture of available technologies (a 'tool kit approach'). This same approach is relevant to rural deployments in other countries.

To deliver broadband access to prospective customers, an Internet service provider will consider a variety of available technologies – from satellite communications technologies to terrestrial fixed wireless technologies to fiber-optic connections. High capacity fiber-optic and other wired technologies, along with emerging higher frequency wireless technologies, are typically most cost-effective technologies for highly dense suburban and urban areas. Satellite communications technologies are typically the most cost-effective solution for the remotest rural areas. Our partners are primarily focused on areas with lower population densities than areas where fiber is most cost-effective and are higher in population density than areas where satellite is most cost-effective. In these areas, our partners are primarily focused on using terrestrial (i.e., non-satellite) fixed wireless technologies that operate on an unlicensed or lightly licensed basis (i.e., without the need to compete and buy an expensive exclusive use spectrum license from the Federal Communications Commission). Mobile wireless technologies are generally not a focus of our efforts.

For purposes of the discussion below, we are focusing on last mile broadband access, although the same principles would apply to the full range of Internet of Things (IoT) applications and in-building coverage. Many of the references below are to the situation in unserved rural areas of the United States. Additional analysis would be needed when looking at other markets.

To deliver the maximum throughput to the greatest number of people in a coverage area, the Internet service provider will leverage wireless technologies that operate on different spectrum bands (or frequencies). Technologies using higher spectrum bands typically offer more throughput, but the signals travel over shorter distances. Think of super high speed ('fiber like') 1+ Gbps connections over short distances, but unable to penetrate many indoor or outdoor obstacles. To ensure reliable service, these connections must be 'line of sight' (i.e., few or no obstacles are in the way like trees, walls or sometimes even rain). Technologies using so-called 'mid-band spectrum,' such as 3.x GHz and 5.x GHz spectrum, offer less throughput than technologies leveraging high-band spectrum, but can still deliver line-of-sight connections measured in 100s Mbps over distances of up to four miles from a tower. Technologies using lower spectrum bands typically offer yet less throughput (because there is more competition for these finite frequencies and the bandwidth assigned is smaller) but have signals that can travel over longer distances. Think of 10s to 100s of Mbps connections over longer distances leveraging small slices of spectrum. These connections can be non-line-of-sight (i.e., able to penetrate obstacles like trees and walls) while still delivering reliable connectivity.

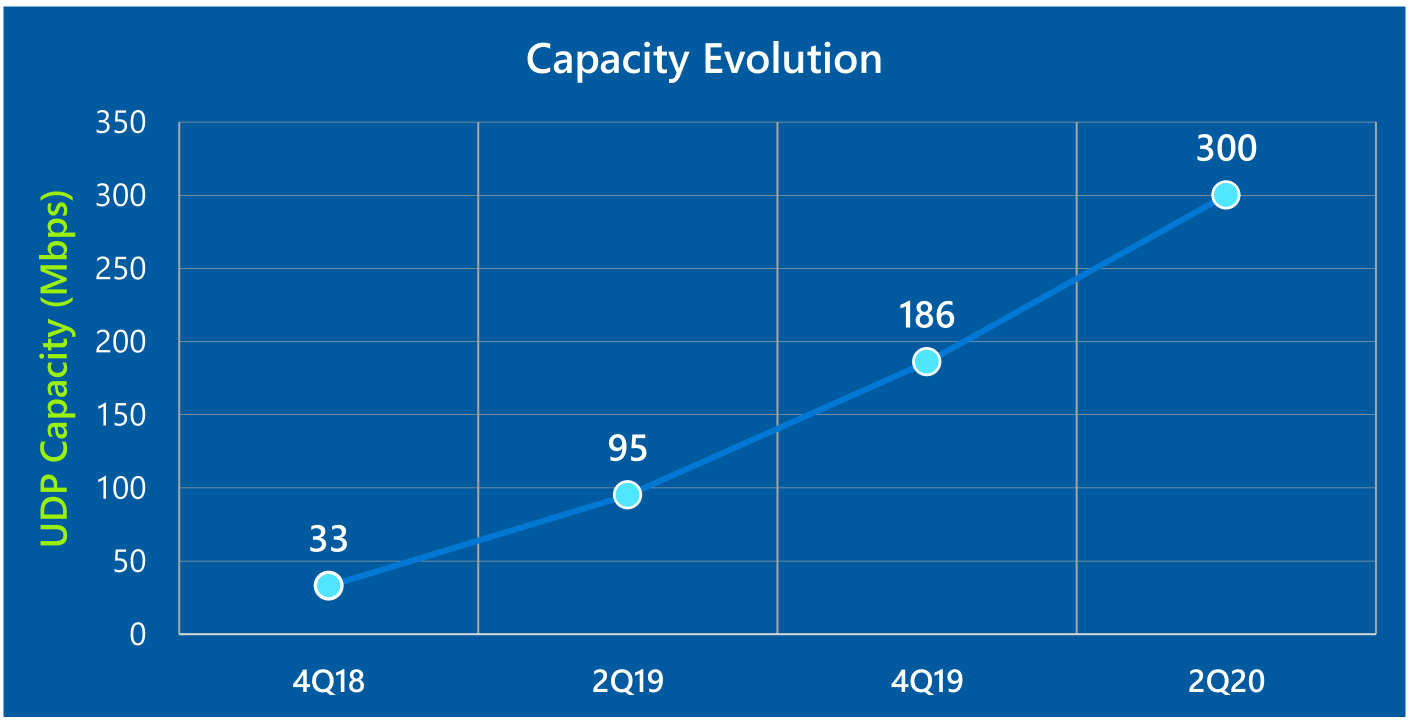
The TV white spaces are frequencies that have not been assigned or are otherwise not being used by broadcasters and other licensees in the VHF and UHF broadcast bands. The TV white spaces are in lower band frequencies and signals can travel over longer distances and penetrate many obstacles. Because competition for lower band ("beachfront") spectrum is so fierce, TV white spaces availability is somewhat limited, so the delivered throughput of TV white space connections typically measures in the 10s of Mbps and can deliver 100s of Mbps when conditions allow, like 3G and 4G mobile wireless technologies using 700 MHz frequencies. In addition to the new modulation techniques, channel bonding and aggregation and more robust radios are allowing this technology to start operating at 100s Mbps, assuming sufficient spectrum is available.

With access to additional TV white spaces spectrum (beyond one or two channels), throughput can increase, so long as the spectrum is interference-free. Current (4 x 6 MHz channels) TV white space radios can deliver a throughput of up to 186 Mbps (8 MHz TV channels in Europe, Africa, and Asia also allow channel bonding up to 24MHz). Indeed, we are already testing radios that will be available in 2020 that can bond and aggregate channels up to 40 MHz wide that will further increase throughput and allow operators to satisfy the FCC's requirement for broadband access of 25 Mbps downlink by 3 Mbps uplink for multiple users on a single link. In addition to gaining access to additional spectrum, radios in the TV white spaces can increase throughput by using capabilities commonly used by Wi-Fi, LTE, and other technologies, such as antenna technologies (e.g., MIMO that can double and quadruple throughput), more efficient higher modulation schemes (e.g., something called 256 QAM which can increase throughput by 20-30% by sending more bits at the same time than usual during the normal transmission cycle), and the ability to bond and/or aggregate pieces of spectrum together (which can increase throughput by 2x or more). In the future, technologies like massive MIMO will increase the capacity of a TV white space link without requiring additional spectrum by using antenna arrays in multiple polarizations while increasing the spectral efficiency by at least 10x over the current products and implementing more advanced modulation techniques.

Another key goal for us is to drive down the cost of TV white space customer equipment to be on par with complementary and more mature technologies already in the market – stimulating both demand and supply and making the cost of reaching rural consumers on par with reaching consumers closer to towers.

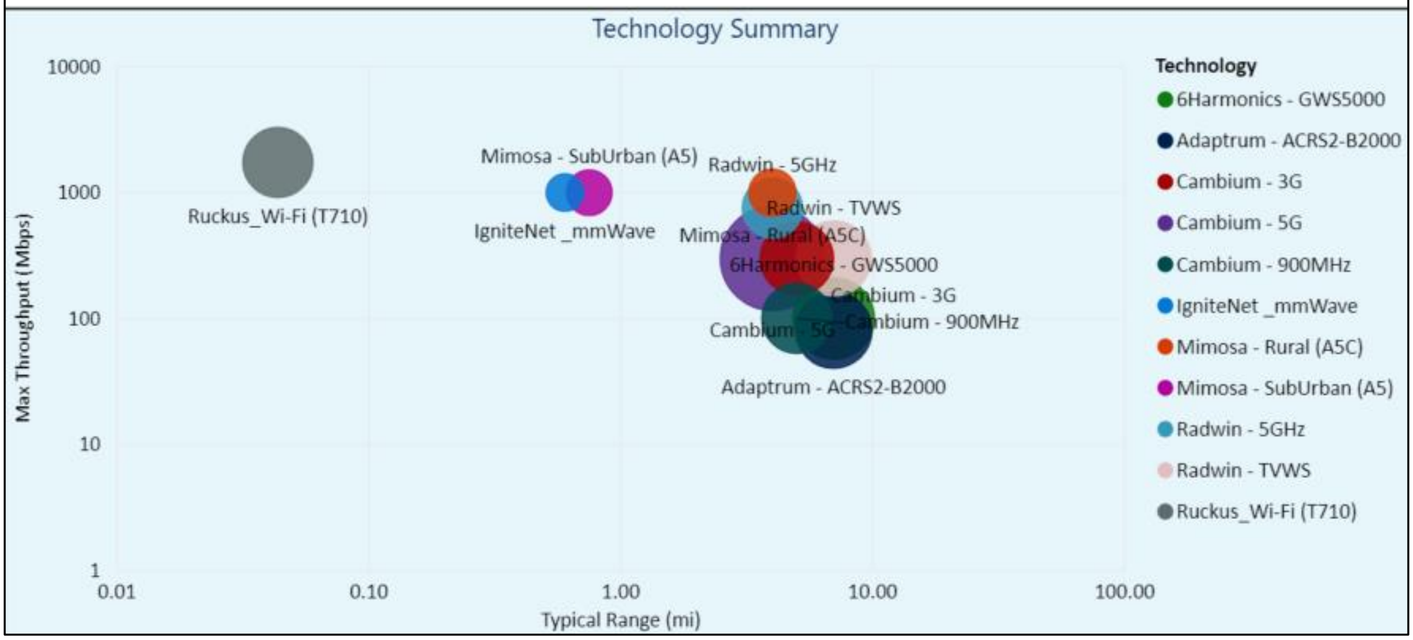
The chart below provides a summary of the evolution in the capacity (throughput) of TV white spaces as well the projection in the next calendar quarter using the features mentioned above, thereby increasing throughput for customers. The highest throughputs below (i.e., 300 Mbps) will require access to larger blocks of clean spectrum, which are more likely to be available in small media markets and rural areas with fewer transmitting broadcasters.

This chart considers the feature functionality of TVWS technologies from vendors including Adaptrum, 6Harmonics and Radwin (other companies are also manufacturing TV white space radios). It's incredible to consider that this group of TV white space technology pioneers have achieved almost a 10x increase in deliverable radio throughput in a span of only 18 months.



The chart below illustrates the performance of different terrestrial fixed wireless technologies on offer from various manufacturers.

Technology	Frequency	Bandwidth (MHz)	Non-Line of Sight	Latency (ms)	Typical Range (mi)	Max Throughput (Mbps)	CPE price($)	Base price ($)
IgniteNet _mmWave	57 - 64 GHz	2000	No	1.00	0.60	1000	998	499
Cambium - 5G	5150 - 5925 MHz	40	No	5.00	4.00	300	449	6995
Mimosa - Rural (A5C)	4900 - 6200 MHz	80	No	8.00	4.00	1000	255	1049
Mimosa - SubUrban (A5)	4900 - 6200 MHz	80	No	8.00	0.75	1000	115	949
Radwin - 5GHz	4900 - 5900 MHz	80	No	3.50	4.00	750	300	1995
Cambium - 3G	3300 - 3900 MHz	40	No	5.00	5.00	300	529	3195
Ruckus_Wi-Fi (T710)	2.4 GHz	80	No	1.00	0.04	1733	150	2900
Cambium - 900MHz	902 - 928 MHz	20	Yes	5.00	5.00	100	299	2895
6Harmonics - GWS5000	470 - 698 MHz	24	Yes	5.00	7.00	100	906	3977
Adaptrum - ACRS2-B2000	400 - 1000 MHz	20	Yes	5.00	7.00	81	480	3470
Radwin - TVWS	470 - 698 MHz	40	Yes	5.00	7.00	300	600	3300



One can see how an Internet service provider would utilize different technologies and products for customers located in different urban, suburban, and rural areas. Think of concentric circles of coverage from a tower utilizing different technologies leveraging different spectrum bands. For example, millimeter wave technologies (e.g., on 60 GHz spectrum) would be ideal for flexible urban deployments (extending fiber by perhaps up to 300 feet). Wi-Fi and microwave technologies (e.g., on 3.5 GHz and 5 GHz spectrum) can be used to reach consumers in higher density areas up to four miles from a tower. TV white space technologies on UHF spectrum become ideal for reaching consumers in lower density areas typically located up to seven miles from a tower (farther on UHF spectrum under ideal circumstances). TV white space technologies are also useful for establishing connections in non-line-of-sight situations, such as when tree canopy prevents connections on other bands. Another product from Cambium in the 902-928 MHz band can also deliver non-line-of-sight connections, at somewhat shorter ranges than TV white spaces, but will be capacity limited in the long run because of limited spectrum availability.

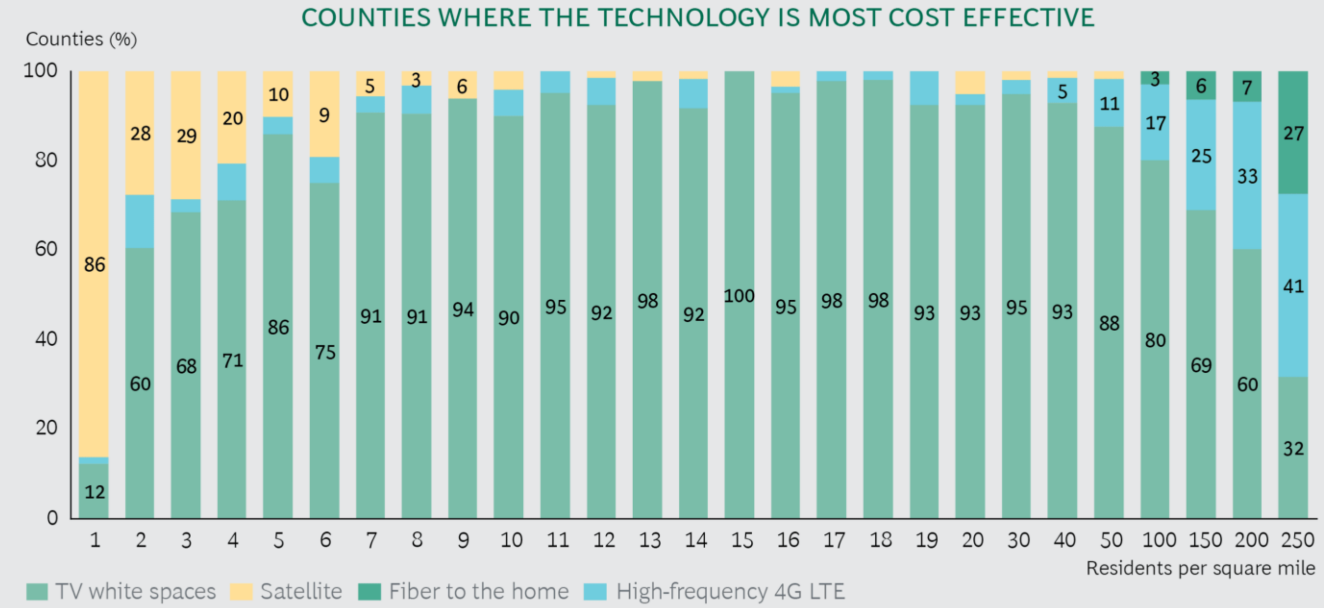
Our various projects around the world have validated that TV white space technologies are a great complement to other technologies when an Internet service provider is looking to cost-effectively deliver broadband access in rural areas. Recent changes to FCC regulations give rural Internet service providers flexibility to increase the power of TV white space base devices, which will also enable long range connections (additional regulatory changes have been requested). Regulations now in place in Canada, Colombia, Ghana, Mozambique, Singapore, South Africa, South Korea, Trinidad & Tobago, and the United Kingdom also allow unlicensed access to TV white spaces. A growing list of other leading regulators are looking at this opportunity.

Another issue to address is the percentage of customers that an Internet service provider will most cost-effectively serve utilizing different technologies – whether those customers are in urban, suburban, or rural areas. For example: *What percentage of customers will be served by millimeter wave connections?* What percentage of customers will be served by outdoor Wi-Fi connections? *What percentage of customers will be served by various types of fixed microwave connections? What percentage of customers will be served by TV white space connections?*

Consistent with the discussion above, the ratio of technologies used will depend on the area(s) of intended service. Internet service providers operating in urban areas will rely more on technologies using higher spectrum bands, offering more throughput, and the ability to serve more customers simultaneously. Internet service providers operating in rural areas will rely more on technologies using lower spectrum bands that have signals that can travel over longer distances. Pricing of technologies also impacts decision making on the technology mix – an issue we are trying to address. Our partners' projects typically involve a mix of high, medium, and low-density areas and therefore involve a mix of technologies.

Our 2017 US Rural Broadband Strategy included reference to a study conducted by the Boston Consulting Group (BCG), which claimed that approximately 80% of the 21.3 million rural Americans without broadband access would be most cost-effectively served by TV white space technologies. This group of 21.3 million people represent about 33% of the 60 million Americans living in rural areas. Part of the reason that TV white spaces is a good solution for this subset of rural customers is that they tend to be in rural areas with low-population densities, where other technologies have traditionally proven uneconomical. BCG stated that these were "directional findings." The analysis also only focused on the costs of five technologies – satellite, TV white spaces, low-band and high-band LTE, and fiber to the home.

EXHIBIT 1 | The Best Solutions for Rural Counties Based on Population Density



Sources: FCC, "2016 Broadband Progress Report"; BCG analysis.
Note: 700 MHz LTE not included because it is not the most cost-effective option for residential service at any population density.

As we noted in our 2017 Rural Broadband Strategy, the BCG study did not include Wi-Fi and other unlicensed fixed wireless technologies, which our Internet service provider partners use in all their rural deployments. Microsoft has worked with t3 Broadband on a Total Cost of Ownership (TCO) analysis where we compared TV white space technologies with other Wi-Fi type technologies operating on the 5.x GHz bands. The analysis confirms that TV white space technology is the most cost-effective solution on a cost per household passed standpoint (coverage). With current average prices of TV white space customer premises equipment (CPE) compared to 5.x GHz, the cost per household connected is at the advantage of TV white space technology only in very low housing density areas (≤15 houses or 36 people per square Mile) at current average CPE pricing levels. With a rapidly evolving TV white space hardware landscape, we can expect this competitive advantage to expand to more dense population areas when CPE pricing falls in the $300-$600 range. Another very interesting outcome of the study is that, in the case of hybrid network deployments, mounting TV white space base radios at the same time as 5 GHz on the same tower reduces TCO of TV white space installation by approximately 85%. The 5 GHz layer will be used for capacity while the TV white space layer can be used for coverage including a larger coverage area where the 5 GHz links cannot reach as well as coverage on locations that cannot be addressed by 5 GHz due to non-line-of-sight requirements.

TV white space ratios will change as more information becomes available and technologies evolve. Also new technological improvements originally conceived for other frequencies and technologies like LTE will eventually be adapted and implemented into TV white spaces. To state the obvious, this is a fast-moving market. The best form of validation will be deploying scale, high-impact projects with Internet service provider partners, which is the Airband Team's primary focus right now.

Cost effectively tackling the rural digital divide will require a mix of approaches. Most consumers in rural areas will be best served by a mix of unlicensed fixed wireless solutions that include TV white spaces. Other solutions will also come into play and we are open to whichever solutions most cost-effectively deliver access to unserved consumers in rural areas. From a policy perspective, the key is a stable legal and regulatory environment that creates a nationwide (scale) marketplace, provides Internet service providers maximum flexibility to deploy the most suitable technologies, and therefore maximizes investment in these technologies.