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March 5, 2018

Ex Parte filed via ECFS

Marlene Dortch, Secretary
Federal Communications Commission
445 12th Street SW
Washington, DC 20554

Re: ET Docket No. 16-56, ET Docket No. 14-165, MB Docket No. 15-146, MB Docket No. 16-306, RM-11745, GN Docket No. 12-268

Dear Ms. Dortch:

On Wednesday, February 28, 2018, Paula Boyd and Paul Garnett of Microsoft Corporation spoke by telephone with Louis Peraertz, Senior Legal Advisor, Wireless, International, and Public Safety to Commissioner Clyburn. During the meeting, Microsoft discussed the deployment of broadband networks using TV white spaces (TVWS) and provided an update on the development of hardware used in these networks.

More specifically, Microsoft made the points noted below and in the attached report that highlights the state of deployment of broadband networks using TV white spaces technologies and describes the benefits of using such networks to serve rural areas.

- Today, FCC certified TVWS radios can bond two contiguous channels resulting in delivered speeds up to 23 Mbps.

- Radios in the TV white spaces will 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., 256 QAM which can increase throughput by 20-30 percent by sending more bits 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).

- Radios utilizing TV white space spectrum will add these capabilities over time. For example, TVWS radios that can bond up to 4 contiguous channels are being trialed under FCC experimental licenses. These radios are delivering throughput of up to 50 Mbps.

- Microsoft is working with Adaptrum, a US-based TV white space radio technology company, and another major US technology company on a baseband chip which leverages the published IEEE 802.11af standard. This chip will

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incorporate all the features discussed above and could be used in a full range of wireless devices from IoT sensors to consumer devices to access points and base stations. This baseband chip will be capable of delivering throughputs exceeding 200 Mbps.

Pursuant to Section 1.1204 of the FCC's rules, I am filing a copy of this notice electronically in the above-referenced dockets. If you require any additional information, please contact the undersigned.

Sincerely,

/s/ Paula Boyd
Paula Boyd
Senior Director, Government and
Regulatory Affairs
Microsoft Corporation

Enclosure

cc: Louis Peraertz

Overview of Internet service provider technology considerations for rural broadband deployments

Prepared by

Paul Garnett & Sid Roberts from the Microsoft Airband Initiative Team

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 that we expect TV white space technologies to play. As we noted in our Rural Airband Initiative announcement, the most cost-effective approach to closing the digital divide for the 23.4 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 markets.

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 for highly dense suburban and urban areas. Satellite communications technologies are typically the most cost effective for the remotest rural areas. Our partners are focused on areas that have 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.

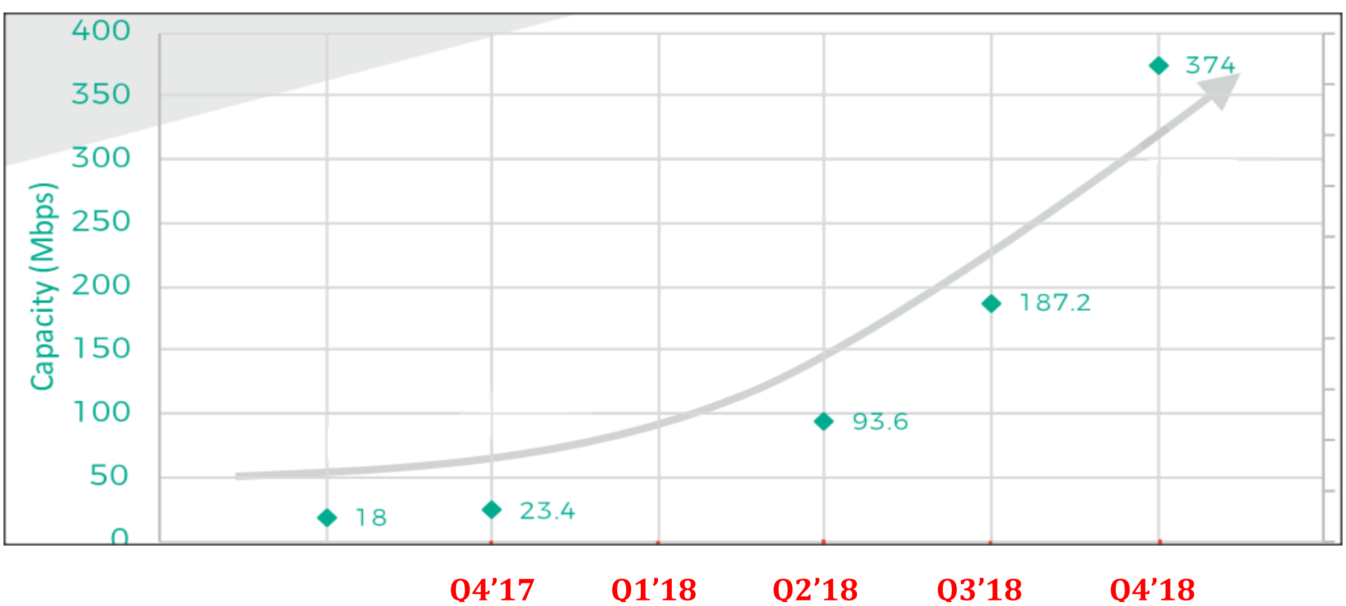
For purposes of the discussion below, we are focusing on last mile broadband access, although the same principles would apply to the full range of Internet of Things (IoT) applications and in-building coverage. Many of the references below are to the situation in unserved rural areas of the United States. 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 and 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 lower spectrum bands typically offer less throughput (because there is more competition for these finite frequencies) but have signals that can travel over longer distances. Think of 10s 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 5s or 10s of Mbps, similar to 3G and 4G mobile wireless technologies using 700 MHz frequencies.

With access to additional TV white spaces spectrum (beyond one or two channels), throughputs can increase, so long as the spectrum is interference-free. Current (2 x 6 MHz channel) TV white space radios can deliver throughput of up to 23 Mbps (8 MHz TV channels in Europe, Africa, and Asia translates to roughly a 33% increase in throughputs). 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 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). Radios utilizing TV white space spectrum will add these capabilities over time.

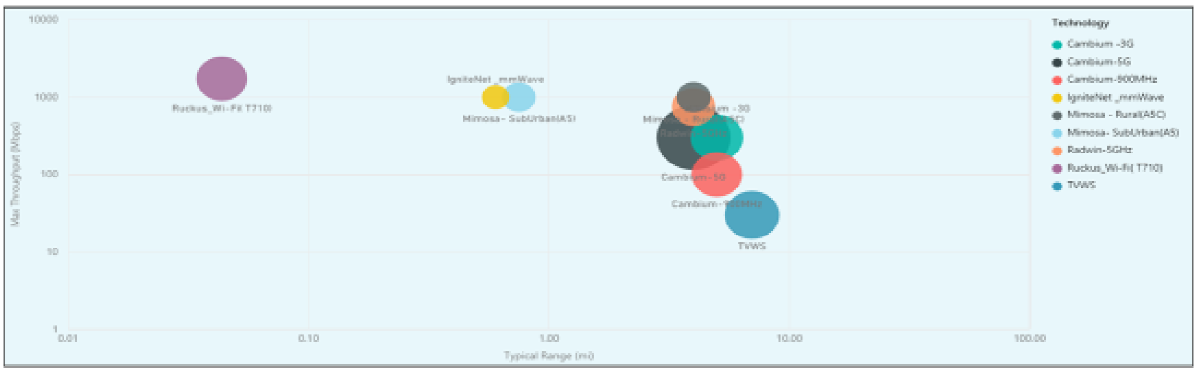
Another key goal for us is to drive down the cost of TV white space customer equipment to be on par with complementary and more mature technologies already in the market – stimulating both demand and supply and making the cost of reaching rural consumers on par with reaching consumers closer to towers. The chart below provides a basic projection of when new capabilities will be introduced into new TV white space systems, using the features mentioned above, thereby increasing throughput for customers. The highest throughputs below (*i.e.*, over 200 Mbps) also will require access to larger blocks of clean spectrum, which are more likely to be available in small media markets and rural areas. As with any product releases, some delays are probable.



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

Fixed Wireless Technical Summary

Technology	Frequency	Bandwidth (MHz)	Non-Line of Sight	Latency (ms)	Typical Range (mi)	Max Throughput (Mbps)
Cambium -3G	3300 - 3900 MHz	40	No	5.00	5.00	300
Cambium-5G	5150 - 5925 MHz	40	No	5.00	4.00	300
Cambium-900MHz	902 - 928 MHz	20	Yes	5.00	5.00	100
IgniteNet _mmWave	57 - 64 GHz	80	No	1.00	0.60	1000
Mimosa - Rural(A5C)	4900 - 6200 MHz	80	No	8.00	4.00	1000
Mimosa- SubUrban(A5)	4900 - 6200 MHz	80	No	8.00	0.75	1000
Radwin-5GHz	4.9-5.9 GHz	80	No	3.50	4.00	750
Ruckus_Wi-Fi(T710)	2.4GHz,5GHz	80	No	1.00	0.04	1733
TVWS	470 - 698 MHz	12	Yes	5.00	7.00	30



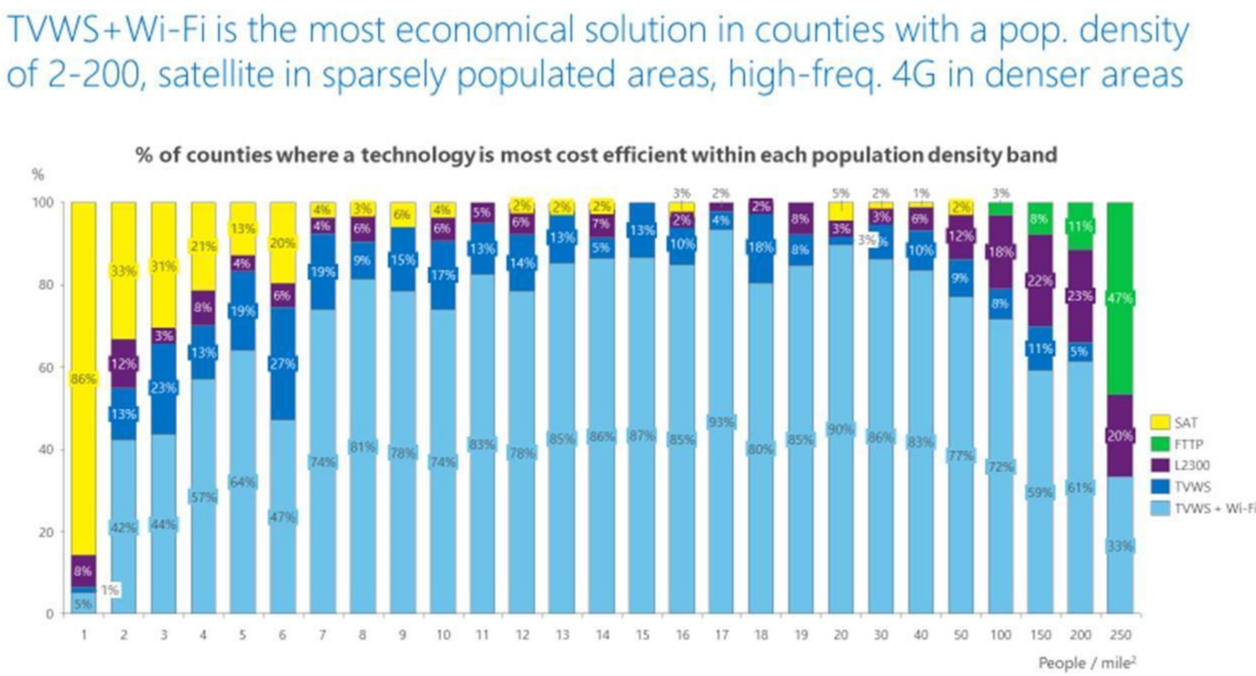
One can see how an Internet service provider would utilize different technologies for customers located in different urban, suburban, and rural areas. Think of co-centric circles of coverage from a tower utilizing different technologies leveraging different spectrum bands. For example, millimeter wave 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). VHF TV white spaces radios would have longer range. 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.

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, Singapore, South Korea, and the United Kingdom also allow unlicensed access to TV white spaces. Several 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 located 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, and what percentage of customers will be served by TV white space connections, etc.? 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 US Rural Broadband Strategy included reference to a study conducted by the Boston Consulting Group (BCG), which claimed that approximately 80% of the 23.4 million rural Americans without broadband access would be most cost-effectively served by TV white space technologies. This group of 23.4 million people represent about 40% 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 located 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. As we noted in our Rural Broadband Strategy, this analysis did not include Wi-Fi and other unlicensed fixed wireless technologies, which our ISP partners use in all of their rural deployments. BCG subsequently revised its study to account for Wi-Fi technologies per below.



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These ratios will change as more information becomes available and technologies evolve. To state the obvious, this is a fast-moving market. The best form of validation will be deploying scale, high-impact projects with ISP partners, which is the Airband Team's primary focus right now.

Cost effectively tackling the rural digital divide will require a mix of approaches. The majority of 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 and therefore maximizes investment in these technologies.