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Intelligent Spectrum Management

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Intelligent Spectrum Management

Executive Summary

The Federal Communications Commission has pledged to “find” 500 MHz of additional licensed broadband spectrum within the next ten years to help meet the growing demand for wireless broadband data services. This spectrum will be used for wide-area networks to augment those in operation today.

Last year, the FCC also released additional spectrum that can be used to provide unlicensed broadband services on a more local level. This spectrum is located between existing TV stations and is called TV White Space. This new spectrum provides the ideal platform for longer-range, but still local, wireless broadband services and will be used for bridging gaps between wired, cable, and fiber connections and locations that cannot be economically served by either wide-area or Wi-Fi systems. Further, it can be used to provide links to remote devices such as security cameras, enabling them to be located where wired connections are unavailable, and it can be used for municipal-sized systems as nomadic networks that provide coverage for an entire area. (A Wi-Fi network is an example of a nomadic network: You can use it while more or less stationary; you cannot use it while moving in a car.) TV White Space can also be used to provide back-end connectivity to remote broadband networks including local Wi-Fi access points. Finally, it can be used for inbuilding broadband extensions where Wi-Fi systems with their limited range are not feasible.

In other words, TV White Space is ideally suited to fill the gap between wide-area and local-area systems. The equipment will be inexpensive, and because it will operate over unlicensed spectrum, it will not require an ISP or other party to spend money for spectrum. Today, the rules to manage this spectrum are in flux. The FCC is working to make sure these new networks and devices do not interfere with TV receivers in homes and commercial establishments. The FCC rules specify how much spectrum needs to be available for TV White Space operation. Under investigation is how to manage the new TV White Space devices to ensure they are operating on the correct portion of the spectrum and not on channels occupied by or close to existing TV stations. This is important because each area of the nation has TV stations licensed on different channels, so the available TV White Space and the part of the spectrum it is in differs from area to area.

Those leading the research and trial systems in TV White Space are divided about how best to accomplish the spectrum management portion of the system. There are those who believe each TV White Space device deployed should contain a computer that will search the spectrum and determine the best channel on which to operate. The downside of this approach is that it will add to the cost of the devices, and the devices will still have to communicate among themselves in order to work together. The other approach is to develop a database of channels available in every area, and have each TV White Space device contact the database, provide its location, and be assigned spectrum that is available in that area. The advantage to this approach is that TV White Space devices are simpler, do not

make erroneous decisions, and can be built without the expensive logic required to track its location, resulting in devices estimated to cost about the same as today's Wi-Fi access points.

This database technology is being tested in trials across the country and initial results are quite positive. These trials demonstrate the viability of the central database approach for TV White Space use and provide real-world experience with this new and important way of allocating spectrum in a dynamic, real-time manner. This has implications for other wireless spectrum in use today. For unlicensed spectrum such as Wi-Fi, there is increasing interference because there is no coordination among access points. Database-driven management of that spectrum could solve this problem. Today's licensed spectrum is statically allocated, and there are times when some spectrum is lightly used while some is overloaded. Again, though not required, database-driven management could dynamically allocate the spectrum for more efficient utilization.

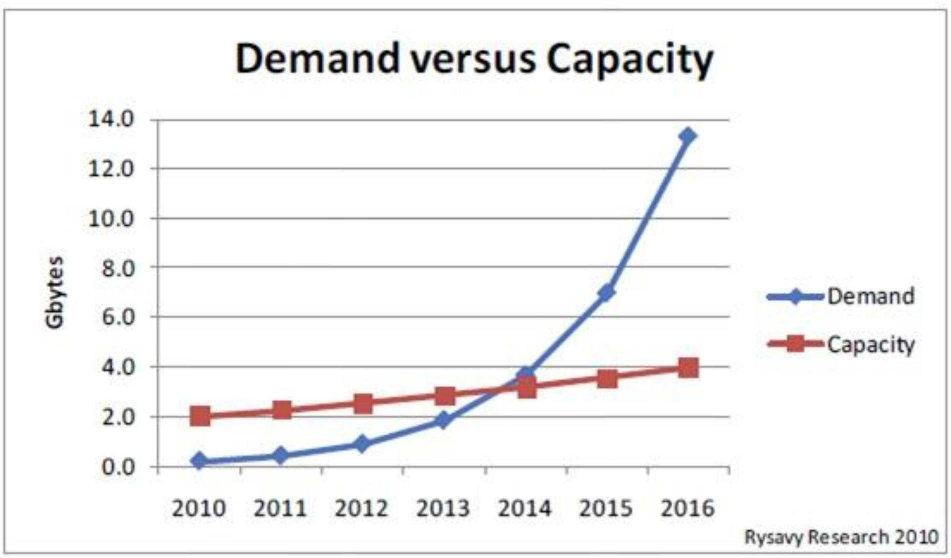
It is not often that a new technology or method to manage spectrum can be field tested under real-world conditions. It is a credit to the FCC that it is working with a number of vendors that are deploying test systems so database spectrum management can be proven and then approved by the FCC for TV White Space use. Once this is done, it makes sense to find other areas of the spectrum where this technology can be deployed.

Intelligent Spectrum Management

As smartphones command an increasing share of the mobile market, demand for wireless data, and therefore the spectrum needed to satisfy that demand, is about to explode. John Killian, Chief Financial Officer of Verizon stated in a June 2010 interview with Bloomberg that its typical smartphone users consume between 600 and 800 megabytes of data each month.

This is similar to the data consumption of iPhone users. Apple reports that iPhone users have downloaded at least 140,000 different apps a total of three billion times. The company also stated in April of 2010, "Watching broadcasts of Major League Baseball games and studying the globe via Google Earth on a palm-size device feels like a promise of the future, but the networks delivering all this data are still just catching up with the present." Indeed, AT&T has been heavily criticized for its network being overwhelmed by the volume of data from all those iPhones.

In the figure below, Rysavy Research confirms this coming shortfall in wireless network capacity: The wide-area networks will not be able to meet the demand of the coming years. It is, of course, far easier to build millions of new devices that consume bandwidth than to expand the networks to meet that increased demand.



What is driving this demand? The iPhone has become a cultural icon and has greatly increased overall awareness in the power and value of mobile applications and Internet access. Thus sales of all types of smartphones have grown. People are moving beyond mobile email as provided by earlier BlackBerry phones to rich visual applications and video streaming. Most smartphones have the ability to capture video, and people are uploading videos to social websites in increasing numbers. Likewise, the many applications that enable people to remain constantly connected to their social networks fuel the same trend.

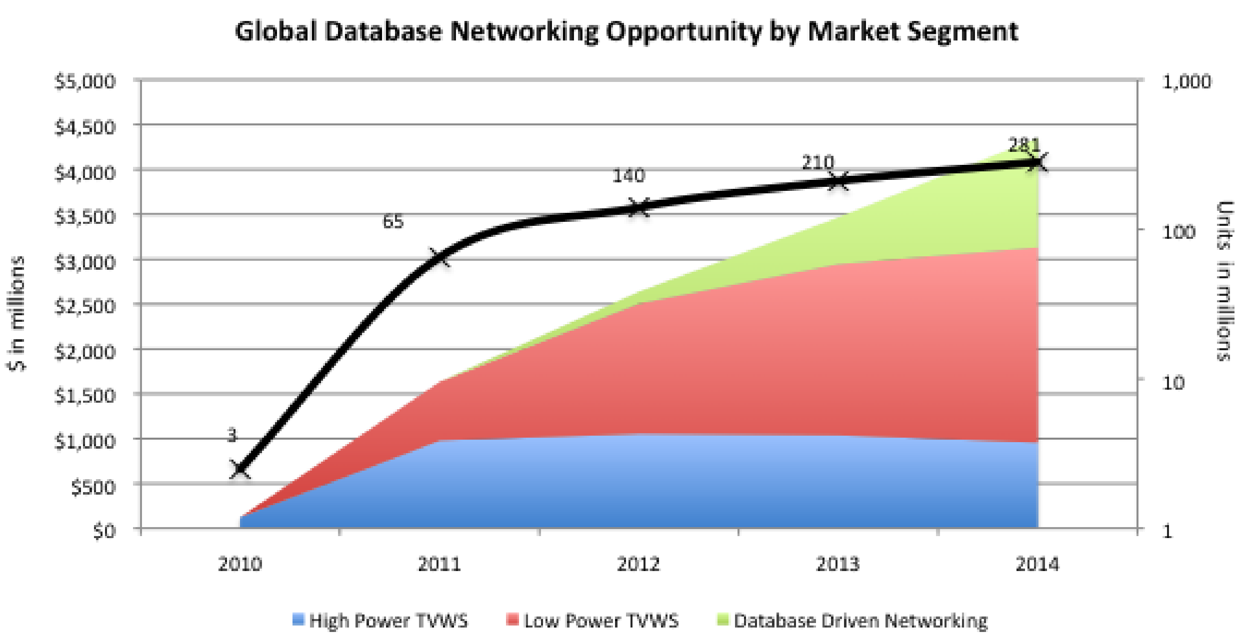
Is it only smartphones driving this demand? Indeed not. Larger-screen devices consume bandwidth at a faster rate than smartphones, as images and videos are displayed at higher resolution.

We can see that there are three key factors driving increased demand for wireless bandwidth:

1. The number of mobile devices that consume wireless data is growing. Smartphones represent 15% to 20% of the market now. Consumers are buying smartphones, netbooks, and iPads in record numbers and this trend shows no sign of slowing. In his interview with Bloomberg, Verizon CEO John Killian said that smartphones represent about 17% of its user base, and that he expected that to grow to 70% over time.
2. The number of innovative and bandwidth-hungry applications for these devices is increasing.
3. The newer, larger-screen devices such as netbooks consume even more data than smaller-screen smartphones.

Thus the number of wireless data subscribers and the amount of data used per subscriber is set to significantly grow over the coming years.

The worldwide total addressable market for Intelligent Spectrum Management as encompassed by TV White Space and Database Networking is projected by our own estimates in addition to research from ABI Research, In-Stat, and Spectrum Bridge, to be more than $4 billion in annual expenditures with more than 280 million units shipped by 2014.



Source: 2010 ABI Research, In-Stat, Andrew Seybold and Spectrum Bridge estimates.

We believe that the growth in TV White Space devices will occur first for high-power devices deployed in fixed locations. This is because a natural use of the TV White Space spectrum is to bring broadband

Internet access to locations where conventional service is costly and difficult. These devices will work with existing Wi-Fi and other networks to complete the connection to the user's device.

Starting around 2013, we see low-power devices making up the first volume shipments. The growth of this market will be slower initially. As the value of dynamically database-managed spectrum via Intelligent Spectrum Management is proven, low-power device numbers should dramatically increase by the end of the decade.

What Is TV White Space?

Last year, the Federal Communications Commission (FCC) passed a ruling permitting unlicensed broadband operation between TV channels in certain portions of the TV spectrum. The FCC became convinced that the vacant TV channels between channels in use could indeed be used to provide additional broadband services using low-power, Wi-Fi-like data devices.

The reason this TV White Space exists in the first place has to do with the fact that TV sets have historically had very poor receivers in them and TV stations broadcasting on adjacent channels would interfere with each other. Therefore, when applications for TV stations were received, the FCC decided that in any given area, the TV channels in use would be spaced so there would be one or more vacant channels between them. Just to make this more confusing, there is already some sharing occurring in the TV channels. The FCC has permitted some Land Mobile Radio (LMR) sharing of TV channels in areas where land mobile radio channels are more in demand than there are channels available. Also, until recently, there were many wireless microphones in use that operated in the TV spectrum. In Appendix A of this paper, you will find a list of broadcast TV channels by spectrum allocation.

Channels 2 through 6 are grouped together on one portion of the spectrum so there will never be both a channel 2 and 3 or 3 and 4 in the same market. In the next group, channels 7 through 13, the channels are also next to each other in another portion of the spectrum so you will not find a channel 7 and 8 station operating in the same market. Because there is a spectrum gap between channels 6 and 7, it is possible that there could be both a channel 6 and 7 in the same city.

The FCC TV White Space ruling for unlicensed spectrum use makes channels 2 through 20 available for high-power usage. Channels 21 and above may be used for either high or low-power systems or a combination. To use a channel for a high-power system, there must be an adjacent empty TV channel above and below it. Thus only when three contiguous channels are unused can they be made available for high-power TV White Space usage. The result of this ruling is that there is now an opportunity in many parts of the United States for this spectrum to be used for unlicensed broadband wireless systems. This does not necessarily mean that these systems will be offered free of charge to those who decide to make use of them, but it does mean that those wanting to provide these services will not have to buy spectrum at auction and can make use of TV White Space in any area where it is available.

Characteristics

In general, the lower the frequency band used, the more distance can be achieved using the same power levels, so TV White Space is ideally suited for city and town-wide systems where existing Wi-Fi spectrum cannot be effectively used. This is because the TV White Space spectrum is lower in frequency than the existing unlicensed bands used by Wi-Fi service (2.4 GHz and 5 GHz). The other property of the lower frequencies of TV White Space as compared to Wi-Fi is that it is significantly better at penetrating foliage, buildings, and other obstructions. Taken together, this means that the smaller cities where this spectrum is available for use will be able to accommodate deployment of local-area systems requiring fewer radios per square mile than traditional municipal Wi-Fi networks. In some cases, higher-powered radio sites can be constructed for outbound traffic on a different portion of the spectrum than inbound signals from the customers.

One of the many uses for TV White Space point-to-point systems will be to provide wireless connections for devices in areas where wire or cable connections are either not available or not economical to deploy. Some examples include:

- Providing video feeds from security cameras located throughout a city or campus. Mounting cameras in many locations is not only expensive, the wired links to receive the video and control the camera can also be expensive or not practical. Consider traffic or security cameras mounted on light standards in a smaller city. There is AC power available at the light pole but no way to easily provide a high-speed wired broadband connection to the light pole. By using TV White Space, the cameras can be deployed with the video feed and controls sent over the TV White Space spectrum.
- Providing broadband service within a college or business campus. TV White Space systems would be used from a main tower or location to each of the buildings on the campus. Within each building, the signals would be transferred to standard Wi-Fi access points. This method of distribution has two key advantages. First, it will provide higher bandwidth to each building, which means that each Wi-Fi system will be able to handle more data users. Second, since inbuilding coverage will be via Wi-Fi, students and employees will be able to use their existing laptops and smartphones without having to purchase any special wireless modems.

Available Bandwidth

As explained above, the amount of bandwidth available in any given part of the country will be determined by how many TV stations are in operation in that area. This includes not only the TV stations we all think of, including local network affiliates and major local stations, but also TV stations run by colleges, universities, and other providers of lower-powered TV systems. These are more prevalent in the urban areas of the United States.

There are several ways to determine how much TV White Space is available in any given area. One of the best sources of information available is the database operated by Spectrum Bridge, online at http://spectrumbridge.com/whitespaces.aspx. This free service provides a searchable database for the entire United States. For example, entering a zip code for San Francisco shows that there is no TV White

Space spectrum available for broadband systems, while entering the zip code for Santa Barbara, California shows that there are four adjacent channels that could potentially be used for broadband service. Entering the zip code of Casper, Wyoming shows there are ten vacant TV channels including seven that are adjacent to each other, meaning that several TV White Space systems could be operated in that area without interference issues.

Coverage

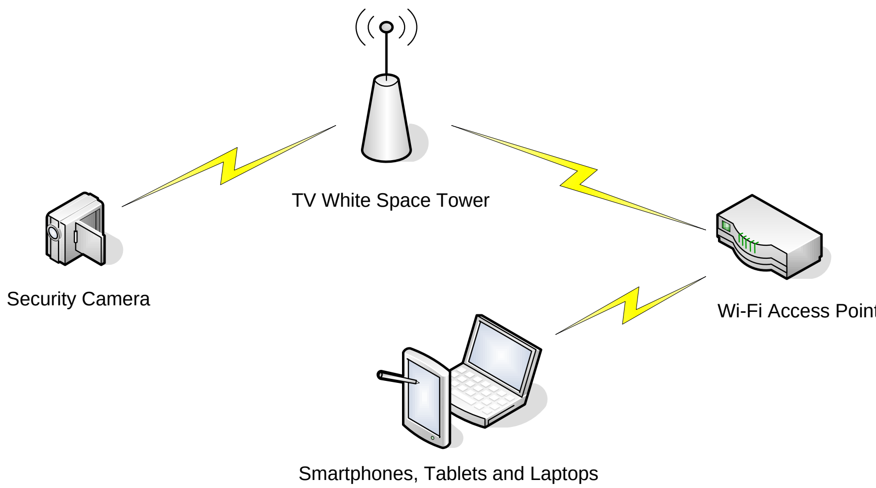
The combination of the lower-frequency spectrum and higher power results in the most economical way to date to provide broadband data services to and from locations, and to cover wide areas for use by nomadic devices (as opposed to mobile devices). This reduced cost and increased coverage makes the use of TV White Space systems the most effective and efficient of all of the available technologies. While Wi-Fi is generally limited to 300 to 500 feet from each wireless node, TV White Space systems are being designed to cover much larger areas and the point-to-point capabilities can provide links of up to four miles. Until now, those wanting to deploy unlicensed systems have never had this type of coverage available.

Costs

While the deployment of TV White Space systems is still in its infancy, it is clear that the devices can be built and offered for sale at prices comparable to their Wi-Fi equivalents, that is, less than $100. This will be far less with high-volume production. These networks will cost less to build and deploy than wide-area networks, and since they will cover more area than Wi-Fi systems, the cost to deploy TV White Space systems will be attractive.

Managing TV White Space Spectrum

Let’s look at a sample TV White Space deployment. The TV White Space tower is at first glance similar to a conventional cellular telephone tower and it communicates with TV White Space devices. In the following diagram, two devices are illustrated—a security camera and a Wi-Fi access point. Both of these are using the TV White Space spectrum to provide the backhaul to the Internet. That is, they only need a power supply; there is no need to provide wired Internet access to either of these devices. Thus the camera might be located on a building remote from any wired data infrastructure. The Wi-Fi access point, in turn, provides Internet access to Wi-Fi devices such as laptop computers and the laptop users see conventional Wi-Fi access. The fact that TV White Space spectrum is being used to gain access to the Internet is completely hidden from the Wi-Fi user.



To set up this installation, the two TV White Space devices are first connected to the Internet in "setup" mode. The devices each obtain a list of available channels (based on device type and location) from an Internet-based TV White Space database. This database maintains detailed status of all protected TV band users. When the device contacts the database provider, it is told what frequency and bandwidth it may use for its communications over the air. In this manner, TV White Space devices can make use of the TV White Space spectrum without interfering with existing TV stations or other users. Now the devices can be deployed as shown above.

In installations such as this, the frequency and spectrum allocated to each device would tend to remain static. However, should the need occur, the network can command each device to move to a different frequency and the network can dynamically reconfigure its wireless spectrum usage at any time.

We can refer to the above scheme as a "smart network" because the network (through the TV White Space database program) is dynamically directing the device to the spectrum (frequency and bandwidth) it is to use. This turns out to be a powerful concept because smart networks can provide a much more powerful and efficient way to use the wireless spectrum.

Other Solutions

The use of TV White Space for broadband services can be considered a third wireless alternative, complementing licensed wide-area commercial networks and unlicensed spectrum in the 2.4-GHz and 5.8-GHz Wi-Fi bands. Wide-area systems are capable of data speeds of between 500 Kbps and 7 Mbps today and will be faster over time. Most of the areas best served by wide-area wireless broadband systems are in the major metropolitan areas of the United States. In contrast, many of the areas that can be best served by TV White Space systems have wide-area networks that only support the lower end of the performance capabilities and have limited inbuilding coverage.

Wi-Fi on the 2.4-GHz and 5.8-GHz bands is generally deployed as wireless extensions to existing wired inbuilding networks. For the past few years, several companies have tried to turn Wi-Fi systems into municipal unlicensed systems. They developed these systems and installed them in many different cities around the United States. Some of these companies signed up the local municipality as an “anchor” tenant so they could provide broadband services for local police, fire, and other public service organizations. In most cases, these systems have been turned off and torn down. There are still a few that are limping along and functioning, but no one made any money on this type of broadband deployment and many cities were disappointed.

A number of problems with these systems led to their demise. In the beginning, most of these deployments called for about 70 access points per square mile resulting in high capital expenditures. Each access point was usually mounted on a telephone pole or streetlight. A “mesh” topology was used, with each access point transferring data to the next, and every third connected to the network back-end and then to the Internet. This resulted in disappointing performance for the users of the network. The performance degraded further due to ongoing interference as more and more individuals and businesses put in their own access points to provide personal and inbuilding coverage. Because the access points were so widely scattered, these systems did not provide reliable coverage inside homes and offices. Finally, the deployment and maintenance of these systems cost far more than estimated.

Another broadband solution to the home over wireless networks is a technology called WiMAX. The licensed spectrum it uses was purchased at auction and was expensive, and because it is located at the high end of the spectrum, it does not provide solid inbuilding coverage. These systems are competing against incumbent broadband companies and are having a hard time finding a business model that will provide them and their investors a return on their investment. Some WiMAX providers are concentrating on smaller cities and towns where there is little or no competition. The main obstacles for them to overcome are the cost of the spectrum, the cost of the equipment they are deploying, and the fact that in many of these areas the population density does not make it economically feasible to provide these networks.

There is proven demand for broadband services where none are now available. There is a demand for providing radio links for cameras and other types of devices where it is too expensive or not possible to run cables. There is a demand for services from various business segments that would like to find an option to trying to identify and acquire licensed spectrum and deploying expensive radios. As discussed above, local-area technologies such as Wi-Fi do not scale well for broad coverage applications. Obtaining licensed spectrum, if it is available at all, is expensive. Commercial networks such as those run by AT&T, Verizon, and Sprint certainly work, but the cost per customer can be quite high and their coverage is also best where there is a higher population density. Because it is available for unlicensed use and because it operates on portions of the spectrum that provide longer-range communications capabilities, TV White Space is the missing link in the ability to provide broadband services over large but confined areas.

Regulatory Issues

Wireless Microphones

Prior to FCC approval of the use of TV White Space, this spectrum was already being used for many other purposes in addition to TV broadcasts. For example, in major metropolitan areas where spectrum for land mobile radio (including police and fire) is in high demand, the FCC has permitted some two-way radio use. In cities such as Los Angeles, Chicago, New York, Boston, and others, several TV White Space channels will not be available since they are already being used for these two-way radio services.

Specifically, the band is currently being used by a variety of wireless microphone users. Some are legitimate users such as large companies and institutions (e.g., media conglomerates such as Disney, Viacom, and NBC/Universal), identified by Part 74 licenses in the Federal Universal Licensing System, though the majority are unlicensed and illegal or noncompliant users (e.g., churches, schools, musical performers). The FCC has published a Notice of Proposed Rulemaking suggesting that these illegal or noncompliant users be provided with the equivalent of Part 15 unlicensed status, but it has not yet ruled on the final dispensation of wireless microphones—which ones will be afforded protection and how. The database will be designed to accommodate wireless microphones to the extent that they are to be provided protection.

Thus for the next five to ten years, wireless microphones will continue to operate in this spectrum and they will cause problems for TV White Space operators. The good news is that the range of these wireless microphones is limited and the TV channels they have been operating on are well known, which should make it somewhat easier to find workarounds for this problem.

Sensing vs. Database

As mentioned, the FCC has not finalized the rules for the devices that will be used in the TV White Space band. However, it has made it clear that whatever final rules it issues will ensure that the devices will not cause interference to TV receivers. One approach to this problem is to add sensing circuits and logic into every low-power device. In this way, the device would be smart enough to sense the presence of TV stations and avoid channels that are in use in any given area. The other approach is the use of master databases that track acceptable TV White Space spectrum for a given location. This database is accessed by the master device on the network and, in turn, the lower-powered slave units are directed away from interfering channels.

If the use of sensing circuits is required in each device in addition to database access, the cost of TV White Space devices will be considerably higher than if the database approach is used exclusively, and the device will be prone to false positive detection. Building both smart sensing capabilities and database capabilities into each and every device does not appear to be the best approach. If this method is required by the FCC, all devices will cost more and be less reliable, which could slow or kill the adoption of TV White Space systems. We believe the database approach is a much better solution to ensure that TV White Space devices do not cause interference. Further, devices that rely exclusively on the database solution can be built at substantially less cost than if each device is required to be "smart" as well.

Interference Problems

Because TV White Space systems are operating on unlicensed spectrum, there is always the chance of interference.

Other sources of interference can come from TV broadcast stations. If a TV White Space system is located too close to a high-power TV station, even though the station is not on the same channel, it is possible that there will be some interference to the TV White Space system. This is unavoidable, but moving the system to a different frequency will mitigate most if not all of this type of interference.

TV White Space systems are only now coming online; there are a few systems up and operating under an experimental license. Several companies including Spectrum Bridge are in the forefront of the deployment of TV White Space systems and information it gathered and presented to the FCC will ultimately be used to help define the final rules that will govern the use of TV White Space.

There could be interference from other TV White Space systems. Technically, since the spectrum is unlicensed, it can be used by anyone. Since a license is not required and there is no way at present to determine if the channel you choose is in use, two systems could end up in the same area on the same channels. However, it appears that employing a master database to coordinate the use of these channels will minimize this type of interference. Unlicensed spectrum is susceptible to interference by its very nature. However, TV White Space spectrum is the only unlicensed spectrum available in the United States that does not also serve licensed users. Devices using unlicensed spectrum must accept any interference caused by any licensed or unlicensed users and they may not cause interference to licensed users.

What You Can Do with TV White Space Spectrum

Because of the amount of bandwidth available in some areas of the country, its location in the spectrum, and the power levels that are permitted, TV White Space is an ideal candidate for many different forms of wireless broadband communications that have been unavailable in unlicensed spectrum.

This being said, there are many different types of applications that are well suited for TV White Space broadband services. TV White Space can be viewed as a medium-distance wireless communications link that can provide a range of applications from to-the-home broadband access to point-to-point radio links to replace wired or microwave systems. The "killer" application for TV White Space communications is that it provides high-speed, low-cost communications links where none have existed before.

Rural Broadband

There is a pent-up demand for broadband access in rural America. The Federal Government established a broadband stimulus fund that totals $7.2 billion to provide broadband services to those who do not have access to them today. Rural America has long been shortchanged on broadband services for a number of reasons. If customers have a wired telephone, they are usually too far from the telephone company's local exchange office for DSL broadband service. Most cable companies do not serve rural areas because the population density is too low, and most wireless commercial networks do not build out their systems in rural areas for the same reason.

With TV White Space systems, it is economical to provide broadband services to many underserved areas within the United States. Since a typical TV White Space cell site can cover distances of up to four miles, and since these cells can use additional TV White Space spectrum to be connected back to the Internet, a TV White Space system can provide coverage at five to ten times less per square mile than other wireless services. This means that many areas of the United States that would otherwise remain uncovered can now have access to broadband services.

Systems are being designed to provide TV White Space service to the home, where it is connected to a Wi-Fi access point to provide in-building coverage. This type of system is not only economical to build, since the homes and offices are served with Wi-Fi equipment, the only additional equipment that is needed is the device that connects to a Wi-Fi network to transmit and receive signals over the TV White Space system.

Last-Mile Broadband Delivery

There are many places within the United States where broadband capabilities are only a mile or so away, but the economics of transporting broadband over that last mile have been too expensive. Consider towns that may only be a few miles from a major highway with a high-capacity fiber cable. Connecting the town to the fiber has never been economically feasible until now. Connecting the fiber to a TV White Space point-to-point or point-to-multipoint network located in the town will provide broadband access to the town and surrounding area. Once the system is installed, the broadband connections can be run to homes, offices, and other locations using additional TV White Space channels and/or Wi-Fi connections.

Other types of last mile service might involve a school that has a broadband connection. Using TV White Space, the broadband service can be wirelessly extended to a radius around the school at a very economical cost. It can be extended even further from the source of the broadband connection by using multiple hops of TV White Space spectrum. Thus the wired Internet connection to a school or government office can be extended to provide broadband connectivity to the greater community. Especially in rural areas, there is an abundance of TV White Space spectrum available and there is little likelihood that there will be interference issues due to other TV White Space systems.

Smart Devices: Water Meters, Delivery Trucks

TV White Space networks are suitable for fixed systems (both client device and cell site are in fixed locations) and for systems where the cell site is fixed and the client device can move about. The client device might be a USB dongle or some other form factor suitable for use in notebooks, netbooks, and tablets. This type of system is known as nomadic in that the user device must be stationary while in use as opposed to being fully mobile and able to be used in a car or on a train while in motion. Similar to Wi-Fi systems, it can be used wherever and whenever the customer is in range of a system and is stationary for some period of time. While it is technically possible to build a TV White Space network that supports full mobility, the costs associated with it would negate the cost savings inherent to these networks. TV White Space networks are best used for fixed and nomadic services.

Because TV White Space devices and networks will be inexpensive, they are suitable for use in any number of smart devices, water meters, traffic monitoring, air quality monitoring, and for any application where communication is essential. TV White Space devices will not only be low in cost, they will also be able to operate for long periods of time on battery power if commercial power is unavailable.

Types of TV White Space Devices

The first devices available for TV White Space networks are fixed wireless devices. These devices are designed to communicate with the network and then to be coupled to a Wi-Fi access point to provide inbuilding broadband capabilities. After the FCC finalizes rules for their use and as TV White Space networks begin to expand, we can expect to see all manner of devices: standalone devices designed to be used in the network, devices designed to be built into other types of devices both fixed and mobile, and devices that will include provisions for TV White Space systems in addition to wide-area and local-area wireless systems. Again, if the spectrum selection is handled by a master database, the price of the chipsets will become sufficiently attractive for them to be built into many different types of devices.

Historically, manufacturers of tablets, notebooks, and netbooks first deployed wireless capabilities that were external to the device. Over the years, these external devices have shrunk from external bricks to PC Cards to USB sticks. We believe TV White Space devices will quickly become available in a USB form factor at reasonable prices and will be integrated into consumer products.

PCs

One of the most clearly practical applications for TV White Space network deployments will be to connect Wi-Fi access points to the Internet. In areas where there is no DSL or cable broadband available, TV White Space systems can provide the link between the nearest broadband connection and a home or office. Once deployed, those inside the home or office (or in a park) can use Wi-Fi to communicate with the system.

This will also enable other devices such as gaming devices, set-top boxes, and others that are also equipped with Wi-Fi to use the same access to broadband with the only additional investment being for the TV White Space to Wi-Fi access point.

Machine-To-Machine

It has taken the wireless industry a long time to realize that there is a significant market for machine-to-machine (M2M) communications. There are more machines in the world than there are people and there is a need for many of them to communicate with each other or a central location. These remote sensing and reporting applications typically produce small amounts of data, and they communicate infrequently. However, they are a good source of recurring income for network operators and many will be targeted by the TV White Space systems.

Some M2M applications include pumps that need to be turned off and on and send their status back to a central point, electric meters, alarm systems for homes and offices, reporting of fuel and other levels in tanks, devices that monitor the condition of a back-up generator, batteries, and other devices that need to be both monitored and controlled.

Today, wide-area network operators are aggressively pursuing the M2M market. However, many of the devices on these networks can be off-loaded to TV White Space systems since many of the machines are not located within coverage of existing wide-area networks but where there will be TV White Space systems built to provide broadband services to others.

Trials Underway

The above discussion is not simply theoretical. Several companies are currently in the field with trials underway including Adaptrum, Google, InfoComm, Microsoft, Motorola, Philips, TV-band services and Spectrum Bridge. Working closely with the FCC, early tests in Washington DC and surrounding areas in Maryland demonstrated that TV White Space radios, working with TV White Space databases, could successfully transmit data in the unused areas of the TV spectrum.

Following this early demonstration, several “real-world” applications of TV White Space are now running in the field.

New Hanover County, North Carolina

In New Hanover County, the available TV White Space spectrum is used to manage the deployed “Smart City” network by dynamically assigning non-interfering frequencies to TV White Space devices throughout the service area. This deployment was an “add-on” to the existing fiber optic infrastructure. A TV White Space software application was installed in three locations to offer high-speed Internet connectivity. Additional transmitters were then connected to a wide range of remote TV White Space devices so TV White Space frequencies could be used to communicate back to the hubs. The initial applications deployed include:

Department of Transportation traffic cameras for real-time traffic monitoring to reduce congestion, fuel consumption, travel time, support local law enforcement, and assist with hurricane and disaster evacuations.

Public safety and Wi-Fi access at community parks to deliver real-time video monitoring to improve overall security and give local law enforcement a virtual presence in the parks. High-speed Wi-Fi access in the parks also enables county employees to be more productive and offers citizens the opportunity to stay connected via laptops, smartphones, and netbooks while in the park.

Access to remote water and wetlands monitoring stations allowing remote monitoring and management of wetland areas, which eliminated the costs associated with physically driving or boating to the monitoring stations to collect data required by the EPA.

Claudville, Virginia

Like many other rural communities, business and residential users in Claudville are limited to dial-up or costly satellite-based Internet delivery that can be unacceptably slow or cost prohibitive. Because of the distances between locations and dense foliage in the area, providing broadband to the community via fiber or copper lines was impractical and cost-prohibitive. Because of its superior ability to penetrate forests, TV White Space provided a solution to this problem. Again using existing infrastructure, TV White Space radios were installed at locations throughout the service area. These radios were set up at the local school, the café located in the business district, and at homes and businesses of users in the community creating “middle mile” connections among multiple Wi-Fi hotspots. This deployment brought high-speed broadband to many of the area residents for the first time.

Plumas County, California

The Plumas-Sierra Rural Electric Cooperative (PSREC) serves two counties located in the Sierra Nevada Mountains. This presents some difficult challenges with respect to wireless coverage. PSREC is using TV White Space to deliver wireless connectivity in mountainous and heavily forested terrain. The application deployed for the PSREC “Smart Grid” wireless network trial delivers real-time broadband connectivity to remote substations and switchgear allowing PSREC system operators to remotely manage the electrical system, request critical data from substations, manage power flow, and protect the systems and employees while maintaining the local grid. The TV White Space wireless network is also providing broadband access to an underserved community in a remote area.

PSREC has also deployed an energy monitoring tool that helps consumers save energy and money using information provided by a smart meter. With the TV White Space network and the “power meter” application, consumers can view real-time detailed energy consumption data online from anywhere.

What's Next

Today, TV White Space enables very low cost wide-area wireless networks. As discussed, they offer better coverage and therefore lower capital expense than other solutions such as Wi-Fi or WiMAX.

What is intriguing to us is that the central database approach to spectrum management has broad application beyond TV White Space. The underlying database architecture can evolve to support a new generation of dynamic networks for both licensed and unlicensed spectrum. This approach is key to making the most efficient use possible of the scarce resource that is wireless spectrum.

There is only a limited amount of spectrum available. The FCC, in its National Broadband report to Congress, has pledged to find and allocate an additional 500 MHz of spectrum for commercial broadband systems, 300 MHz within five years and an additional 200 MHz by year ten. Others are offering ways to make more efficient use of the spectrum we have including cognitive or smart radio systems designed to monitor the spectrum, select segments that are not in use, and make use of that spectrum on a part-time basis.

The problem with all of these proposed solutions is that the FCC has not set aside any spectrum that can be used to test these theories prior to their adoption. The TV White Space unlicensed spectrum recently released by the FCC can not only provide economical broadband communication services where none have been available before, it can also be used to prove out a number of different ways to better manage our spectrum.

The database approach to spectrum management, that is, use of a master database that tracks spectrum usage, is an example of the type of experimentation that can be conducted in TV White Space spectrum and then moved into other spectrum bands. The database approach makes a lot of sense—the "smarts" do not have to be built into each radio, rather, the system relies on database technology that can track spectrum in a given area and assign spectrum for systems that require communications on an as-needed basis. The beauty of this database approach is that it can be proven first in the TV White Space allocations and then moved into other unlicensed and licensed systems to provide for additional spectrum reuse in portions of the spectrum where it is not available today.

As mentioned, the biggest issue with using spectrum more effectively is to prove the technology not only in a laboratory environment but also in real-world systems. This is one reason that several companies have undertaken trials of TV White Space systems to test and refine their database methodology so it can be applied to other portions of both licensed and unlicensed spectrum.

This methodology has already proven successful in TV White Space systems that have been deployed by several companies and we believe these systems will provide proof for the FCC and the wireless industry that this approach is a viable and economical way of better managing our spectrum, which is a finite resource.

Conclusion

The FCC's allocation of additional unlicensed spectrum for wireless broadband in the form of TV White Space systems is being well received. This technology is the missing link between wide-area and local-area wireless systems and enables connections that have not been practical or economical before. Typical wide-area systems cover hundreds of miles of area, typical Wi-Fi or local-area wireless covers several hundred feet, but TV White Space systems can cover areas in two to four-mile increments, making them ideal to provide the "last mile" between a wired or fiber broadband connection and homes and offices. They are also for wireless broadband links for cameras and other devices where presently there is no way to connect them.

TV White Space systems will breathe new life into municipal wireless systems that were based on citywide Wi-Fi deployments. These systems proved to be flawed in their design and incapable of providing the type of broadband services needed. TV White Space systems will fill this void and provide the final link to bridge the gaps in broadband coverage.

Just as important, by use of intelligent network management (database-driven spectrum allocation), these systems will operate without worry of interfering with TV receivers in the same areas, and the lessons learned in the deployment of these intelligent network management systems will prove out the technology for other types of spectrum management.

It is not often we have an opportunity to prove out a technology that could have a tremendous and positive impact on spectrum management in many different portions of the spectrum. This is one real benefit of the FCC releasing TV White Space for unlicensed but managed operation. Once these systems are fully developed and the rules have been finalized, this technology can be easily adapted to help manage many different portions of the spectrum.

TV White Space will also help provide broadband connectivity in a much more economical fashion than before. It will bring broadband to places where it would not have been built. It will prove to be an economical link between various machines including cameras, pumps, meters, and other devices that need broadband connections in order to be monitored and controlled. Since the price of the device is expected to be on a par or less expensive than the cost of Wi-Fi devices today, but with much broader coverage capabilities, TV White Space is the final piece in the wireless broadband puzzle.

What is being learned today will be of great benefit to those who want an opportunity to provide broadband services in areas where there are none today, and it will benefit all of us in the future.

The combination of TV White Space spectrum and intelligent network management is coming together quickly. The tests and deployments that are underway and those being planned for the future will serve to prove the concepts and to refine the technologies so we can more effectively manage the finite amount of spectrum we have available.

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