WHITE PAPER

EXPANDING WIRELESS COMMUNICATIONS WITH "WHITE SPACES"

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In the U.S., recent public dialogue in the Congress, Federal Communications Commission (FCC), and press has centered on a concept known as the "White Spaces." With demand for scarce wireless bandwidth trending sharply upward, the FCC has undertaken initiatives to open up some of the currently under-used broadcast TV spectrum—referred to as the White Spaces—to wireless devices. Increasingly sophisticated wireless radio and antenna technologies are beginning to make it possible for unlicensed wireless devices to take advantage of this under-used spectrum without interfering with existing licensed users.

Dell has joined the IT and consumer electronics industries—including Google, HP, Microsoft, Motorola, Philips, and others—in supporting the proposal to open up the White Spaces to unlicensed wireless devices. Dell believes that expanding the available wireless bandwidth could trigger a new wave of wireless technology innovation in the U.S. that revolutionizes communications in the U.S. and the rest of the world.

From "Rabbit Ears" to Broadband Wireless

The current broadcast TV spectrum allocation in the U.S. dates from the mid-20th century when you needed a TV equipped with "rabbit-ear" antennas to receive over-the-air broadcast TV. The shift to cable/satellite TV over the past 30 years and the upcoming transition to digital TV leaves much of this prime spectrum unused today. If freed up for unlicensed wireless devices, the White Spaces can help to revolutionize communications in the 21st century.

In this paper, we explain the White Spaces concept and look at how the White Spaces can be used to bring new applications and usages to customers.

See video "Welcome to the White Space"
www.dell.com/innovation

What Are the "White Spaces"?

The White Spaces are vacant frequency bands between occupied (licensed) broadcast channels. For the purposes of this discussion, the White Spaces refer to the under-used portion of the radio spectrum from 512-698 MHz assigned to broadcast TV. (See Figure 1.) This under-used spectrum results from the way broadcast TV evolved after its introduction in the 1930s and 40s. At that time, the U.S. government—specifically, the FCC—set aside radio spectrum for TV broadcasts. Radio spectrum is typically identified as the frequency at which a radio device operates, usually stated in megahertz (MHz) or gigahertz (GHz). The FCC originally set aside spectrum in the 54- to 200-MHz range, each divided into 6-MHz bands called channels. These channels, identified as channels 2-13 (VHF), accommodated early TV broadcasts.

As broadcast TV became more popular and more U.S. households purchased TV sets, the FCC set aside additional spectrum—channels 14–69 (UHF)—in hopes that someday there would be dozens of broadcast TV channels in the U.S.

Broadcast TV channels increased in popularity during the 1960s, 70s, and 80s, reaching nearly every household in America. At the same time, the number of non-broadcast channels increased to the point where hundreds are available to U.S.

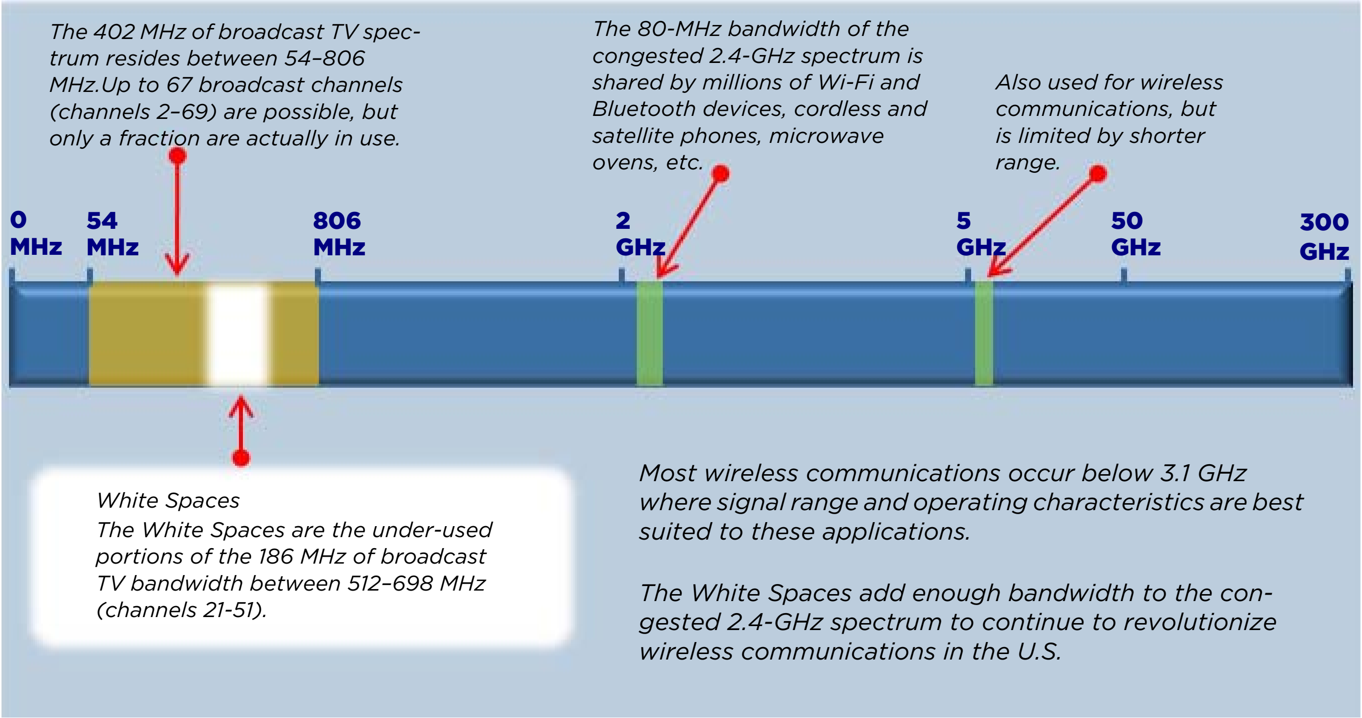


Figure 1. Wireless Communications Spectrum: Broadcast TV, White Spaces, and Wi-Fi®

consumers. The result is that, today, broadcast channels are far outnumbered by cable TV and satellite TV channels:

- **Cable TV (CATV) —** Introduced in the 1950s and originally referred to as community antenna TV, CATV allowed customers to plug into a cable TV jack to receive television signals, rather than using an antenna ("rabbit ears") to receive broadcast TV.
- **Satellite TV —** Introduced in the 1980s, high-powered, direct-broadcast satellite systems allowed customers to receive television signals via a relatively small satellite dish.

Cable and satellite TV ushered in an era in which U.S. consumers could receive hundreds of TV channels. In the U.S. today, only a handful of national broadcast TV channels such as ABC, CBS, CBS/ Warner Brothers (CW), FOX, NBC, and PBS remain. The rest such as CNN, ESPN, HBO, Showtime, Discovery, USA, Disney, and Nickelodeon are only available via cable or satellite TV.

As a result, much of the broadcast channel map—channels 2–13 and 14–69—in most U.S. cities is vacant and not being used. The current migration from analog to digital TV (DTV) in the U.S. presents an opportunity to reallocate a portion of this under-used spectrum to meet the expanding demand for wireless communications bandwidth. (See sidebar, "What Is the Digital TV Transition?")

Making Use of the White Spaces

In the 1980s, the FCC began work on migrating TV in the U.S. from a standard-definition analog signal known as NTSC to a high-definition digital signal known as ATSC. The FCC soon realized that many broadcast TV channels were unused and highly unlikely to ever be used, because cable and satellite TV served 85–90% of all U.S. households. As a

What is the Digital TV Transition?

The DTV transition refers to the switch from traditional analog TV, which uses electromagnetic waves to transmit and display TV pictures and sound, to digital TV, which uses information transmitted as "data bits" (like those transmitted by a computer) to display movie-quality pictures and sound. DTV provides higher picture and sound quality, and makes more efficient use of the spectrum.

result, the FCC reclaimed a portion of the unused broadcast TV spectrum—channels 52–69—and auctioned them off for other purposes. This auction was completed in 2008, the spectrum sold to companies with plans to deploy next-generation cell phone and data services.

Additional under-used channels remain, even after this auction. These channels, which will still be under-used when the transition to digital high-definition (HDTV) is complete in February 2009, make up the White Spaces spectrum, shown in Figure 1.

The map of available White Spaces channels differs in each city and zip code in the U.S. In large cities, where there are more broadcast channels, less bandwidth is available in the White Spaces. On the other hand, rural areas typically have fewer broadcast channels and, thus, more of the White Spaces bandwidth is available. The sidebar, "How Much White Spaces Bandwidth Is Available for Reuse?" shows the potential bandwidth available in a mid-size U.S. city, Austin, Texas.

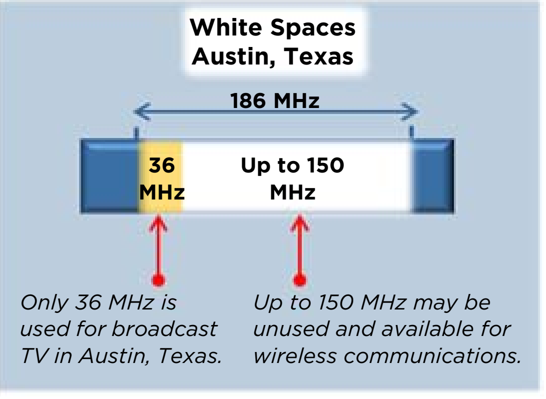
Because the map of available channels varies from place to place, making use of this valuable spectrum presents technical challenges. However, technological innovation over the past few decades can make it possible to use the White Spaces for wireless communications without interfering with local broadcast channels.

Peaceful Coexistence in the White Spaces

In its overall HDTV transition strategy, the FCC recognized the potential of the White Spaces. The agency also knew that a variety of technology approaches could make it feasible to use low-power wireless devices in the White Spaces without interfering with nearby high-power broadcast TV channels. As the FCC considered allowing new types of unlicensed devices to operate in the White Spaces, it released a Notice for Proposed Rule Making (NPRM) in 2004. The NPRM invited comments from industry and the public on the best ways to protect incumbent users of the TV broadcast spectrum, while allowing new unlicensed devices.

How Much White Spaces Bandwidth Is Available for Reuse?

Only a fraction of the bandwidth reserved for broadcast TV is actually used. For instance, in the Austin, Texas area, there are 8 high-power broadcast channels, 6 of which operate in the White Spaces. Each channel uses 6 MHz of bandwidth for a total of 36 MHz (6 channels x 6 MHz). This leaves up to 150 MHz of spectrum that could be used for wireless



NOTE: This is an estimate and may vary if additional broadcast channels enter the market or if wireless microphones are in use.

Figure 2. White Spaces in Austin, Texas

Peaceful coexistence between incumbent and new devices is required because various devices use the TV broadcast bands for valuable customer uses. In addition to the TV sets that receive broadcast TV signals "over the air" via antennas, there are medical telemetry devices used in hospitals to monitor patients and licensed wireless microphones that transmit at low power in vacant TV bands. Technology approaches exist that make coexistence both possible and practical.

Medical Telemetry Devices

A straightforward technology solution has already been put into place to avoid interference with medical telemetry devices. The FCC and industry have agreed to reserve channel 37 exclusively for these devices. In addition, the IT industry and leading medical telemetry device manufacturer, GE Healthcare, have agreed on an approach to ensure that White Spaces devices operating in the adjacent channels 36 and 38 do not cause interference. The combination of setting aside channel 37 and implementing operating limits on adjacent channels ensures peaceful coexistence between White Spaces devices and medical telemetry devices.

Wireless Microphones

Licensed wireless microphones use the White Spaces to transmit voice data. Typically, multiple wireless microphones share the same White Spaces channel when used at an event or venue. For example, several wireless microphones may be used by the broadcaster at a football stadium, all sharing the same channel. To avoid interference, White Spaces devices must be able to detect licensed wireless microphone signals and automatically switch to a different frequency/channel.

The IT industry has proposed a combination of two technologies—spectrum sensing and beacons—to provide two layers of protection from interference.

- **Spectrum sensing —** Uses a “listen before talk” approach in which the White Spaces device listens for a wireless microphone transmission to determine whether a TV channel is vacant. If no wireless microphone transmission is detected, the White Spaces device proceeds with transmission.
- **Beacon (optional) —** An easily identifiable signal generated by the microphone itself or by associated equipment that creates a circle of protection larger than the radius of the wireless microphone signal. Because the beacon is easily identifiable and slightly higher power, the White Spaces devices can detect it and automatically switch to a different frequency/channel.

TV Receivers

TV broadcasts are very high power (tens of thousands of watts), have an easily identifiable signal, and are stationary. These characteristics allow for two complementary approaches to coexisting with White Spaces devices. The first is the spectrum-sensing “listen before talk” approach discussed earlier. This technique has been proven to reliably detect TV broadcasts in order to avoid interference. The second proposed technology is geolocation. Geolocation establishes the location of a White Spaces device via its latitude and longitude coordinates, then refers to a database to determine which TV channels are in use at that location and must be avoided. The combination of spectrum sensing and geolocation could provide two layers of protection against interference with broadcast TV signals.

The FCC is currently studying the effectiveness of these proposed approaches.

Status of FCC Deliberations

The FCC's established process for ruling on spectrum issues was initiated with the 2004 NPRM. The NPRM outlined the known facts and historical background of the proposal to open up the White Spaces to new low-power licensed wireless devices, asked a series of questions, and invited comment from industry and the public.

The FCC followed up with an additional NPRM in October 2006, receiving comments from a variety of industry entities and the public. The IT and consumer electronics industries—including Dell, Google, HP, Microsoft, Motorola, Philips, and others—support the proposal. In contrast, the TV broadcast industry, including the National Association of Broadcasters (NAB), Microsoft® TV (MSTV), and wireless microphone manufacturers such as Shure are against the proposal.

With conflicting input, the FCC turned to its Office of Engineering and Test (OET) to independently analyze the engineering data and test the alternative approaches. The OET is playing a leading role in evaluating alternative technology approaches to ensure peaceful coexistence with incumbent broadcasters.

The OET developed a test plan that includes lab and field testing of the various coexistence technologies. For example, the OET plans to test how well spectrum sensing and geolocation work. These tests use engineering prototypes of White Spaces devices that demonstrate one or more of the coexistence technologies. With test results, the OET can determine which technology or combination of technologies works best.

The FCC will use the resulting OET report, expected in Winter 2008, to release a final rule-making order. If the FCC determines that it is appropriate to move forward with opening up the White Spaces to new devices, it will issue a rule-making order that establishes the rules for allowing White Spaces devices. New devices would require this certification for sale in the U.S. and would be available after the DTV transition in February 2009—perhaps as early as December 2009.

How Will the White Spaces Benefit Consumers and Businesses?

Wireless radio technology has transformed the lives of millions of Americans over the last two decades. Prior to that, for most Americans in the 1960s and 70s, wireless radio devices at work and in the home were limited to AM/FM radio, broadcast TV, and, for some, Citizen's Band (CB) radios or walkie-talkies.

This changed during the early 1990s after a landmark 1985 FCC decision opened up radio spectrum in the 2.4-GHz band to unlicensed uses. Although industry was initially unsure how to use the newly available spectrum, over time multiple radio technologies emerged that share the 2.4-GHz spectrum. The two most successful technologies were Wi-Fi and Bluetooth®. Wi-Fi has revolutionized lives for consumers and businesses by enabling wireless networks in homes and offices. In addition, Wi-Fi "hot spots" allow customers to access the Internet wirelessly at tens of thousands of locations globally.

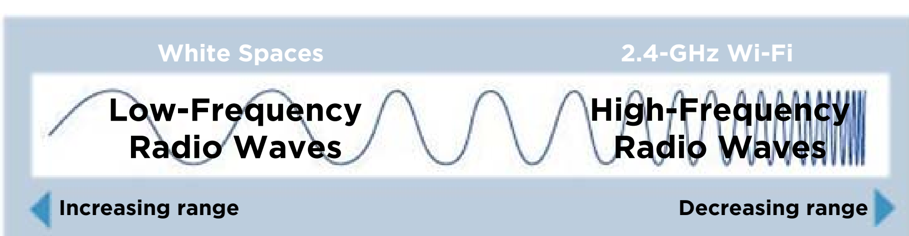
Similarly, Bluetooth has revolutionized personal wireless communications by allowing wireless links between a cell phone and a wireless microphone, car, or PC, as well as between a headphone and MP3 player.

Moving forward using 2.4-GHz spectrum, however, is difficult due to its bandwidth and range limitations.

- **Limited bandwidth —** With only three non-overlapping channels in Wi-Fi, its limited bandwidth results in interference in crowded areas such as apartment buildings and other urban locations.
- **Limited Range —** 2.4-GHz signals have limited range in buildings because they do not penetrate well through common household building materials such as brick, metal, and sheetrock. In fact, Wi-Fi solutions often require the use of repeaters or expensive antenna solutions to provide adequate coverage in a typical two-story home. This issue becomes acute when setting up a Wi-Fi network over a broad area such as a business, university campus, or metropolitan area.

Access to the White Spaces can help solve these challenges. Because the White Spaces are a lower-frequency spectrum (512-698 MHz), its signals can travel much further without being obstructed by buildings and objects. (See Figure 3.)

As a result, the coverage area of a White Spaces access point could increase by as much as 200% over that of a device operating in the 2.4-GHz spectrum. (See Figure 4.)



The low-frequency, longer radio waves of the White Spaces can carry information over longer distances and through denser objects (buildings, walls, etc.) than the high-frequency, short-range radio waves of the current 2.4-GHz Wi-Fi spectrum.

Figure 3. Low- and High-Frequency Radio Waves

Figure 4. Comparison of Wi-Fi and White Spaces Access Point Coverage

The White Spaces also adds enough bandwidth to do complex data transmission tasks such as streaming multiple video and audio channels wirelessly within a home. Because of its greater range (i.e., coverage) and additional bandwidth, the White Spaces present compelling opportunities to advance wireless communications applications. Like 2.4-GHz before it, it is impossible to predict all the ways that the White Spaces will be used, but it is safe to say there will be new devices and applications that have not been dreamed of yet.

Expanded Connectivity in Homes and Businesses

Opening up the White Spaces will almost certainly greatly expand connectivity among computing and consumer electronics devices. Figure 5 shows an access point or wireless router with a built-in Wi-Fi and White Spaces combination radio. Such a device could connect to existing Wi-Fi devices, as well as new White Spaces devices such as notebook computers, TVs, MP3 players, cars, and video cameras. The White Spaces add sufficient bandwidth to allow these devices to move large amounts of data quickly.

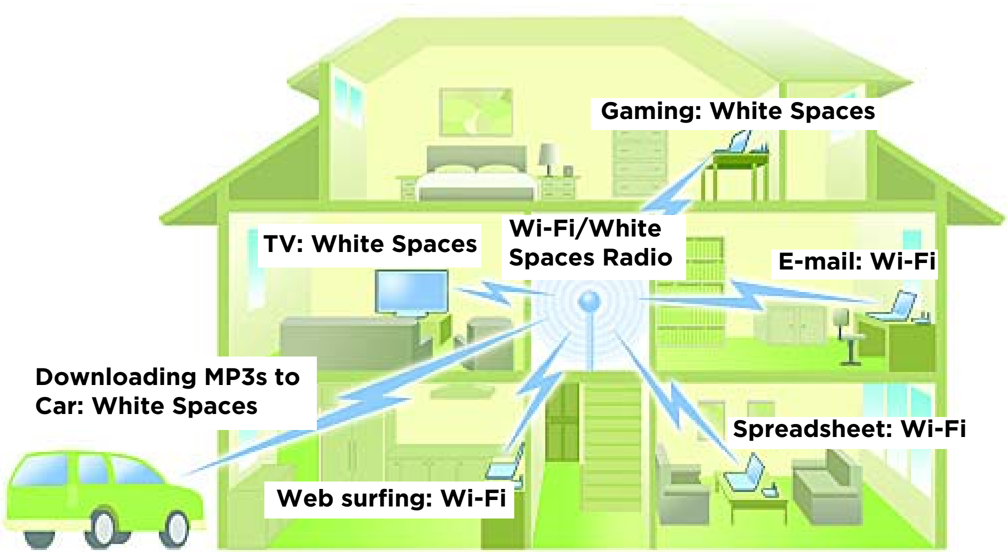


Figure 5. Combination Wi-Fi/White Spaces Access Point Supports Wi-Fi and New White Spaces Devices and Applications

Improved Communication During Emergencies

Effective communication is indispensable during an emergency. Because existing network infrastructure is often out of commission, first responders must quickly set up *ad hoc* wireless networks to enable communication between different agencies and organizations involved in the life-saving efforts. For example, during the Hurricane Katrina rescue efforts, existing network infrastructure was not available, so emergency workers set up a wireless Wi-Fi network for communication purposes. In the future, emergency services throughout the U.S. can use the White Spaces for these first-responder networks.

Reduced Wireless Networking Complexity

In addition, new radio technologies developed in the past few years can be applied to White Spaces devices to reduce the complexity of wireless communications and networking. The industry has an opportunity to build devices and applications that simplify set up by automatically discovering and linking to nearby White Spaces devices without human intervention.This can make wireless networking faster, broader reaching, and less complex to set up and operate than it is today.

Greater Wireless "Hot Spot" Coverage

Today, Wi-Fi "hot spots" provide Internet and network connectivity. These hot spots range in size from a small coffee shop to a multi-building college or business campus to an entire metropolitan area. This low-cost wireless networking enables consumers to be mobile and stay connected at the same time.

A disadvantage of using Wi-Fi is that is not designed to provide coverage over a large geographic area. Many access points, spaced closely together, are required, which increases the cost and complexity of the network.

With significantly better range and coverage, as shown in Figure 4, the White Spaces enable each access point to service a larger area. White Spaces and Wi-Fi access points are expected to be comparably priced because they both use similar radio technology. As result, building large geographic

What's the Potential Impact of the White Spaces on Rural Areas?

The White Spaces offer intriguing possibilities for distributing wireless connectivity in rural areas with limited broadband access to the Internet. In less populous rural areas, the cost of building out physical cable infrastructure to individual homes and businesses for broadband access is often not economically feasible.

When combined with a backbone technology such as WiMAX, the White Spaces could be a cost-effective alternative because of the long range and high bandwidth that can be achieved. In fact, the White Spaces bandwidth is likely to be highest in rural areas, where more of the analog TV spectrum is unused and, therefore, potentially available for White Spaces applications.

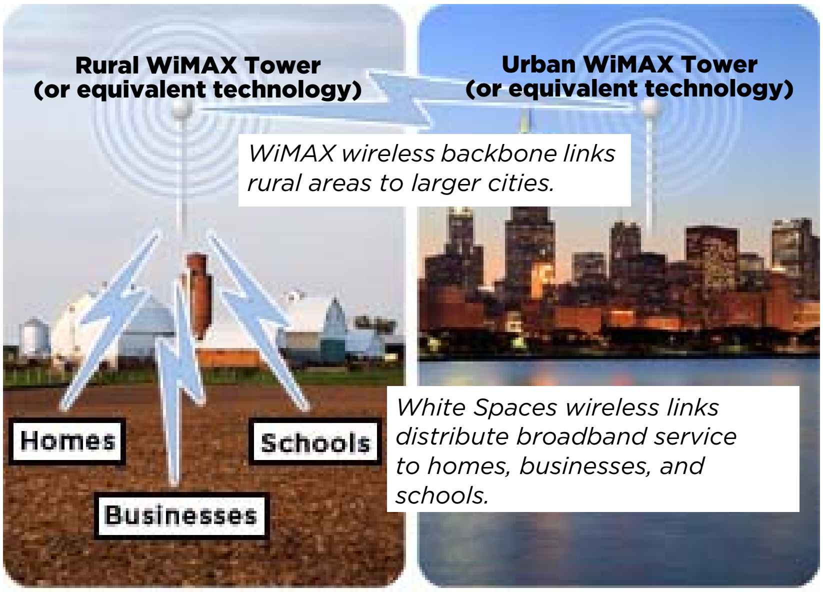


Figure 6. White Spaces in Rural Areas

hot spots using White Spaces devices could potentially allow networks to be built for as little as one-fourth the cost of an equivalent Wi-Fi network. This should dramatically increase the number and size of hot spots available to consumers as they travel for work and recreation.

White Spaces Worldwide

Other countries are also looking into the possibility of opening up the White Spaces to new applications and devices. In the U.K., the FCC-equivalent organization known as Ofcom has determined that there are significant public benefits. Ofcom has decided to move forward and is studying technology approaches to coexistence. The agency will perform engineering studies and testing, like those done by the FCC. The industry is working with Ofcom, and proposing that the U.K. use the technology approaches chosen for the U.S.

The rest of Europe is on a later time table for the DTV transition. The European Commission plans future study to understand how the European Union can best take advantage of the opportunities posed by the White Spaces.

Conclusion

Valuable White Spaces spectrum in the underused broadcast TV channels is freed up by the DTV transition in the U.S. This spectrum can be used to expand the bandwidth available for wireless communications. Using the White Spaces requires coexistence technologies to ensure that incumbent users such as TV broadcasts, wireless microphones, and medical telemetry devices are not inadvertently subjected to interference. With strong advances in radio technology, engineering solutions to the coexistence challenge are within sight. The IT and consumer electronics industries, including Dell, are working with the FCC to develop and test these coexistence technologies and bring them to market when they are proven and mature.

The White Spaces have the potential to build on the success of the 2.4-GHz spectrum in wireless communications. In the U.S., consumers can look forward to new types of wireless devices, applications, and services that keep the U.S. at the forefront of the wireless communications revolution.

For More Information

- Wireless Innovation Alliance: www.wirelessinnovationalliance.org
- *Welcome to the White Space* video presentation, www.wirelessinnovationalliance.org