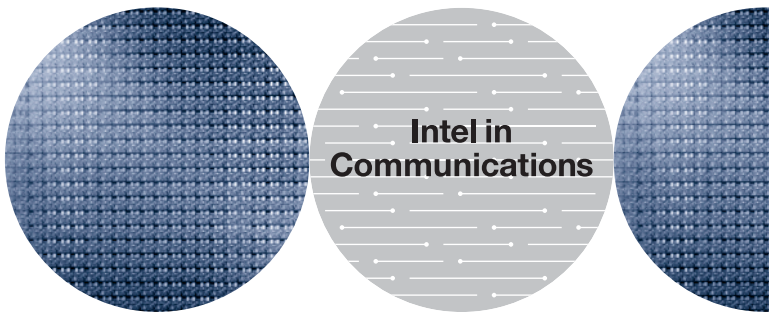
White Paper

Ultra-Wideband (UWB) Technology

Enabling high-speed wireless personal area networks



Contents

Executive Summary

Wireless connectivity has enabled a new mobile lifestyle filled with conveniences for mobile computing users. Consumers will soon demand the same conveniences throughout their digital home, connecting their PCs, personal digital recorders, MP3 recorders and players, digital camcorders and digital cameras, high-definition TVs (HDTVs), set-top boxes (STBs), gaming systems, personal digital assistants (PDAs), and cell phones, to connect to each other in a wireless personal area network (WPAN) in the home. But today's wireless LAN and WPAN technologies cannot meet the needs of tomorrow's connectivity of such a host of emerging consumer electronic devices that require high bandwidth. A new technology is needed to meet the needs of high-speed WPANs.

Ultra-wideband (UWB) technology offers a solution for the bandwidth, cost, power consumption, and physical size requirements of next-generation consumer electronic devices. UWB enables wireless connectivity with consistent high data rates across multiple devices and PCs within the digital home and the office. This emerging technology provides the high bandwidth that multiple digital video and audio streams require throughout the home.

With the support of industry workgroups, such as the wireless universal serial bus (USB) workgroup, and technology leaders, like Intel, UWB technology promises to make it easy to create high-speed WPANs that can connect devices throughout the home.

Introduction

The benefits of an increasingly mobile lifestyle introduced by wireless technologies in cell phones and home PCs have resulted in greater demand for the same benefits in other consumer devices. Consumers enjoy the increased convenience of wireless connectivity. They will soon demand it for their video recording and storage devices, for real-time audio and video (AV) streaming, interactive gaming, and AV conferencing services as the need for digital media becomes more predominate in the home.

Many technologies used in the digital home, such as digital video and audio streaming, require high-bandwidth connections to communicate. Considering the number of devices used throughout the digital home, the bandwidth demand for wireless connectivity among these devices becomes very large indeed. The wireless networking technologies developed for wirelessly connecting PCs, such as Wi-Fi* and Bluetooth* Technology, are not optimized

for multiple high-bandwidth usage models of the digital home. Although data rates can reach 54 Mbps for Wi-Fi, for example, the technology has limitations in a consumer electronics environment, including power consumption and bandwidth. When it comes to connecting multiple consumer electronics (CE) devices in a short-range network, or WPAN, a wireless technology needs to support multiple high data rate streams, consume very little power, and maintain low cost, while sometimes fitting into a very small physical package, such as PDA or cell phone. The emerging UWB wireless technology and silicon developed for UWB applications offer a compelling solution.

This document describes UWB technology and presents potential applications for UWB technology for use in WPANs in the digital home.

The Case for UWB

The emerging digital home environment is made up of many different CE devices (e.g., digital video and audio players), mobile devices (e.g., cellular phones and PDAs), and personal computing devices (e.g., mobile notebook PCs) that will support a multitude of applications. These devices fall into three general overlapping categories (Figure 1):

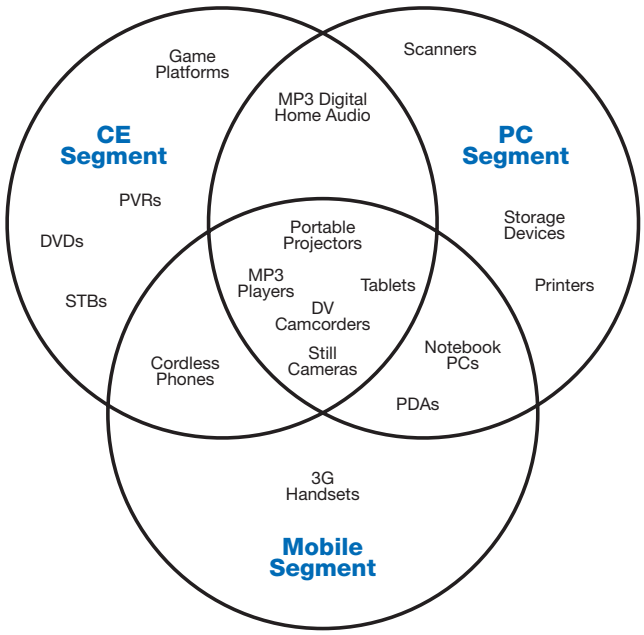
- PC and the Internet
- Consumer electronics and the broadcast system
- Mobile and handheld devices

These devices have traditionally been kept in different rooms and used for different functions. Increasingly, however, owners expect them to interact—MP3 players exchanging files with PCs, digital video recorders communicating with STBs, etc. This convergence of device segments calls for a common wireless technology and radio that allows them to easily interoperate and delivers high throughput to accommodate multiple, high-speed applications. Currently, these segments utilize different interfaces and content formats.

The next generation of PC, consumer electronics, and mobile applications demand connectivity speeds beyond the 1 Mbps peak data rate of Bluetooth Technology, which is used by many devices to create WPANs today. But many CE devices cannot support the cost and power required by the higher speed 802.11a/g radios for Wi-Fi networking.

While Wi-Fi is much faster than Bluetooth Technology, it still does not deliver sufficient performance to effectively allow streaming of multiple simultaneous high-quality video streams. UWB technology provides the throughput required by the next generation of converged devices. Plus, the support of industry initiatives, such as the WiMedia* Alliance, will help ensure interoperability across multiple protocols, including IEEE 1394, USB, and Universal Plug and Play (UPnP*), making UWB a broad technology solution for creating high-speed, low-cost, and low-power WPANs.

Figure 1. Convergence of device segments



UWB Technology

UWB differs substantially from conventional narrowband radio frequency (RF) and spread spectrum technologies (SS), such as Bluetooth Technology and 802.11a/g. UWB uses an extremely wide band of RF spectrum to transmit data (Figure 2). In so doing, UWB is able to transmit more data in a given period of time than the more traditional technologies.

The potential data rate over a given RF link is proportional to the bandwidth of the channel and the logarithm of the signal-to-noise ratio (Shannon's Law). RF design engineers typically have little control over the bandwidth parameter, because this is dictated by FCC regulations that stipulate the allowable bandwidth of the signal for a given radio type and application. Bluetooth Technology, 802.11a/g Wi-Fi, cordless phones, and numerous other devices are relegated to the unlicensed frequency bands that are provided at 900 MHz, 2.4 GHz, and 5.1 GHz. Each radio channel is constrained to occupy only a narrow band of frequencies, relative to what is allowed for UWB.

UWB is a unique and new usage of a recently legalized frequency spectrum. UWB radios can use frequencies from 3.1 GHz to 10.6 GHz—a band more than 7 GHz wide. Each radio channel can have a bandwidth of more than 500 MHz, depending on its center frequency. To allow for such a large signal bandwidth, the FCC put in place severe broadcast power restrictions. By doing so, UWB devices can make use of an extremely wide frequency band while not emitting enough energy to be noticed by narrower band devices nearby, such as 802.11a/g radios. This sharing of spectrum allows devices to obtain very high data throughput, but they must be within close proximity.

Strict power limits mean the radios themselves must be low-power consumers. Because of the low power requirements, it is feasible to develop cost-effective CMOS implementations of UWB radios. With the characteristics of low power, low cost, and very high data rates at limited range, UWB is positioned to address the market for a high-speed WPAN.

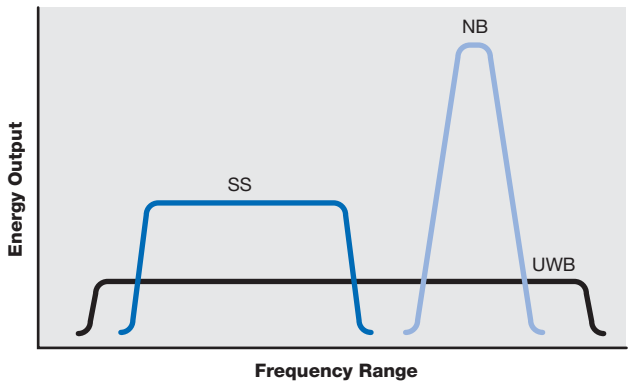
UWB technology also allows spectrum reuse. A cluster of devices in proximity (for example, an entertainment system in a living area) can communicate on the same channel as another cluster of devices in another room (for example, a gaming system in a bedroom). UWB-based WPANs have such a short range that nearby clusters can use the same channel without causing interference. An 802.11g WLAN solution, however, would quickly use up the available data bandwidth in a single device cluster, and that radio channel would be unavailable for reuse anywhere else in the home. Because of UWB technology's limited range, 802.11 WLAN solutions are an excellent complement to a WPAN, serving as a backbone for data transmission between home clusters.

UWB Applications

UWB technology can enable a wide variety of WPAN applications. Examples include:

- Replacing IEEE1394 cables between portable multimedia CE devices, such as camcorders, digital cameras, and portable MP3 players, with wireless connectivity
- Enabling high-speed wireless universal serial bus (WUSB) connectivity for PCs and PC peripherals, including printers, scanners, and external storage devices
- Replacing cables in next-generation Bluetooth Technology devices, such as 3G cell phones, as well as IP/UPnP-based

Figure 2. Comparison of narrowband (NB), spread spectrum (SS), and ultra-wideband (UWB) signal concepts



SS = Spread Spectrum
NB = Narrowband
UWB = Ultra-Wideband

connectivity for the next generation of IP-based PC/CE/mobile devices

- Creating ad-hoc high-bit-rate wireless connectivity for CE, PC, and mobile devices

Wireless PC peripheral connectivity

For wireless PC peripheral connectivity, UWB technology can take the performance and ease-of-use found in USB to the next level. Presently, wired USB has significant market segment share as the cable interconnect of choice for the PC platform (Figure 3). But the cable can get in the way. Bluetooth Technology has resolved this issue to some degree, but it has enjoyed little success so far due to performance limitations and interoperability problems. A UWB-enabled WUSB solution provides the performance users have come to expect from wired USB without the cable. Enabling un-tethered USB connectivity, UWB has the possibility of gaining significant volume in the PC peripheral interconnect market segment. The recently announced Wireless USB Working Group objective is to define a specification that delivers on this promise by providing speeds up to 480 Mbps—equivalent to wired USB 2.0—within a 10-meter range.

With WUSB, a user can bring a mobile device, such as a portable media player (PMP), in proximity to a content source, like a PC, laptop, or external hard disk drive, and, once authentication and authorization are complete, video files can be streamed onto the PMP for later viewing.

Wireless multimedia connectivity for AV CE devices

Closely related to PC peripheral connectivity is wireless multimedia connectivity for audio and video consumer electronics (AV CE) devices. The benefits are similar to those of PCs and peripherals; wireless ease-of-use and data transfer performance are key advantages. The variety of devices within the entertainment cluster (Figure 4) is wide: digital video disc players (DVDs), HDTVs, STBs, personal video recorders (PVRs), MP3 players and stereos, digital camcorders and digital cameras, and other CE devices found throughout the home. For example, UWB could connect a wall-mounted plasma display or HDTV to an STB or DVD player, without annoying and unaesthetic cables. UWB can also enable multiple streams to multiple devices, simultaneously. This would allow picture-in-picture functionality or the ability to view the same or different content on multiple devices throughout the home.

UWB can also connect devices between the PC and entertainment clusters, such as a digital camcorder to a media PC for digital video editing or to a large LCD for viewing. Connect a digital camera to a mobile notebook PC for editing, compiling, and sending pictures via e-mail to a family member while sitting at a public hotspot. UWB offers key benefits for these kinds of uses (Table 1, on the next page). With UWB-enabled WPANs, once the devices are within proximity, they recognize each other, and streaming occurs when the user presses the Play button.

Figure 3. PC clusters interconnected through USB

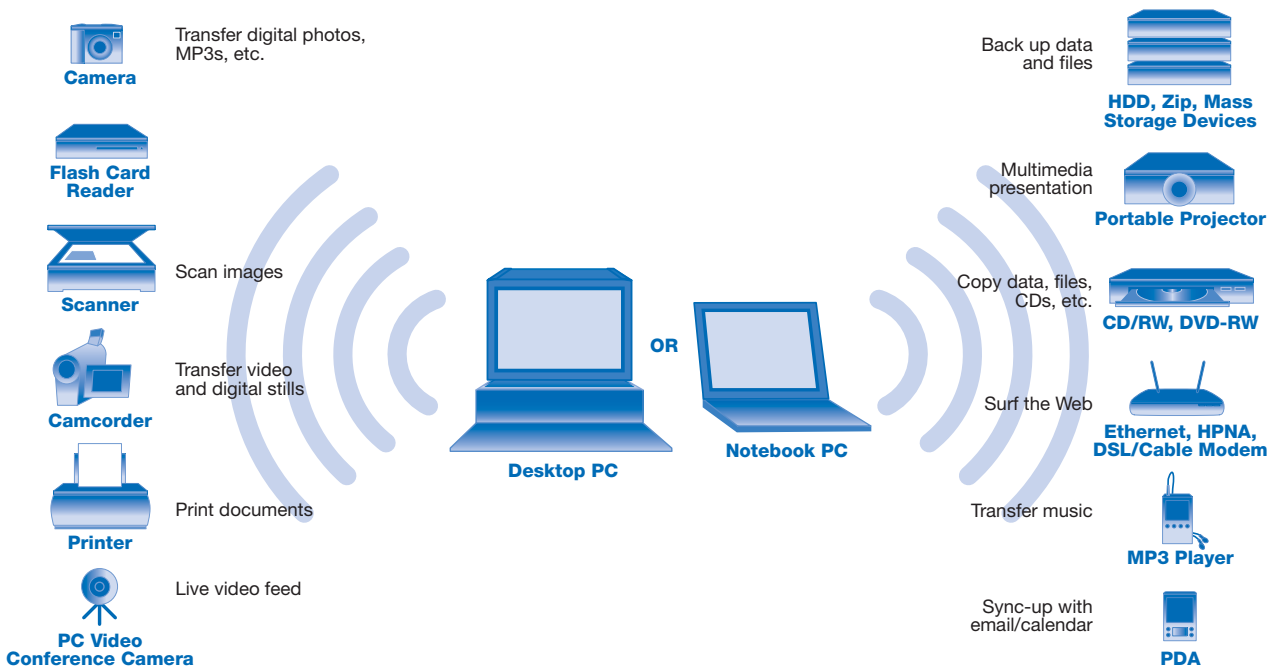


Table 1. Features and benefits of UWB in entertainment and PC environments

Feature	Benefit
High-speed throughput	Fast, high-quality transfers
Low power consumption	Long battery life of portable devices
Silicon-based, standards-based radios	Low cost
Wired connectivity options	Convenience and flexibility

Portable AV CE devices, such as digital camcorders, digital still cameras, portable MP3 players, and emerging personal video players are expected to create the sweet spot of the early UWB mainstream market.

Cable replacement and network access for mobile computing devices

For users of multiple mobile devices, cable management can be a large inconvenience when devices need to communicate with each other. Many devices, such as personal digital assistants, connect through USB ports, but others, like 3G cellular phones, might require a special connector or adapter for a USB cable. UWB technology allows these devices to interoperate—without cables—as soon as they are in proximity. UWB could also be used to enable high-speed, low-power network access within hotspot locations.

Hotspot Internet coverage is generating a great deal of market interest for broadband Internet access for mobile computing devices at remote locations. Today, two technologies enable hotspots: 802.11a/g WLAN and Bluetooth Technology-based WPAN. Both have limitations for addressing the combined needs for high-bandwidth connectivity: high spatial capacity for serving many users in a given space and low power consumption. UWB promises to help overcome these challenges and could provide a significantly improved user experience once this segment matures.

Ad-hoc connections between UWB-enabled devices

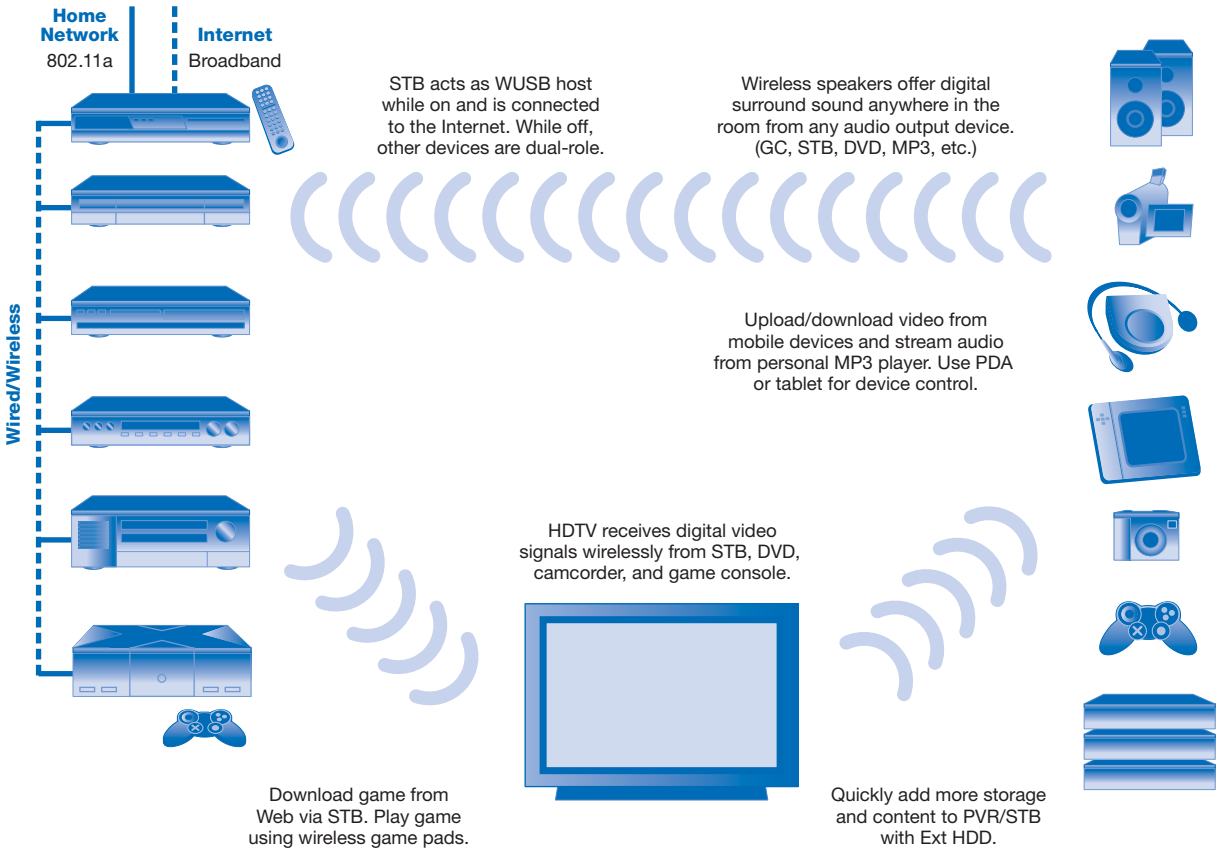
Like with Bluetooth Technology, every UWB-enabled device can be both a content source and recipient. The device gains the value of all the devices that it can connect with in a cluster. Useful applications would include connecting a digital camera directly to a printer for printing pictures.

Technology Considerations

For UWB technology to become a widely adopted radio solution, a few key areas need to be resolved:

- Performance (including over-the-air data rate performance, power consumption, co-existence with other wireless devices, immunity to interference, and link robustness)

Figure 4. Entertainment cluster



- Interoperability
- Time-to-market considerations
- Ease of product integration and certification
- Overall solution cost (to the OEM)
- Fulfillment and support
- Quality of service
- Global spectrum allocation

Intel is addressing a number of these issues through investment strategies, research, participation in wired and wireless communications initiatives, and product development.

Figure 5 represents the full solution stack required to make UWB a viable radio alternative in the marketplace. At the physical (PHY) and media access control (MAC) level, Intel is a member of the MultiBand OFDM Alliance (MBOA) and is working with other members to set standards for both the PHY and MAC layers. This effort will address quality of service (QoS) needs and ensure interoperability between UWB radios, regardless of the manufacturer. Intel is also a member of the WiMedia Alliance, another industry organization focused on developing a convergence layer that will allow the UWB MAC to interface with a number of standard protocols, such as USB, WUSB, IEEE 1394, and UPnP.

Finally, Intel is developing protocols that will take full advantage of the strengths of UWB technology. The WUSB specification developed through the Wireless USB Working Group and the UPnP work done through the Digital Home Working Group (DHWG) are examples of Intel contributions.

Figure 5. Application and protocol layers for UWB

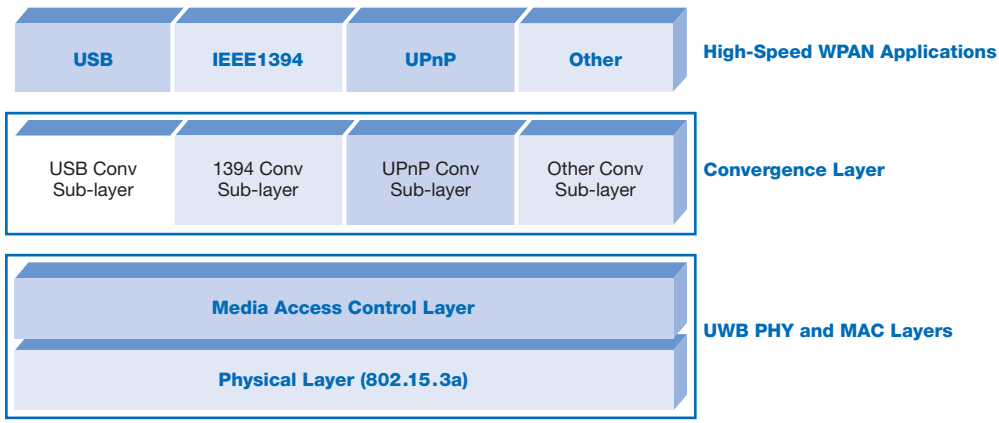
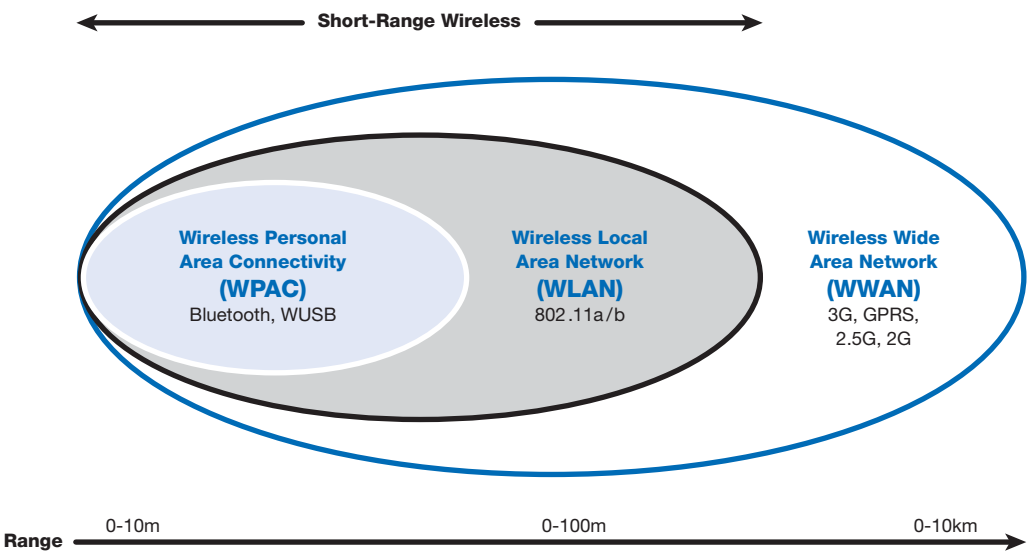


Figure 6. RF data communications coverage range



The Future: Radio Free Intel

Intel is committed to wireless technologies. The company envisions a future in which all devices are connected by smart radios. The vision is called Radio Free Intel, and it embodies the concept of a smart radio that can reprogram and reconfigure itself based on available spectrum, the desired application, and the device at hand. Configurations would include an 802.11 radio for communicating with a WLAN hotspot, a Bluetooth Technology radio for communication with a cell phone, or a UWB radio for participation in a WPAN. To promote this vision, Intel is involved in all areas of the RF space (Figure 6, on the previous page). In wireless wide area networks (WWAN), Intel is a supporter of WiMAX.* In the WLAN space, Intel continues to push forward with Intel® Centrino™ mobile technology. Now, with support of UWB technology for the WPAN space, the concept of Radio Free Intel is one step closer to reality.

Conclusion

UWB and the associated networking protocol efforts are in the early stages of development, and several key deployment scenarios are being defined and evaluated. UWB complements currently deployed wireless networks in the WLAN environment, plus it extends high bit-rate, multimedia connectivity to WPANs supporting PC and CE devices. This combination will enable true convergence of computers and consumer electronics.

A common radio platform that connects seamlessly with the existing networking protocols and cost effectively enables connectivity solutions among CE peripherals will shift the home entertainment environment. It will enable multiple usage models from cable replacement to the streaming of video, audio, and other entertainment media.

Many UWB components and systems are already in the testing and demonstration phases, with actual release dates for final consumer products expected in early 2005. Intel Corporation is working with the industry to enable this exciting technology and help ensure its success.

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