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UWB - Best Choice to Enable WPANs

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UWB best choice to enable WPANs

Offering advantages in performance, immunity to interference, and low power, WiMedia ultra wideband (UWB) technology will enable an entirely new generation of high-performance wireless personal area networks (WPANs)

Introduction

With a typical range of under 10 meters, wireless personal area networks (WPAN) are popular for hands-free access to mobile handsets as well as linking desktop peripherals and personal devices, such as PDAs and smartphones. It is important to distinguish WPANs from wireless local area networks (WLANs); these two technologies are separately defined and governed by different technical specifications, standards, and industry alliances. For instance, WPAN standards have been developed by the IEEE 802.15 working group[i] while the WLAN standards have been developed by the IEEE 802.11 working group[ii]. The Wi-Fi Alliance[iii] is the industry consortium with the mission to drive the adoption of a single worldwide-accepted standard for high-speed WLAN, while the Bluetooth SIG[iv] and the USB-IF[v] are the industry organizations with the objective to promote WPAN technologies, such as Bluetooth and Certified Wireless USB (C-WUSB). Typically, WLANs offer greater range while WPANs feature higher throughput and lower power. Figure 1 lays out the range and data rate requirements typically associated with WPANs and WLANs.

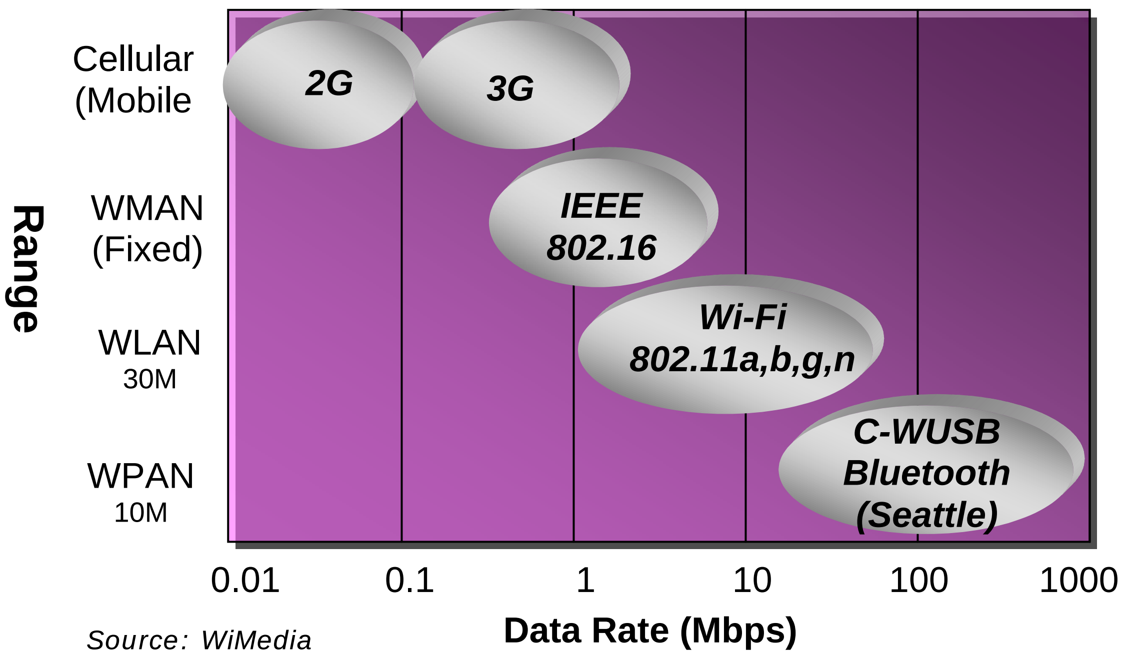

Figure 1: WLANs and WPANs have different requirements in terms of both data rates and range.

WPANs products are currently enjoying good market success, and next-generation WPANs solutions (such as Bluetooth's Seattle Release) look to increase data rates in order to handle additional applications, such as short-range streaming video. New functionalities and storage capabilities are regularly being added to portable devices, which is driving the need for fast wireless connectivity. The main application today for new WPANs is file transfer, but a more interesting emerging application is streaming video.

Streaming video is a unique application because it requires continuous periods of high bandwidth consumption in order to provide a good user experience. Compromising on throughput or bandwidth would likely make this application unsuitable. Maximum throughput required for compressed video is shown in the following table:

Video resolution	Max Req throughput
320 x 240	8Mbps
352 x 480	16Mbps
720 x 480	40Mbps
1280 x 720	56Mbps

1920 x 1088	80Mbps
2048 x 1024	200Mbps

Table 1: Max throughput for H.264 high 4:2:2 and high 4:4:4 Predictive Profiles at 30 frames per sec (Source: WiMedia)

The required throughput is also dependent on the type of content. For example, a sporting event requires higher throughput than a typical television program, because of sport's rapidly changing images. The wireless system still needs to support the maximum required throughput, but the requirements for file transfer can be relaxed. For example, average file transfer requirements for HDTV are 5 to 6Mbps[vi]. This means that a system capable of supporting 80Mbps will be able to transfer a file containing a two hour movie in only nine minutes; this is certainly a highly desirable feature for consumers.

UWB is the obvious choice to enable these new high-bandwidth applications because its key feature is high throughput at short ranges, which is precisely what WPANs require. For this reason, both the Bluetooth SIG and the USB-IF have selected UWB for next-generation WPANs. In order to be used as a Bluetooth Alternate MAC/PHY, WiMedia UWB meets the following requirements:

Requirement	Value
Throughput	>100Mbps
Power consumption	1mW/Mbps
Operating frequency	Above 6GHz*

* C-WUSB operates also at 3.1-4.8GHz

Table 2: Next-Generation WPAN Performance Requirements

It is useful to elaborate on the last two parameters in the table:

1. The power consumption is given in terms of energy rather than peak power, with the intent being to extend the battery lifetime. As an example, compare two systems that consume the same power but offer different throughput, in this case 20Mbps versus 200Mbps. It will take the slower technology 10 times longer to transfer the same amount of information, so the battery will need to supply the same power 10 times longer, and the battery lifetime will be significantly reduced.
2. Most of the radios integrated in mobile handsets today operate below 6GHz. A WPAN radio operating above 6GHz allows co-location in the same handset without interference with existing or future cellular technologies. A WPAN operating below 6GHz, for example in the 3.1 to 4.8GHz frequency for UWB or 2.4GHz for 802.11, would require special interference management techniques to allow co-location with the cellular radio.

UWB Features

Work with UWB technology dates back to the 1950s when very short pulses were transmitted in rapid succession across wide bandwidths for commercial and military applications. Current UWB technology, however, is based on the very open definition given to it by the FCC in 2002, which purposefully did not specify the techniques used to generate and detect the RF energy. Instead, the FCC simply defined UWB as any radio transmitter with a spectrum that occupies more than 20 percent of the center frequency, or a minimum of 500 MHz while adhering to certain output power limits.

In the US, UWB technology is currently approved by the FCC for use between 3.1 and 10.6 GHz. By its nature, UWB technology offers flexibility, robustness, and good ranging capabilities, making it well suited for applications that need a high data rate over a short transmission range. UWB technology has reached a state of market maturity, and a common UWB radio platform is in use that is maintained by the WiMedia Alliance.
Some of the earliest UWB applications gaining market traction are cable replacement applications, such as C-WUSB.[vii] Silicon is already in production to enable those applications, and the USB-IF has certified numerous profiles to ensure product interoperability. Some of the first integrated circuits (ICs) to enable commercial C-WUSB connections were introduced by Alereon, Intel, Lucidport, NEC, NXP, Realtek, Staccato, and WiQuest. To date, the WiMedia Alliance has certified 22 UWB unique products.

Best technology for WPAN?

There are several types of WLANs on the market, and all are based on a different type of IEEE 802.11 standards: 802.11a, b, and g are widely deployed today and the draft 2.0 802.11n is currently being fielded. The most popular of the standards is 802.11g, because its advanced coding allows higher throughput than 802.11b and it operates in the 2.4GHz band, which offers greater range than 802.11a. The newer 802.11n has received much press on its promise to enable higher data-rate and longer range wireless networking applications. Indoor ranges for 802.11n are expected to reach up to 70 meters, and outdoor rangers may approach 160 meters. Without a doubt, this is a clear advancement in WLAN performance in terms of throughput and range. This performance improvement, however, comes with a necessary increase in power consumption and cost because it requires multiple radio chains (Multiple Input Multiple Output MIMO technology).

Because of 802.11's success in WLANs, some are thinking of using the same technology in the next generation of short-range WPAN applications. This approach, however, is short sighted for the following reasons, as shown in this paper:

1. WPAN requirements cannot be met by 802.11 systems and consumers would be disappointed by its performance, specifically in terms of throughput and power consumption.
2. A WPAN operating in the 2.4GHz band for high throughput applications such as streaming video has the potential to cause interference to nearby WLANs and cellular systems

Throughput

Recent testing has shown that, without interferers, 802.11n actually achieves throughputs of 20 to 100 Mb/s[viii], while 802.11g achieves 25Mbps. WiMedia UWB products today can achieve up to 377Mbps[ix], while the C-WUSB products on the market today (HWA and DWA) are limited to less than 80Mbps because of the legacy protocol related to USB[x]. In addition, the WiMedia MAC (Media Access Control), has been specifically designed to support streaming as compared to bursty internet access.

Power Consumption

Power consumption is one of the most important requirements for WPANs because they are intended for use with portable, battery-operated devices. To be successful in the marketplace, next-generation WPANs must be optimized for low power consumption in order to satisfy consumer expectations.

State-of-the-art 802.11g radios typically consume 300mW in receive mode and 400mW in transmit mode[xi]. This translates to 15 to 20mW/Mbps, assuming 20-30Mbps throughput. This value is 15 to 20 times larger than WPAN's power consumption requirement of 1mW/Mbps (see Table 2).

802.11n radios are further optimized for long range instead of low power. As a result, the power consumption is quite high and it is difficult to obtain 802.11n power consumption characteristics because manufacturers do not provide them. However, since the 802.11n standard requires multiple radios to achieve 100Mbps throughput, we can extrapolate that these multiple radios must require more power than comparable 802.11g solutions. Using the data available for 802.11g systems, and assuming 100Mbps and two transmit and receive chains, the power consumption would be 600 to 800mW, which results in 6 to 8mW/Mbps. This is prohibitively higher than the WPAN requirement of 1mW/Mbps (see Table 2).

WiMedia UWB systems, on the other hand, have been designed for low power consumption from the beginning, taking advantage of the low transmit power allowed by the regulatory rules for this technology. Typical peak power values are comparable to 802.11g, but they offer 200-300Mbps throughput, resulting in an order of magnitude higher efficiency, currently at 1.5 to 2mW/Mbps and with a roadmap well below the target 1mW/Mbps.

Technology	Value
Bluetooth requirement	1mW/Mbps
802.11g	15-20mW/Mbps
802.11n (roadmap)	6-8mW/Mbps
UWB (actual)	1.5-2mW/Mbps
UWB (roadmap)	1mW/Mbps

Table 3: Power consumption characteristics

Table 3: Shows that current and projected UWB systems meet WPAN's power consumption, while 802.11 systems fall short

Interference
Current 802.11 systems considered for WPAN operate in the 2.4GHz range. This spectrum is also used by numerous applications, including Bluetooth, WiMAX (2.5-2.7GHz), cordless telephones, and microwave ovens. Consequently, interference must be carefully managed in order to allow channel availability in this spectrum.

One of the main applications for next-generation WPAN will be video streaming, which requires the radios to use large amounts of spectrum. Because of this, next-generation WPANs need to provide some level of spectrum planning in order to avoid interference. If an 802.11 radio is used (instead of an UWB one) for WPAN, then there are at least three risks of interference caused by the 802.11 radio to other applications in the 2.4GHz range:

1. *Interference to Bluetooth*. In recognition of the risk from WLAN radios, specific mechanisms have been adopted in the latest versions of the Bluetooth specification to combat interference caused by 802.11 Wi-Fi. To be successful, these techniques rely on certain properties of Wi-Fi operation—such as traffic burstiness—that are characteristics of WLAN operation. Specifically, a Bluetooth radio can avoid certain channels that are being used by a nearby Wi-Fi radio at specific times. This technique would be much less efficient, and likely fail, if an 802.11 radio were being used for WPAN video streaming applications. (These streaming applications transmit most of the time, which would leave little opportunity for Bluetooth operation.)
2. *Interference to Wi-Fi*. Wi-Fi systems are very successfully used in homes and offices to provide wireless Internet access. The bursty nature of the traffic characteristic of Internet access allows a large number of users to share the same 2.4GHz spectrum. Using 802.11 radios for WPANs will cause the 2.4GHz spectrum to be much more crowded (by a factor of 20)[xii], and it is likely to cause serious performance degradation for existing WLANs. In addition, operating 802.11n in the vicinity of 802.11g can lead to as much as a 50% reduction in performance[xiii]. Given that, it is likely that either 802.11n will have a slow adoption or that the industry will migrate directly from 802.11g to 802.11n. This means that if a desktop is enabled with a next-generation WPAN using 802.11n, and it is operating in an environment that uses 802.11g (the most common WLAN deployed to date), connections could be dropped and functionality lost. In fact, if a WPAN using 802.11 technology disrupts the office's Wi-Fi network, many may erroneously blame the network, the operating system, or the hardware.
3. *Interference to WiMAX*. In the US, the 2.5-2.7GHz range is licensed for use by WiMAX systems. Given its nearby proximity to the 2.4GHz spectrum, WiMAX has no isolation from Wi-Fi, which could dramatically hinder high-reliability WiMAX operation. The impact of WiMAX on neighboring 2.4GHz systems is being taken very seriously by designers. Industry leaders are now suggesting a coexistence mechanism be added in Wi-Fi so that it does not transmit during WiMAX[xiv] operation. If next-generation WPANs use Wi-Fi technology to link desktop peripherals, then, the results can be disastrous. For example, if a user receives a streaming video WiMAX transmission on a mobile handset, the nearby desktop connections will drop and the user will be staring at a blank PC display with an inoperable mouse/keyboard.

Next-generation mobile devices and laptops are expected to integrate many different radio modules into the same platform. Many designers believe that it will be difficult to manage the interference between these different radios. One proposed technique is to coordinate traffic scheduling of the various radios using hardware level signaling. This will be more difficult to achieve if the 802.11 radio transmits at high duty cycles for video streaming applications. Further, this method won't work if WiMAX and 802.11 radios are in close proximity but in different devices.

Clearly, the impact of all of this interference cannot be overlooked. The allowable emissions in the 2.5-2.7GHz band used by WiMAX are shown in the following table:

Technology	Value
WiMAX Requirement	-70dBm/MHz
802.11 (FCC req)	-41dBm/MHz
UWB (FCC req)	-61.5dBm/MHz
UWB (3.1-4.8GHz)	-70dBm/MHz
UWB (>6GHz)	-90dBm/MHz

Table 4: Emission requirements for WiMAX

Note that WiMAX requires a maximum emission of -70dBm/MHz from other radios, so that the level of interference won't affect its operation. That level which is 10dB lower than the FCC limit for UWB and 30dB lower than the FCC limit for 802.11. The table shows that UWB transmitters operating at 3.1GHz or above meet the WiMAX required emission, but the 802.11 emission of -41dBm/MHz is much higher than the maximum allowable emission for WiMAX. Obviously UWB transmitters operating above 6GHz exceed that limit by a large amount.

Cost

Unit cost for 802.11g is low enough to enable high volume applications. Most manufacturers integrate a majority of the radio components (with exception of power amplifiers) in a single CMOS IC. The same is true for UWB, where multiple companies have demonstrated highly-integrated single-chip CMOS implementations. On the other hand, 802.11n implementations are still expensive and currently ship for four times as much as their 802.11g or UWB counterparts. It is reasonable to expect that the cost of 802.11n will eventually be reduced to 2X that of 802.11g because they include, at minimum, two or more radios.

Availability

Systems using 802.11a, b, g are currently shipping. However, although 802.11n technology shows great promise for increased throughput in WLANs, but it is only a draft specification to date. The IEEE anticipates the specification will be approved sometime in 2009. UWB, on the other hand, is based on an ISO standard and is already being deployed and products are readily available to implement next-generation WPANs.

UWB is the Best Choice for WPAN

Designers of next-generation WPANs who want radios with low power consumption and high throughput (that is not adversely influenced by other wireless systems operating in-band) should look closely at UWB technology. Though the temptation may be high to utilize an 802.11 system for the short term, this solution would unnecessarily increase the BOM, consume more power, and be subject to more interference than a comparable UWB solution.

Technology	Range	Throughput	Power	Cost	WiMAX Interference
WPAN req	<10m	>100Mbps	1mW/Mbps	Low	Low
802.11g	>50m	20-30Mbps	15-20mW/Mbps	Low	High
802.11n	>50m	>100Mbps	6-7mW/Mbps	High	High
UWB	<10m	>100Mbps	1mW/Mbps	Low	None

Table 5: WPAN/WLAN technology characteristics

Table 5 summarizes how different technologies compare for WPAN applications. It is clear that 802.11 is optimized for WLAN, because it performs at much higher range than required by WPAN, at higher power, and the cost of 802.11n is too high for WPAN applications. The interference from 802.11 to WiMAX is not a problem when the system is used for Internet access, but it can become a serious problem when applications stream video.

The best alternative is to continue using 802.11 for its intended purpose—WLAN—and use UWB for WPAN. UWB has the distinct advantage of operating at much lower transmit power levels in the 3.1GHz to 10.6GHz ranges, which is well out of the range of Wi-Fi, WiMAX, and Bluetooth 2.0 signals. Implementing UWB technology in WPAN systems avoids all of the interference problems that plague WLAN.

Clearly, WLAN technology is challenged to meet the market requirements of next-generation WPANs, especially in terms of power consumption, throughput, interference, availability, and cost. Fortunately, UWB technology is already available and it can meet and exceed the needs for current and advanced WPANs.

[i] http://www.ieee802.org/15/
[ii] http://www.ieee802.org/11/
[iii] http://www.wi-fi.org/
[iv] http://www.bluetooth.com/bluetooth/
[v] http://www.usb.org/developers/wusb/
[vi] Source: Apple
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[viii] Veriwave Presentation
[ix] Source: WiMedia
[x] Source: USB-IF
[xi] Broadcom, BCM4348 Product Brief
[xii] Source: ITU
[xiii] Source: Veriwave
[xiv] Source: Motorola