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How Bluetooth, UWB, and 802.11 stack up on power consumption

By Gadi Shor, CTO, Wisair 04.15.2008  0

Today, for example, nearly 2 billion people use mobile phones on a daily basis, for voice services as well as for a growing number of data-centric Internet applications.

By 2013, analysts predict that one in every three mobile phones sold will be a smartphone. Entertainment-based mobile devices are also on the rise with the digital still camera (DSC) household penetration rate expected to reach 80% by 2010 in the United States alone.

Wireless technologies such as Bluetooth, Ultra-wideband (UWB) and WLAN, all make this **wireless** data transfer viable today, yet each has its own obstacles which makes its use in the mobile market challenging. Additionally, due to the inherent nature of each of these technologies, some may be better suited than others in applications requiring, for example, a high **bandwidth** or a wide operating range.

In the case of the mobile market, one of the main requirements is long battery life. Therefore, one key factor that must be evaluated when determining which technology to implement in a mobile device design is power consumption.

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Throughput is also an important factor as it contributes to the technology's overall power consumption. Choosing the right wireless technology is crucial to developing an optimal, commercially-viable mobile device.

Understanding power consumption

At the end of the trip, the consumer returns home only to find that the camera has a mere 5% of its battery power left, making it impossible to transfer the camera's content to another device, such as a desktop computer.

During typical camera usage, this is exactly the type of capability that today's consumer demands.

Given this scenario, it is easy to see why low power consumption and high throughput are so critical. Standby power and active power consumption (e.g., in a cellular phone the power attributed to talk time, or in this case, attributed to data transfer) must therefore be reduced in order to increase battery life.

Consequently, today's designers require implementation of a wireless technology which supports multiple low power modes, regardless of whether the device's active power is on or it is in standby mode.

Throughput (e.g., power per Mbit of data) also plays a critical role here because even if a protocol's active power is high, it may ultimately exhibit the lowest total power energy consumption, and therefore provide the best power efficiency, if it transfers data extremely fast.

Technology options

Given the mobile market's demand for minimized power consumption and maximized throughput, it is now time to look at the range of viable wireless technologies to determine which one is best suited to meet these needs. They include:

- Bluetooth is a wireless personal area network (PAN) standard designed primarily for low power consumption, with a range of 1 meter for a Class 1 device, 10 meters for a Class 2 device, or 100 meters for a Class 3 device. Bluetooth provides a way to connect and exchange information between devices such as mobile phones, laptops, personal computers, printers, GPS receivers, digital cameras, and video game consoles over a secure, globally unlicensed short-range radio frequency. Bluetooth Version 1.2 features a 1 Mbps data rate, while Version 2.0 + EDR features a 3 Mbits/s data rate. In a few years, a new proposed high-speed, high data rate version of the protocol will combine Bluetooth technology with the WiMedia Alliance's multiband orthogonal frequency division multiplexing (MB-OFDM) version of UWB. With a data rate of 53 " 480 Mbps, this version of Bluetooth will meet the

high-speed demands of synchronizing and transferring large amounts of data, as well as enabling high quality video and audio applications for portable devices, multi-media projectors and television sets. In terms of power consumption, the proposed protocol offers the best of both worlds. The basic idea is that the Bluetooth radio would reside in the UWB chip. The chip would then easily switch between Bluetooth and UWB, as necessary, to take advantage of the power savings offered by each of the technologies. Bluetooth, for example, is extremely low power in standby mode — even better than either UWB or WLAN. UWB, on the other hand, is much better than Bluetooth or WLAN when it comes to consuming power during the active mode.

- UWB technology is a wireless radio technology for short-range, high-bandwidth communication at very low energy levels, using a larger portion of the radio spectrum. In terms of joules per bit, it is considered the most efficient technology employed today.

Wireless USB, also known as Certified Wireless USB, is based on the UWB common radio platform from the WiMedia Alliance.

Because it combines the speed, security and ease-of-use of USB 2.0 with the convenience of wireless technology, it holds great promise for a range of applications including high-speed digital media transfer between devices in personal and home area networks. Wireless USB currently delivers a bandwidth of up to 480 Mb/s at 3 meters and 110Mb/s at 10 meters. Wireless USB 1.1 is currently in development by the USB Implementers Forum (USB-IF) and is expected to be finalized in the first half of 2008.

Designed to enhance the ease of use of Wireless USB, the specification will feature new options for first-time association of devices, improved power efficiency for better battery life, and support for UWB frequencies above 6 GHz. Typically, UWB is associated with high, as opposed to low, data rates. If implemented correctly, Wireless USB 1.1 would enable UWB to reach low data rates and therefore be used for applications like video streaming.

- A Wireless local Area Network (WLAN), based on the 802.11 standards, utilizes spread-spectrum or OFDM modulation

technology based on radio waves to enable communication between devices in a limited area. This gives users the mobility to move around within a broad coverage area and still be connected to the network. The 802.11 family is comprised of various over-the-air modulation techniques that use the same basic protocol (e.g., 802.11a, 802.11b, 802.11g, 802.11n, and 802.11y). The two most popular WLAN standards – 802.11 b and 802.11g – feature a throughput of 4.3 Mbps and a 11-Mbps data rate, and a throughput of 19-Mbits/s and a 54 Mbits/s data rate, respectively. While 802.11 is relatively power efficient, in active mode it consumes more power than UWB.

Comparing wireless protocols

We now have a clearer understanding of the power consumption requirement and the wireless protocols which hope to address it, but which technology provides the most power efficient solution?

To make this assessment, let's turn our attention back to the example of the digital still camera, which is used throughout a consumer's vacation. Recall that by the end of the trip, the camera is full of content – both photos and video – and has just 5% of its battery remaining. Given the following camera configuration: a 4-GB memory card and a dedicated lithium battery with 3 watt-hours (Wh), that would equate to just 150 mWh of battery left.

Given this scenario, the logical question to ask is: how would the DSC behave using three different technologies: 802.11, Bluetooth and UWB? Let's take a closer look.

802.11

Assume that the DSC was designed using a Wi-Fi implementation. It features an average power consumption of 500-mW in active-mode and an average data transfer rate of 20 Mbps. Based on these assumptions, transmitting 4 GB of the camera's data with 802.11 would take 1638 seconds ($4096/2.5$). Given the camera's 500-mW average power consumption, this data transfer would consume 228 mWh – approximately 7.6 % of the camera's battery.

Bluetooth

Assume that the DSC was designed using the Bluetooth protocol and features an average power consumption, in active mode, of 60 mW. It also features a 1-Mbps data transfer rate. Based on these assumptions, transmitting 4 GB of data from the camera to another device with Bluetooth would take 32,768 seconds ($4096/0.125$). Given the camera's 60-mW average power consumption, this data transfer would consume 546 mWh, or roughly 18% of the camera battery.

UWB

Assume that the DSC was designed using UWB technology with an average power consumption of 250 mW during active mode and an average data transfer rate of 100-Mbps.

Realizing this data rate assumes a 400-Mbps physical layer (PHY) rate which is active half the time. Based on these assumptions, transmitting 4 GB of data over the air would take UWB 328 seconds ($4096/12.5$). Given the camera's 250-mW average power consumption, this data transfer would consume 22.7 mWh – less than 0.75% of the camera's battery.

It's clear from this quick comparison that for battery-powered devices, a solution based on a UWB radio would provide the most efficient solution in terms of the battery (see Figure 1).

[Click here for Figure 1.](#)

Figure 1: Given a typical DSC usage scenario, and a DSC designed using 802.11, Bluetooth and UWB implementations, its obvious to see that UWB offers the most power efficient solution.

One reason for this efficiency is that UWB simply works much faster than other wireless technologies (see Figure 2). A similar benefit to the battery would be possible via a Bluetooth over UWB implementation, as previously described, since it provides the best of both worlds: the lowest standby power using Bluetooth and the lowest power per **Mb** during active mode using the UWB radio.

[Click here for Figure 2.](#)

Figure 2: When comparing a 4-GB wireless data transfer performed by Bluetooth-, 802.11- and UWB-enabled devices, the clear winner in terms of speed is UWB.

In addition to its inherent speed, another key reason for the UWB protocol's low-power capability is that it has a well defined superframe structure with specific time slots. Because of this, the protocol is able to support multiple low-power modes (apart from the obvious 'standby' mode found in other wireless protocols and the 'hibernate' mode found in Wireless USB), which can be used during data transmission.

In Wireless USB, these modes are labeled 'ready,' 'standby' and 'sleep,' and allow both the host and device to sleep in a synchronized way for short periods during data transmission. As a result, the average power consumption of UWB is significantly lower in comparison to other wireless technologies (see Figure 3).

[Click here for Figure 3.](#)

Figure 3: UWB's superframe structure is a key factor in allowing it to achieve significantly lower power consumption then either Bluetooth or 802.11 when transferring 4GB of wireless data.

Design considerations

Granted, UWB/Wireless **USB** offers outstanding power efficiency. At the same time though, designing a UWB chip to support a low-power consumption requirement poses a number of interesting challenges. One crucial challenge□especially given the need for minimized power consumption in mobile devices□is how to make the technology affordable to the average consumer.

Migrating UWB to a single-chip **CMOS** solution currently offers the best hope of driving its cost down. This single-chip solution would need to include the radio, PHY, WiMedia MAC layer, and Wireless USB layer, as well as all relevant interfaces.

Here again though, realizing this single-chip solution is fraught with challenges. As an example, consider that the UWB chip design must have low leakage power. But this is not easy to achieve given the amount of elements in the design and the fact that those elements must run extremely fast during active mode.

Consequently, selecting the correct **architecture** and process is absolutely critical. Additionally, the UWB radio must support both high frequency bands and wide bandwidth. Implementing a low-power, high-frequency CMOS radio at 3 to 10 **GHz** therefore, necessitates special techniques for reducing power consumption while maintaining the design's sensitivity and linearity.

Another unique challenge in developing a single-chip UWB solution is in enabling its higher layers (e.g., the complete MAC, conversion layers and security engine) to be able to process data of several hundred Mbits/ in real time.

To accomplish this task, the design must be very efficient in order to keep the power consumption of the various blocks low.

Some of the other issues which the designer will need to address when developing a single-chip UWB solution that meets the low-power consumption requirement include:

- Hopping local oscillator: When designing a single-chip UWB solution, the on-chip hopping local oscillator must cover the entire 3- to 10-GHz range and be able to change its frequency by 1 GHz within a few nanoseconds.
- Power management: The UWB chip's power-management architecture must allow for easy transition between active and low power modes.
- Viterbi decoder and FFT/IFFT block: The FFT/IFFT block and the Viterbi decoder (located in the digital section of the UWB chip) must work at a few hundred MHz, making them difficult to implement while still adhering to the low power consumption requirement.

Conclusion

It is virtually impossible these days to ignore the grasp of battery-operated, mobile devices like cellular phones, DSCs and PMPs on today's society. Such devices require high bandwidth and low power consumption, and therefore demand a wireless data connectivity technology capable of addressing these needs.

UWB and subsequently Wireless USB, with its low power nature and speed, is especially well suited to address the needs of the mobile marketplace, as well as to enable the next generation of wireless connectivity in mobile devices.

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