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Embedded COMPUTING DESIGN

Wireless for wearables

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As wearable devices need more throughput, and as more accurate location positioning and distance measurement becomes important, UWB will be a building block for wearable device infrastructure. This increased location accuracy and throughput will enable wearable devices to really compute.

In the past two years, wearable computing has gone from an unrealistic Star Trek-like fantasy to the next hot market that everyone's trying to enter. In only two years, Google Glass, I'm Watch, Sony SmartWatch, Samsung Galaxy Gear, and, most recently, the Apple Watch have all moved wearable devices into the forefront of the world's attention. The $700 million smartwatch market in 2012 has become a $2.5 billion market in 2014. More recently, we've seen a burst of new fitness tracker wristbands, Bluetooth rings, LifeBlogging devices, and other more esoteric wearable devices reach market.

The first generation of wearable devices has, for the most part, used Bluetooth to communicate with the wearer's smartphone. This makes sense given Bluetooth's pervasiveness in the market – the maker of a wearable device can connect over Bluetooth to virtually any smartphone on the market.

Early wearable devices have used wireless to communicate brief and low-bandwidth content, such as SMS-sized messages or updates, notifications of incoming calls, and the like. But as wearable devices advance, and consumers want their devices to do more, other wireless technologies may be stronger than Bluetooth at meeting the needs of wireless wearable devices.

As wearable devices are entering the market, their connectivity to users' smartphones is handled on a one-by-one basis. This is perfectly reasonable, as devices are entering an empty market. But if wearable devices take off as expected, more sophisticated connectivity will be needed, such as a mesh network in which a large number of devices connect to each other dynamically. This is not possible in standard Bluetooth Low Energy (BLE, a.k.a. Bluetooth 4.0), although it has been developed in a proprietary manner by some BLE chipmakers. Mesh networking is not important when users have one smartphone and one wearable device, but will become more important as users start having more wearable devices, such as a smartwatch, an eyeglass display, and a fitness band. Moreover, as these devices begin to connect to smart homes and smart offices for applications such as security, environment personalization, and more, connecting dynamically to many devices in a mesh fashion will be even more important.

Another important use of wireless technology for wearable devices is location tracking. Wearables can interact with their environment based on their location, such as turning on lights when entering a room or approaching a particular area of a room. Wearables can notify you when you get too far from your smartphone or wallet. Wearables can augment reality based on the exact location and orientation of the wearable device. Wearables can track your fitness as you move around.

But all of these features require precise and fast location awareness. If I want to know when I go more than 5 meters from my smartphone, I won't want a false alarm every time an obstruction of some sort causes my phone to think it's farther from the wireless access point than it really is. And if I want to know when I'm near a friend, I need to know it as I'm nearing that friend, not 5 minutes later and not while I'm still far away.

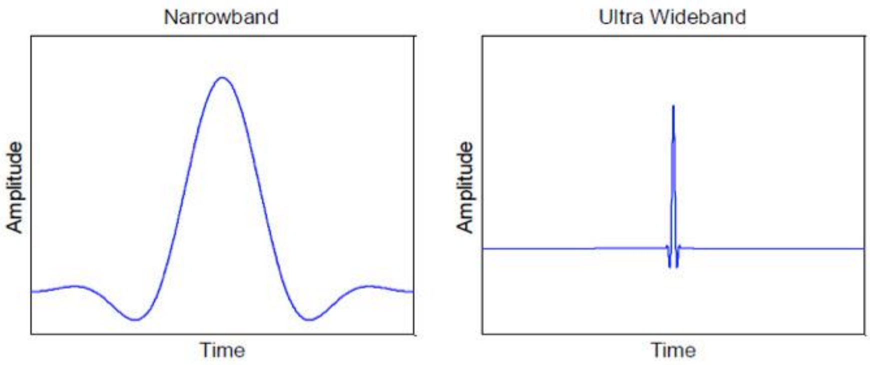
Unfortunately many people have had trouble with location tracking using Bluetooth, with measurable problems in accuracy, latency, and consistency. Location proximity systems based on BLE can take up to 20 seconds to notice you've entered into a critical region, and BLE-based location tracking is generally only accurate to within 3-6 meters. And the farther two devices are from each other, the worse the accuracy.

The lack of accuracy and speed in location positioning sets back location-based applications on wearable devices and smartphones alike. "Indoor location positioning needs to deliver higher accuracy, quickly and more reliably, in order for indoor location applications to really take off on mobile devices and wearables," said Grizzly Analytics analyst Dr. Bruce Krulwich.

The reason for Bluetooth's lack of location accuracy is clear. Virtually all Bluetooth-based location and distances are measured by signal strength. Logically, this makes sense – the farther away two devices are from each other, the weaker the signal will be between them. Unfortunately, the converse is not really true. If signal strength is low, is it because the second device is far away, or because there is an obstruction between the two devices? Many wireless network effects, including obstructions, reflections, refractions, multi-path reception, and more all make signal strength an unreliable indicator of distance.

There are, of course, many other ways of measuring distance and location wirelessly, such as measuring the time of arrival (ToA) or time difference of arrival (TDoA), which tend to be more accurate than signal strength. But narrowband radio, such as Bluetooth and Wi-Fi signals, tends to be hard to use for ToA. Narrowband transmissions are shaped as long pulses that start and end gradually. This is well suited for high-bandwidth and resilient transmission, but it means that there is not a clear start and stop to the radio wave that can be measured precisely and consistently. It also means that wireless effects such as reflection and refraction can significantly damage the clarity of the radio waves.

One solution to this challenge now entering the market, particularly in Internet of Things (IoT) and wearable devices, is ultra-wideband (UWB) radio. UWB radio is designed in a way that enables location and distance measurements that are accurate, consistent, and resilient. This figure shows how UWB compares to narrowband systems like Bluetooth:



The narrow and clearly-defined radio pulses of UWB make it much easier to measure time of arrival, for much more accurate distance measurements than is possible with Bluetooth.

Even more importantly, the following figure shows how each radio system fares in the presence of reflections:

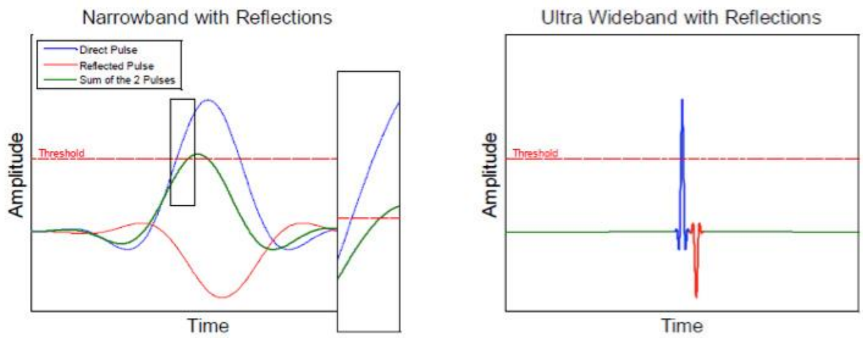


Figure 2: Bluetooth vs. UWB reflection handling comparison.
(Click graphic to zoom)

The narrowband radio ends up damaged by reflections, such that its content is still transmitted, but its signals are weaker, and cannot be used for distance measurement. UWB, on the other hand, remains very amenable to time-of-arrival measurement.

UWB can also be easily implemented in mesh networks. Unlike Bluetooth's design for paired communication between two devices, UWB supports many-to-many mesh communications.

UWB's data rate is not as high as Wi-Fi's, but at 6-7 Mbps is higher than Bluetooth, and is high enough for wireless communication between wearable devices. Most wearable devices transmit short messages, sensor data, location tracking, and the like, but have little need so far for higher-bandwidth communication. (Note that older UWB protocols had much higher throughput, above 100 Mbps, but these were not successful for small devices due to power requirements. Modern UWB systems deliver 6-7 Mbps.)

The recent launch by DecaWave of a single-chip implementation of UWB wireless, compliant with the IEEE 802.15.4 standard, opens up UWB to wearable devices. Other companies deliver UWB in devices or printed circuit board (PCB) modules, but a single-chip implementation is much more fitting for wearable device integration. DecaWave's UWB chip was used by SK Telecom to deliver a very precise location tracking demo at the 2014 Mobile World Congress, making clear that the rationale for improved location measurement does in fact come about in practice.

At this time, UWB has been used for networked devices, but cannot interact with smartphones until UWB-equipped smartphones reach market. UWB-enabled smartphones have been demonstrated, and a number of phone makers are evaluating UWB chips for integration to future models.

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