Enabling sub 10cm positioning accuracy

By Mickael Viot and Matt Gross

GPS WAS THE FIRST major revolution to happen in the domain of navigation in centuries, allowing us to find our way around without maps or landmarks. Unfortunately, GPS does not operate indoors, where 85% of our time is spent.

This is the start point of navigation and geo-location for indoor positioning. The first examples of indoor positioning are already around us, with many shopping malls and public places offering services and apps to help consumers and visitors navigate their way around.

However, people are used to very accurate and reliable outdoor GPS systems. What they require – and expect - is the same level of user experience indoors. While being able to locate a 50m wide shop in a large mall is nice, being able to find a pair of shoes within a store is much better. And this was simply impossible with existing indoor positioning technologies.

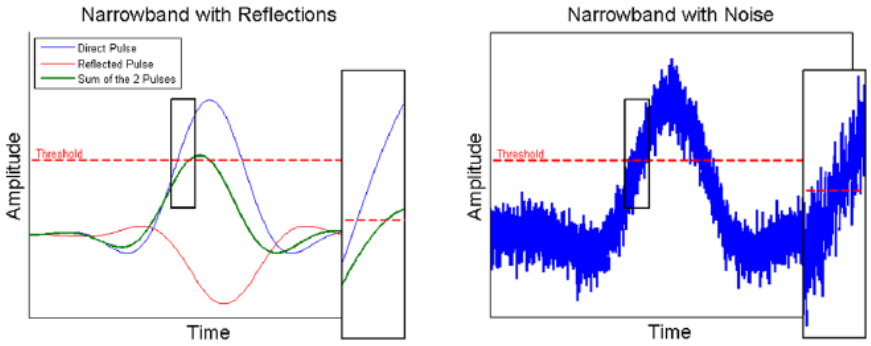

Fig. 1: Narrowband time based.

Many technologies currently being used for indoor positioning are based on measuring RF signal strength. The positioning is based on the assumption that signal strength and distance have a deterministic relationship, according to the Friis equation. Unfortunately, the Friis equation is only applicable in free space. In an indoor environment, multi-path interference and lack of sight channels can cause the range estimate to have an accuracy of tens of meters.

With post-filtering and fingerprinting, these systems are able to improve reliability and accuracy to a few meters in a friendly environment, but any change in the floor plan will require a new round of calibration. This approach will never reach the accuracy required by many applications.

The idea of building indoor location systems on the time of flight of the RF signal is relatively new. By simply measuring the time of flight, you can accurately estimate the distance between an RF transmitter and RF receiver.

There have been attempts to build time of flight systems using standard narrowband RF Wi-Fi or other 2.4 GHz signals. The problem here is that due to the narrow bandwidth, the rising edge of the signal is slow and it is difficult to determine the exact time of arrival in multi-path and low signal to noise ratio environment - see figure 1 - resulting in accuracy of several meters, with reliability still very dependent on the environment.

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IR-UWB: a game changer

Impulse Response Ultra Wideband (IR-UWB) and it implementation as per the IEEE802.14.4-2011 strandard finally offers the performance needed for accurate and reliable indoor positioning. This UWB signal consists of narrow pulses, typically no more than 2ns wide.

This makes it highly immune to multi-path and interference - see figure 2. The IEEE802.15.4 UWB technology supports 10cm of geolocation accuracy with a reliability of over 99%, with a range varying from up to 35m in Non Line of Sight, up to 250m in Line Of Sight.

The high-ranging makes possible to achieve accurate positioning, precise enough to pinpoint an object in a drawer. The time-based ranging also allows a deployment that is cost effective without time-consuming calibration and environment dependent processes. With IR-UWB, it is possible to implement a real-time location system (RTLS) that can offers two different location services, separately or simultaneously.

Tracking of people and assets

In tracking, the location of an object or a person is provided to the system via tags that transmit data packets to be received by fixed beacons. As the beacon clocks are synchronized, it is possible to determine the Time Difference of Arrival (TDOA) to the beacons. By using TDOA and multi-lateration algorithms the system virtually draws hyperboles - see figure 3.

The intersection of those hyperboles determines the exact position of the object that transmitted the blink. This localization can be achieved in 2D or in 3D with an accuracy of 30cm in 3D and a reliability of 95% or better.

It is now possible to locate in which drawer an ECG machine resides or to determine whether staff has stopped to wash their hands before entering the surgery room.

Navigation

Navigation provides location information to a moving object such as a person, a robot, or a forklift. Unlike tracking, where the information flows from the mobile device to the system, the location information is flowing the opposite way.

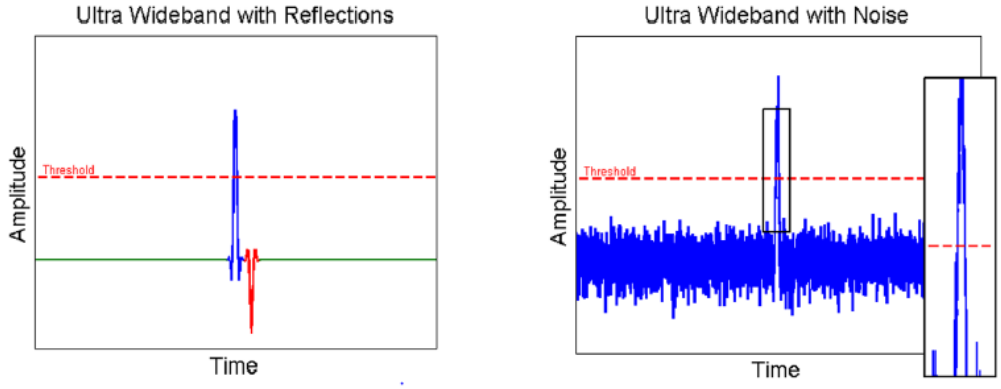

Fig. 2: UWB time based.

It is possible to extend the tracking scheme previously discussed and let the mobile device retrieve the location information from the system. This is, however, rather cumbersome and bandwidth inefficient. The latency incurred may be too large to meet the requirement for real-time navigation. Additionally, the privacy may also be a concern in such an implementation since the mobile device location information is available to the system.

The best option in this case is to use the beacons in broadcast mode and have the tag do the positioning computation. Once again, the clocks from the beacons are synchronized so the tag can apply exactly the same algorithms described above and determine its position.

This approach is similar to GPS, where the infrastructure network acts like the satellites and mobile devices like GPS receivers. Since the mobile node does not need to transmit at all, there are two significant benefits of such an implementation: the mobile location is kept at the node and therefore guarantee of complete privacy; the mobile nodes do not take up any bandwidth and therefore there can be a very large number of devices operating in the navigation mode in a network.

Hardware and software requirements

At first glance, a UWB-based RTLS system might appear to be very complex, requiring high computation and thus not really cost effective. However, a close look at the hardware and software requirement will show that such a system can actually be more cost-effective than existing products. On the hardware side, thanks to the latest advances from the semiconductor industry, there are single chip CMOS solutions available on the market.

A complete radio device can be built in a compact form factor using the IR-UWB radio chip. Taking advantage of power efficient protocols and positioning algorithms, a radio node can be capable of operating for more than 3 years in tracking mode and more than 48 hours in navigation mode. There are significant developments on the software side. Efficient stacks and location algorithms have been developed to allow excellent power efficiency and bandwidth efficiency.

The radio node can have a low cost, low power MCU that is powerful enough to run the complete stack and positioning engine all at once. Abundant software is already available for indoor mapping, route planning and navigation on both desktop and smartphone/tablet and can be easily harvested for UWB-based applications.

What's next?

Highly accurate and highly reliable indoor positioning is now a reality thanks to IR-UWB. Enterprise applications such as healthcare, factory automation, and warehousing are already leveraging this technology to track goods, tools, staff and increase their productivity.

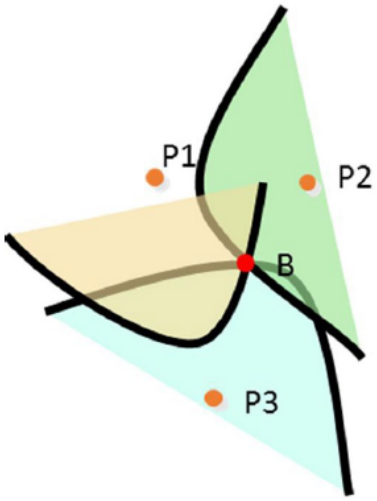

Fig. 3: Multi-lateration based on time difference of arrival.

Car manufacturers are also integrating this technology to offer secure passive entry systems by measuring the real distance between the key and the car avoiding relay attack.

Consumers will benefit from this technology in the near future. The number of applications enabled by a sub-10cm positioning is endless: from carts that will guide them directly to a product on a shelf to intelligent homes capable of controlling light, HVAC and alarm based on the user's exact position. Exactly as GPS has become so important in our daily life and has been integrated into the mobile phone to offer outdoor navigation, the integration of IR-UWB technology will allow anyone to seamlessly navigate outdoors and indoors with a high level of accuracy.