

BLE Channel Sounding Ranging

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Abstract

The recent introduction of Bluetooth channel sounding has opened up new possibilities for device tracking using Bluetooth Low Energy (BLE) devices. By exchanging measurement data between two BLE devices and primarily utilizing phase based ranging but also round trip time, a distance estimation between the two can be produced. This study looks into different ranging algorithms and how to use them to compute an accurate distance estimate. The results show that when a combination of ranging algorithms are used together with a Kalman Filter, the accuracy can be as good as 30 cm short range (1-2 m) and gradually dropping off to 2 m for longer range (16-20 m).

Introduction

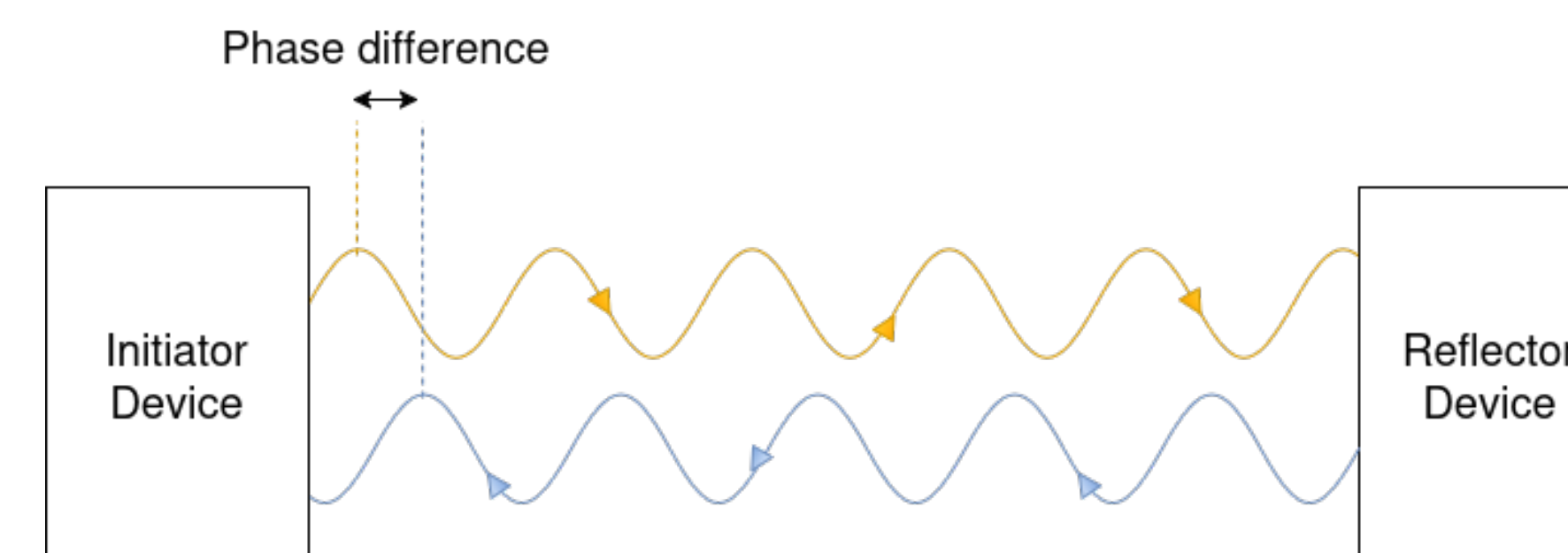
Bluetooth channel sounding is a new feature that has been added to Bluetooth Low Energy (BLE) that enables accurate distance estimation between two BLE devices. Previously, ranging methods has mainly used signal strength which works well in controlled environments but would fail to be accurate in most real world cases. Channel Sounding (CS) is a well-known method that has been used to characterize radio frequencies in wireless communication. The devices, initiator and reflector, exchange measurement data that can produce distance estimation between the two BLE devices, primarily utilizing phase based ranging but also Round Trip Time (RTT).

The goal is to test the accuracy of CS and also to find ways to improve the accuracy. The BLE devices that have been used

are two nRF54L15 development kits made by Nordic Semiconductor. The result is presented in a Graphical User Interface (GUI) as shown in the figure in this section.

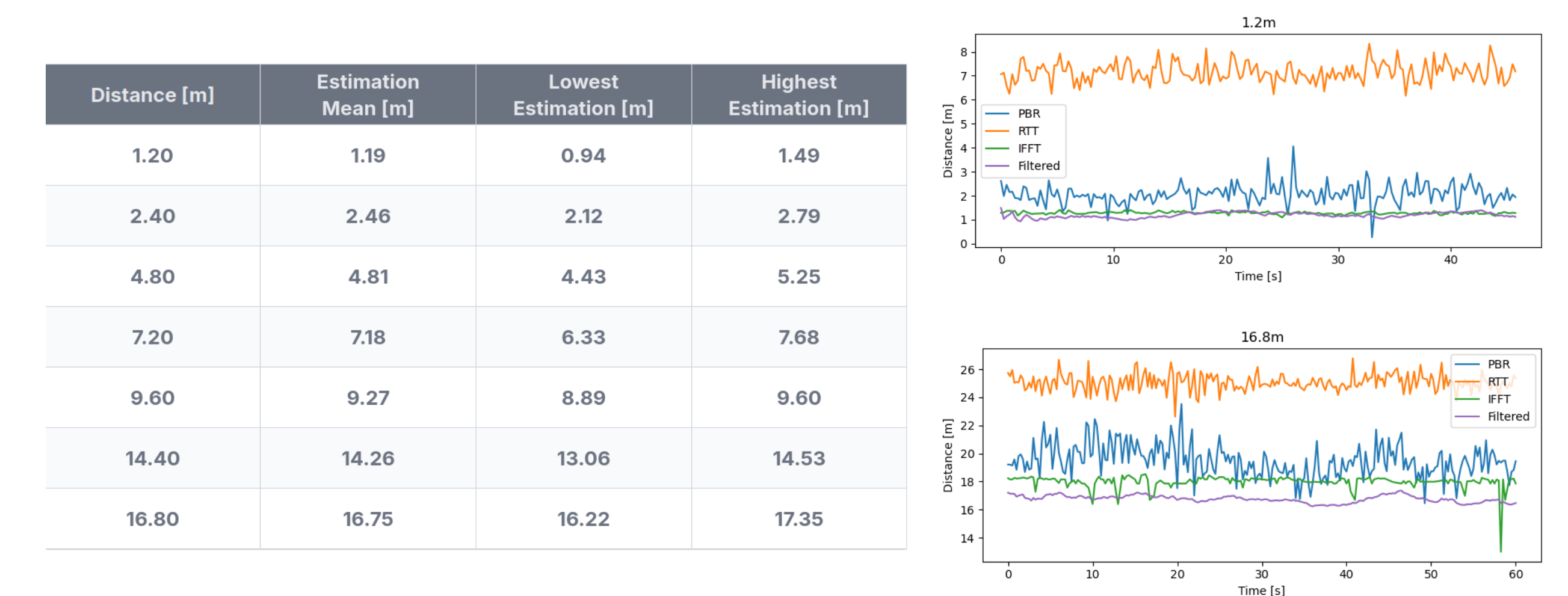
Background

Nordic Semiconductor has made a test-demo for CS. This demo provides three different distance estimation algorithms. Two phase-based ranging methods and a RTT calculation. The two different phase based methods use the same data, i.e., I/Q data samples that contain signal information. Multiple signals in different frequencies are sent out by an initiator device and a reflector reflects these signals. The phase difference between the sent out signals and the received signals can be used to calculate a distance. The phase-slope algorithm bases its estimation on the slope of phase differences across the different frequencies while the other algorithm utilizes an Inverse Fast Fourier Transform (IFFT) to calculate the distance.



Results

Even after bias correction, the three different algorithms produce inaccurate results. They give a general sense of the distance but are prone to sudden shifts, sometimes by several meters. Because of this, a Kalman Filter (KF) was used on a model that combines all three estimations into one more accurate estimate. This results in a distance tracker that is both accurate and smooth, even when the devices are moving.



The implementation of a KF leads to an accuracy around 30 cm within 1–2 m, gradually dropping off to about 2 m accuracy up to 20 m away. The table and graphs above show the results of 60 second tests on different distances in a parking lot outside. Beyond 20 m it gets increasingly difficult to get measurements that are sufficient enough to be used. However as long as there are some, the accuracy is only slightly worse compared to the displayed tests. In an indoor environment with many walls and electrical devices, there are limitations. However, if the devices manage to sustain a reasonable connection to one another, the accuracy is still below 2 m.

Example

The GUI simulates a digital key solution where the distance to a lock is shown both in meters but also graphically. Depending on the distance, a specific range interval glows up and reaching the < 2 meter interval unlocks the lock. In a digital car key application, the other intervals could be used to gradually unlock or activate features, such as turning on lights or unlocking specific doors as the user approaches.

