BLE Indoor Localization System

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Abstract

This proposal details the specifications for a pilot implementation of a wireless indoor localization system. The system can provide anonymized positional data that will consist of occupancy, dwell time, and route information of users as they move throughout the building. This data can be used to reduce the energy footprint of the building, improve security, and help determine optimal locations for event advertising and resource allocation. The proposal details two different approaches towards implementing the localization system which include Bluetooth Low Energy (BLE) beacons and BLE/WiFi scanners. Each system communicates with a centralized hub which provides an interface for data visualization and API to access the data. In order to eliminate any cost to the school, we will pre-purchase and install the hardware devices and will maintain active development over the localization software. Use cases of the system have been outlined below.

1. Introduction

Bluetooth Low Energy (BLE) was introduced with Bluetooth 4.0 with the function of providing wireless communication with a significant reduction in power consumption [1]. The low-power design is ideal for applications that have low data transmission requirements and can be found in healthcare, fitness, and wearable devices. BLE supported devices can operate in a peripheral mode in which they send advertisement packets, a central mode in which they receive advertisement packets, or both [2]. This functionality allows for BLE supported devices to be discovered by scanning for advertisement packets. Our system design takes advantage of this low-power communication to determine the position of BLE supported devices.

Received Signal Strength Indicator (RSSI) measures the relative strength of a signal transmission. When devices communicate over BLE or WiFi, the transmitter of the signal will include an RSSI value within a transmission packet. The receiving device can use this value to determine its relative distance to the transmitter [3]. Our proposed systems take advantage of this value to determine the relative position of a BLE device using trilateration as it moves throughout the building.

Trilateration is a method that determines the position of a movable or stationary point in space using multiple distances between the point and spatially known locations. In our case, the known locations are the hardware devices and the point is the user's device. As the user moves through the building, the distributed hardware devices communicate with the user's device to determine its relative location and relay this data to the central hub where it is made available. All positional data will remain anonymous and all data transmission will be encrypted to ensure the privacy and integrity of the data.

2. System Implementation

This section looks at the implementation details of the two proposed systems. Each system communicates positional data with a central hub that performs aggregation, storage, and visualization. Each hardware device will be concealed within a plastic casing.

2.1 - Bluetooth Beacon

The Bluetooth Beacon design consists of BLE devices that advertise signals to mobile devices. As the mobile device moves through the building, the beacons advertise data packets containing a unique identifier, UUID, and RSSI value. An application running on the mobile device translates the UUID into the known location of each beacon and converts the RSSI values distances. The application then employs trilateration, as observed in Figure 1, to determine the location of the device within the building and transmits this data to a central hub.

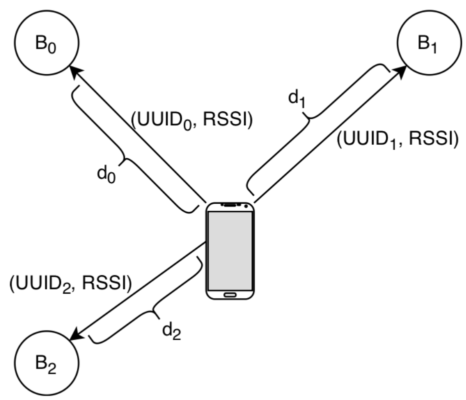

Figure 1. Bluetooth Scanner trilateration design.

2.2 - WiFI/BLE Scanner

The WiFI/BLE Scanner design consists of WiFi/BLE enabled hardware devices and operates in both modalities. Within the BLE modality, the devices passively scan for advertisement signals from BLE supported devices. Most smart phones, wearables, and wireless headphones operate using BLE and continuously advertise data packets. The broadcasted data includes the device's unique MAC address and RSSI value, as observed in Figure 2. Each time an advertisement is received, the scanner transmits the MAC address and distance to the central hub. An application running on the central hub performs trilateration for each unique device which is then made available through the provided interface and API.

Within the WiFi modality, the device acts as an Access Point (AP) and operates by broadcasting data packets to WiFI enabled devices then scanning for replies. Within the reply, the AP receives a MAC address and RSSI value from each device. This data is then relayed to the central hub where it is converted into positional data and made available, as described above. Both operating modes can be coupled together to provide a higher degree of accuracy through cross-validation of positional data.

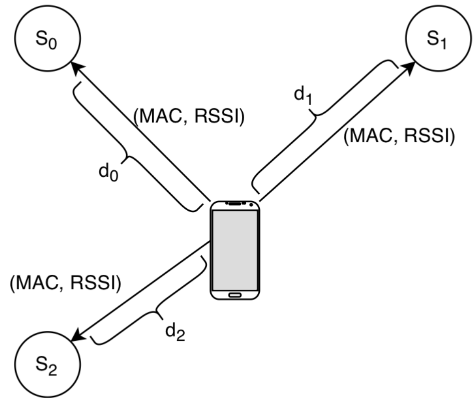

Figure 2. Bluetooth Scanner trilateration design.

2.3 - Future Directions

Bluetooth Core Specification v5.1 introduced high-accuracy direction finding for BLE enabled devices [8]. This design allows for devices to determine the Angle of Arrival (AoA) or the Angle of Departure (AoD) of a signal. When coupled with RSSI metrics or multiple points of detection, this design is capable of estimating the location of a device within 10 cm of its actual location [8]. We plan on following the development of this nascent technology and integrating it into our system as the supporting software improves.

3. Use Cases

This section presents a number of use cases of the localization data. We believe the data will be valuable to administrators and students.

3.1 - Reduced Energy Footprint

The localization data can be used to determine traffic patterns and room utilization at different times throughout the day. This data can be used to schedule HVAC system maintenance or improve facility management decisions to optimize energy usage and save money.

3.2 - Building Security

The system can compare real-time localization data against base-line localization data collected across a longer time span. This will help with the identification of anomalous behavior by monitoring for significant deviations from the base-line.

3.3 - Event Advertising and Resource Allocation

The localization data can be used to determine areas of high foot traffic. This will assist the administration in determining the optimal position to display important announcements and implement new services. Further, students can use these areas for advertising. This will help drive student engagement within the school.

3.4 - Social Map

The real-time data can be used to monitor and track room occupancy. Students can use this feature to determine the occupancy of shared work areas. The data can be presented in an anonymized e.g. aggregated heat map. Additionally, students can opt-in to a de-anonymized version of the platform to allow them to share their location with friends in real-time.

References

[1] Ray, Brian. "Bluetooth Vs. Bluetooth Low Energy: What's The Difference." (2015).

[2] Townsend, K. "Introduction to Bluetooth Low Energy-A basic overview of key concepts for BLE." (2014).

[3] Benkic, Karl, et al. "Using RSSI value for distance estimation in wireless sensor networks based on ZigBee." 2008 15th International Conference on Systems, Signals and Image Processing. IEEE, 2008.

[4] Gimbal Prox Beacon Series 22. https://store.gimbal.com/collections/beacons/products/s22.

[5] Estimote Proximity Beacon. https://estimote.com/products/.

[6] Raspberry Pi Zero W. https://www.raspberrypi.org/products/raspberry-pi-zero-w/.

[7] Arduino MKR WiFi 1010. https://store.arduino.cc/usa/mkr-wifi-1010.

[8] Woolley, Martin. “Bluetooth Direction Finding: A Technical Overview.” (2019).