



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Special Issue 2, April 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

9940 572 462

6381 907 438

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www.ijirset.com



Localizing Presence of Person on a Multiple Floor Building

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ABSTRACT: The major elements of indoor structures are walls and roofs, which weaken GPS signals and make it impossible to use the conventional method of external navigation in an indoor environment [1] because it doesn't produce reliable results. The use of Bluetooth beacons to determine the user's location and assist the user in navigating from one point to another is proposed in this paper. Strategically placing beacons inside large buildings such as malls and hospitals will allow for easy detection of one's location and navigation from one point to another within the building. The paper also proposes a service that detects crowds inside buildings, allowing for easier navigation throughout the complex. The location is determined using the trilateration technique, and the proposed step path is calculated by counting the number of nearby tenants. Dijkstra's algorithm is used for navigation. In this experiment, the sensors and wifi access adapters are used by transmitting the signal to the cloud server. This will prevent users, particularly children, from becoming disoriented in mega-structures with a multi floor buildings, ensuring their safety.

KEYWORDS: Navigation, Bluetooth, Adapters, GPS, Location, Beacons, Wi-Fi

I. INTRODUCTION

Systems that track objects or people, or "tracking systems," have proliferated in contemporary technology. Locating and following someone or anything has various benefits in a number of situations, such as following a youngster around a theme park, finding co-workers in an office, or following luggage through an airport. The most common methods for tracking people[2] involve the deployment of surveillance cameras. The CCTV images must be centralized Ly monitored by a human operator using these systems. Fatigue frequently causes a loss of concentration. Typically, trackers with a Global Positioning System (GPS) implementation are used to monitor vehicles and other objects (GPS). Due to its poor coverage in densely populated areas, the primary issue with GSM is location determination accuracy. The ability to find and follow the movements of items becomes possible thanks to the wide array of personal gadgets [3]that support Bluetooth. The position of a communicating device can now be determined using the growing technology of Bluetooth both within and occasionally outdoors. Although Bluetooth technology does not specifically enable positioning services, it is nevertheless utilised primarily for signal strength measurement, link quality, and bit error rate, all of which rely on the services of the Host Controller Interface. As a result, the Bluetooth protocol's Received Signal Strength Indicator (RSSI) value is utilised to determine how far apart sender and receiver are in a network. The Golden Receiver Power Rank (RSSI value) indicates the disparity between the received signal intensity and the ideal received power rank (GRPR).

1.1 BEACONS

Beacon is a wireless network device that functions as a transmitter to find and locate cell phones using Bluetooth Low Energy (BLE). Push alerts and location-based services that make use of BLE's ability to link wireless devices automatically can be provided using the Apple iBeacon protocol. With the iPad third generation or later, iPad mini, and iPod Touch fifth generation or later, iBeacon is supported, which specifies how BLE connection requests should be delivered. Android phones and tablets can also use iBeacon. When near an iBeacon, smartphones, tablets, and other devices can now do actions thanks to the technology.



Version	Year	Speed	Range
1.0	1999	0.7 Mbit/s	10 m
2.0	2004	2.1 Mbit/s	10 m
3.0	2009	24 Mbit/s	10 m
4.0	2010	24 Mbit/s	60 m
5.0	2016	50 Mbit/s	240 m

TABLE I: Overview of Bluetooth Releases

1.2 TRACKING

There are Bluetooth Low Energy (BLE) beacons positioned all over the indoor area. In order for the system to track the user's location and deliver directions to their desired location, these beacons communicate a special identification to a user's device, such as a smartphone or tablet. The BLE beacons perform dual roles as Wi-Fi access points and navigation beacons, enabling users to connect to the internet[4] and use cloud-based applications. The information gathered by the beacons, including user location data and other pertinent information like the locations of shops or other points of interest inside the building, is stored using cloud server technology. This information can then be used by the cloud server to provide real-time maps and directions for users, which are displayed on their devices.

1.3 TRILATERATION

Trilateration is a method for locating an object by measuring its separation from three known-to-beacon reference locations, or beacons, whose positions are known. The reference points used for indoor navigation are often Bluetooth Low Energy (BLE) beacons positioned in well-known locations all across the indoor environment. As a user reaches the area, their device can recognise the beacon signals[5] and calculate the separation between them and each beacon based on the signal intensity. The user's device can then utilise trilateration to determine the user's position within the indoor space using this distance information. This is accomplished by locating the intersection of three spheres, each with a radius equal to the separation between the user and each beacon and centred on one of the beacons.

II. RELATED WORK

According to Markets, the indoor positioning market will reach \$4.4 billion by 2019 thanks to a persistent demand from industries including healthcare, tourism, and hospitality. Currently, people spend more than 80% to 90% of their time inside buildings (Strategy Analytics). The fact that with rising smartphone penetration and changing client mobile purchasing actions, it is no sensation that start-ups and recognised organisations are swiftly hunting for strategies to give tracking-based applications to engage their users indoors. Indoor Positioning System[6] locates items and persons inside a building utilising many technologies via a smart-tracking or other smart manoeuvre. Businesses can build features for their tracking-based applications using indoor positioning systems. The most widely used way at the moment is Wi-Fi when it comes to the many Indoor Positioning strategies that are available for businesses to choose from. Less than half (50%) of the accused organizations have or intend to utilize indoor positioning systems via Wi-Fi, while slightly more than a quarter (26%) use indoor positioning systems via beacons. Solutions for Indoor Positioning Systems that are scalable and accurate are desired in order to meet user engagement standards quickly and affordably. The fact that many respondents are simply unaware of the IPS alternatives available on the market to handle their business concerns may perhaps be the biggest obstacle[7] in the way of progress today. The cornerstones of indoor positioning are BLE beacons. With the use of this technology, the tracking gadget can detect when it is within range of a beacon and even determine its location when there are multiple beacons nearby. Placement based on BLE has grown in popularity recently. Initially, prototypes could only determine which beacon was closest to the user, but today, we can leverage position data and distance information from numerous beacons.



III. METHODOLOGY

The components used to implement a tracking system based on BLE beacons are iBeacons, BLE nodes, and a cloud-based server. IBeacons are strategically placed throughout a venue. The user created a database of iBeacon identifiers detected throughout the space by first scanning the iBeacons signals. BLE beacons are mobile, whereas BLE nodes are stationary. In this case, BLE receivers, known as BLE nodes, are strategically placed throughout a venue. This time, the Bluetooth Low Energy beacons are moving, attached to objects, or carried by people. Each beacon is programmed to recognise an object or person. IBeacons move around promoting their unique identifiers. BLE nodes collect iBeacon advertisements and upload them to the server. The system can triangulate the location of a beacon when three or more BLE nodes detect it. The Server[8] estimates the clients' locations in relation to the known location of the BLE node. Beacons are a type of BLE hardware transmitter that broadcasts its identifier to nearby electronic devices. Each beacon BLE device must be configured with the following parameters: transmission power, UUID, Major and Minor. At the fixed point, the application compiles their RSSI readings. Hence, the distance between each signal and the client is calculated using these data. The application uses both the whirligig and compass built into the cell phone[9] to determine the direction the user is going since the reference locations do not provide any information that would indicate their position in relation to the beneficiary. A guide will show the position of the client and the reference points as well as the distance between them.

DISTANCE BETWEEN USER AND BEACONS

The Friis transmission equation, a well-known equation in radio frequency (RF) engineering, is the basis for the calculation for estimating the distance between a user and a beacon based on the RSSI value. The transmit power, frequency, route loss, distance, and received signal power are all related by the Friis equation. In the context of indoor positioning systems, we can calculate the separation between a mobile device (user) and a beacon based on the RSSI value using the Friis equation.

The equation is:

$$\text{distance} = 10^{((\text{RSSI} - A)/(10*n))}$$

where:

RSSI represents the received signal strength Indicator as dBm.

A is the benchmark RSSI at a predetermined distance (usually 1 meter).

The path loss exponent is n. (typically between 2 and 4).

The path loss exponent (n) represents the rate at which the signal strength decreases with distance, and depends on factors such as the environment, frequency, and antenna characteristics. The reference RSSI (A) is the received signal strength at a known distance (usually 1 meter) and is used to calibrate the path loss model. The formula works by first calculating the difference between the received signal strength (RSSI) and the reference RSSI (A), and dividing this by the path loss exponent (n) multiplied by 10. This value is then raised to the power of 10, and the result is the estimated distance between the user and the beacon in meters. It is important to note that this formula provides an estimate of the distance between the user and the beacon, and the actual distance may vary due to factors such as signal interference, multi-path propagation, and variations in the environment. However, the formula is widely used in indoor positioning systems and provides a reasonable approximation of the distance.

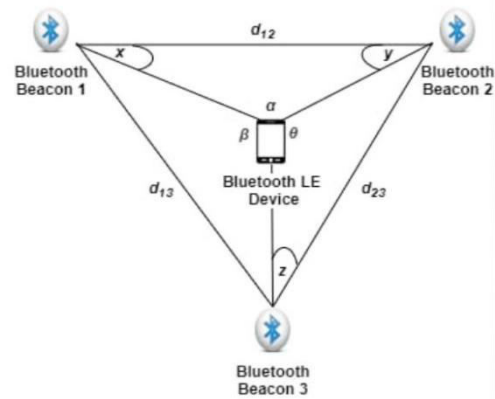
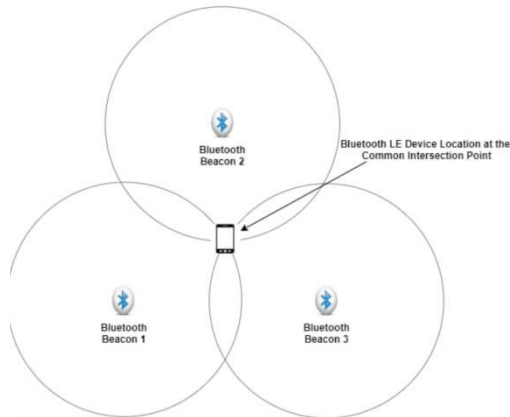


Figure 3.1: BLE Device location at common intersection point.

Figure 3.2: Trilateration Based Location Estimation

CALIBRATION

In order to estimate the distance between a user and a beacon based on the RSSI value, calibration is a crucial step in the approach. At a predetermined distance (often 1 metre) between the user and the beacon, the reference RSSI (A) is measured as part of the calibration procedure. For a certain beacon and user, this reference RSSI value is utilised to calibrate the path loss model, which is crucial for precise distance estimates. Place the mobile device (user) a known distance from the beacon (typically 1 metre) and measure the RSSI value to calibrate [10] the path loss model. This can be done by physically moving the device to the known distance or by using a calibration app that provides a fixed distance between the device and the beacon. Once the RSSI value is measured at the known distance, we can calculate the reference RSSI (A) for the beacon and user using the formula.

$$A = \text{RSSI} + 10 * n * \log_{10}(\text{distance})$$

The reference RSSI (A) can then be stored in the database for the beacon and user, and used in the distance estimation formula to estimate the distance between the user and the beacon.

IV. EXPERIMENTAL RESULTS

The accuracy and effectiveness of the system can then be assessed using the findings of the analysis. Experiments done in a real-world indoor setting to gather data, and use of mobile device (such a smartphone or tablet equipped with a wireless receiver) to measure the RSSI values from the beacons. Based on the RSSI value, reference RSSI (A), and path loss exponent, we can then apply the method to calculate the distance between the user and each beacon (n). To locate the user based on the predicted distances, we can alternatively use trilateration or other positioning methods. Metrics like accuracy, precision, and reliability can be used to evaluate the experimental outcomes. The accuracy of the predicted distance relates to how near it is to the real distance between the user and the beacons. The estimated distance's precision is defined as its consistency throughout a range of measurements. The term "reliability" describes how well a system functions over time and under various circumstances. The accuracy of distance estimation using the method typically varies based on the environment, beacon placement, and device features, according to experimental results. In general, accuracy increases as the user gets closer to the beacon and diminishes as the distance between the user and the beacon grows.

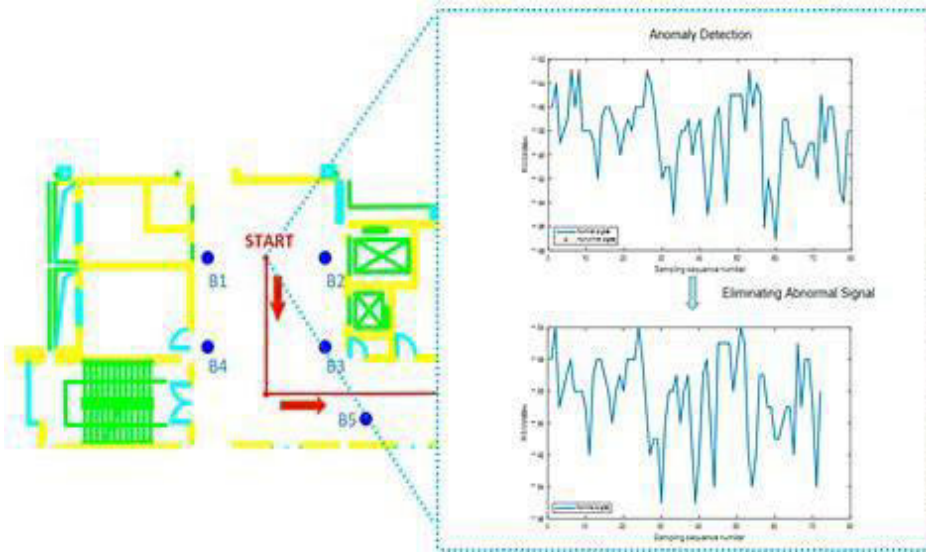


Figure 4.1: Detection of Signal

A variety of issues, including signal interference, multi-path propagation, and device or beacon malfunction, might result in anomalous signals in an indoor positioning project that uses beacons. The system's overall performance may be impacted by these aberrant signals, which might result in erroneous distance measurement and positioning outputs. Many strategies can be employed to get rid of erroneous signals and increase the system's accuracy. Many methods can be employed to get rid of erroneous signals and increase the system's accuracy, including, the signal can be filtered to remove noise and interference, which will increase the distance estimation's precision. Averaging, median filtering, and Kalman filtering are common methods for signal filtering.

Techniques for outlier detection can be used to spot anomalous signals and eliminate them from the dataset. Setting thresholds based on statistical parameters like the standard deviation or interquartile range can accomplish this. The ability to eliminate unusual signals and maintain precise distance estimation over time can be improved with proper calibration and routine device maintenance. Maintenance entails routine battery replacement, lens cleaning for beacons, and firmware updates.

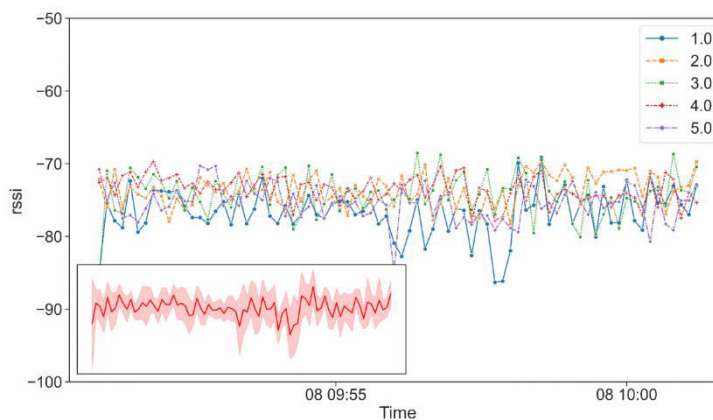


Figure 4.2: RSSI Time Series of 5 tags

The Bluetooth LE's variable channel (frequency) and environmental factors like obstructions, fading, and signal reflections, according to the researchers, are to blame for the significant variations in RSSI values they obtained for



various tags. The Distance-based Proximity Method was used by the system to effectively identify the proper artwork with an accuracy of up to 95%.

V. CONCLUSION

For interior locating, beacons provide a scalable and affordable solution, especially in locations where GPS is unavailable or unreliable. When paired with trilateration or other positioning algorithms, RSSI-based distance estimate formulas can offer reasonable accuracy for indoor location. Continual optimization is required to ensure accurate and dependable positioning because the interior positioning system's performance can vary depending on elements including beacon placement, ambient circumstances, and device characteristics. Overall, beacon-based indoor positioning can deliver useful location-based services for a range of applications, including asset tracking, navigation, and indoor analytics.

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