

Indoor Localization using BLE Technology

Rajashree H S^{#1}, Sahana B^{#1}, Surabhi S^{#1}, T N Apoorva^{#1}, Dr. Parameshachari B D^{#2}

¹Students, BE, Department of TCE, GSSSIETW, Mysuru, Karnataka, India,

²Professor & Head, department, Department of TCE, GSSSIETW, Mysuru, Karnataka, India

Abstract—Implementations of tracking systems have become prevalent issues in modern technology due to its advantage of location detection of objects. Objects are usually tracked using trackers based on GPS, GSM, RFID and Bluetooth signal strength implementation. These mechanisms usually require line of-sight operations, limited coverage and low-level programming language for accessing Bluetooth signal strength. This paper presents an alternative technique for tracking the movement of indoor objects based on Bluetooth communication technology and trilateration. Algorithms are designed and implemented using python.

Keywords-Beacons, ESP32, Python software

I. INTRODUCTION

Tracking systems, systems designed to monitor devices or persons, have become prevalent issues in modern technology. There are many advantages of locating and tracking a person or object, in a variety of contexts such as following the movements of a child around an amusement park, locating colleagues in an office or tracking the movement of luggage through an airport. The predominant mechanisms for tracking humans involve the use of video surveillance systems. These systems require human operator to monitor the CCTV images at a central location. Loss of concentration usually occurs when fatigue sets. Vehicles and other objects are usually tracked using trackers whose implementation is based on Global Positioning System (GPS). These systems display the location of a vehicle within a specified time frame. GPS, however, supports outdoor navigation since it requires lines-of-sight operation with at least three satellites. Another technique for implementing tracking system is by using Radio Frequency Identification (RFID). RFID uses either passive or active tags to track objects. Passive RFID tracking is very common in shops and libraries where tags are attached to products and are checked as they leave the shop by passing through receivers near the doors. Active RFID is popularly used in warehouses and locations like airports where a larger range is needed. RFID tracking uses ultra-low power and there is no need for line-of-sight operation. While RFID tags are very cheap, small and suitable for tracking objects, the sensors are considerably more expensive and require extensive configuration and software installations. RFID signals are easily blocked by objects and other radio waves. One more method for tracking objects is based on GSM communication technology. The GSM equipment communicates with the GSM network through relay stations. The times at which signal arrive together with the angle of arrival from at least three stations allow location detection through triangulation. The main

problem with GSM is inaccuracy in location determination due to its limited coverage in densely populated area.

With the range of personal devices using Bluetooth, the possibility arises to locate and track the movements of objects. Bluetooth has become an emerging technology for determining indoor and sometimes outdoor position of a communicating device. Although there is no specific support for positioning service in Bluetooth technology yet the predominant technology used are signal strength measurement, link quality and bit error rate which rely on the services of the Host Controller Interface. Thus the Received Signal Strength Indicator (RSSI) value of the Bluetooth protocol is used to get a correlation to the distance between sender and receiver in a network. The RSSI value in providing the distance between the received signal strength and an optimal received power rank is called the Golden Receiver Power Rank (GRPR)

If the value of RSSI is in GRPR defined by zero, no unique function can be approximated [8], [9]. This paper presents an alternative technique to track the movement of indoor objects based on Bluetooth technology, least square statistical method and principles of motion. The device being tracked is connected to three Access Points and a Central Monitoring System. PC's with Bluetooth radio adaptors which run multi-threaded Java based desktop applications are used to implement the Access Points and the Central Monitoring System. The device being tracked runs a J2ME application. The Bluetooth communication protocol has client-server architecture. The client initiates the connection and the server accepts or receives the connection. Bluetooth Specification [10] consists of Bluetooth protocol stack and profiles. The protocol stack is a software that has direct access to the Bluetooth device controlling device settings, communication parameters and power levels for the Bluetooth device. The main implemented layers in the stack are the Host Controller Interface (HCI), Logical Link Controller Adaptation Protocol (L2CAP), Service Discovery Protocol (SDP) and Object Exchange Protocol (OBEX) [8], [10]. Communication between devices depends on the type of data transferred.

1.1 Beacons

iBeacon is a protocol developed by Apple and introduced at the Apple Worldwide Developers Conference in 2013. Various vendors have since made iBeacon-compatible hardware transmitters – typically called beacons – a class of Bluetooth low energy (BLE) devices that broadcast their identifier to nearby portable electronic devices.

The technology enables smartphones, tablets and other devices to perform actions when in close proximity to an iBeacon. The identifier and several bytes sent with it can be used to determine the device's physical location, track customers, or trigger a location-based action on the device such as a check-in on social media or a push notification. iBeacon can also be used with an application as an indoor positioning system, which helps smartphones determine their approximate location or context. With the help of an iBeacon, a smartphone's software can approximately find its relative location to an iBeacon in a store. Brick and mortar retail stores use the beacons for mobile commerce, offering customers special deals through mobile marketing.

1.2 Trackers

Tracking objects with BLE receivers are referred as BLE nodes, are placed at a known location throughout a venue. BLE beacons are movable whereas the trackers are fixed. BLE beacons can be tagged with objects and can be carried by the people. Each beacon is configured such that, it had to identify an object or a person. When three or more BLE nodes detect the same beacon, the system can triangulate beacon's location. Bluetooth beacon tracker provides a dashboard for system administration and management. BLE nodes are placed in each floor in grid pattern. While beacons move around advertising their identifiers, BLE nodes collect the client advertisements and upload that data to the server. Then server estimates the clients' location relative to BLE nodes. ESP32 is the combination of BLE and Wi-Fi device which are used to receive RSSI signals from ibeacon.

1.3 Python Software

Python is an interpreted high-level programming language for general-purpose programming. Created by Guido van Rossum and first released in 1991, Python has a design philosophy that emphasizes code readability, notably using significant whitespace. It provides constructs that enable clear programming on both small and large scales.^[26]

Python features a dynamic type system and automatic memory management. It supports multiple programming paradigms, including object-oriented, imperative, functional and procedural, and has a large and comprehensive standard library.^[27]

Python interpreters are available for many operating systems. C Python, the reference implementation of Python, is open source software^[28] and has a community-based development model, as do nearly all of its variant implementations. C Python is managed by the non-profit Python Software Foundation.

1.4 Trilateration

Trilateration is, like triangulation, a technique used in order to calculate a position. While angles are crucial if you want to use triangulation, trilateration is about measuring distances. This technique requires three known access points (APs) and the measured distance from them to the searched device. These distances can be measured by the RSSI value. When the positions and the distances are known, the position of the

searched device can be calculated. This technique can however be used with more or less APs. A position will be more accurate the more APs are used. If only the AP A is used, the exact position cannot be calculated. It is located somewhere on the circle with center A and radius being the distance from A to the device.

II.RELATED WORK

An Indoor Positioning Algorithm Using Bluetooth Low Energy RSSI

As the Bluetooth technology evolves to its 4.0 version, great applicational opportunities emerge based on the inquiry of Received Signal Strength Index (RSSI). In this paper, a positioning algorithm using Bluetooth Low Energy RSSI is proposed for indoor application. First in our algorithm, RSSI value is pre-processed: outliers of RSSI are removed, and moving average of RSSI is calculated. Finally, a triangulation algorithm is used to calculate the current location of the mobile device.

An Indoor Tracking System Based on Bluetooth Technology

The mechanisms used in this paper require line of-sight operations, limited coverage and low-level programming language for accessing Bluetooth signal strength. It presents an alternative technique for tracking the movement of indoor objects based on Bluetooth communication technology, principles of motion and least square statistical method. Algorithms are designed and implemented using Java.

An Analysis of the Accuracy of Bluetooth Low Energy for Indoor Positioning Applications

This study investigated the impact of Bluetooth Low Energy devices in advertising/beaconing mode on fingerprint-based indoor positioning schemes. Early experimentation demonstrated that the low bandwidth of BLE signals compared to Wi-Fi is the cause of significant measurement error when coupled with the use of three BLE advertising channels. A multipath mitigation scheme is proposed and tested. It is determined that the optimal positioning performance is provided by 10Hz beacons and a 1 second multipath mitigation processing window size.

Survey of Wireless Indoor Positioning Techniques and Systems.

This paper provides an overview of existing wireless indoor positioning solutions and attempts to classify different technique and system. The typical location estimation schemes of triangulation, scene analysis, and proximity are analyzed. We also discuss location fingerprinting in detail since it is used in most current system or solutions. We then examine a set of properties by which location systems are evaluated, and apply this evaluation method to survey a number of existing systems. Comprehensive performance comparisons including accuracy, precision, complexity, scalability, robustness, and cost are presented.

Model-Based Localization and Tracking Using Bluetooth Low-Energy Beacons

In describes a high precision localization and tracking method that makes use of cheap Bluetooth low-energy (BLE) beacons

only. Here tracks the position of a moving sensor by integrating highly unreliable and noisy BLE observations streaming from multiple locations. A novel aspect of this approach is the development of an observation model, specifically tailored for received signal strength indicator (RSSI) fingerprints: a combination based on the optimal transport model of Wasserstein distance.

Indoor positioning system using Bluetooth beacon Technology

In describes the algorithms for determining a user's position in an indoor positioning system (IPS) significantly affects the accuracy of the results. An effective algorithm moderates and in a best-case scenario cancels out factors that negatively affect the positioning result. The purpose of this is to research which algorithms are currently used for indoor positioning using BLE Beacons, and to evaluate one of these algorithms in a real-world experiment with regard to different error factors.

Vision and RFID data fusion for Tracking people in crowds by a mobile Robot

In describes an active perception system, consisting of a camera mounted on a pan-tilt unit and a 360° RFID detection system, both embedded on a mobile robot. To perform such a task, it is necessary to efficiently track humans in crowds. In a first step, dealt with this problem using the particle filtering framework because it enables the fusion of heterogeneous data, which improves the tracking robustness. In a second step, considered the problem of controlling the robot motion to make the robot follow the person of interest.

The Study on Using Passive RFID Tags for Indoor Positioning

In describes the Radio frequency identification (RFID) technology that put an RFID tag on objects or people, so that they can be identified, tracked, and managed automatically. With its wide application in the automobile assembly industry, warehouse management and the supply chain network, RFID has been recognized as the next promising technology in serving the positioning purpose. Existing positioning technologies such as GPS are not available indoors as the terminal cannot get the signal from satellites.

In certain scenarios, tracking technology provides significant benefits over traditional such as RFID and has fuelled the development of BLE receivers. These devices are mounted to Permanent Fixtures and continuously monitor the environment for beacons or other BLE signals. When a tagged asset is nearby, the BLE receiver broadcasts this information back to cloud service via Wi-Fi or cellular data. Implement a tracking system based on BLE beacons has included the components are ibeacons, BLE nodes, and a cloud-based server.

IBeacons are placed throughout a venue. By first scanning the iBeacons signals, user built a database of iBeacons identifiers detected throughout the space. BLE beacons are movable while the BLE nodes are fixed. In this case BLE receivers referred to as BLE nodes, are placed at known locations throughout a venue. This time, the BLE beacons are moving, attached to the object or carried by people. Each beacon is configured to identify an object or person.

Ibeacons move around advertising their identifiers. BLE nodes collect the ibeacons advertisements and upload that data to the server. When three or more BLE nodes detect the same beacon, the system can triangulate that beacon's location. The Server estimates the clients' locations relative to the BLE node's known location.

Beacons are hardware transmitter having class of BLE device that broadcast their identifier to nearby electronic devices. Each beacon BLE device must set with transmission power, UUID, Major and Minor parameter. Whereas Esp32 is the combined device of BLE and Wi-Fi module. Each beacon are differentiated by their major parameter and ibeacons are advertising their identifiers. Whereas Esp32 will scan the all

the parameters of ibeacons and then uploaded to server. In server by using the python software ,RSSI signal is converted into distance. From the beacons parameters , distance is calculated by using the formula

$$d = a * (r/t)^b + c \quad \dots \dots \dots (1)$$

where a,b,c-constant

d-distance

r-RSSI signal

t-RSSI reference power at 1 meter

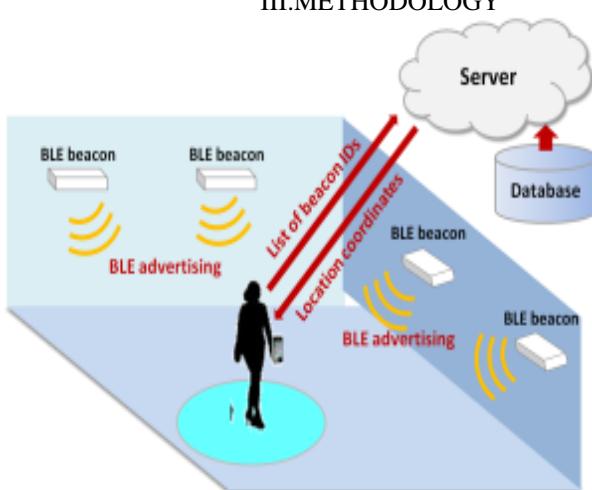


Figure 2: Sketch of Indoor Localization

Here 3 different i beacons are used to track the tracker using trilateration method. In trilateration method, the (X, Y) is unknown points and known points are (X_i, Y_i) of the 3 different beacon which are distance r_i from the unknown point that is given as

$$(X-X_1)^2 + (Y-Y_1)^2 = r_1^2 \dots\dots\dots (1)$$

$$(X-X_2)^2 + (Y-Y_2)^2 = r_2^2 \dots\dots\dots (2)$$

$$(X - X_3)^2 + (Y - Y_3)^2 = r_3^2 \quad \dots \dots \dots \quad (3)$$

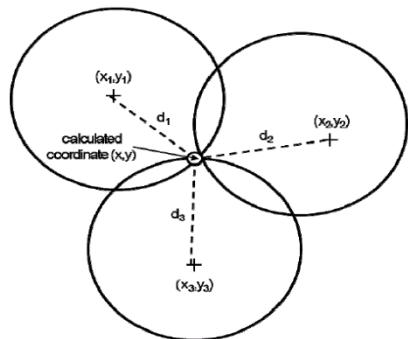


Figure2: Trilateration technique



Figure 3:ESP32

ESP32 is a series of low cost, low power system on a chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. The ESP32 series employs a Ten silica Xtensa LX6 microprocessor in both dual-core and single-core variations and includes in-built antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power management modules. ESP32 is created and developed by Espressif Systems, a Shanghai-based Chinese company, and is manufactured by TSMC using their 40 nm process. It is a successor to the ESP8266 microcontroller.



Figure4: Kontakt Beacon

Beacons are small Bluetooth-powered radio transmitters that can trigger real-world actions or identify a physical location by relaying contextual information to nearby smart devices.

Test, demo, and manage your beacon application securely at scale from anywhere in the world. Locate and track the location and flow of assets and staff with our Bluetooth Low Energy tags and solutions.

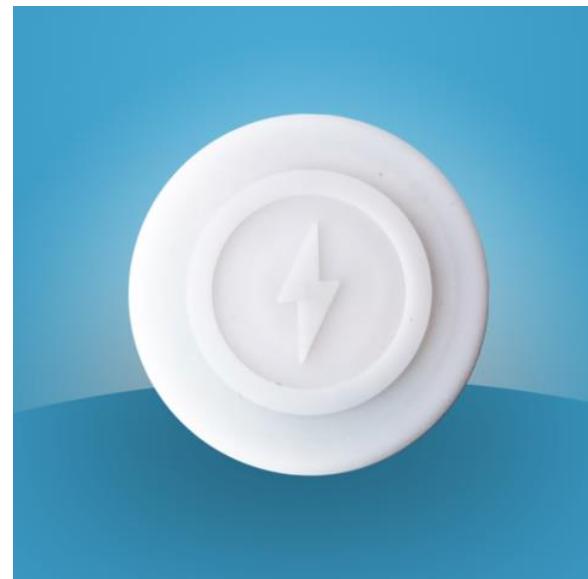


Figure 5: Radius network beacon

RadBeacon USB is a fully standalone Bluetooth Smart proximity beacon using iBeacon, AltBeacon and Eddystone technology, implemented in a tiny USB package.

As the industry's first multi-beacon, with concurrent support for all major industry-standard proximity technologies, the RadBeacon USB enables simultaneous proximity services across iOS, Android, and other emerging mobile environments. Supported beacon proximity technologies include

- iBeacon
- AltBeacon
- Eddystone UID
- Eddystone URL

No batteries means no *dead* batteries. RadBeacon USB is powered from any standard USB port. You can use any USB AC adaptor, car adaptor, or computer with a spare USB port. However, we recommend using our official RadBeacon USB Power Supply. Its UL listed and certified.

The most flexible coin cell battery beacon.

1. Officially the first beacon compatible with iBeacon and Eddystone (UID, URL, TLM, EID) at the same time.
2. iBKS 105 is cost efficient and reliable, the main keys for your beacon deployments.
3. From 30 to 40 months of battery lifetime (CR2477) advertising once per second.

All the parameters of this product can be modified. Please check out our 'iBKS Config Tool' app, available for iOS and Android.

iBKS 105 is a Bluetooth Low Energy (BLE) beacon based on **Nordic Semiconductors nrf51822** chipset that uses a CR2477 coin cell battery



Figure 6: Accent system Beacon

The PCB is ready to implement different **sensors** that could be assembled for big orders.

The plastic enclosure can be opened with a simple movement (applying some force) without tools.

This model can be attached to any surface using its double-sided sticker.

This model is 100% compatible with our Eddystone + iBeacon firmware updates.

VI RESULT

The concept of tracking indoor object has been proposed based on BLE Beacons. The object being tracked is initialized using the least square statistical method where the principles of motion supported by the Bluetooth communication technology are used to track the object.

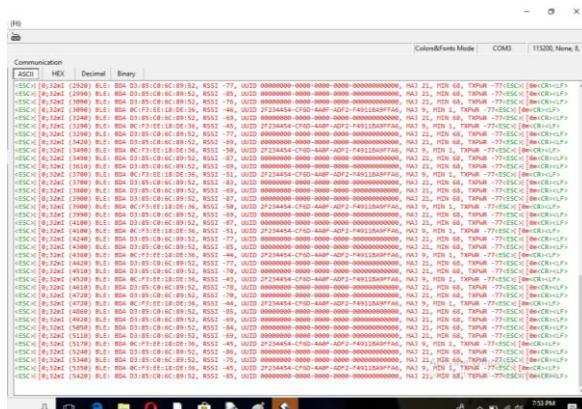


Figure7: Scanning of ibeacons components by esp32

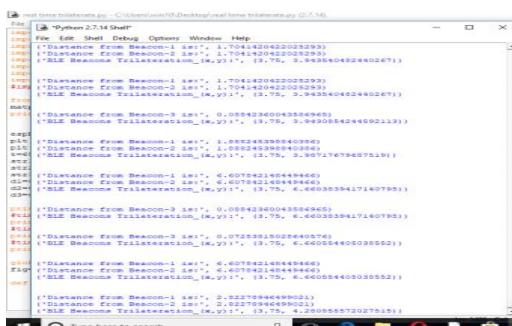


Figure8: Result of distance between the ibeacons and esp32

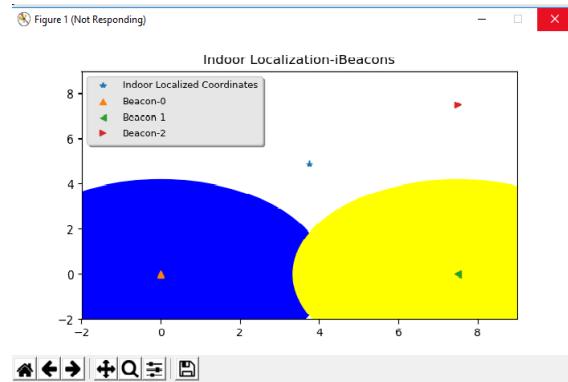


Figure9: Output of trilateration method to locate the esp32 location

IV. CONCLUSION

In this paper, an algorithm is proposed for indoor positioning. The proposed algorithm first pre-processes RSSI by single-direction outlier removal and moving average. Then distance between mobile devices and beacon is calculated using python. Finally, beacons location is determined by trilateration. The system serves as a basis for implementing tracking system that has the following characteristics to enhance its performance and functionalities. It does not require line-of-sight operation. The tracker system and the Access Point system implementations require low memory and computational overload.

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