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Indoor Localization using BLE Technology

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Abstract:
This document provides a comprehensive review of indoor localization techniques and stimulate new research effort in this feild Implementations of tracking systems have become 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.

Key words*:* Beacons, ESP32

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) .

1.1. Trilateration

Trilateration method is used to determine the relative location of use by measuring distances using geometry. Trilateration method does not have an offline phase unlike like fingerprinting method . However, it needs coordinates location of Access Point (AP) as well as AP's Mac Address stored in a centralized database. Trilateration based positioning technologies uses three fixed noncollinear reference nodes to calculate the physical position of the target node n 2D . Figure 31shows the trilateration based positioning.

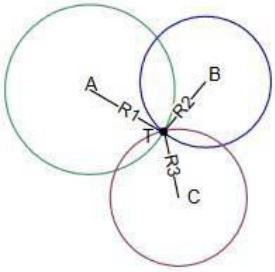


Figure.1: Trilateration based positioning

1.2 Beacons

I Beacon 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.

1.3 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 ibeacons 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.

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**.**

2.1 Location Detection Techniques and Location Algorithms

Several different methods are used for location techniques and algorithms in wireless based localization. Location detection techniques can be divided into three general categories: proximity, triangulation and scene analysis as shown in Figure. Proximity Detection (Connectivity Based Positioning*).* Proximity detection or connectivity based is one of the simplest positioning methods to implement. It provides symbolic relative location information. The position of mobile client is determined by cell of origin (CoO) method with known position and limited range . When more than one beacon detects the mobile target, it simply forwards the position nearest where the strongest signal is received. The accuracy of CoO relates to the density of beacon point deployment and signal range. This method is implemented with several wireless positioning technologies, in particular, the system running infrared radiation (IR), radio frequency identification (RFID) GSM (Cell-ID), bluetooth, and custom radio devices .

III.METHODOLOGY

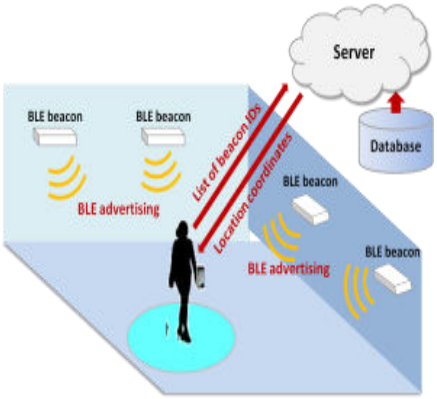


Figure.2: Sketch of Indoor Localization

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 BLEreceiver broadcasts this information back to cloud service via Wi-Fi or cellular data. Implement a 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. beacons 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.

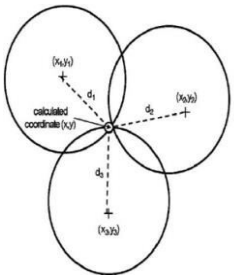


Figure.3: Trilateration technique

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

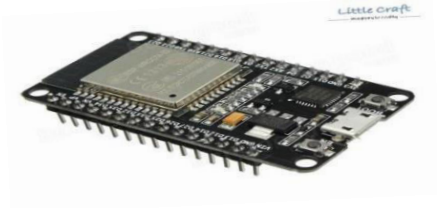


Figure.4:ESP32

Figure.5: Radius network beacon

III.Architecture

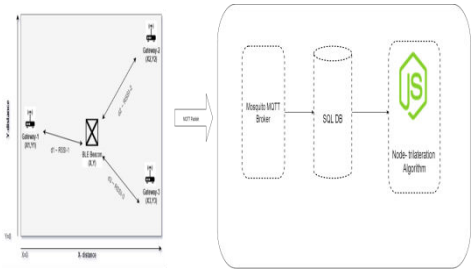


Figure.6:System architecture of Indoor Localization

- Movable BLE iBeacons with custom UUID, Major, Minor, RSSI Profile.
- Zone Specific ESP32 based BLE Gateways with connectivity to the MQTT Broker.

A).Working Scenarios :

- The Beacon will advertise its data on the interval of every X seconds.
- The MQTT broker will be hosted on the Windows/Linux Based Computer
- The Gateway will send the data on the MQTT topics on an interval of every Y seconds
- The MQTT broker will receive the data on the specific topic and then it will store the data with timestamp in the SQL DB hosted on the same machine
- The NodeJS based separate function will be developed to pull the latest data of the sensor from the SQL DB and filter out the Coordinates X&Y of the beacon

B).Implementation

(i). Implementation:

Measure the X & Y distance of the room.
Place the Gateways at 3 location in triangular pattern.
Note down the coordinates of the gateways - G1(x1,y1), G2(x2,y2) & G3(x3,y3).

(i). Calculating the reference distance with RSSI mean values :

Place the BLE beacon in the triangle at various locations and take the multiple readings of the location, calculate the average value.

(ii). Calculate the ratio of Distance : RSSI

(iii). Calculating the B(x,y) values:
Take the last 10 RSSI values of the beacon from each gateway, calculate the average.
Convert the RSSI to distance using the ratio
Use the 3-border positioning formula to calculate the B(x,y)

C).Gateway Placement

The ESP32 based Gateways are places at 3 corners of the rectangle which having coordinates (X,Y).
The Coordinates of the each gateway captured and calculated in meters. Ex. G1 – (X1,Y1), G2-(X2,Y2) & G3- (X3,Y3). For the future calculation of trilateration algorithm

The BLE beacon is placed at distance of exact 1 meter to capture the reference RSSI for the distance calculation formulae
The Gateways are configured to work with the IoT and Cloud technology. The gateways are programmed to send the BLE scan data to MQTT end point. The MQTT broker is hosted by mqtt://test.mosquitto.org. with the topic name /ble to publish the data
The nodeJS code hosted on the machine is subscribing to the /ble topic and receives the data when available.
The code filters the mac ID of the scanned BLE beacon and then filters their RSSI.
Once we get the RSSI values of same Beacon from all 3 gateways, the distance calculator algorithm calculates the d1,d2,& d3 i.e. distance between beacon to Gateway1 , 2 and 3.
Once we get all the values from the distance algorithm, we pass those values to the trilateration function
Since we already inserted the values of the Gateway placements in the trilateration algorithm, inserting the values of the distance will calculate the X,Y coordinate of the beacon.
In our project, BLE beacon (iBeacon) is simulated by our mobile phones.

D).Data Flow:

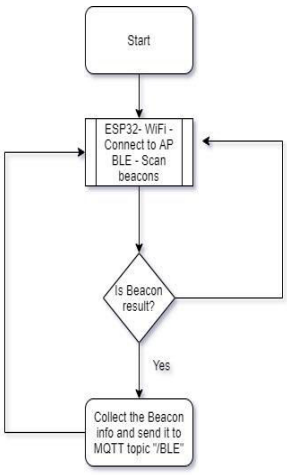


Figure.7(a): Data flow of User

IV. RESULTS

The results shows that positions can be determined with an accuracy.We have used a data set gathered by beacons in an indoor building environment.

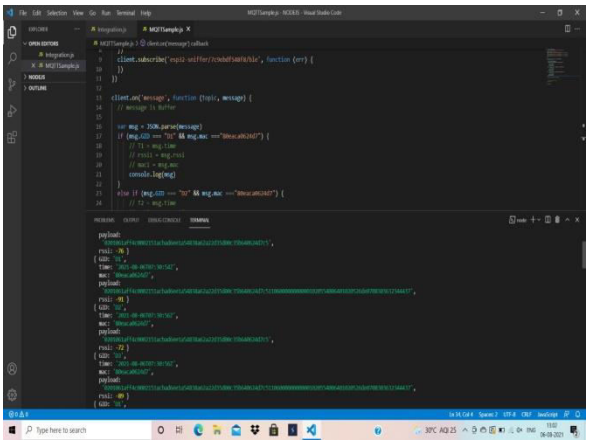
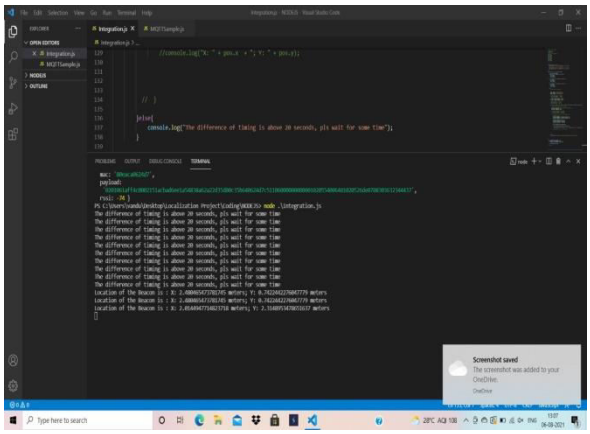
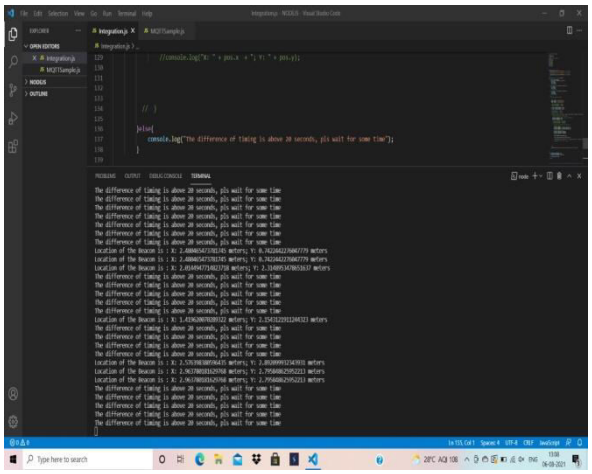


Figure.8(a):Scanning the ESP32

Here, the user will check that all the three gateways are connected with the X & Y co-ordinates.i.e D1,D2,D3.



Figure(b):The difference of timing is above 20 seconds.



Figure(b):The difference of timing is above 20 seconds.

Tracking the object by ESP32,it show the actual co-ordinate of object.

V.CONCLUSION

In this paper, an algorithm is proposed for indoor positioning. The proposed algorithm first preprocesses RSSI by singledirection 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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