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Realtime Indoor Location-Based Passenger Tracking System using Bluetooth Beacon for Airport Authority

Radhika Karwa[1], Inderjeet Saluja[2], Prof. Charusheela Nehete[3]
[1, 2, 3]*Department of Information Technology, Vivekanand Education Society's , Institute of Technology, Maharashtra, India*

Abstract: ***For years, airport operators have tried to make visitor experiences a little better. Security & quality of service provided is always been an important part of airport management team. For example, Security and quality of service shows the growth from a preliminary target operations and facilities, into a chief focus on remitting a passenger-absorbed service proficiency. The project was galvanised by the requirement to assess the whole airports performance stationed on the complete security aspect from arrival to departure terminals and vice versa, this need has not been so far addressed by people. For this reason, with Bluetooth beacons, airport operators will get the chance to connect better with their passengers. In the proposed system, we have developed a real-time position locating system with the help of the Bluetooth Low Energy (BLE) technology to pillar the collaborative communications by using star topology option to increase the suitability of the suggested beacon proposal. We have used a range-average algorithm that measures the shortest distance. The execution result dipits that our beacon will detect the presence of passengers at certain time and locations, and then the passenger current location will be sent to the administering server via reader/gateway through the broadcast from the beacon. Moreover, the administering server will generate alert based on location which are marked as restricted area.Thus, our system successfully implements indoor positioning using BLE beacons technology thereby providing most efficient and completely automated airport security system.***

Keywords: Bluetooth Low Energy, Real Time Location Services, Range-Average Algorithm , Alerts , Airport Security, Indoor Positioning, Readers, Beacons.

I. INTRODUCTION

Real-time location systems (RTLS) are becoming much more used since wireless technologies started to provide the necessary infrastructure to develop useful services. Real-time location systems cites to a general region of technology which permits to decide the current position of an object of interest based on real-time information collected through a wireless device or set of devices of some nature [1]. When speaking about RTLS systems,we mainly can have two perspectives systems are built upon: server-based and client-based RTLS systems.

And they mainly differ on whether the object being located is moving or standing still. The global positioning system (GPS) was one of the first well-known cases of RTLS to track vehicles but currently we assist this technology being used in outdoor environment in several scenarios such as logistics applications, transportation management or land-based transports. In the case of client based system, the positioning of the wireless device is made right in the direction of the device and normally it uses an application which examines the signals from Wi-Fi or access points, LED or Beacons and usually also comprises of a database in which the signal strength is recorded. Asset tracking depend of its nature and location. Indoor environment changes radically the technologies that can be used and almost excludes GPS and cellular based systems due to their lack of signal. In these type of conditions, different technologies are considered like Wi-Fi or Radio-Frequency Identification (RFID) or the recently developed Bluetooth Low Energy (BLE) technology.

Some existent scenarios that use some of these technologies include equipment tracking, real time personnel finding, patient and guest finding [2], among others. Some of these scenarios represent typical server-based RTLS scenarios that is characterized by devices which have Wi-Fi built-in and enabled in them, or have a Bluetooth enabled tag / Bluetooth enabled beacon which is transmitting a unique key that will be recorded by a specific device that transmits it to a server that calculates positioning using a specific algorithm or techniques. Server-based scenarios are totally adequate and currently very used for asset tracking in Airports.

Let's consider a feasible scenario of the proposed system. A company which is providing services to the airport & the company constructs an real-time locating system by placing adequate number of smart BLE Beacon and wireless Beacon Receiver in the

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airport building. When a passenger arrives at the checkin counter, he/she will receive an Beacon attached to the backside of the boarding pass, at the same moment, message of the passenger details which contains the encrypted passenger ID, flight details, gate number and his current position inside the airport. Shortly after the beacon device determines the presence signals, it promptly starts forwarding the presence signals hop-by-hop through the network into the backend database. If any of the passenger enters the danger zone a alert is sent to the admin telling that this particular beacon is in the danger zone. All this is possible by using BLE beacons and readers. Due to the fact that the system is continually tracking the real-time location of all the passengers, so even if he / she leaves the location where the passenger had requested for help, the airline team will still be able to reach the passenger at his / hers current location.

II. RELATED WORK

BLE-based locating systems has several applications,most known consists of Smart Home, Smart cities and Smart hospitals to name a few. Bluetooth can utilize RSSI to be a technique for measuring positions indoors. In this particular section we will review the literature in the field of BLE based locating systems and applications.

A. Indoor Positioning System using BLE.

The ability to navigate indoors using BLE and a smartphones has been studied by Milan Herrera Vargas. The author set up an indoor environment composed of two BLE beacons and a smartphone. He claims that the main purpose of his report was to introduce indoor navigation based on BLE but that this technology is still limited which led to unstable measurements and bad
accuracy [3]. The bad accuracy is an interesting aspect of IPS and is an known issue. Silke Feldmann et al. have in their scientific paper tried to overcome this problem with and optimization method least square [4]. They got aprecision of 2 meters but think it could be even better by using a Kalman Filter.

B. Position Tracking for Blind People using BLE

Tengqingqing Ge made a comparable research about indoor navigation but focused on making it available for blind people [4].By using BLE beacons and a smartphone, he developed and compared two different positioning softwares. The first one, based on triangulation and fingerprinting, gave good a static performance, but was not a reliable navigation system. In the second software a proximity algorithm was instead used, along with a real blind person. This experiment gave on the other hand a better output letting him conclude that a blind person was able to navigate through the route without any help from other people.

C. Wheelchair Tracking at Airports

Wheelchairs in huge areas, for example airports which are usually very big areas, visited by a large number of people. A typical airport is divided into different security zones, where both employees and passengers are moving around. Wheelchairs are often used to transport a disabled passenger from one of the airports entries to the gate. Wheelchairs could easily be temporary lost and it can require time and energy to track them down. Fortunately they could be equipped with BLE beacons and be positioned inside an application to make the search easier. Since there are a lot of smartphones covering the biggest part of an airport, these beacons could be located with the help of this big crowd. Even if the passengers do not want to use this application, the employees could at least all
have this application running on their smartphones.[6]

D. RTLS in Hospitals

Main goal of the system was to provide technicians the possibility to quickly find for a given equipment, through a website in a desktop computer we assume to exist in each floor. Real Time Location System or RTLS systems can help the organization to identify, locate, monitor patients, visitors, physicians, auxiliaries, equipment and objects. Next problem dealt here was with Emergency Rooms, the most severe effect of overcrowding in ED is an increased mortality or death rate. Other effects include increased severity of medical errors, prolonged length of stay in the hospital, and delayed time-critical interventions. Ohashi defend that the use of a RTLS in a hospital can increase hospital workflow and efficiency, through the use of a workflow analysis framework and detection of inefficient routes in Emergency Department from by medical staff made possible by the use of a bracelet or tag that registers movements inside ED. [7]

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III. SYSTEM BLUEPRINT

A. *System Design*

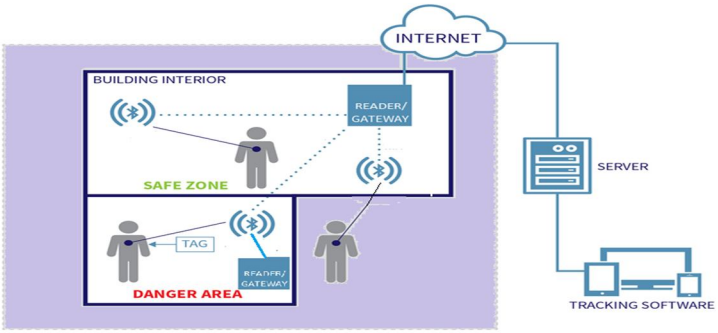

Figure 1: System Architecture

We are using BLE beacons technology & Real Time Location Services (RTLS), to implement indoor passenger positioning system for airport. Using this we constantly track the current position of passenger within airport and ensure that the security of airport is also maintained. The airport authority (ie Admin) will have the following accessible / manageable:

1) *Dashboard:* The dashboard will indicates all the active beacons and their respective readers which will be displayed to the admin in a tabular format. The table will contain the following:

a) The status of the beacon (Green indicating Active, Grey indicating Inactive).
b) Name of the Beacon linked with particular Reader along with the name of the reader.
c) The closeness of the beacon to reader is displayed as strength in the form of percentage.
d) Time which the beacon sent the last data transmission to the reader.

2) *Beacons & Readers:* As there will be many beacons and readers in the airport therefore the Admin will be given a grant by which they will be able to add, edit & delete both Beacons and Readers.

3) *Floor Map:* A map will be available to the admin which will be having the whole airport mapped into it. Admin will be able to view the whole airport along with all the passengers moving on the map. When an passenger goes into the danger zone an alert will be generated & displayed to admin. Apart from this the application has been developed using:

a) *REST API:* REST or Representational State Transfer is a software architectural style that characterize a set of constraints to be used for creating Web services which can used for communication between web services. Web services that follow to the REST architectural style, are termed as RESTful Web services, provide interoperability between computer systems on the Internet.[9] A REST API also referred to as a RESTful web service is based on REST technology, which is an architectural style and approach for communications often used in web services development. A REST API is developed in the system which helps in getting and posting the data to and from the beacons and readers. Using this data we can come to know about the current location of the passenger within the airport.

b) *MQTT Broker Integration with REST API:* MQTT Broker integration with a application is very crucial for any process / production management application in Industrial and Customer implementation. MQTT broker was built with options to store data into any back end data storage via the custom data store.[8] MQTT helps the IoT devices and the IoT Application to form a connect and enables data transmission between them.It fetches the data from cloud MQTT Broker to web servers MySQL Database. The data is parsed using json and stored in corresponding table. Whenever required this data can be displayed to the user.

c) *MySQL Database:* MySQL is an open source RDBMS (i.e relational database management system) & is a component of the LAMP web application .This implies that very new record will be inserted row wise keeping the column static. In the application we have used MySQL database for storage and retrieval purposes.

d) *BLE Beacon:* Bluetooth beacons are hardware transmitters - a class of Bluetooth low energy (LE) 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 a beacon. Bluetooth beacons use Bluetooth low energy proximity sensing to transmit a universally unique identifier picked up by a compatible app or operating system. 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. One application is distributing messages at a specific Point of Interest, for example a store, a

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bus stop, a room or a more specific location like a piece of furniture or a vending machine. This is similar to previously used geo push technology based on GPS, but with a much reduced impact on battery life and much extended precision.Another application is an indoor positioning system, which helps smartphones determine their approximate location or context [10].

e) *Reader:* Readers are devices capable of receiving and processing Bluetooth signals. Reader will receive data from the BLE Beacons and will send it to the server or database.

B. *Flow of Operations*

The major components of the system are Beacon and Reader, which help to track the passengers around the airport. So as soon as the Beacons are Switched ON, they repeatedly start broadcasting encrypted messages containing all the essential information about the beacon to the respective reader. These signals / messages are transmitted over the broadcasting channel, similar to an normal beacon. Furthermore, devices like Beacons send out the messages having the passengers present location to the Reader or Gateway currently near them on the same time. In the succeeding content, we will demonstrate the proposed systems flow of operations, Wherein we depict a scenario when a beacon attached to boarding pass which is with the passenger comes in the communication spectrum of multiple readers. Secondly as soon as the beacon is on it starts discovering the distance from another Beacons & therefore it locates itself based on the distances values calculated. According to our application the beacon calculates the distance between it and various readers and it locates itself, so that the determined position in the airport can be displayed on the administrator dashboard instantly.

Formerly after the location determining process has been concluded, the Beacon comprises of the positioning signal containing the encrypted Passenger ID along with other informations, the identified distance values, and then broadcasts the positioning signal. The purpose of transmission of the positioning signal is to alert the backend that this particular passenger has been reported at this particular location. When any of the Beacons sends the positioning signal, it utilises the Range-Average based approach to rebroadcast the positioning signal. The purpose / need of rebroadcasting the positioning signal by the beacon is to relay the signal to the Reader / Gateway. The Range-Average approach provides an confirmation that once a particular positioning signal by a Beacon has been broadcasted, the Beacon does not rebroadcast the same signal again. As soon as the Reader acquires the positioning signal commenced from a particular Beacon, it uploads the parameters of the positioning signal to the database. When any Beacon senses the location change of the passenger then, it rebroadcasts the message by using the Range-Average Algorithm again. The purpose / need of rebroadcasting the positioning signal by the beacon is to relay the signal to the Reader / Gateway. As soon as the server receives the data from the Reader, it forwards the same data to the database. Within the database the system then makes an new entry and stores it in a new row, since all the locations of a particular passenger is stored in the database therefore the admin will be able to see the location history of all the passengers. Then the positioning message is sent from the database to the Application, and finally the Application displays the data of the message giving a confirmation that the backend of the system is conscious of the passenger's presence within the airport. The figure 2 given below shows an illustration for sequence of operations taking place in the system, wherein the designated numbers correlate with several items explained in the lines above. For this particular illustration we would consider that there are 3 Beacons in the conveyance path between the Application and the Reader. From the Figure 2, we make out the intercommunication between the backend system and the application. From the system admin view, they will be able to detect the positions of all the passengers at particular location in a particular time interval. [11]

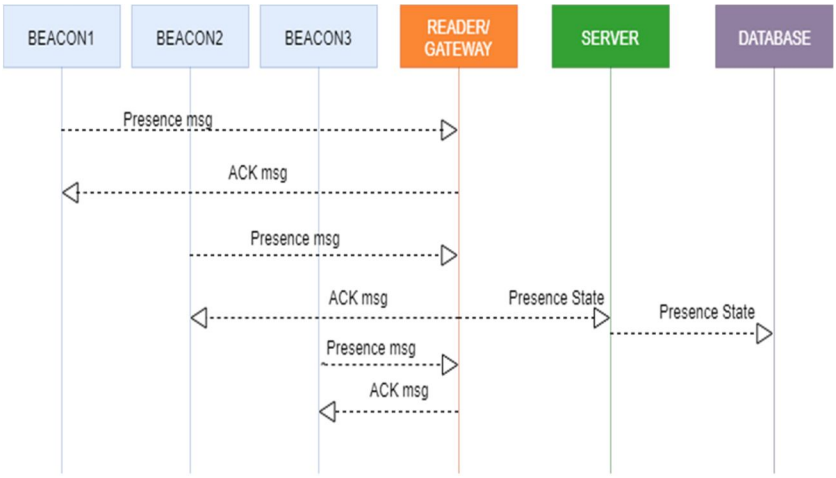

Figure 2: Illustration of Flow of operation.

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C. Positioning Method

We have used a IPS positioning method which is known as Trilateration. Trilateration is, like triangulation, a technique used in order to calculate a position. This technique requires three known access points (APs) and the measured distance from them to the searched device. While angles are crucial if you want to use triangulation, trilateration is about measuring distances. RSSI, or "Received Signal Strength Indicator," is a measurement of how well your device can hear a signal from an access point or router. It's a value that is useful for determining if you have enough signal to get a good wireless connection.When the positions and the distances are known, then the position of the searched device can be calculated.[12,13,14]

$$RSSI = 10n \log(d) A$$

where d = distance between devices, A = txPower produced at distance of 1m, n = signal generation constant, usually in free space n = 2, but it will vary based on structure geometry / shape - for example, a wall will reduce RSSI by ~4dBm and will affect n accordingly and [RSSI] = dB.

As seen in figure below 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.

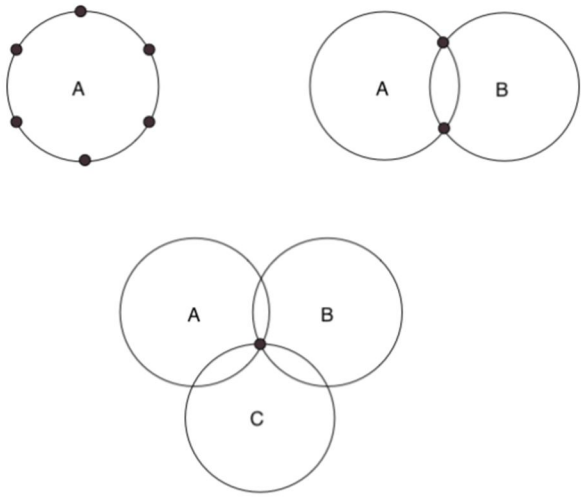

Figure 3: Trilateration illustrated for one, two and three transmitters. By adding transmitters, possible positions will be excluded.

This is also known as proximity based positioning. The equation describing this circle is:

$$d^2 = (x - x_a)^2 + (y - y_a)^2$$

where d is the distance, {xa, ya} are the coordinates of A and {x, y} are the unknown coordinates of the searched device.

But adding the AP B, it is possible to exclude all but two positions. Since both APs A and B know their distance to the searched device it is possible to calculate the two points, more particularly the two intersections of the circles. It is also known as bilateration and the solution is obtained by solving:

$$d_a^2 = (x - x_a)^2 + (y - y_a)^2$$
$$d_b^2 = (x - x_b)^2 + (y - y_b)^2$$

where da, db are the two known distances, {xa, ya} and {xb, yb} the known coordinates of A and B and {x, y} the unknown coordinates.

To calculate the exact location of the searched device, a third AP C needs to be added. It is then possible to exclude one of the earlier computed intersecting points and thus get a final position. This is done by solving these three equations:

$$d_a^2 = (x - x_a)^2 + (y - y_a)^2$$
$$d_b^2 = (x - x_b)^2 + (y - y_b)^2$$
$$d_c^2 = (x - x_c)^2 + (y - y_c)^2$$

where the two first equations are the same as in equation 3.5, referring to A and B, and the third referring to C.

One unique point with coordinates {x, y} which satisfies this system.[6]

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IV. IMPLEMENTATION

In this module , we have shown the implementation details including the hardware and the software used in our proposed system.

Item	Technology
Web App	Desktop Browser.
Beacon	E7.
Reader	G1 (WiFi & BLE Gateway).
Server	Django web server with REST API & MQTT Broker.
Database	MySQL.

Table 1: Details about System Hardware & Software.

A. Hardware Description

1) The Beacon Used In This System

a) Model: E7 (Manufactured by SHENZHEN MINEW TECHNOLOGIES CO LTD)
b) Battery Life: 3 years
c) Transmission Range: 100m
d) Feature: Waterproof IP67, Casing Screw Design, Accelerometer Sensor

2) The Gateway Used In This System

a) Model: G1 (Manufactured by SHENZHEN MINEW TECHNOLOGIES CO LTD)
b) BLuetooth Version: 5.0
c) Transmission Range: 300m
d) Feature: LED Lights, Fast Read and Monitor BLE Devices.

B. Software

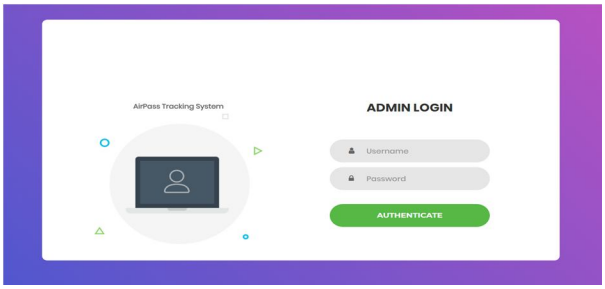

Figure 4: Admin Login

This will be the admin login page which will be operated by authorised user of the airport authority .

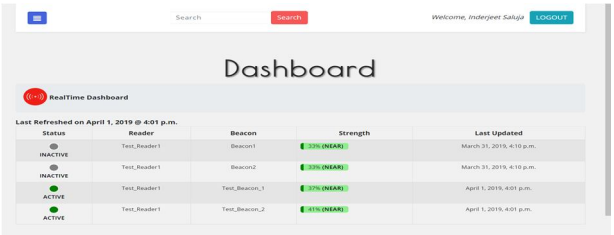

Figure 5: RealTime Dashboard

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This will be the main page which will show all the active beacons and the readers. Along with this it will show the mapping of beacon respected to the particular reader and its signal strength with respect to different readers which helps in finding the actual location. The signal strength will be divided into 3 categories which would indicate that if the signal is strong or weak. The strong signal would indicate that the beacon is near to the corresponding reader and similarly a weak signal would indicate that the beacon is far from the corresponding reader which is capturing the signal from it and there is chance that the beacon would disconnect after time.

The following pages are implemented for Beacons and Readers and below mentioned are pages for Beacons:

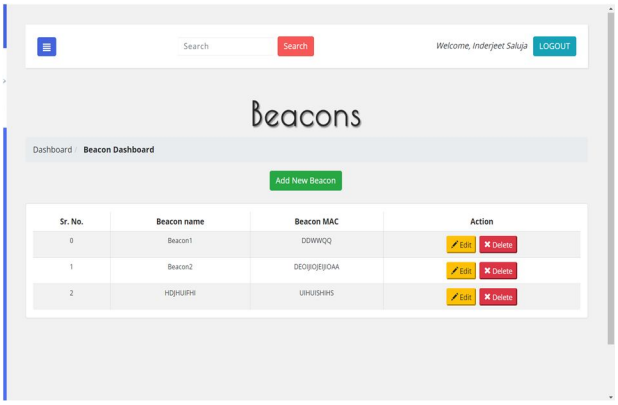

Figure 6: Beacons Dashboard

This is an example of beacon dashboard which will be similar for reader also. This page is the beacon dashboard & will show all the beacons along with operations such as beacon addition, updation and deletion as per the requirements. It would display the details of each and every beacon which are Beacon Name and Beacon MAC. Appropriate alerts will also be displayed on the beacon dashboard when a beacon is added or updated or deleted.

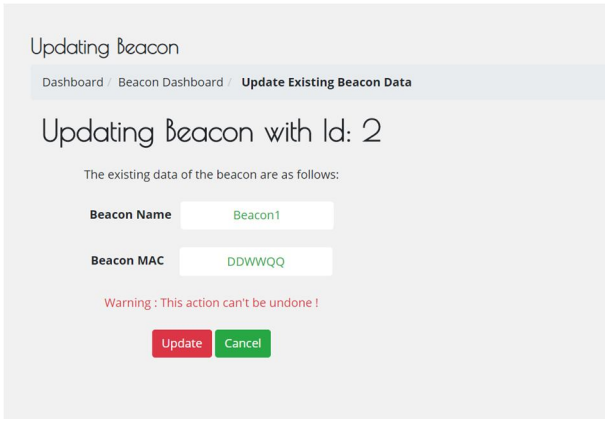

Figure 7: Alerting the existing beacon.

This page will help the authorised admin to modify particular beacon and updating its status.

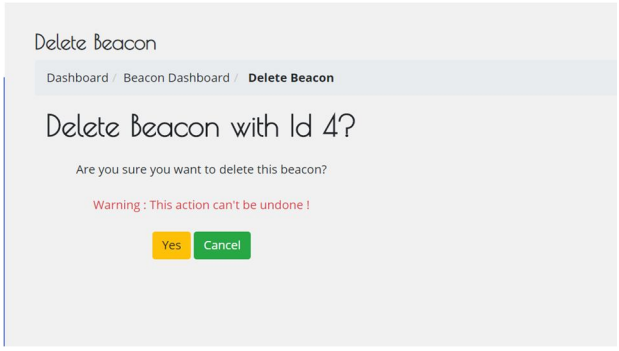

Figure 8: Delete the existing beacon.

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This page will help to delete or to remove the unwanted beacon in the system.

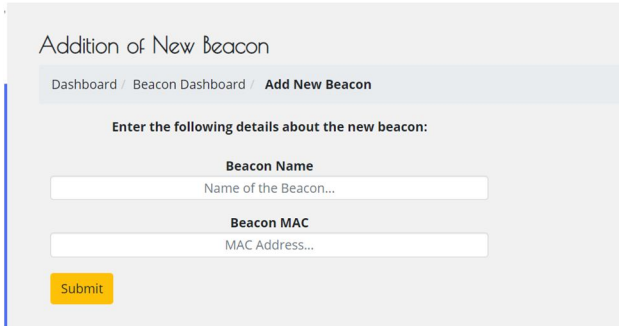

Figure 9: Addition of New Beacon

This page will help in adding the new beacons in the system by mentioning their Name and MAC Address.

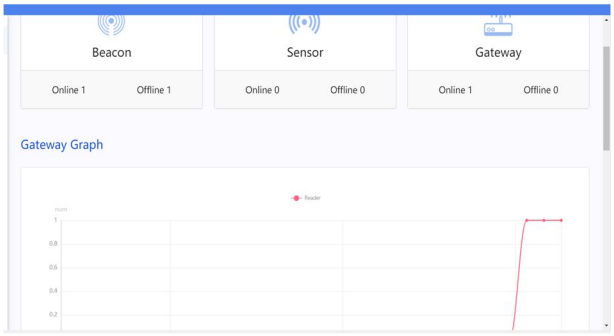

Figure 10:Graphical Representation Dashboard

The Graphical Dashboard displays the numbers of online and offline Beacons, Sensors and Gateways. If all gateways or sensors or beacons are offline, will display blank graph and indicate the online field as zero.

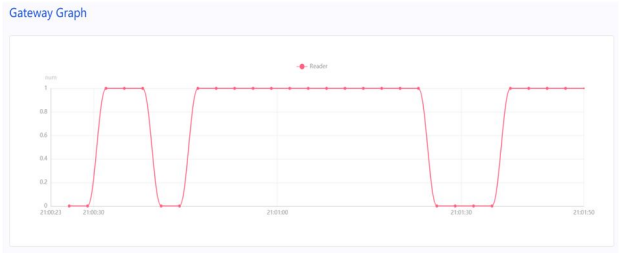

Figure 11: Gateway Signals Graphical Representation

The Gateway Graph displays the numbers of BLE devices scanned by online gateways in line chart and updates dynamically every 3 seconds and then displays to the admin.



Figure 12:Beacon b2 Signal Graphical Representation

In Beacon Graph section we can select the beacon from the left hand side and then the system will display its Rssi value scanned by the online gateway in line chart on the right side, which is updated in real time. If all gateways are offline or no gateway scans the device, will display blank graph.

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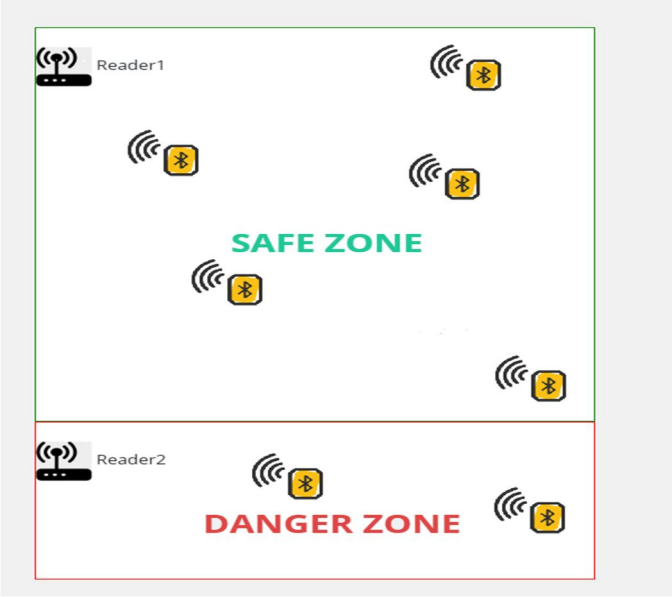

Figure 13: Live Floor Map for Indoor Positioning

This Live map will be available to the admin. Admin will be able to view the whole area along with all the passengers moving on the map. You can select the gateway that you are interested in, and when the number of iBeacons received by the concerned gateway increases or decreases, it will be displayed dynamically on the corresponding device list and floor plan. When an passenger goes into the danger zone an alert will be generated & displayed to admin on the dashboard. Figure 10 is an illustration of the concept described above where different beacons navigating through the airport are displayed on the map with their respective updated locations.

V. RESULTS

In this module, the results from the experiments conducted during the system testing has been demonstrated, including the static positioning result.

A. Static Positioning Test

We have placed one reader in one corner and other in opposite position direction while one on wall.Than we stood at various varying location with beacons(behind the wall also) and collected 20 samples at each location. We have use average of the 20 collected samples at each location to represent the real RSSI value. The below Table 2 have tabulated the collected data and correlated.

Distance (m)	RSSI (dB)
1.0	-48.1
1.11	-52.5
1.41	-53.1
1.80	-61.4
2.23	-60.9
2.69	-61.9
3.16	-70.3

Table 2: RSSI value calculated s at different position from a beacon.(with or without wall).

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B. Results Obtained

1) Tracking of passengers in the airport using beacons attached to their Boarding Pass.

2) Alert the admin if the passengers walk / go to danger areas in the airport.

VI. CONCLUSION

Considering the proposed architecture and various literature studies, we have developed a web based application. The techniques proposed will positively help us in achieving the objectives successfully. We have performed various testing experiments in term of positioning system and evaluated the feedback about the UI from users, we gained various perception. One of the inspection was the accuracy, as it vary greatly for navigation systems and static positioning systems. As compared to the other indoor positioning systems , the performance of the first system of the static positioning is not that bad as they use similar hardware and technologies, also since there are many ways to optimize navigation performance and the user experience. The most crucial key is to entirely use the surrounding information obtained. To describe the path using elements in the surrounding and to give instruction to users to follow elements in the surrounding interpret the navigation. Based on the performance of navigation systems and the user feedback help us to tie a conclusion that by using the proposed method the travel security measure and experience of passenger of the airport will increase to greater level along with giving better results.

VII. FUTURE SCOPE

(i)Since this application makes use of a combination of processing elements which are: beacons , readers, desktop PC's ,mobile application, there might be a possibility of the full system failure which could be caused due to a specific sort of attack, which is known as DoS (Denial of Service) attack. To prevent this kind of attacks a strong security Method for Ad Hoc Networks can be used.

(ii)Also as we are able to track the real time location of particular passenger in the airport therefore we can develop an android application by which if any of the passengers are lost or are not able to find their direction toward their assigned gate, they can use this android application by which the app will direct them towards their gate on time such that they do not miss their flight or the flight is not delayed as the passenger has not boarded the aircraft on time. The will display a path with markers on the app which should be followed by the passenger such that they will reach their assigned gate.The app will have the entire airport map feeded into it by which direction to the gate will be done.

(iii)The data which is sent from beacons to readers and from readers to the database will be encrypted for security purposes making it less possible to tamper the data which is sent or received.

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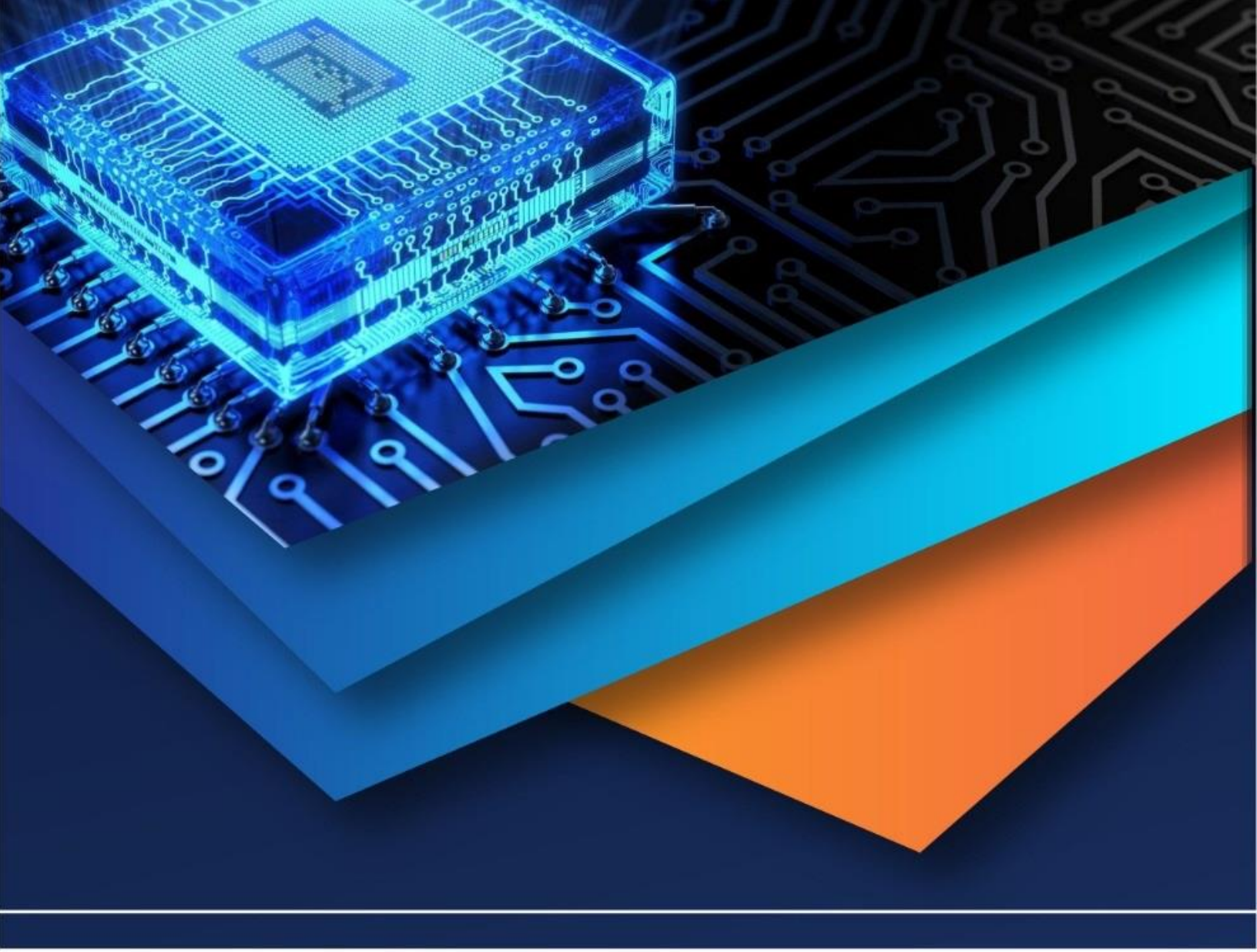

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