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Development of Pilgrim's Automatic Counting System and Health Monitoring using Machine Learning

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Abstract: *Every year, thousands of people will be gathered at Mecca and Madinah to perform Hajj and Umrah. This massive congregation need an efficient and organized monitoring system by respective management to ensure the safety of the pilgrims using the modern technology nowadays. In this paper, it will discuss an idea to help the mutawwif to monitor their pilgrim's group members with an automatic ID system and localisation system tracking. The device will use Bluetooth architecture system to communicate with the server system where each device will have its own unique address ID that represent each pilgrim member. So, each one of them will automatically counted based on its user ID. Besides, the average recieved signal strength from the Bluetooth is measured to identify the distance of the pilgrim from the server using Path Loss Model. Next, the device will also be compact with a health safety features to update the current condition of the pilgrim. This feature will allow the mutawwif to keep track the pilgrim situation if any emergency occur during the congregation. Proving the trilateration method in estimating a location has successfully been achieved by using Bluetooth communication with ESP32 module. While conducting the testing, error in defining pilgrim's location is analysed. As the reference point is at the least stable received signal strength range, the bigger the error between real coordinate and estimated coordinate. Therefore, in this research, it hopes to benefit other in managing pilgrim during hajj time. Improvement can be made in ensuring the system can be run smoothly to process real time data. So, estimation of the location will be more accurate.*

Keywords: Bluetooth Light Energy, Localization, Path Loss Model, Trilateration

1. Introduction

On the 12th month of Hijrah calendar, there will be an annual occasion of Hajj that will be perform by Muslim. During Hajj and Umrah occasion, there will be huge number of Muslim gathered in Macca and Medina. The occasion normally happens during the summer season where the weather is very dry as the temperature could reach up to 40°C. This could cause a difficulty in managing and monitoring each of the pilgrim especially for the first timer.

This paper brought an idea on the development of automatic counting system by manipulating Path Loss Model (PLM) to calculate the distance of pilgrim around mutawwif. Besides, a health monitoring system is also embedded to the pilgrim's device which will let the guider monitor daily health of the pilgrim. This device allows mutawwif to estimate the location of the pilgrims around them without requiring any manual head count. At the end of this project, a localization algorithm using trilateration method was proven to be used which could autonomously tracked

the pilgrim in an area of 15m radius from mutawwif with an additional feature of push button as health monitoring system for the pilgrim.

2. Literature Review

Pilgrim Difficulties During Hajj

The date of Hajj is determined by Islamic calendar where the events of Hajj need to be completed at fixed dates over a 6-day period from 8th Zulhijjah to 12th Zulhijjah which is a onetime event per year. Due to this fact, around two to three million pilgrims attend the Hajj pilgrimage in Saudi Arabia annually (Atique & Itumalla, 2020). These numbers do not include those who came there to perform Umrah which increase gradually during the month of Ramadan as umrah can be perform anytime. This showed one of the largest religious gatherings that could anticipate producing serious challenges in terms of safety and health care management by Kingdom of Saudi Arabia (KSA) and Hajj guider appointed as mutawwif (Atique & Itumalla, 2020).

To ensure the safety and security of Hajj pilgrims based on Taibah, Arlikatti, Andrew, Maghelal, and DelGrosso (2020), the Saudi Ministry of Health (MOH) invests huge amounts of money to keep the hygiene of the pilgrim in a good condition and give clear guidelines of preventive measures that pilgrims can take. This shown that a proper planning, preparation, coordination, and emergency responses is required by the respected management in handling mass gathering. Normally, the Hajj season will come during the summer season where the desert country temperatures become as low as 13°C (55°F) in January and as high as 43°C (110°F) starting from June to October (Taibah et al., 2020). This causes dry weather during the pilgrimage session and mutawwif always need to check their group members all time in ensuring that they are in a good health condition.

The mass gatherings there, may pose significant public health challenges where it involves a large number of individuals at a particular location with different backgrounds, nationalities, employment, and language skills. Based on Bhaskar and Chung (2013), during religious mass gatherings, traumatic events can happen. The fatality rate would be exacerbated by a lack of health system preparedness to adapt to stressful incidents (Bhatti, 2018). Therefore, here came the duty of mutawwif to keep their pilgrim members under control. Over millions of people there, it is important for the mutawwif to know the location and current health condition of the pilgrim. This will ensure that everyone is in a good health condition to perform Hajj.

Bluetooth Technology

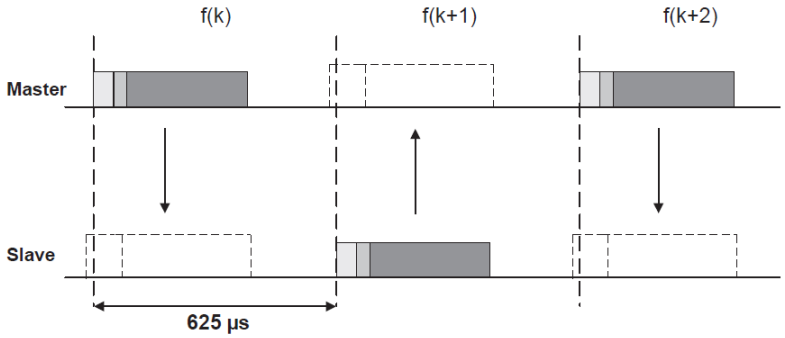

Figure 1: Master to slave connection (iBeacon - Apple Developer. (2021)

Bluetooth classic is a wireless communication technology that allows any device to transmit and receive data in a short-range of distance which developed from Personal Area Network (PAN) (Bluetooth protocol stack | Bluetooth protocol layers | tutorials, 2020). The distance between two devices depends on the strength of the Bluetooth radio transmitter, the sensitivity of the receiver and the rate of media absorption. Pairing is the process of connecting two Bluetooth units where the user must validate the ID connection devices. Figure 1 above shows the connection of master and slave connection. Bluetooth networks use a master/slave paradigm to monitor the speed rate and the transmitted or received data destination of a computer. The master will coordinate the communication throughout the network to either send or receive any data while the slave could only receive data from the master.

Bluetooth Low Energy (BLE) is the newer Bluetooth standard that has been defined by Bluetooth Special Interest Group (SIG) which is also called Bluetooth 4.0 that hit the market since 2011 ("'What is Bluetooth?': A beginner's guide to the wireless technology", 2021). The biggest distinction is the low power consumption of Bluetooth 4.0, where it is used by devices that do not need to exchange vast volumes of data from Machine to Machine (M2M) and can operate on a small battery for many years ("'What is Bluetooth?': A beginner's guide to the wireless technology", 2021).

BLE has been introduced in a wide area, such as wellness, fitness, security, smart home, digital media, smart industry and the Internet of Things (IoT), which is also implemented in smartphones and laptops (Karampourian, Ghomian, & Khorasani-Zavareh, 2019). The BLE system may act either as a central (client) or peripheral (server) function for a device to initiate commands and accept responses, or for a device to receive commands and return responses. In other words, the peripheral function advertises connectivity availability and offers an interaction interface, while a device that identifies, interfaces to, and communicates with peripherals plays a central role (Karampourian, Ghomian, & Khorasani-Zavareh, 2019). To describe the information sharing structure, BLE uses a hierarchical data structure. The peripheral function will support services and features that can be used for device-to-device communication, which are defined as the Generic Attributes (GATT) profile which have been reserved by Bluetooth SIG (Karampourian, Ghomian, & Khorasani-Zavareh, 2019).

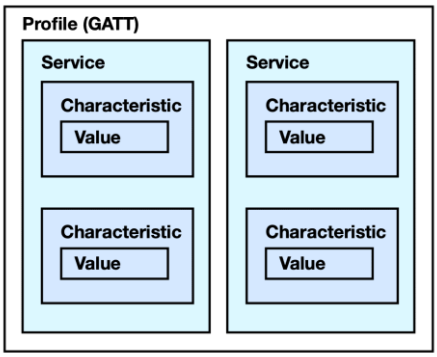

Figure 2: Bluetooth Low Energy Generic Attribute (GATT) profile (Karampourian, Ghomian, & Khorasani-Zavareh, 2019)

In recent years, Bluetooth LE become a power-and-application-friendly version of Bluetooth that enables any devices and beacons to connect. In combination with mobile applications, beacons function to enable special rules-based alerts or actions, such as initiating a push message when a user is within a certain distance from a beacon. Thus, BLE has already been used and the basis feature for iBeacon since 2013. iBeacon is the name of Apple's technology standard, which helps mobile applications that are running on both iOS and Android devices, to listen to and respond correctly to beacon signals in the real world (Shao, Shuo, & Kubota, 2018). The example of iBeacon showed that the Bluetooth needs to be localised to a certain distance. Therefore, localization refers to the method of estimating position in a Wireless Sensor Network (WSN) which consist of a big amount of resource constrained Sensor Nodes (SNs) (nRF Connect for Mobile, 2021).

Localization Method

Normally, location information is obtained from Global Positioning System (GPS), but it cannot locate things in indoor areas as GPS have big scale detection area settings with five-meter accuracy. So, it is not suitable to be used for indoor location detection. Estimating the position of indoor location where small sensors (beacons) are installed allows the sensors to communicate with each other and to capture the appropriate data in estimating the sensor location. Before that, indoor localization is a system that is used to locate objects or devices inside an environment (Sadowski, & Spachos, 2018). Some complications when performing indoor localization are many more obstacles indoors based on (Sadowski, & Spachos, 2018), large number of wireless electronic devices utilizing Wi-Fi and BLE which accessing the same medium and transmitting information.

Wi-Fi, Bluetooth, Radio Frequency Identification (RFID), Ultra-Wide Band (UWB), and cellular are the most common technologies, each of which has its own set of benefits and drawbacks (Boukerche & Nakamura, 2007). Angle of Arrival (AoA), Time of Arrival (ToA), Time Difference of Arrival (TDoA), and Received Signal Strength Indicator (RSSI) are just a few of the most popular models used in localization systems (Sadowski, & Spachos, 2018). One of the most commonly used characteristics for indoor localization is the Received Signal Strength Indication (RSSI). It works by determining the amount of power in a signal sent from an access point to a client device or vice versa. The fact that range measurements are frequently associated with errors is a major challenge in wireless localization systems. RSSI techniques are among the most cost-effective and simple to use, but they do not provide the best accuracy (Boukerche & Nakamura, 2007).

Trilateration is a model-based technique for determining an object's 2D position based on the distance between three reference points as well as the location of those points (Boukerche & Nakamura, 2007). Three transmitting nodes in predetermine locations, as well as a receiver, are required to calculate using trilateration. The transmitting nodes are set to broadcast packets indefinitely. This allows the receiver to obtain any transmissions that occur over the medium and record the packets' RSSI values. To relate the determined RSSI values to a distance, the Path Loss Model (PLM) (Boukerche & Nakamura, 2007) was used, which can be seen here:

$$RSSI = -10nlog10(d) + Tx \qquad (1)$$

In this equation, n is the environmental path loss exponent, d is the distance between transmitting and receiving devices, and Tx is a fixed constant that accounts for system losses (Boukerche & Nakamura, 2007). One assumption that needs to be made is the location of all the transmitting nodes is known.

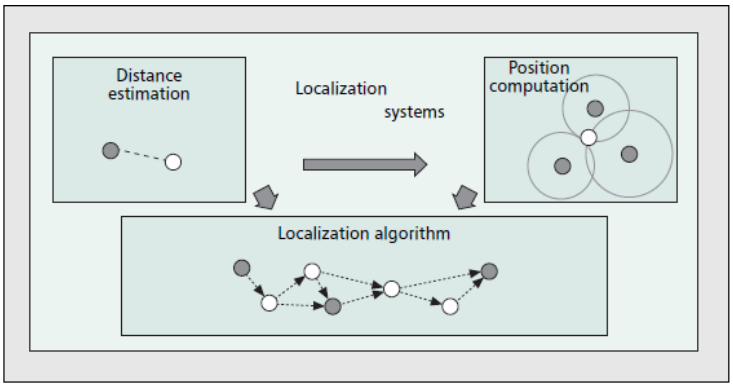

Figure 3: Division of localization systems into three components (Boukerche & Nakamura, 2007).

The main purpose of localization is to assign a node position to an unknown node so that it can be transformed into settled nodes. The distance estimation, position computation, and localization algorithm components of localization systems can be divided into three categories as shown in the diagram above. There is no perfect solution for every scenario in WSNs, according to a general rule. The function of distance estimation is to predict information about the distances and/or angles between two nodes. The other components of the localization system will use this information in calculating distance (Boukerche & Nakamura, 2007). However, other factors such as the node's size and cost (in terms of hardware, processor, and energy) must be considered. As a result, the method used to estimate distances is determined by the application's needs as well as available resources (Boukerche & Nakamura, 2007).

In terms of position computation, it is in charge of calculating a node's position based on available information such as distances/angles and reference node positions (Boukerche & Nakamura, 2007). Trilateration, multilateration, triangulation, probabilistic approaches, bounding box, and the central position are some of the methods that can be used to compute the position of a node (Boukerche & Nakamura, 2007). The method chosen has an effect on the final performance of the localization system. A node should normally know the positions of three reference nodes as well as its distance from each of these nodes in order to estimate its position using trilateration (Mehta, Virparia, Patel, & Valera, 2016). The errors in distance estimations are modelled as normal random variables when using probability approaches. When an unknown node receives a packet from a reference node, it will equate the probabilities and receive several packets until the unknown node's location can be determined (Boukerche & Nakamura, 2007).

Last but not least, location algorithms demonstrate how available data is manipulated to allow most or all nodes in a WSN to estimate their positions (Boukerche & Nakamura, 2007). The Ad Hoc Positioning System (APS) is a localization algorithm in which three beacon nodes estimate their distances in a multihop manner and then compute their positions using trilateration, Recursive Position Estimation (RPE) is a localization algorithm in which nodes estimate their positions based on a set of initial beacon nodes using only local information, and Localization with Mobile Beacon (LMB) is a localization algorithm in which nodes estimate their positions based on a set of initial beacon nodes (Yu, Min, & Choi, 2015). The position estimations are based on the same node of the mobile beacon, which keeps the mean localization error low and prevents it from spreading (Mehta, Virparia, Patel, & Valera, 2016).

Implementation of technology nowadays in saving human life and creating a better future have been developed vastly by professional industry people. This technology can help an organization to improve the efficiency of the management system. This research hope to have an innovation of systematic counting and tracking systems using Bluetooth communication for the pilgrim's usage will enhance the reachability of mutawwif to keep their pilgrim's safety. This could ensure the pilgrim have a great experience doing their ibadah and give an ease to mutawwif managing their pilgrim members. Therefore, application of technology in daily usage could create a convenient system in dealing people life.

3. Methodology

Establish Bluetooth Connection

As the first step for setting up the hardware of the project, Bluetooth ID connection must be established between the server and client. This will help the mutawwif to identify the pilgrim identity based on the UUID. A unique ID for the service is set to be 0x1821 which indicates indoor positioning service while for characteristic UUID is randomly set to any value. The module is also given a name which are Server Centre (pilgrim) and BLE observer (mutawwif). Figure 4 shows three receivers and one server of ESP32 Bluetooth module which indicate three mutawwif and one pilgrim. The server advertises its presence, so that it can be discovered by other devices and contains information that can be read by the client. While client will search it surrounding devices, and it will only establish a connection with the same service ID and read for any incoming data. This is called point-to-point communication where one transmitter can connect to one receiver.

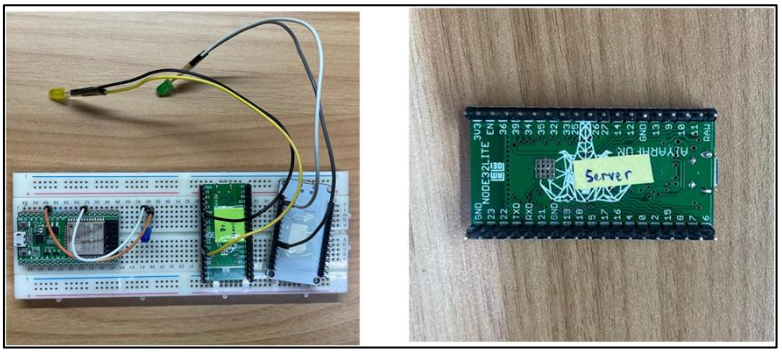

Figure 4: 3 clients (mutawwif) and 1 server (pilgrim)

Effective Range Detection of Received Signal Strength

As each BT have different effective detection range, so the graph above shown the result of effective detection range of ESP32 module. The testing occurs to determine the stability of the

signal received from the server. A hypothesis was made where the smaller the signal strength in dBm, the further the distance. In 5m scale of distance, the decrement of signal received is stable, so the hypothesis is accepted, and this data is used as the reference RSSI for this research. Thus, the coordinate of the testing area can be defined to continue for the testing.

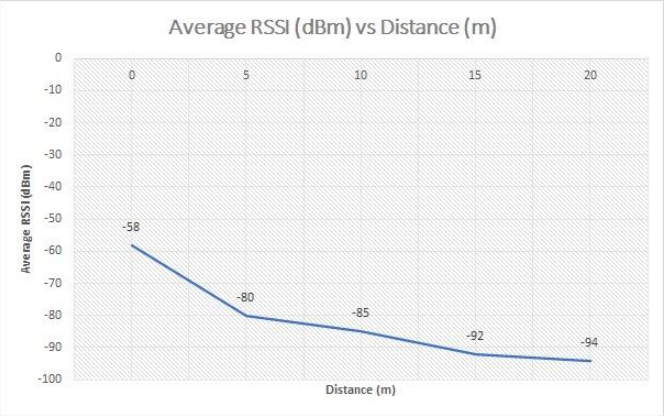

Figure 5: RSSI graph of 20m with 5m scale

Tracking system using Trilateration Method

The significant of getting a stable RSSI value will help to define the coordinate of the testing area. After setting the coordinate, localization algorithm using trilateration method can be tested where three reference coordinates need to be pre-determine in this project as it use trilateration method in estimating the pilgrim coordinate. A pilgrim (server) will standing on a coordinate in the testing field, and 10 RSSI reading were collected by each mutawwif (clients). With average RSSI, the distance (d1, d2, d3) were calculated by manipulating the PLM formula and coordinates of the pilgrim can be estimated using trilateration algorithm method.

In figure 6, black circle indicates the effective detection circumference from M1 position while blue circle is 15m scale from M1. The location of the mutawwif must be less than 80% of the effective detection range to ensure mutawwif can read a stable signal strength from pilgrim's device. So, the reference point of the mutawwif is set to (0,0), (-15,0) and (0,15). Then, the pilgrim was moving to another position and the estimated coordinated is predicted. From the table 2, we can analyse the distance error is becoming higher as the pilgrim moving further from M1.

Then, testing 3 took place as the pilgrim is moving toward ineffective RSSI value calculated from M1. From the table 3, an unstable Bluetooth connection between pilgrim and mutawwif was shown. In real situation, mutawwif needs to take an action by finding the pilgrim location based on its last advertised RSSI value. From there, mutawwif can estimate the distance of pilgrim based on the reference RSSI. Besides, distance error is calculated and tabulated in table 1,2 and 3, between real coordinate and estimated coordinate for each testing point. It is shown that around 10% to 70% error for all points are composed. From data collected, it can be determined that trilateration method of localization algorithm need to be improve.

Table 1: Result testing of distance estimation (Testing Point 1)

Testing 1	
Expected Coordinate	(-5,0)
Reference Coordinate	RSSI
M1: (0,0)	-83.10
M2: (-20,0)	-90.40
M3: (0,20)	-94.75
Estimated Coordinate	(-3.6,-2.7)
Distance Error	Ex: -5 + 3.6 = -1.4m (28%) Ey: -2.7 – 0 = -2.7m

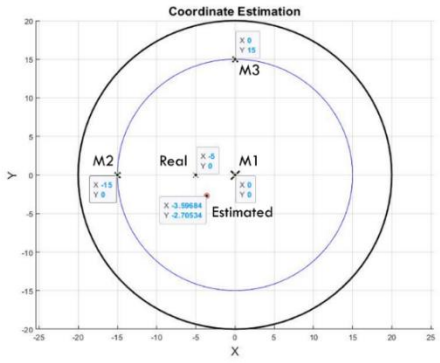

Figure 6: Plotted point of real and estimate coordinate (Testing Point 1)

Table 2: Result testing of distance estimation (Testing Point 2)

Testing 2	
Expected Coordinate	(-5,8)
Reference Coordinate	RSSI
M1: (0,0)	-88.09
M2: (-20,0)	-88.18
M3: (0,20)	-91.55
Estimated Coordinate	(-7.4,4.5)
Distance Error	Ex: -7.4 + 5 = -2.4m (32%) Ey: 4.5 – 8 = -3.5m (77%)

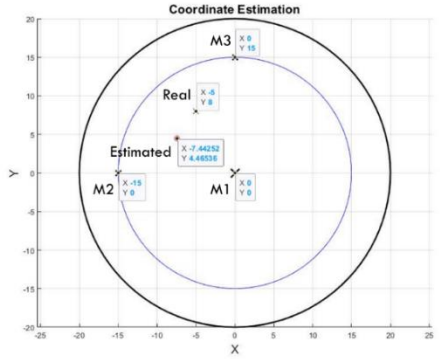

Figure 7: Plotted point of real and estimate coordinate (Testing Point 2)

Table3: Result testing of distance estimation (Testing Point 3)

Testing 3	
Expected Coordinate	(-18,10)
Reference Coordinate	RSSI
M1: (0,0)	-95.00
M2: (-20,0)	-91.53
M3: (0,20)	-92.90
Estimated Coordinate	(-13.1,11.3)
Distance Error	Ex: -13.11 +18 = 4.9m (37%) Ey: 11.3 -10 = 1.3m (13%)

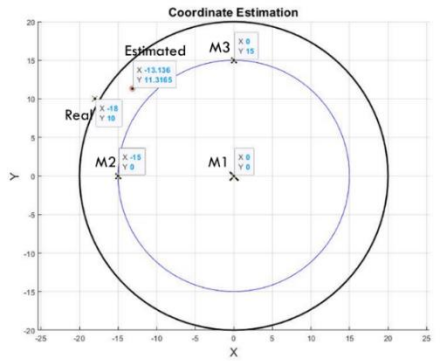

Figure 8: Plotted point of real and estimate coordinate (Testing Point 3)

From all the testing experiment, many factors can be considered as the cause effecting the distance error between real coordinate and estimated coordinate. One of the factors is difference high of Bluetooth device while doing the testing. This can cause difference reading of RSSI value as lower the Bluetooth location, the greater the ground reflection effect.

Moreover, the quality of the access point, as well as the quality of the wireless clients, will determine the success of a wireless network. When used with high-quality wireless device, the received signal strength will be better. So, communication module selection must be done carefully to get the best signal strength. In terms of algorithm, the localization algorithm also can be one of the factors effecting the distance error as no filtration on signal strength had been done before predicting the pilgrim coordinate.

Safety Button Features

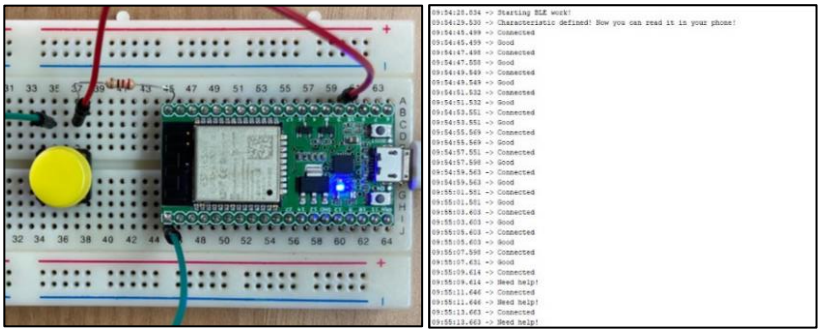

Figure 9:(i) Push button on pilgrim (ii) Respond from push button.

As additional feature that pilgrim's device will have was a safety button which will track the current condition of the pilgrim. Each time the pilgrim pushes the button, the server will get a message from the pilgrim. In emergency cases, the push button can help the mutawwif to act immediately on the pilgrim's condition. This will ease the guidance of mutawwif towards their pilgrim as the device helps them to track the pilgrim situation. In figure 9, it shows the output from the pilgrim with state their condition and when the button is pressed, different message will be appeared.

4. Conclusion

As the summary, management of pilgrims during Hajj or Umrah occasion can be enhanced with the help of technology nowadays. A systematic system that has been developed which contains a device tracking system could ease the mutawwif to handle a group of pilgrims and prove that technology could benefit human life. In this research, the devices used Bluetooth communication systems from ESP 32 module to advertise data containing RSSI value and message from server to client. Usage of Bluetooth has been chosen as it is only connected to programmed unique service ID between server and client so random service ID will be ignored. Additional points of using BLE is it consumes less amount of energy to power up the device which increases the life spend of devices and least maintenance is needed.

In conclusion, the objectives of this project are achieved as the problem faced can be resolved with the idea proposed in this paper. As recommendation to this research, localization of the pilgrim based on RSSI value using the trilateration method algorithm has been proven to estimate coordinate in indoor location, but high distance error was determined. Therefore, it is suggested to use a different type of localization method along with Kalman filtering method to refine the RSSI value in reducing the distance error. Besides, a real time data is recommended to be collected from the server so, the coordinate of the pilgrim will be calculated in real time where it will help the mutawwif to track the current location of the pilgrim.

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