International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-1, October, 2019

Location Identification Methods for IOT Devices Using Bluetooth Low Energy (BLE)

T.Y. Leong, R.H. Ramlee, A.I. Tarmizi, M.N. Shah Zainudin, Raihaan Kamarudin

Abstract*: Indoor localization is a positioning method that used for closed environment condition. Since Internet of Things or IOT devices come with small size microcontroller units, positioning algorithms are studied and three of them are tested based on three parameters which are accuracy, algorithms response time and programming bit size. In this project, three Radio Signal Strength Indicator or RSSI based positioning algorithms are used to get the results which are trilateration, fingerprinting and proximity. Based on the data collected, proximity algorithm gives the highest accuracy, lowest response time, and lowest programming bit size. This project can be improved by sending the location of IOT devices to cloud so that it can be track by other IOT devices.

Index Terms*: Beacons, Bluetooth Low Energy, Fingerprinting, Indoor localization, Proximity, RSSI, Trilateration.

I. INTRODUCTION

Localization is a technology that used to detect the location of an object. IOT is defined as a set of technologies that used to access the data collected by individual or multiple devices through wireless and wired Internet networks [1]. In recent year, indoor localization is widely used in a variety of applications to track and locate people or IOT devices inside a building or closed area such as locating patients in hospital [2] and customer tracking [3]. There have several positioning systems for indoor localization such as Global positioning system (GPS), wireless local area network (WLAN), radio frequency identification (RFID) and Bluetooth Low Energy (BLE). BLE beacon is used to identify the location of the IOT devices in a closed environment. BLE is a wireless personal area network (PAN) which can provide low power consumption and cost while maintaining the similar communication range [4]. The beacon is an energy saving device which come in a small size that can broadcast a Bluetooth signal periodically [5]. Nowadays, most IOT devices come with small size microcontroller units which results in a small memory size. To overcome this problem, three algorithms are used to make the positioning estimation and the performance of these algorithms are compared according to the parameter set. At last, the algorithm with the algorithm that give the best accuracy on localization predict, fast response time and with small programming bit size will be chosen. In this paper, three Nordic NRF 51422 dongles were used as BLE beacons and the indoor localization algorithms were applied on the STM32 F411RE microcontroller IOT board with three difference types of beacons' arrangement.

Revised Manuscript Received on October 30, 2019.
* Correspondence Author
T.Y. Leong*, CeTRI, Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia.
R.H. Ramlee, CeTRI, Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia.
A.I. Tarmizi, CeRIA, Faculty of Electric, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia.
M.N. Shah Zainudin, CeTRI, Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia.
Raihaan Kamarudin, CeTRI, Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia.

II. BACKGROUND STUDY

In this paper, various type of well-known positioning methods was studied and the difference between them were compared where included their advantages and limitation as shown in Table 1.

Table 1. Comparison between positioning technology.

Ref.	Positioning Technology	Application	Advantage	Limitation	Accuracy
[2], [6], [7]	GPS	Outdoor	Huge coverage area	Huge energy consumption, costly	Within 10 meters
[7]–[9]	Bluetooth 4.0 / Bluetooth Low Energy	Indoor	Low cost, low power consumption, easy to deploy, small signal attenuation coefficient	Not spread widely, received signal strength is low	0.22-0.89 meters
[2], [9]	Infrared	Indoor	Moderate cost	Room level location	Low
[2], [7], [9]	Ultrasonic	Indoor	Wide range	Costly, high power consumption, low precision, sensitive alignments needed	High
[9]	Wi-Fi /WLAN	Indoor	Spread widely, high received signal strength	Hard to eliminate the difference between Aps, need large fingerprint database	High

Received Signal Strength Indicator (RSSI) based localization algorithms were chosen because no extra hardware needed, no extra load of network communication required, simplicity and low complexity are the advantage of using RSSI technique [10].
In this paper, four algorithms were studied and three of them were chosen for evaluation which are trilateration, fingerprinting, and proximity.

III. METTHODOLOGY

A. Trilateration

Trilateration is a method that estimate the device position with at least 3 RSSI values from three beacons. The interception point of these three beacons signal strength will be the estimation location of the object.

$$RSSI(d) = RSSI(d_0) - 10 * n * \log\left(\frac{d}{d_0}\right) \quad (1)$$

$$n = \frac{RSSI(d_0) - RSSI(d)}{10 * \log\left(\frac{d}{d_0}\right)} \quad (2)$$

$$d = 10^{\frac{RSSI(d_0) - RSSI(d)}{10*n}} \quad (3)$$

where: d_0 = Value on 1 meter
d = Value on distance measured
n = Path Loss Index or attenuation factor

By using Pythagoras theorem equation (4), the distance can be defined. Through some substitution and Cramer's rule in equation (5), the estimation location in x and y axis can be calculated.

$$d_k^2 = (x - x_k)^2 + (y - y_k)^2 \quad (4)$$

$$X_A = \frac{\begin{vmatrix} (d_1^2 - d_2^2) - (x_1^2 - x_2^2) - (y_1^2 - y_2^2) & 2(y_2 - y_1) \\ (d_1^2 - d_3^2) - (x_1^2 - x_3^2) - (y_1^2 - y_3^2) & 2(y_3 - y_1) \end{vmatrix}}{\begin{vmatrix} 2(x_2 - x_1) & 2(y_2 - y_1) \\ 2(x_3 - x_1) & 2(y_3 - y_1) \end{vmatrix}}$$

$$Y_A = \frac{\begin{vmatrix} 2(x_2 - x_1) & (d_1^2 - d_2^2) - (x_1^2 - x_2^2) - (y_1^2 - y_2^2) \\ 2(x_3 - x_1) & (d_1^2 - d_3^2) - (x_1^2 - x_3^2) - (y_1^2 - y_3^2) \end{vmatrix}}{\begin{vmatrix} 2(x_2 - x_1) & 2(y_2 - y_1) \\ 2(x_3 - x_1) & 2(y_3 - y_1) \end{vmatrix}} \quad (5)$$

where: k = beacon referred
x_k = known x axis value of beacon k
y_k = known y axis value of beacon k

B. Fingerprinting

In this paper, fingerprinting method having two stages (as shown in Figure 1) which are data collecting state and data compare state. All the RSSI values of beacons received by IOT board that located on the tested coordinate position were collected in database and used for comparing during real time position estimation process.

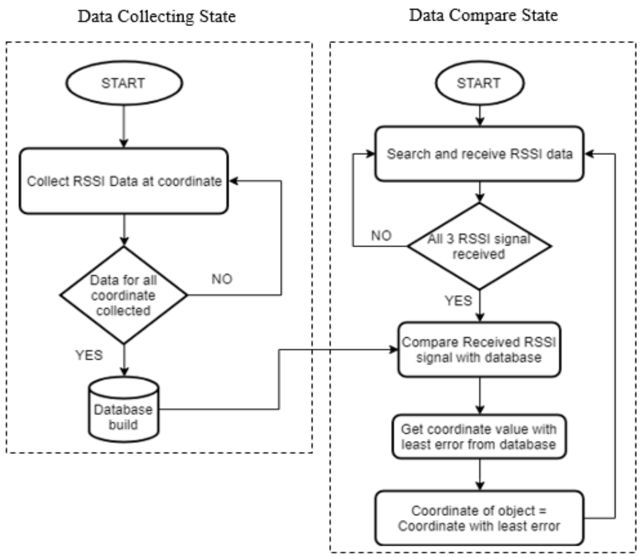

Figure 1. Flow chart of fingerprinting algorithm.

C. Proximity

Proximity is a method that pointed the estimation location of the object to the nearest beacon's location and not giving the exact position of the device. This will cause it having a low accuracy and not giving the exact position of the device. However, proximity technique is easy to implement, and no calibration needed [11], [12]. To overcome the low accuracy problem, the authors [11] state that a dense deployment of BLE beacons are required to achieve the highest accuracy.

D. Type of Beacons Arrangement

In this paper, the area used to collect the data was 3 meters x 2 meters. Three types of beacons placement had been used in evaluation which are shown in Figure 2, Figure 3, and Figure 4. Each beacon has their own represented color where red for beacon 1, yellow for beacon 2 and blue for beacon 3. The color on the coordinates point pointed to the beacon that was theoretically shortest displacement from that coordinate point which also the expected output of that coordinate point. Orange color represented the coordinate point was theoretically nearer to the beacon 1 (red) and 2 (yellow). The displacement, d_k between the beacon and coordinate point was calculated using equation (4). The proximity method accuracy calculated based on the hit and miss of the predicted output on the theoretical or expected output.

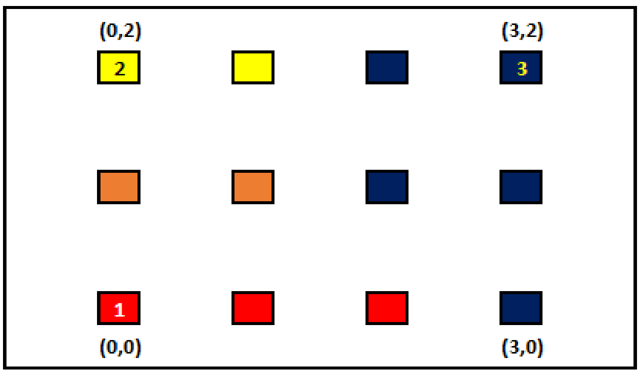

Figure 2. Type A.

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-1, October, 2019

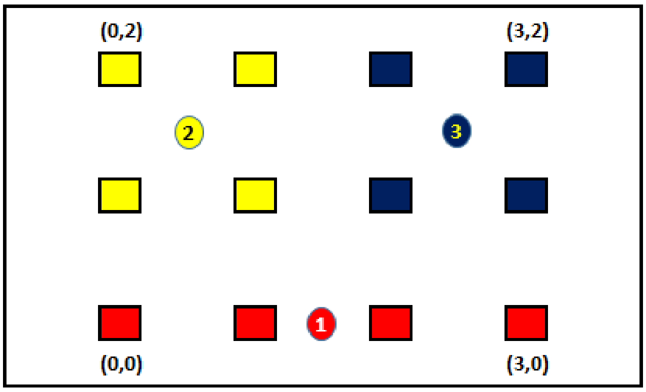

Figure 3. Type B.

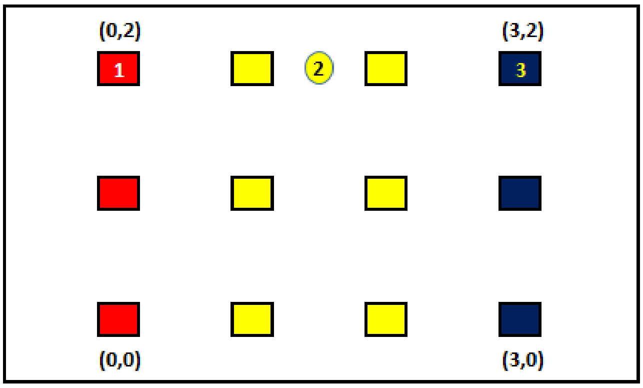

Figure 4. Type C.

IV. RESULTS

In this session, the performance of the three chosen algorithms were tested and the data were collected and analyzed. In this session, method 1 refers to the trilateration method, method 2 refers to fingerprinting method, while method 3 refers to proximity method. Table 2 shows the Path loss index where n was calculated for the used in method 1.

Table 2. Path Loss Index.

Distance (m)	RSSI Average (10 maximum values) (dBm)	Path Loss Index, n	Average Path Loss index
0.5	-60.00	0.133	3.11
1	-60.40		
1.5	-69.10	4.941	
2	-75.80	5.116	
2.5	-72.70	3.091	
3	-71.20	2.264	

As shown in Figure 5, method 1 works well in type A arrangement but poor performance in type B arrangement and totally cannot be used in type C arrangement because there had a critical session happen during the calculation process. Although method 2 works well for all three types of arrangement, the average accuracy was around 61%. Method 3 perform well on both type A and type B arrangement with average accuracy around 72% but poor performance in type C arrangement which was only 53.33% average accuracy. Noise is one of the reasons that cause the low accuracy in method 1 and 2 which produced when the signal bounces off on a certain surface such as wall, floor and furniture before received by the receiver.

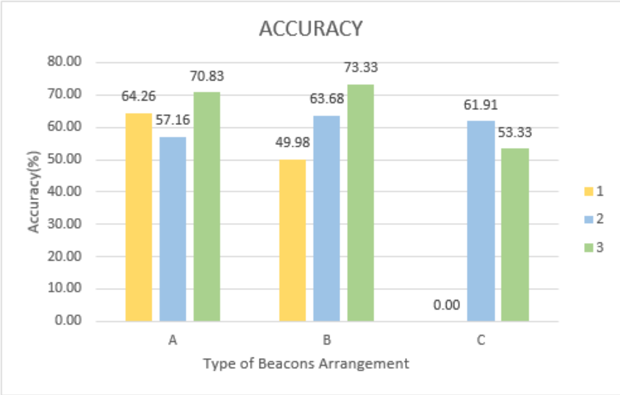

Figure 5. Accuracy overview.

Method 2 had the highest response time as tabulated in Figure 6 because it needs to compare with all the database values when it received the real time RSSI values. Since it needs to compare with 12 coordinates point values and with total of 36 values for three beacons, it took longer time in comparing.

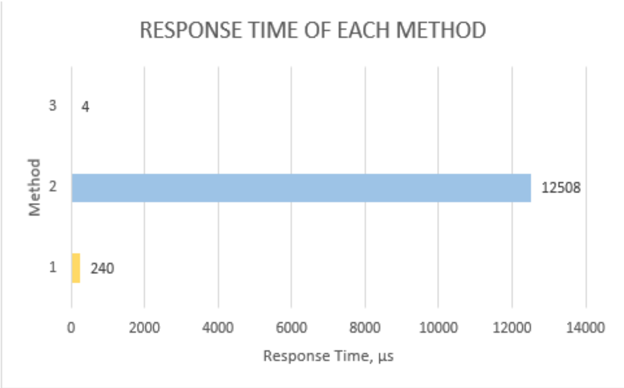

Figure 6. Response time.

As can be seen from Figure 7, method 1 had the largest programming bit size because it needs more lines to code for the equation that use for calculating the output results. More lines of codes result larger programming bit size.

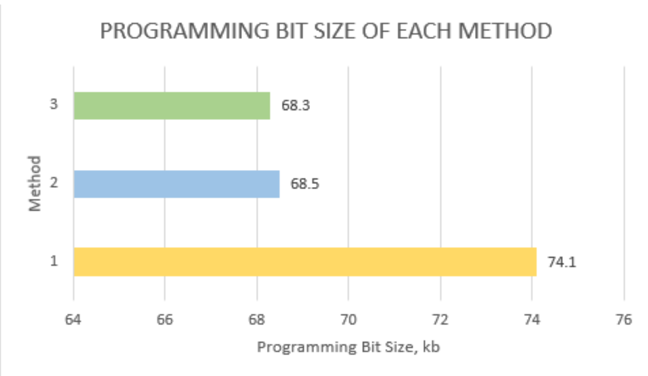

Figure 7. Programming bit size.

Retrieval Number: A1755109119/2019©BEIESP
DOI: 10.35940/ijeat.A1755.109119
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

V. CONCLUSION

As a conclusion, proximity method gives the highest performance with highest accuracy on location estimation, lowest algorithms response time and lowest programming bit size. However, if the user prefers the algorithm that will give the actual location and beacon's location, trilateration method will be the suitable choice. Fingerprinting method is not recommended because it was sensitive to the environment change and calibration process needed frequently to have good accuracy.

ACKNOWLEDGMENT

The author would like to thank the Universiti Teknikal Malaysia Melaka (UTeM) and Centre for Telecommunication Research and Innovation (CeTRI) for sponsoring this article.

REFERENCES

1. E. Park, "The Role of Internet of Things (IoT) in Smart Cities : Technology Roadmap-oriented Approaches," pp. 1–13, 2018.
2. H. Koyuncu and S. H. Yang, "A Survey of Indoor Positioning and Object Locating Systems," *Int. J. Comput. Sci. Netw. Secur. (IJCSNS '10)*, vol. 10, no. 5, pp. 121–128, 2010.
3. D. Oosterlinck, D. F. Benoit, P. Baecke, and N. Van De Weghe, "Bluetooth tracking of humans in an indoor environment : An application to shopping mall visits," *Appl. Geogr.*, vol. 78, pp. 55–65, 2017.
4. Agustí Corbacho Salas, "Indoor Positioning System based on Bluetooth Low Energy," no. June, 2014.
5. A. Gomes, C. Soares, and P. Sobral, "Trends and Advances in Information Systems and Technologies," vol. 746, pp. 565–580, 2018.
6. Y. Gu, A. Lo, and I. Niemegeers, "A survey of indoor positioning systems for wireless personal networks," *IEEE Commun. Surv. Tutorials*, vol. 11, no. 1, pp. 13–32, 2009.
7. M. E. Rida, F. Liu, Y. Jadi, A. Ali, A. Algawhari, and A. Askourih, "Indoor location position based on Bluetooth Signal Strength," pp. 769–773, 2015.
8. M. Ji, J. Kim, J. Jeon, and Y. Cho, "Analysis of positioning accuracy corresponding to the number of BLE beacons in indoor positioning system," *Int. Conf. Adv. Commun. Technol. ICACT*, vol. 2015-Augus, pp. 92–95, 2015.
9. Z. Jianyong, L. Haiyong, C. Zili, and L. Zhaohui, "RSSI based Bluetooth low energy indoor positioning," *IPIN 2014 - 2014 Int. Conf. Indoor Position. Indoor Navig.*, no. October, pp. 526–533, 2014.
10. J. Luo, "Range Error Correction In RSSI-based Wireless Sensor Node Localization," pp. 379–383, 2014.
11. D. Čabarkapa, I. Grujić, and P. Pavlović, "Comparative Analysis of the Bluetooth Low-Energy Indoor Positioning Systems," no. October 2015, 2016.
12. F. Orujov, "Comparative Analysis of the Indoor Positioning Algorithms using Bluetooth Low Energy Beacons," pp. 53–57.

AUTHORS PROFILE

T.Y. Leong is an undergraduate student from Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka, Malaysia.

R.H. Ramlee is an academician from Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka, Malaysia. His research interest is in broadly areas of FPGA applications and embedded system.

A.I. Tarmizi is an academician from Faculty of Electric, Universiti Teknikal Malaysia Melaka, Malaysia. Her research interest is in broadly areas of power system, high voltage and EMC.

M. N. Shah Zainudin is an academician from Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka, Malaysia. His research interest is in broadly areas of machine learning application, data mining, pattern recognition and smart home. He has published a number of articles related to wide areas of artificial intelligence.

M.R. Kamaruddin is an academician from Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka, Malaysia. His research interest is in broadly areas of neuroscience, brain computer interface and signal processing and embedded system.