INTL JOURNAL OF ELECTRONICS AND TELECOMMUNICATIONS, 2022, VOL. 68, NO. 2, PP. 293-298
Manuscript received June 25, 2021; revised May, 2022. DOI: 10.24425/ijet.2022.139881

MyLib: Smart Library Indoor Navigation Using Bluetooth Low Energy with Triangulation Method

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***Abstract*—this paper proposes an android-based application to help the users to navigate in finding books in the library easily and interactively. This navigation application is connected to a Bluetooth Low Energy (BLE) device that will emit an RSSI signal received by the Smartphone user and show the desired distance to the bookshelf position. The method of triangulation and mean filter were used to eliminate noise in the test environment to make the position of the bookshelf can be found precisely based on the RSSI BLE Beacon value. The test results showed the largest RSSI value for LOS conditions at -48dBm and NLOS at -63 dBm; while the lowest RRSI values for LOS conditions was at -84dBm and NLOS was at -96dBm.**

***Keywords*—Indoor Navigation; BLE; RSSI; Triangulation**

I. INTRODUCTION

NOWADAYS, Bluetooth Low Energy (BLE) comes to be one wireless communication device that is comfortable in use. It is because BLE, in addition to be affordable, requires low level of power without any limits for the number of devices connected. BLE is more efficient compared to use of previous Bluetooth [1-3]. Based on its characteristics, the BLE device is widely used for any applications such as the localization system using the wireless sensing technology. This system is widely applied in navigation and mobility of human particularly in indoor activity [4]. The studies on the indoor location tracking have been conducted such as in the use of Wi-Fi hybrid using Bluetooth [5], camera, [6], Wi-Fi [7], or Radio Frequency (RF) [8]. Of the uses of these devices, Wi-Fi and Bluetooth devices are widely used for indoor location tracking - especially after the development of Bluetooth Low Energy (BLE) technology for the use of the Indoor Positioning System, one of which has been reported by [9] to monitor the daily life of elderly parents or people with disabilities.

In addition to monitoring system, BLE technology is used for the information system tracking for instance for the interactive smart museum as reported by [10] that is by substituting QR Code technology. BLE device can be connected to the applications that will give a recommendation of data in the form of distance from space of museum to be visited. Along with the development of Internet of Things (IoT) technology that can be connected to the smartphone, it has provided a significant development for the use of BLE device. The IoT device connected to the application of Smartphone with the placement of BLE device in anywhere is able to change the space into the smart space. The visitors are able to interact with any objects in smart space without any interfere of human. Any objects needed can be recognized based upon the distance from the visitors.

This research proposes an android application using the Bluetooth Low Energy (BLE) device to navigate the book searching in library. The tracking for the object of book proposed used the trilateration algorithm as well as Mean Filter to reduce the noise in environment to obtain the information of book position based on the strength of signal received (RSSI) from the closest BLE.

The rest of this paper is presented as follows. Section two is to review any studies related to the proposed one, and Section three contains the system of the proposed design. Section four respectively present the results and discussion of the test on the evaluation of system performance and and Section five presents the conclusion.

II. RELATED WORK

There have been many researches on the tracking of the indoor object position tracking using the Wi-Fi device along with the increasing use of smartphone and internet [11] [12]. Most of indoor object position tracking use the fingerprint and propagation method. Say, the propagation method proposed by [13] used the strength of the detected Wi-Fi signals more rather than the threshold signals. When the signal detected by Wi-Fi exceeds the threshold signal during the zero update (ZUPT), it will obtain the information of the indoor object position. Meanwhile, fingerprint method used by [14] was to evaluate the indoor object position by verifying and updating the database in each change occurred on Wi-Fi signal.

The development of research on the indoor navigation is increasing after the invention of Bluetooth Low Energy (BLE) technology [15-18]. The use of BLE technology for the indoor navigation using the smartphone to assist the customers in finding the needed shops in one area of shopping mall with a complex architecture has been proposed by [19-20]. Internet of Things (IoT) technology also has brought a significant effect on the BLE research for the indoor navigation with a help of the smart devices such as smartphone, laptop or tablet. Such smart devices are able to detect the RSSI signal emitted by the BLE device installed in the room near the object. The use of BLE device connected to the android application by IoT can facilitate the visitors to find the location of space in smart museum to be visited rapidly and accurately [10].

This work is supported by the grant No KWR.0015/LIT2/LIT/2020, received by School of Applied Science, Telkom University, Indonesia.

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There have been many studied on smart libraries; say, [21] reported the use of RFID where visitors were able to see the availability of the required books along with information on the book location in the library. The use of face recognition combined with QR code technology in smart libraries [22] - a system proposed made it easier for book publication, book borrowing and book return. However, the studies mentioned above are not able to navigate the library visitors in real time to the location of the book objects intended.

In the study proposed, the BLE device was integrated with the android based application that functioned to collect and direct the visitors of library to the information of location of books desired in library in real-time by using RSSI signal of BLE device installed on each bookshelf in the library.

III. PROPOSED SYSTEM

A. *System Application*

The system proposed is shown in Fig. 1 where BLE beacon was placed on each of bookshelf. Each of BLE beacons would emit the signal with each of ID that could be received by Smartphone user. Data displayed in the application were in the form of the names of bookshelves, number of bookshelves, strength of RSSI and number of minor on each beacon.

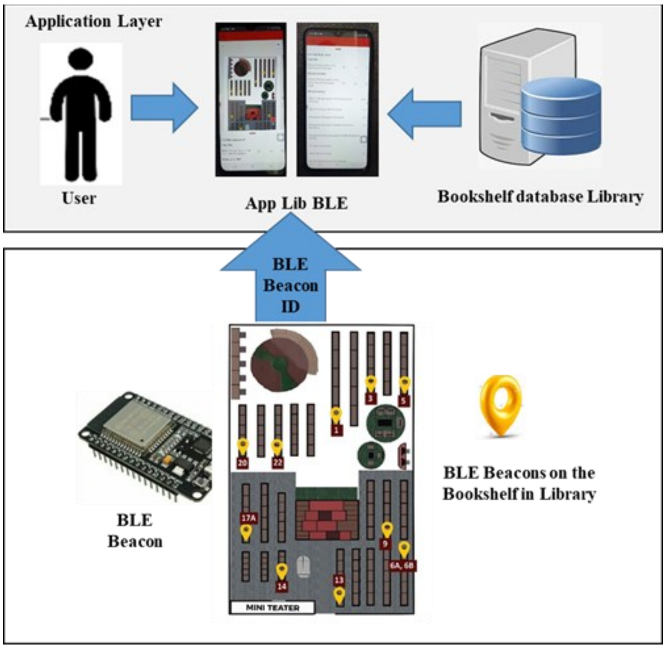

Fig 1. Proposed Model System

The mechanism of system proposed is described as follows, First, the library visitor will install the BLE library application. Then, BLE beacon will scan the signal to check whether the device of Bluetooth smartphone used by the user is in the position of On or Off. If in the position of Off, then the notification will appear on the user application to switch on the Bluetooth. If it is in the position of ON, the visitors will receive the information related to the location of books that are sought. The information is obtained through the filter of Kalman device that will filter UUID and minor from BLE Beacon to ascertain hat the application is only connected to certain UUID andminor. Once the filtering process is completed, the users can see the strength of signal of RSSI BLE Beacon including the color of the signal. When the user walks through each area of bookshelf in the library, he or she will be covered by the signal of BLE *beacon* that will form the *coverage* area. When the user is in the coverage area, he or she will find the position of bookshelf based upon the value of RSSI and distance. The values of RSSI and distance in the application are remarked with the difference of marker color on the application mapping. When the marker turns into red, then the user is in the area that quite close to the bookshelf sought and when the marker turns into green, it means that the user is far from the bookshelf sought. The use of this marker facilitates the user in identifying the position of bookshelf closest to him or her. The data automatically will be updated when the user moves to other location. The division of coverage area in the proposed system used the *Trilateration* method based on the coverage of RSSI strength.

B. *BLE Beacon*

BLE Beacon is the wireless communication technology with the low power developed by Special Interest Group (SIG) and used to control or monitor an application [23]. BLE works at the frequency of 2.4 GHz with the transmitting speed of 1 Mbit/s using the modulation of Gaussian Frequency Shift Keying (GFSK) [24]. BLE Beacon will emit the ID signal and send the data packet periodically to each set of electronic such as smartphone or tablet supporting the BLE Beacon signal. The signal can be transmitted to the interval of 20ms to 10 s with the capability reaching 25 Mbps in the distance of 60 m. Each of BLE Beacon used in this research had major and minor UUID. The configuration of each BLE used was differentiated only based on the minor. Major and minor can be determined based on the need. Fig 2 shows the flowchart of programming of BLE Beacon configuration used in this research.

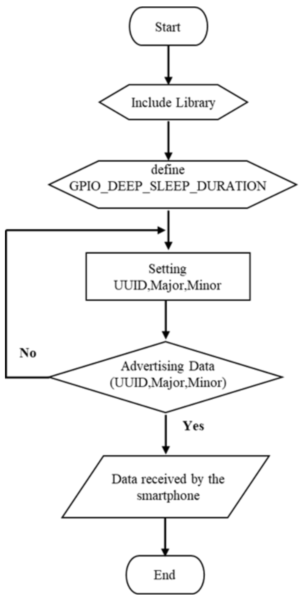

Fig.2. Flowchart of BLE Beacon Configuration Programming

C. *Received Signal Strength Indicator (RSSI)*

BLE Received Signal Strength Indicator (RSSI) is one of parameters used to measure the strength of signal received by the device. The measurement unit used is dBm. The results of the measuring the RSSI can be used to calculate the distance between BLE Beacon and the receiving device. When a device detects ID signal and transmission power from BLE B*eacon*, if the signal is strong, then the distance between the BLE beacon and the user is close. If the signal is weak, the distance between the user and the BLE beacon is far. The RSSI value can be calculated based on the following equation [25]:

$$RSSI[dBm] = -10\, n\, log\, d + \text{Tx} \quad (1)$$

Where n refers to the signal attenuation coefficient [dB], Tx is the value of the strength of signal transmission measured in the distance of 1 meter from the transmitter and receiver (m). The value of d when measured refers to what extent the distance reached from BLE B*eacon* and it can be presented with the equation [25]:

$$d(m) = 10^{\frac{RSSI-TX}{-10n}} \quad (2)$$

In this research, RSSI programming used is shown in Fig. 3.

```
mAdapter?.submitList(lastDetectedBookshelf.values
      .toList()
      .filter { it.rssi > -75 }
      .sortedByDescending { it.rssi })

markers.forEach {

it.value.setIcon(BitmapDescriptorFactory.fromResource(
R.drawable.point))
}

lastDetectedBookshelf.values.forEach {

markers[it.minor]?.setIcon(BitmapDescriptorFactory.def
aultMarker(BitmapDescriptorFactory.HUE_GREEN))
}

lastDetectedBookshelf.values.toList()
      .sortedByDescending { it.rssi }
      .let {
         if (!it.isEmpty()) {
            val nearest = it.first()
            positionViewHolder?.submitDetected(nearest)

markers[nearest.minor]?.setIcon(BitmapDescriptorFactor
y.defaultMarker(BitmapDescriptorFactory.HUE_RED))
         }
```

Fig 3. RSSI Configure

D. *Trilateration*

The determination of the position of object distance in a room is mostly done using the lateration technique. This technique is used to estimate the location of the receiver by calculating the distance of the location of one BLE Beacon to the location identified. If we use three points BLE Beacon, this technique is then called as Trilateration [26]. In this research, the distance was measured for the estimation of BLE Beacon position and the device (smartphone) in which the measurement was done in three points of bookshelf that have been determined. In this method, the beacon signal was received by the device and formed a circle of area coverage. Those three coverage areas formed an intersection point showing the position of user as illustrated in Fig. 4

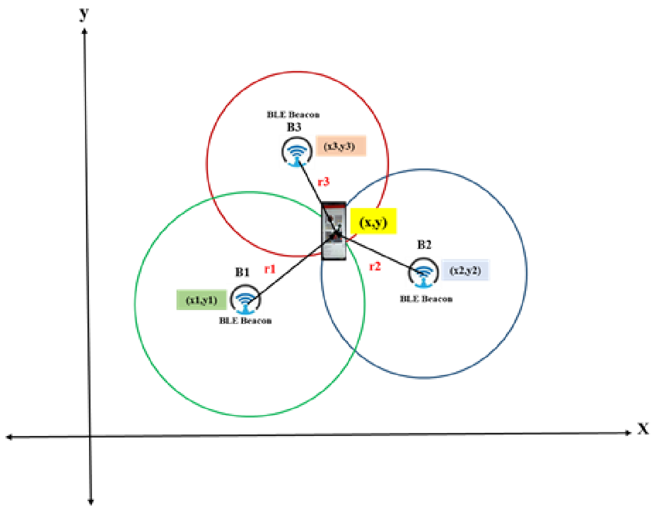

Fig 4. Trilateration with three BLE Beacons

As seen in Fig 4, the position of smartphone is in the central coordinate at (x, y) as the center point of each BLE Beacon in which the radius of each BLE Beacon is known. Each equation of a circle can be expressed as follows [26] :

$$(x - x_1)^2 + (y - y_1)^2 = r_1^2, \quad (3)$$
$$(x - x_2)^2 + (y - y_2)^2 = r_2^2, \quad (4)$$
$$(x - x_3)^2 + (y - y_3)^2 = r_3^2, \quad (5)$$

Based on equation 3, equation 4 and equation 5, if we assume that the position of BLE Beacon B1 is at the coordinate (0, 0), BLE Beacon B2 is at the coordinate (x_2, y_2) and BLE Beacon B3 is at the coordinate $(x_3, 0)$, then the equation will become:

$$x^2 + y^2 = r_1^2\ , \quad (6)$$
$$(x - x_2)^2 + (y - y_2)^2 = r_2^2, \quad (7)$$
$$(x - x_3)^2 + y^2 = r_3^2, \quad (8)$$

Using equation 6, equation 7 and equation 8, the coordinate of location from Smartphone can be stated with the equation:

$$x = \frac{r_1^2 - r_3^2 + x_3^2}{2x_3}, \quad (9)$$

$$y = \frac{r_1^2 - r_2^2 + x_2^2 + y_2^2}{2y_2} - \frac{x_2}{y_2}x \quad (10)$$

E. *Mean Filter*

Objects in the room environment used in the study included rooms with walls, bookshelves and other devices. Due to the condition of the room environment, the transmitter signal emitted by the BLE Beacon was blocked. The transmitter signal was disturbed by reflection, scattering and diffraction causing the signal to not be received by the receiver. Based on such condition, a filter technique that is able to reduce the signal due to noise and multipath effects on the Received Signal Strength (RSS) BLE Beacon is needed. In this research, mean filter was used to reduce the variance signal. The equation of mean filter used in this research can be stated with the following equation [27]:

$$RSSI_{mean} = \frac{1}{n+1}\sum_{i=0}^{n} RSSI\ (i) \quad (11)$$

Where i states the number of BLE Beacons, and n states the total number of measured RSS.

F. Database Repository

Bookshelf Repository is a set of data like database that functions as both the data storage and correlation between beacon and position of bookshelf. Fig. 5 shows the coding from the database used.

```
object BookshelfRepository {
  val bookshelfList = mutableListOf<Bookshelf>(
      Bookshelf(
          "Computer Graphic, Information Center, jurnalistik ",
          "5",
          LatLng(-6.971999611527834, 107.63278372585773),
          5

      ),
      Bookshelf(
          "Filosofi, Psikologi, Agama, Ilmu Sosial, Ekonomi Keuangan",
          "6A,6B",
          LatLng(-6.971748349757242, 107.63247359544039),
          10

      ),
      Bookshelf(
          "Signal Processing, Teknik Komputer ",
          "13",
          LatLng(-6.9715663096882885, 107.63247661292552),
          7
      )
```

Fig 5. Bookshelf Repository Database

IV. RESULTS AND DISCUSSION

In the proposed research, the test of system was conducted in the rooms of library of university. The test aimed to evaluate the factor of system performance proposed through a number of testing scenarios.

A. BLE Beacon RSSI

The test was conducted to observe the effects of the distance of installed BLE Beacon on the value of RSSI. The test was conducted through two scenarios: when the room environment in the LOS condition and in the NLOS condition. The condition of LOS measured by installing the BLE Beacon in the corridor of room entry and condition of NLOS was measured by installing BLE Beacon on the bookshelves in the library.The test was conducted using Android based Smartphone that has been installed with the application of library connected to the set of BLE Beacon. In every 1 meter to 10 meters, Smartphone in users would collect the value of RSSI received from BLE Beacon. The value of RSSI obtained in two scenarios: when Line Of Sight (LOS) i.e. environment without obstruction and when Non Line of Sight (NLOS) i.e. environment with obstruction is shown in Fig 6.

Fig.6 shows that the presence of a barrier greatly affects the RSSI value received by the user. The strength of the RSSI signal without a barrier (LOS condition) was greater than thepresence of a barrier (NLOS). The graph also shows that user movement can affect the received RSSI values. The farther the user from the BLE Beacon, the smaller the RSSI will be.

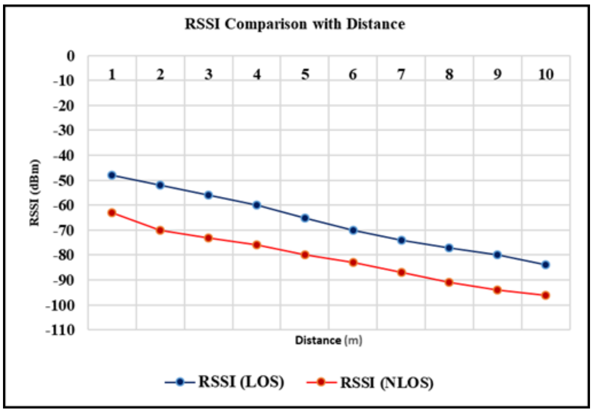

Fig 6. Comparison RSSI LOS and NLOS with Distance

Based on equation 2 after the test, it was found that n value, which is the signal attenuation constant, was affected by RSSI magnitude, distance and environmental conditions of the test as shown in Fig 7. The n value in the environment without barrier (LOS) was greater than that of with presence of a barrier (NLOS). In Fig.7, at the same distance observation at 6 meters with no barrier (LOS) condition, the n value obtained was 2.8 while in the condition with a barrier, n value was 2.57.

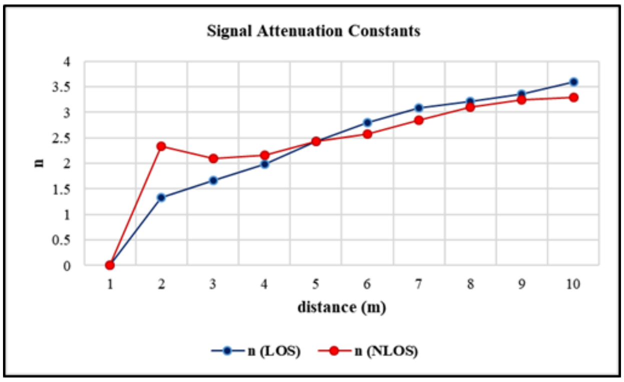

Fig 7. Signal Attenuation Constants

B. Trilateration Coverage Area

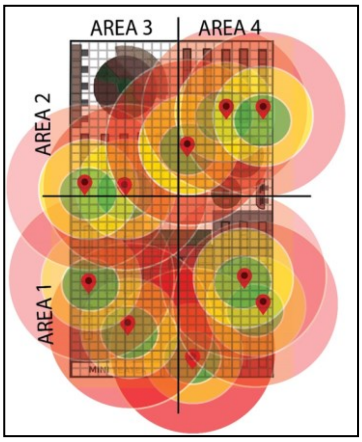

Fig 8. Scenario Coverage Area BLE Beacon

Trilateration coverage area is a test to evaluate the user's position based on the coverage area of 3 intersecting BLE beacon points. The test scenario was carried out by dividing the

BLE Beacon coverage area into four coverage areas where each distance represented the results of the RSSI measurements as shown in Fig. 8.

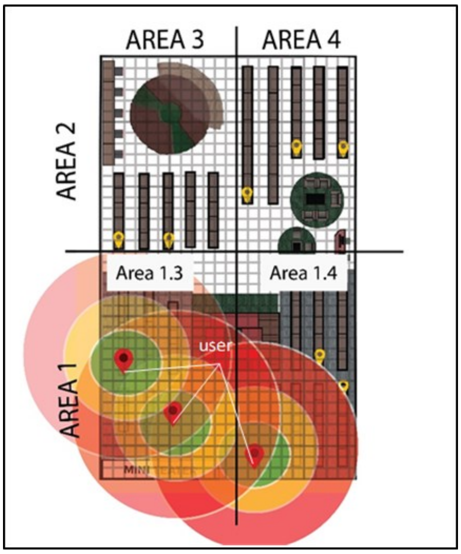

Fig 9. User Mobility in Coverage Area

Fig 9 shows the condition of 3 coverage of RSSI signal when the mobility of user in the coverage area 1.3 covered by 3 BLE B*eacon* with the intersecting coverage circles, i.e. BLE B*eacon* 7, BLE B*eacon* 2, and BLE B*eacon* 3. Each of BLE B*eacon* had the *coverage* area determined based upon RSSI and distance. User position was determined based upon the coverage area of each BLE Beacon. When the user was at the intersection of the green and yellow zones, the user's position was in the green zone, i.e. a zone with a high RSSI for distance. When the user's position was in the yellow and red zones, the user's position was at the strength of the received RSSI. The intersection between the 3 red zones in each BLE Beacon was the user's last position covered in each area division, which then switched to the next coverage area when the user walked.

C. *Application Information Data*

The test of the application of data information about the navigation of book position was based on the position of bookshelf in the library. The scenario of the test was conducted by placing the BLE Beacon installed on the bookshelf based on the latitude and longitude point in accordance with the maps as shown in Table 1. The concept in this application was based on RSSI and the distance remarked with the differences in color of marker on the mapping of application. When the marker was red, the user was in the area that was quite close with the bookshelf. When the marker was green, the user was far from the bookshelf; thus, the user would identify the position of any bookshelf closest to the user.

Fig 10 shows the mobility of user when going to the bookshelf number 20 in which the user must pass through a number of *coverage* areas from each bookshelf. When the user started to walk into the right wing area of library, the user would first be in the area of bookshelf 13 and the application showed that the bookshelf number 13 was the closest to the position of the user. When the user started walking again, the user would enter the area of bookshelf number 14 and the application showed that bookshelf number 14 was the shelf closest to the user. Each change of the green marker into red indicated the user's movement from the coverage area of bookshelf number 13 to the coverage area of bookshelf number 14. Similarly, when the user walked to the next bookshelf, i.e. bookshelf number 19, the marker on bookshelf number 14 turned into green and the marker on bookshelf number 19 turned into red, showing to the user that the closest bookshelf was number 19 in the application, until the user walked closer to the position of bookshelf number 20 and the application showed a color change on the marker.

TABLE I
POSITION OF BLE BEACON IN LIBRARY

No Bookshelf	Name Bookshelf	No. Minor BLE Beacon	Latitude, Longitude
9	Tax, Telecommunication	1	-6.971753341714249, 107.63253796845675
14	Audit, Public Accounting	2	-6.97150074862236,107.63260468840599
19	Executive Management, Strategic Management	3	-6.971505074987399, 107.63273108750582
20	Project Management, Conflict Management, Production Management	6	-6.971632869136695,107.6328967139125
13	Signal Processing, Computer Engineering	7	-6.9715663096882885, 107.63247661292552
1	General knowledge, Computer Science	8	-6.971840867352016,107.63282865285872
3	Computer Program, System Programming	9	-6.971943368838568, 107.63283871114254
6A, 6B	Philosophy, Psychology, Religion, Social Science, financial economics	10	-6.971748349757242, 107.63247359544039

Fig 10. Experimental Application Navigation

CONCLUSION

In this paper, the application of navigation in searching the book in library connected to the proposed BLE Beacon could facilitate the visitors of library in finding the position of bookshelf sought. This application has made the book searching more interactive in finding the position of bookshelf based upon the *coverage* area from the signal of BLE Beacon installed and known through the value of RSSI and distance. The father the distance, the lower the RSSI; thus impacting the coverage area and causing the value of path loss greater. This is remarked by the differences in the color of marker in the mapping of application. The change of the marker color from green to red showed the movement of the user from one coverage area to other.

REFERENCES

[1] A. K. Mikhaylov, N. Plevritakis, and J. Tervonen, "Performance analysis and comparison of bluetooth low energy with IEEE 802.15.4 and SimpliciTI," *J. Sens. Actuator Networks*, vol. 2, no. 3, pp. 589–613, 2013.https://doi.org/10.3390/jsan2030589

[2] J. Tosi, F. Taffoni, M. Santacatterina, R. Sannino, and D. Formica, "Performance evaluation of bluetooth low energy: A systematic review," *Sensors (Switzerland)*, vol. 17, no. 12, pp. 1–34, 2017. http://dx.doi.org/10.3390/s17122898

[3] P. Bulić, G. Kojek, and A. Biasizzo, "Data transmission efficiency in bluetooth low energy versions," *Sensors (Switzerland)*, vol. 19, no. 17, 2019. https://dx.doi.org/10.3390%2Fs19173746

[4] P. Baronti, P. Barsocchi, S. Chessa, F. Mavilia, and F. Palumbo, "Indoor Bluetooth Low Energy Dataset for Localization, Tracking, Occupancy, and Social Interaction," 2018. https://doi.org/10.3390/s18124462

[5] A. Baniukevic, C. S. Jensen, and H. Lu, "Hybrid Indoor Positioning With Wi-Fi and Bluetooth: Architecture and Performance," 2013. https://doi.org/10.1109/MDM.2013.30

[6] A. Ghofrani, R. M. Toroghi, and S. M. Tabatabaie, "ICPS-net : An End-to-End RGB-based Indoor Camera Positioning System using deep convolutional neural networks," https://doi.org/10.48550/arXiv.1910.06219

[7] T. T. Khanh, V. Nguyen, X. Q. Pham, and E. N. Huh, "Wi - Fi indoor positioning and navigation: a cloudlet - based cloud computing approach," *Human-centric Comput. Inf. Sci.*, 2020. https://doi.org/ 10.1186/s13673-020-00236-8

[8] S. Ezpeleta, "Analysis of RF-based Indoor Localization with Multiple Channels and Signal Strengths Analysis of RF-based Indoor Localization with Multiple Channels and Signal," no. November, 2014. http://dx.doi.org/10.1007/978-3-319-18802-7_10

[9] L. U. Bai, F. Ciravegna, R. Bond, M. Mulvenna, and S. Member, "A Low Cost Indoor Positioning System Using Bluetooth Low Energy," vol. 8, 2020. https://doi.org/10.1109/ACCESS.2020.3012342

[10] I. I. S. Museum, P. Spachos, S. Member, and K. N. Plataniotis, "BLE Beacons for Indoor Positioning at an Interactive IoT-Based Smart Museum," pp. 1–11. https://doi.org/10.1109/JSYST.2020.2969088

[11] B. Kim, M. Kwak, J. Lee, and T. . Kwon, "A Multippronged Approach for Indoor Positioning With WiFi, Magnetic and Cellular signals," in *2014 International Conference on Indoor Positioning and Indoor Navigation (IPIN)*, 2014, vol. 015, pp. 27–30. https://doi.org/10.1109/IPIN.2014.7275551

[12] H.-K. Su, Z.-X. Liao, and C.-H. Lin, "A hybrid indoor-position mechanism based on bluetooth and WiFi communications for smart mobile devices," in *2015 International Symposium on Bioelectronics and Bioinformatics (ISBB)*, 2015, pp. 188–191. https://doi.org/10.1109/ISBB.2015.7344955

[13] X. Yang, M. Deng, and T. Jiang, "Indoor Positioning System Based on INS / WiFi Propagation Model," in *2017 Progress In Electromagnetics Research Symposium - Spring (PIERS)*, 2017, no. 1, pp. 3478–3480. http://dx.doi.org/10.1109/PIERS.2017.8262362

[14] H. Cui and K. Liu, "Indoor Positioning and Fingerprint Updating Based on Affinity Propagation Clustering," *2018 Eighth Int. Conf. Instrum. Meas. Comput. Commun. Control*, pp. 226–230, 2018. https://doi.org/10.1109/IMCCC.2018.00055

[15] A. A. Kalbandhe and S. C. Patil, "Indoor Positioning System using Bluetooth Low Energy," in *2016 International Conference on Computing, Analytics and Security Trends (CAST)*, 2016, pp. 451–455. https://doi.org/10.1109/CAST.2016.7915011

[16] D. G. A and C. Villalba, "Centralized indoor positioning system using bluetooth low energy," in *2018 XLIV Latin American Computer Conference (CLEI)*, 2018, pp. 860–869. https://doi.org/10.1109/CLEI.2018.00109

[17] E. Essa, B. A. Abdullah, and A. Wahba, "Improve Performance of Indoor Positioning System using BLE," in *2019 14th International Conference on Computer Engineering and Systems (ICCES)*, 2019, pp. 234–237. https://doi.org/10.1109/ICCES48960.2019.9068142

[18] T. T. Dinh, N. Duong, and K. Sandrasegaran, "Smartphone-based Indoor Positioning Using BLE iBeacon and Reliable Lightweight," vol. 20, no. 17, pp. 10283–10294, 2020. https://doi.org/10.1109/JSEN.2020.2989411

[19] C. Uttraphan, F. A. Aziz, M. Helmy, A. Wahab, and S. Z. Syed, "Bluetooth Based Indoor Navigation System," in *International Conference on Technology, Engineering and Sciences (ICTES)*, 2020, pp. 1–10. http://dx.doi.org/10.1088/1757-899X/917/1/012055

[20] C. J. Oh, E. K. Jwa, and J. W. Jwa, "Development of Smart Tourism app Using Bluetooth Low Energy Beacons," no. 6, pp. 1276–1280, 2019.

[21] N. Malipatil, V. Roopashree, R. H. S. Gowda, M. R. Shobha, and H. C. S. Kumar, "RFID Based Library Management System," *Int. J. Res. Eng. Sci. Manag.*, vol. 3, no. 7, pp. 112–115, 2020.

[22] D. Bagal and P. Saindane, "Library - A Face Recognition and QR Code Technology based Smart Library System," in *Proceedings of the Fourth International Conference on Communication and Electronics Systems (ICCES 2019)*, 2019, no. Icces, pp. 253–258. https://doi.org/10.1109/ICCES45898.2019.9002530

[23] C. Gomez, J. Oller, and J. Paradells, "Overview and Evaluation of Bluetooth Low Energy: An Emerging Low-Power Wireless Technology," *Sensors*, vol. 12, no. 9, pp. 11734–11753, 2012. https://dx.doi.org/10.3390%2Fs120911734

[24] M. Collotta and G. Pau, "A solution based on bluetooth low energy for smart home energy management," *Energies*, vol. 8, no. 10, pp. 11916–11938, 2015. https://doi.org/10.3390/en81011916

[25] J. Huh and K. Seo, "An Indoor Location-Based Control System Using Bluetooth Beacons for IoT Systems," *Sensors*, vol. 17, no. 12, pp. 4–22, 2017. https://dx.doi.org/10.3390%2Fs17122917

[26] N. Pakanon, M. Chamchoy, and P. Supanakoon, "Study on Accuracy of Trilateration Method for Indoor Positioning with BLE Beacons," in *2020 6th International Conference on Engineering, Applied Sciences and Technology (ICEAST)*, 2020, pp. 1–4. https://doi.org/10.1109/ICEAST50382.2020.9165464

[27] S. Chou *et al.*, "Application of Bluetooth low energy indoor positioning to optical lenses manufacturing factory," in *2018 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)*, 2018, pp. 1–6. https://doi.org/10.1109/I2MTC.2018.8409674