Indoor Location Tracking System Based on Android Application Using Bluetooth Low Energy Beacons for Ubiquitous Computing Environment

Khamla NonAlinsavath[1, 2], Lukito Edi Nugroho[1], Widyawan[1], and Kazuhiko Hamamoto[2]
[1]Department of Electrical Engineering and Information Technology, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia
[2]Department of Information Media Technology, School of Information and Telecommunication Engineering, Tokai University, Takanawa Campus, Tokyo, Japan
Email: khamla@mail.ugm.ac.id, {lukito, widyawan}@ugm.ac.id, hama@keyaki.cc.u-tokai.ac.jp

***Abstract*—**Indoor positioning and tracking systems have become enormous issue in location awareness computing due to its improvement of location detection and positioning identification. The locations are normally detected using position technologies such as Global Positioning System, radio frequency identification, Bluetooth Beacon, Wi-Fi fingerprinting, pedometer and so on. This research presents an indoor positioning system based on Bluetooth low energy 4.0 Beacons; we have implemented Bluetooth signal strength for tracking the specific location and detect the movement of user through Android application platform. Bluetooth low energy was addressed to be an experiment technique to set up into the real environment of interior the building. The signal strength of beacons is evaluated and measured the quality of accuracy as well as the improvement of provide raw data from Beacons to the system to get better performance of the direction map and precise distance from current location to desire's positioning. A smartphone application detects the location-based Bluetooth signal strength accurately and can be achieved the destination by provided direction map and distance perfectly.

***Index Terms*—**Location context, indoor location system, bluetooth low energy, ubiquitous computing

I. Introduction

Location tracking systems have become essential issues in the pervasive computing approaches to specify positioning based indoor environment. They rely on many technologies in order to apply real application into real situation including Wi-Fi Fingerprinting [1], Bluetooth low energy (BLE) Beacons [2], Machine Learning algorithm [3], Radio Frequency Identification (RFID) [4] and so on. Bluetooth low energy Beacon 4.0 is one of extraordinary characteristics that play an important role for indoor positioning specification. Bluetooth technology for indoor localization provides high accuracy and identifies the specific position of the destination of user precisely; it can be applied to the real environment with advanced benefits such as low energy consumption, cheap, easy to adopt and high accuracy. BLE 4.0 Beacon has been developed to be used with smart device to support in smart environment that supplies short range of broadcasting. Furthermore, BLE technology distributes the feature called received signal strength indicator (RSSI) that can be used to predict and analysis the position information [5]. Bluetooth BLE can be used to work together with other indoor technologies with the purpose of finding the exact location with the average-range error within 2 meters with small spaces such as rooms, high quality and real-time responding.

However, there are some challenges remain in term of positioning service, positioning information of beacons and an accuracy of the system when apply this system to the real environment, the system is challenging to locate and track BLE device in the setup environment using smartphone [6]. Another limiting existing of BLE is that the quality of the signal which is relies on many structures such as the layout of the room, propagation of the signal in indoor condition and high risk of multipath. The complexity of the indoor environment needs to be evaluated sensitively due to obtain high performance with smartphone

In order to address these challenges, we introduced an indoor positioning system based on Bluetooth low energy 4.0 Beacon to locate and provide the direction map to users from current location to desire's destination with high accuracy and position information is provided in term of being guidance for user perfectly. The system-based Android platform is supposed to track the location from overlapped area between outdoor and indoor conditions by real-time supporting and provide service continuously. BLE 4.0 Beacon is proposed to be technology of indoor localization to detect the environment with low energy consumption and determine the current location to the destination accurately using signal strength indicator.

This research is categorized as following details: section 2 presents the related works and theoretical for indoor positioning system, section 3 introduces the performance and implementation of the proposed work, section 4 has figured out the outcome of the experimental based indoor location specification, furthermore, conclusion has been provided in the section 5 and ends up with the references of this research.

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Corresponding author email: khamla@mail.ugm.ac.id.
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II. Related Works

Indoor localization systems [7], [8] have been developed for a long time ago and many developers based commercial and academia purposes have done and provided an overview of indoor technologies [9]. They have become critical technology to detect indoor navigation and tracking including indoor sport stadium, shopping centers, apartment, and business centers. Indoor positioning systems have been implemented with ease as point to point navigation. Users can choose the suitable direction in the lists that they would like to visit from current positioning to destination point together with supporting the best route through the map of the building. It also allows user to turn the distance measurement by offering high accuracy and venue information precisely.

Kriz *et al.* [10] proposed Bluetooth low energy technology with good alternative supplementing with Wi-Fi access points, the combination will get more accuracy localization with the advantages of low energy consumption, power batteries continuously from month to year and BLE will be replaced in the spots where Wi-Fi access points are difficult to power and setup. The experimental was performed where the original Wi-Fi access points and BLE were used for localization of stationary device inside the building and with the main walk through corridors and rectangular in the classrooms and offices, 17 Bluetooth low energy beacons were placed in the corridors and classroom on the floor. As the result of that experiment figured out that the system improved the performance and enabled light-of sight propagation, beacon broadcasting parameters were set to the advertising interval of 100 ms. Furthermore, the resulting data have shown that it is possible to improve the median accuracy by 23% and to reduce the variance.

Kumareson *et al.* [11] introduces a proximity estimation model to identify the distance based on the RSSI values of Bluetooth and light sensor data in different environment based Android platform with respect to accuracy and power consumption with a several real world scenarios. The relationship between Bluetooth RSSI and distance in real world have been implemented to improve the accuracy and apply any condition by face to face proximity accuracy of Bluetooth, smoothing data and different environments. Regarded to the result can be concluded that Bluetooth offers an effective mechanism that is accurate and power efficient for measuring face to face proximity to increase Bluetooth signal strength level and the Bluetooth RSSI values are much smaller than the indoor ones when phone is the backpack or outdoors.

Huh *et al.* [12] proposed indoor localization system by deploying the BLE under the Wireless local area network environment, the developed system can determine the current location of users as soon as they enter a closed space and control household device based on location information. The indoor location-based control system consists of a localization server, user application, service provision client and positioning technology. All components have been worked together but different tasks to operate the whole control system, the experiment set up for the schematic of the system included android application, indoor location-based server and monitoring program to provide real time data and indoor map to the users. The experiment result showed that 199 out of 269 estimated locations fell within the margin of error when error range was 1 meter; the accuracy of the localization server is approximately 74%. The other 14% were found to be far apart from the actual locations which lead to improve the accuracy up to 88% if the system can estimate location more precisely.

III. Performance and Implementation

The system has been developed to specify indoor positioning and location information using Bluetooth low energy 4.0 Beacons to direct and provide indoor mapping information with high accuracy and completed information for users-based Android application. Bluetooth BLE 4.0 Beacon is light device and low energy consumption that can be used to manage indoor information importantly. BLE 4.0 utilizes to be a technique to measure positions indoors with the ability of navigates indoor condition via smartphone (Samsung Galaxy S7 Edge). Moreover, BLE can be used to be a tracking technology that provides an information and coverage for indoor and overlapped areas with narrow accuracy in the installment venues.

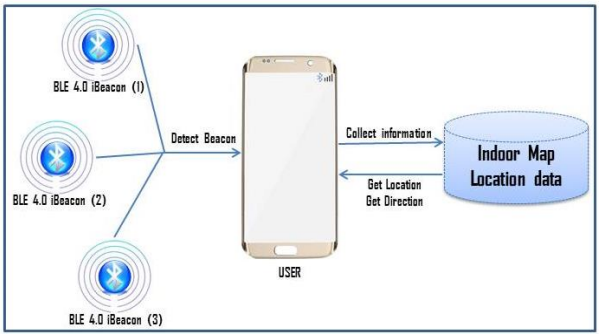

Fig. 1. Proposed system architecture

A basic scenario of the proposed system, 3 BLE 4.0 Beacons were located on the provided positions inside the building (Fig. 1) with 10 meters extend network ranges while user holds the smartphone and operate the application then walk into the building. Several BLE 4.0 Beacons have implemented inside the building in different position and distance in order to classify the ability of received signals through different obstacles such as wall, floor. The running application detects the availability beacon signal in the nearest point of BLE settlement, after that the location information will be indicated on the application which is being guidance for user to direct the route and distance until reach the destination. In order to make BLE to be enabled the performance of the application, user need to activate the Bluetooth signal and accept BLE beacon to make both interact each other and make sure that they are being communicated and provide all needed information to user.

Smartphone (Samsung Galaxy S7 Edge) with Bluetooth signal is used to collect information of signal strength of beacons signals. Android application has been developed in order to be a media for user to collect signal

data and detect the specific location. The scanned signal which was the strongest value will be detected by application and then all required information is provided such as indoor map, direction guide and distance data. Furthermore, the existing signals are applied in the application and indicate the value of signals as the table to compare the received value with the distance of each beacon.

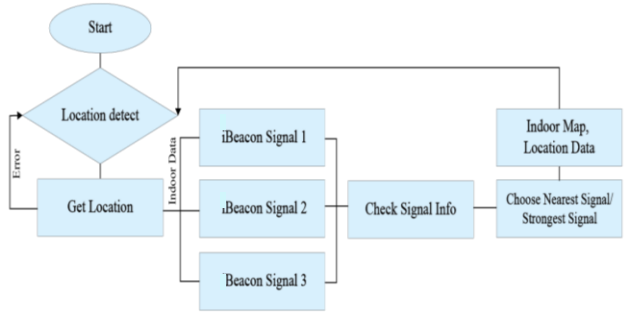

Fig. 2. Flow diagram of the proposed system

IV. Resulf and Discussion

The concept of indoor positioning system has been proposed based on Bluetooth low energy Beacon technology. The tracked location is identified and initialized using signal strength method where beacons have detected from user through smartphone in order to evaluate the accuracy in an indoor current location, the distance and direction map have been initialized while user starts moving to the destination. The application can be tracked, managed automatically when user supplies positioning and location information, and then system will automatically switch to the nearest available signal.

In proposed scenarios, tracking and mapping provide significant value of real environment through provided application to continuously guide user via beacon signals, when the signal has tagged nearby BLE set up place, this information will be collected in the database to make sure that the received information is corrected and matched to the input data from the real space, the beacon identifiers detected location through several BLEs to estimate the distance between the installment place of each beacons by triangulation which classified the different absolute location information.

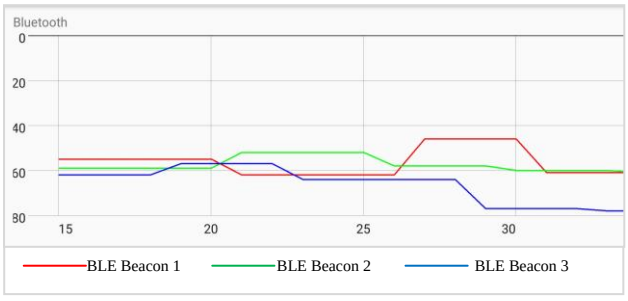

Fig. 3. The availability signal strength of Beacons

The signal strength of beacons (Fig. 3) indicated 3 different patterns of each signal which were regarded to the distance of Beacons installment places. All values and plotters have been adjusted by the movement of user through smartphone that can be received directly from the placing of beacons. The signal will be detected by every 5 seconds of time to make sure that the location keeps update and not to complicate detecting.

The system detects the signals not just only Bluetooth, but also Wi-Fi signal has been detected (Fig. 4) through this system in order to have multi-choices to users when have other obstacles while operating and searching the available signals. This helps them a lot when one device or one application can detect multi-signals to obtain better performance and full service using proposed system and application.

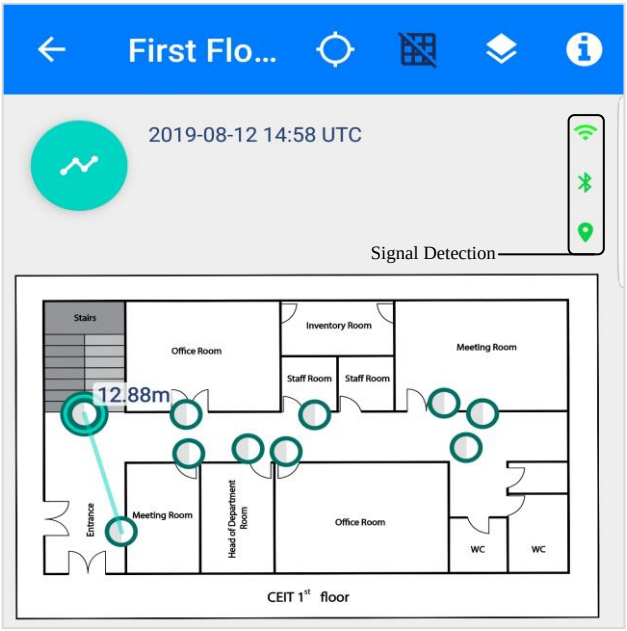

Fig. 4. Distance measurement of current point to another positioning of the first floor

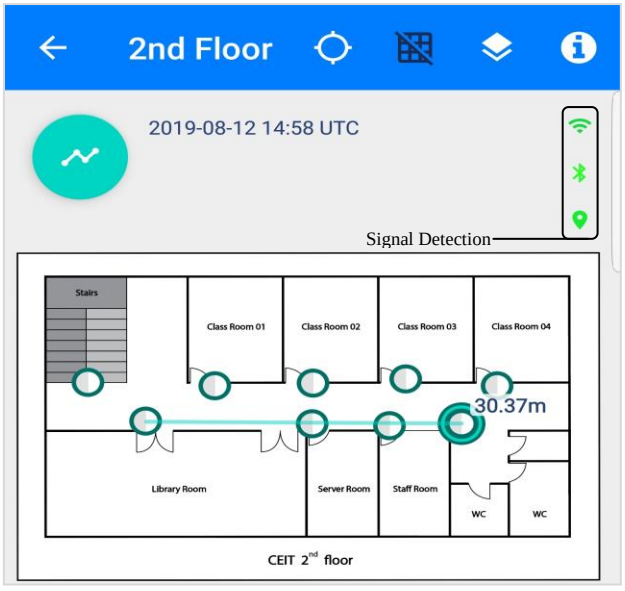

Fig. 5. Distance measurement of current point to another positioning of the second floor

In order to evaluate how the beacons performed. Three different beacons have been implemented and the beacons value corresponding are able to achieve from the

lowest to the highest values which depend on the signal strength of the different distances from smartphone (user). The measured distance (Fig. 4) between user and the beacons can be estimated from 1 m, 3m, 5m and 10m from the movement of user to the destination.

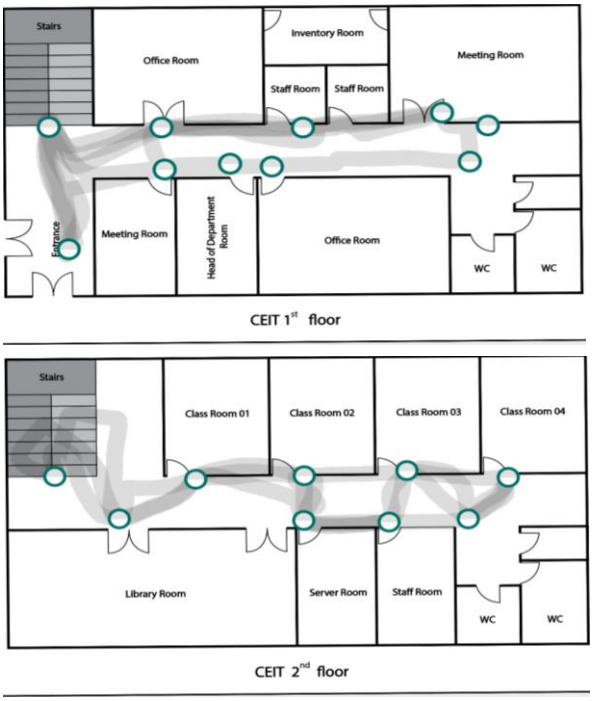

Fig. 6. Pathway recording for indoor environment

The other interesting things of the measurement can be explained by the fact that the Bluetooth beacons signal can be affected by multipath and path loss between base stations to an end device, without obstacles between them the system will be performed well, but the room of measurement however quite small and thick wall so that the propagation problems of multipath can be happened. On the other hand, an indoor environment (Fig. 6) identified the direction while user is moving from current location to final destination; the system detects the beacon signals from the installment place then sends to system to classify the strength signal that used to estimate the distance in the building. Experiments are recorded the pathway of the user by providing an accuracy and satisfy of the position based indoor condition, the complexity of the direction can be improved. However, this system can handle and adapt to other indoor environment when applying this application user needs to have indoor mapping to input to the system and the experiment can detect many signal in the meantime, new input maps will generate theirs mapping and when starts operate the application, pathway will be recorded to the database whenever user is moving to the other positioning.

V. Conclusions

There are numerous of different entities are related to system such as location context, user context and application. Also, some technologies have been attached to the system such as Bluetooth Low Energy beacons, smart phone. They have affected to each other using an approach to merge that technology to become more precise distance positioning. We have implemented a system to test in the different indoor environment based on Android application in indoor and overlapped conditions, the received signal can be analyzed to identify how the signals are affected to each condition and obstacles for indoor location. The system chooses the shortest direction to achieve the destination using smartphone platform, it is also able to provide sub-location in the small space by detecting the strongest beacons signal. For the experimental, we found out that the combination between Bluetooth low energy, positioning technique and developed application is increased the improvement and able to provide through small specific localization. In the future works, we will apply this scenario to integrate with other positioning technologies such as Wi-Fi fingerprint, pedometer and RFID in order to obtain more alternative and better performance of the localization based indoor and outdoor environments.

Conflict of Interest

The authors declare no conflict of interest

Author Contribution

The research was conducted by Khamla NonAlinsavath, Lukito Edi Nugroho, Widyawan and Kazuhiko HAMOTO; this work was carried out as a part of my Ph.D. dissertation; Khamla NonAlinsavath wrote the paper and collected data from other authors. Lukito Edi Nugroho, Widyawan and Kazuhiko HAMAMOTO analyzed the data and checked all content of this research; They also acted as supervisors and guided of this research work; all authors had approved the final version.

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References

[1] M. A. A. A. Mazlan, M. H. M. Khir, M. N. M. Saad, and S. C. Dass, "Wifi fingerprinting indoor positioning with multiple access points in a single base station using probabilistic method," vol. 12, 2017.

[2] Z. Zuo, L. Liu, L. Zhang, and Y. Fang, "Indoor positioning based on Bluetooth low-energy beacons adopting graph optimization," *Sensors*, vol. 18, no. 11, p. 3736, 2018.

[3] S. Bozkurt, G. Elibol, S. Gunal, and U. Yayan, "A comparative study on machine learning algorithms for indoor positioning," in *Proc. International Symposium on Innovations in Intelligent Systems and Applications (INISTA)*, 2015, pp. 1–8.

[4] X. Peng, K. Yang, and C. Liu, "Maneuvering target tracking using current statistical model based adaptive UKF for wireless sensor network," *J. Commun.*, vol. 10, pp. 579–588, 2015.

[5] F. Daniş and A. Cemgil, "Model-based localization and tracking using Bluetooth low-energy beacons," *Sensors*, vol. 17, no. 11, p. 2484, 2017.
[6] D. Chen, K. G. Shin, Y. Jiang, and K.-H. Kim, "Locating and tracking BLE beacons with smartphones," in *Proc. 13th International Conference on Emerging Networking Experiments and Technologies*, 2017, pp. 263–275.
[7] G. S. Bellutagi, D. Priya, and M. Amith, "Indoor navigation using QR code, pedometer and IBeacon," in *Proc. 2nd International Conference on Computational Systems and Information Technology for Sustainable Solution (CSITSS)*, 2017, pp. 1–8.
[8] S. Alletto, *et al.*, "An indoor location-aware system for an IoT-Based smart museum," *IEEE Internet Things J.*, vol. 3, pp. 244–253, 2016.
[9] S. Safei, "Indoor position detection using Wifi and trilateration technique," in *Proc. Int. Conf. Inform. Appl. ICIA2012*, 2012, pp. 362–366.
[10] P. Kriz, F. Maly, and T. Kozel, "Improving indoor localization using bluetooth low energy beacons," *Mob. Inf. Syst.*, 2016.
[11] P. Kumareson, R. Rajasekar, and P. Prakasam, "Accurate location identification using bluetooth in android smart phone," *Int. Dly. J.*, vol. 30, pp. 81–86, 2015.
[12] J. H. Huh and K. Seo, "An indoor location-based control system using bluetooth beacons for IoT systems," *Sensors*, vol. 17, no. 12, p. 2917, 2017.

Khamla Non Alinsavath was born in Xiengkhuang province, Lao P.D.R, on May 15, 1989. He has received a Bachelor of Engineering, majoring in information technology, National University of Laos, Laos in 2011. Master's degree of information technology, Universitas Gadjah Mada, Yogyakarta, Indonesia in 2016. Currently he is a Ph.D. candidate at electrical Engineering and Information Technology, Universitas Gadjah Mada, Yogyakarta, Indonesia and Tokai University, Tokyo, Japan. His areas of interests are computer network, ubiquitous computing, Context-Aware computing, wireless sensor network, localization tracking.

Lukito Edi Nugroho is currently working as senior lecturer at Electrical Engineering and Information Technology, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia. He was Ph. D candidate at school of Computer Science and Software Engineering, Monash University, Australia (2000), the master, James Cook University of North Queensland, Australia (1992), Undergraduate, Universitas Gadjah Mada, Indonesia. His areas of interests are context-aware system, mobile computing, software engineering, and information system.

Widyawan respectively received his Bachelor, Master and Ph.D. degrees from Universitas Gadjah Mada, Yogyakarta, Indonesia in 1999, Medical Informatics, NIHES, Erasmus University, Rotterdam, Netherland in 2003, Adaptive Wireless System, Electronic Department, CIT, Ireland in 2009. He is currently the director of center of system and information resource, Universitas Gadjah Mada, Yogyakarta, Indonesia. His research is focused on computer network, embedded system, pervasive computing, location and tracking system, multimedia system

Kazuhiko HAMAMOTO is currently a Professor and Dean at the Department of Information Media Technology, School of Information and Telecommunication Engineering, Tokai University, Japan. He received his BEng., MEng., and DEng degrees from Tokyo University of Agriculture and Technology in 1989, 1991, and 1994, respectively. His research lies in the area of medical information, human interface design and virtual reality. He published around 50 journal/transaction papers and more than 75 international conference papers. He is a member of IEEE and many national societies in Japan.