IP&SF: Indoor Positioning and Service Framework by using Information about BLE-based Beacons in Indoor Spaces

[1*]Bongen Gu
[1,] *Dept. of Computer Engineering, Korea National University of Transportation, Chungju-si, Chungcheongbuk-do, 27469, Korea, bggoo@ut.ac.kr*

Abstract

User location is one of the important factors to provide services based on a user's location. For user location determination especially in indoor spaces, various methods can be used including beacon, mobile network, NFC and QR code. Mobile network has a difficulty to apply them in indoor spaces. In addition, since a tag needs to be close to a reader device, NFC and QR code require relatively longer time for tag recognition, causing user inconvenience such as recognition error. In this paper, we suggest a user location recognition method using BLE-based beacon, and propose indoor positioning and service framework. The proposed framework is based on information about BLE-based beacons fetched from the remote database system.

Keywords: *Indoor Positioning, Beacon, BLE, Framework, Location-based services*

1. Introduction

The spread of smart devices equipped with various types of sensors has facilitated location-based services. User location information is one of the key context to provide users with context-awareness services. The methods to detect a user's location vary depending on indoor or outdoor situations. Indoor positioning can be implemented using GPS and mobile network, but there may be positioning errors of several meters to tens of meters. User location-based services at exhibition centers, shopping centers, etc. require the indoor positioning method. Many recent studies on indoor positioning use beacon devices. Beacons are small low-energy wireless devices that periodically broadcast signals to transmit location information. Lately, beacons using Bluetooth low energy (BLE) have become popular [1,2].

Indoor positioning using BLE-based beacons is based on the calculation of the distance between a beacon and a user's device such as a smart device. The distance between two devices can be calculated using the difference between the output signal strength of a beacon and the received signal strength of a smart device [3,4]. User location can also be determined by identifying a beacon adjacent to a user's device through signals which a smart device receives from such beacon. However, indoor positioning using beacons has some problems as follows.

The BLE-based beacon technology is not designed with the purpose of measuring distances through signal strengths. Therefore, the measurement of the distance between two devices through the difference between the output signal strength of a beacon and the received signal strength of a device reveals low accuracy. In addition, the detected environmental information service (i.e. temperature, humidity, acceleration, etc.) from sensors equipped in beacons is identified under the universally unique identifier (UUID), but this UUID can be variable for each new service. Thus, even if the same service is offered, a UUID and the type and length of provided information can vary depending on the manufacturers of beacons, resulting in the difficulty of the standardization of services based on information from beacons.

The provision of an independent service for a certain beacon requires additional software layers associated with service requests and information provision, in order not to be dependent on a manufacturer of a beacon and its information. This study proposes a new indoor positioning and

---

[*] Corresponding Author
Received: Jun. 13, 2016, Revised: Jun. 27, 2016, Accepted: Jul. 4, 2016

service framework which is a software layer for providing independent services for a certain beacon. The framework proposed in this study stores information of each beacon in database, and offers relevant information by using beacon signals which a device such as a user's smart device detects. Based on the information fetched from the framework, this device provides location-based services for the relevant user.

This study is organized as follows: Section 2 introduces studies on indoor positioning using BLE beacons. Section 3 addresses the indoor positioning and service framework using BLE beacons, which is proposed in the present study. Section 4 demonstrates its implementation methods. Finally, in Section 5, the conclusions and further research directions are presented.

2. Studies on indoor positioning using beacons

Navigation devices for automobiles offers a route guidance service to destinations on the basis of the current location of automobiles, while the exhibits-related information provided in large-scale exhibition centers can vary depending on the location of visitors. In other words, the location information of objects is the key information for services that they are used for as well as services that may be provided for them. For this reason, many different methods to measure the location of objects have been developed and suggested.

Object positioning in indoor spaces, namely indoor positioning, can be performed by recognizing a user's fingerprint, barcode, RFID, NFC, QR code, tag, etc. through devices such as a reader or a scanner. In this method, the user location can be determined by swiping a user's RFID tag, etc. on a reader installed at a certain location. In other words, as the location where a reader is installed is known in advance, the location of a user who has an RFID tag recognized in such reader can be identified. However, if a number of users are in a certain space such as large-scale exhibition center or shopping center, positioning using this method may not be efficient due to the recognition processing time, recognition errors, and users' tag-related information registration. In addition, this method requires devices such as a scanner for the recognition of users' tags, and consequently, comes with a high cost for the simultaneous positioning of multiple users.

Another indoor positioning method is to use beacons that periodically transmit wireless signals [3]. Many research groups have conducted studies on indoor positioning based on the wireless LAN technology [5], but more recently, many research teams became interested in indoor positioning using Bluetooth Low Energy (BLE)-based beacons [1,2,3]. The key technology of indoor positioning using BLE-based beacons is the assessment of proximity between BLE-based beacons and devices through the strength of Bluetooth signals that devices such as smart devices receive from BLE-based beacons. This assessment of proximity is based on the fact that the strength of signals, which a device receives, is stronger when it is closer to BLE-based beacons. As the place or location where BLE-based beacons are installed is known in advance, BLE beacon-based indoor positioning of a user can be performed based on the fact that a device of such user is adjacent to a certain beacon.

Taking advantage of the fact that strength of signals received by a device is in inverse proportion to the distance of BLE beacons, many research groups work on the measurement of the distance between devices and BLE beacons. However, the BLE beacon technology is not designed with the purpose of measuring distances through signal strengths. Therefore, the measurement of the distance based on signal strengths incurs large errors. In particular, various factors, including an interference phenomenon of signals transmitted by BLE beacons, a change in signal strength depending on surrounding geographical features, and the location of an antenna equipped in a device, can cause the different strengths of signals received by various types of devices at the same location. Moreover, the distances between devices and BLE beacons, which are calculated based on these different strengths, become different as well. In order to reduce errors in calculating the distance between devices and BLE beacons based on the strengths of received signals, many researches have been conducted on the methods to eliminate or normalize signal abnormalities [1,3,4,6].

To reduce errors in measuring the distance between devices and BLE beacons, the strength of signals received at the same location 1 meter away from BLE beacons was suggested to be set as a standard signal strength [7]. However, as the strengths of output signals vary depending on beacons, the standard signal strength from a distance of a meter may vary as well. Apple Inc. When launching iBeacon technology, Apple Inc. set the received signal strength from a distance of a meter, and based on this strength, defined three types of distance profiles between an iBeacon and a device: immediate, near, and far.

3. Indoor positioning and service framework using BLE beacons

Above we stated that indoor positioning using BLE beacons is based on the received signal strength of devices. In order to improve the accuracy of the measurement of the distance between a beacon and a device and of the assessment of proximity between them, information regarding output signals from beacons (e.g., standard signal strength or output signal strength) is needed. BLE beacons also offer environmental information such as temperature, humidity, and acceleration through various embedded sensors. To utilize this information in a device, a UUID for information from BLE beacons should be used. However, the types of environmental information that BLE beacons provide, as well as the types of data that BLE beacons are provided with, vary depending on beacons, and UUIDs also vary for every information service. Therefore, devices using such environmental information are required to have the preliminary knowledge of UUIDs of the relevant environmental information services.

The provision of a location-based user customized service using indoor positioning and environmental information from BLE beacons requires a device to secure BLE beacon-related information. However, because a user’s route in indoor spaces cannot be known in advance, the preloading of BLE beacon-related information in a device upon consideration of a user’s potential route may degrade service quality. Therefore, a system providing information about BLE beacons from which devices receive signals in response to a user’s movement is required to offer effective location-based user-customized services in indoor spaces. The present study proposes the indoor positioning and service framework which offers location-based user-customized services through the provision of information about BLE beacons installed in each space for devices in response to a user’s movement in spaces.

3.1 BLE beacon-related information

The BLE beacon-related information that can be offered by the framework proposed in this study needs to be independent from beacons and sufficient for the implementation of effective location-based user customized services. The information offered by the framework can be categorized into three: information for indoor positioning, information for environmental information, and information for control of beacon operation. The beacon information for indoor positioning, which consists of location of BLE beacons and transmission signal strength, is the key information to determine a user’s location, and through which a device can perform indoor positioning of a user. The information for environmental information, which includes temperature, humidity, and acceleration, is obtained from sensors embedded in beacons, and through which a temperature of a certain place where a user is located can be adjusted to an optimal level. Finally, the information for control of beacon operation, including the control of output signals from beacons and the control of access, is needed when many different beacons are controlled under the integrated management.

All kinds of information from beacons is identified by UUIDs. However, UUIDs for all kinds of information can vary depending on manufacturers and types of beacons and user settings. For example, because UUIDs to access temperature information of a certain space can vary depending on beacons, the access of a device to this information requires the preliminary knowledge of UUIDs that are assigned to each beacon. Securing all information of every beacon installed in large-scale indoor spaces (e.g., large-scale exhibition center or shopping center) is not considered a good approach.

Information that the framework offers for indoor positioning includes spaces where BLE beacons are installed, space dimension, locations where BLE beacons are installed in spaces, output signal strength of BLE beacons, standard signal strength measured at a distance of a meter away, and constant for distance calculation based on signal strength. The framework provides devices with this information by using values that a manager sets or measures when BLE beacons are installed in certain spaces.

Offering of information for environmental information by the framework does not mean that it directly provides environmental information. What the framework provides for devices is UUIDs assigned to relevant beacons for environmental information. Using the UUIDs received from the framework, devices can access to environmental information detected by sensors of BLE beacons. For example, in order to access to temperature information detected by BLE beacons installed in a space where a user is located, the user’s device receives the UUIDs of the relevant beacon services for the access to temperature information from the framework, and through these UUIDs obtains temperature information from beacons.

Information for control of beacon operation is mainly used by beacon managers. Just as the information for environmental information, the framework does not directly perform a beacon management function. Instead, the framework transmits UUIDs for the management (e.g., password settings to control output signals of beacons and management access) to devices, and through these UUIDs, devices request and perform the management function of BLE beacons.

3.2 Interaction between the framework and devices

The framework proposed in this study offers the information required to obtain the relevant information from beacons, not directly offering signal strength of beacons and environmental information. Therefore, the interaction among a user’s device, the framework, and beacons is needed to provide location-based user-customized services. Figure 1 presents the interaction among a user’s device, the framework, and beacons.

In Figure 1, ‘Smart Device’ represents a user’s device and IP&SF (Indoor Positioning and Service Framework) represents the framework proposed in the present study. When a user enter a space, his/her device receives signals of beacons installed in the space. At this moment, the device can detect the MAC (media access control) address of beacons. However, since services offered by the beacons cannot be determined only with the MAC address, the device transmits the MAC address of the beacons to the framework (IP&SF). Because the signals that the device receives in the space where the user is located can be more than two, the device may transmit several MAC addresses to the framework. Then, from the database the framework searches the information about the location of the beacons with the MAC addresses received by the device and transmits the searched information to the device. If the location information obtained from the framework is one or indicates an identical location, the device again transmits it to the framework. If several location information is obtained, the device offers an opportunity of selecting a location to the user, and the information of the selected location is transmitted to the framework.

The framework transmits the information of beacons in the selected location to the device, which includes UUIDs regarding services that such beacons can offer. The device receiving these UUIDs from the framework can request necessary services, depending on the application by using the UUIDs, of the beacons. According to this request, the beacons can transmit the relevant information to the device.

As stated above, the calculation of the distance between a device and a beacon by using the received signal strength of the device can incur large errors. However, the application requiring the calculation of such distance may use the received signal strength of a device. In this regard, the device needs a constant value for the distance calculation and information such as the signal strength transmitted by beacons and the signal strength measured at a distance of a meter away. The device can calculate the distance by obtaining such information from the framework. Even though a constant value can vary depending on smart devices and types of their operation system, if the framework obtains a constant value from each combination of them in advance and transmits it to the device, the accuracy of the calculated distance based on the received signal strength can be improved.

Devices can not only determine the user location based on the information from the framework, but also obtain environmental information measured by sensors embedded in beacons. The types of services that devices can offer using such information can vary depending on application fields. For example, in the case that exhibits are on display in separate spaces in a large-scale exhibition center according to their themes, the application of analyzing the information of preferable exhibits through the number of audiences of every exhibit can be carried out by collecting the information on the number of the audiences who stay at a certain space and the duration of their stay. For this application, the number of devices accessed to the information of beacons in each exhibition space, as well as the initial and final access time, can be collected and used for a statistical analysis.

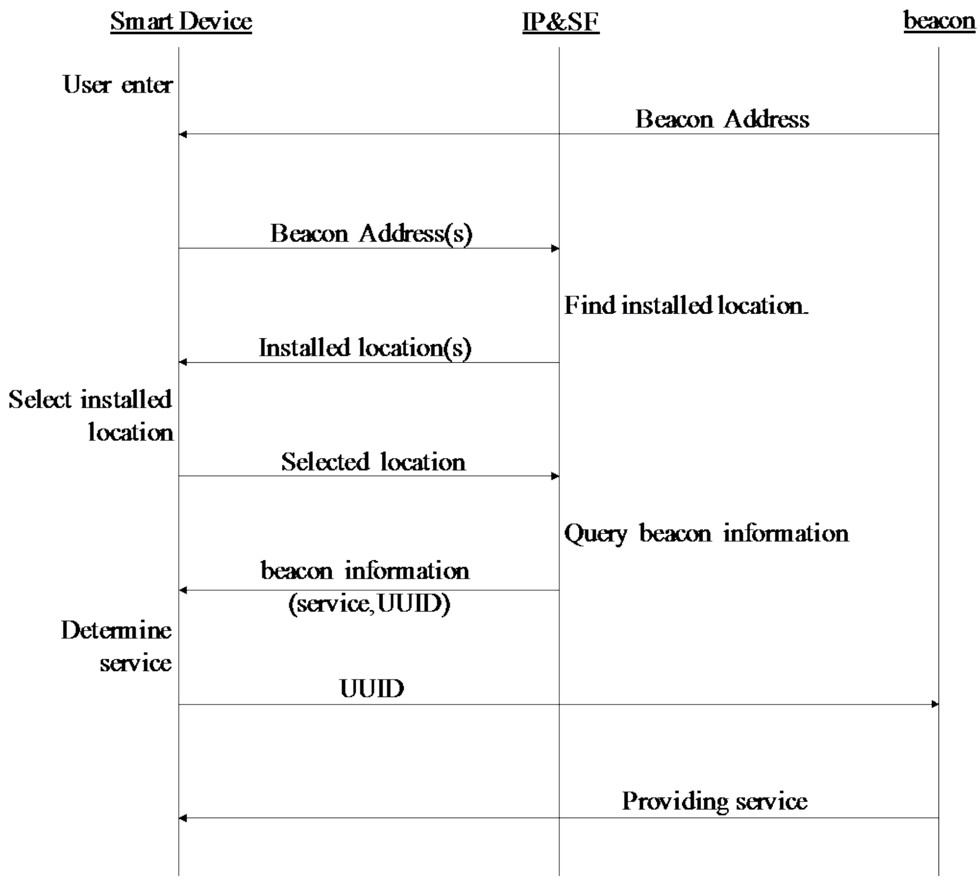

Figure 1. Interaction between the framework and devices

4. Methods to implement the IP&SF

The IP&SP interacts with users' devices through an internet connection. Methods for this framework to interact with devices include a server-client model and a web service model. In the server-client model, a user's device acts as a client and the framework acts as a server. However, there are some disadvantages: If services from beacons are changed or added while using the server-client model, the modification of server-side software is required. If devices offer location-based services, a client software module needs to be created for the interaction with the framework.

Meanwhile, the implementation of the framework proposed in this study by using the web service model has several advantages. First of all, the interaction between the framework and devices can be simplified. Unlike the interaction using the server-client model, devices can interact with the framework simply via an API for web services as well as a URL for web service requests, without following the procedures of creating a socket for acting as client, requesting the connection of a server, and requesting relevant information after the connection.

The response to changes in services that beacons offer is also simple. If a service is newly added to or deleted from beacons, the framework can response to this change by adding, deleting, or modifying an API related with the service. In other words, a flexible configuration of beacons can be established. Therefore, even if a new type of beacon is installed, its effects on the existing services for users and the framework can be minimized or eliminated. For example, even if a dysfunctional beacon in a location is eliminated and another beacon is newly installed, the existing services for users can be continuously provided without any modification. In addition, the productivity of the development of a new service can be improved because devices interact with the framework through the web service. In other words, when developing a new service, a developer can focus on the development of the service itself, and the interaction with the framework can be handled in a relatively simple way.

In this regard, Figure 2 illustrates a configuration of the framework. The Web Service module of the framework provides APIs that a user's device uses to obtain beacon-related information, and implements each API through the database for such information. In order to provide beacon-related information, this module provides more than one APIs for every single piece of information, such as APIs to provide output signal strength of beacons for the device and APIs to provide UUIDs to access to the measured temperature information. The Web Interface, which is a web-based interface provided for a manager with the purpose of maintenance, enables a manager to register a new beacon and a new beacon service, and to eliminate and modify a service. The Service Logger is set to record logs of services provided while the framework operates. In this logger, the minimal information required to perform a statistical analysis for further service improvement is collected. When analyzing these logs, a service provider can analyze the number of users who stay in each space, duration of their stay, and type of services they use. These analysis data may contribute to further development and improvement of new services.

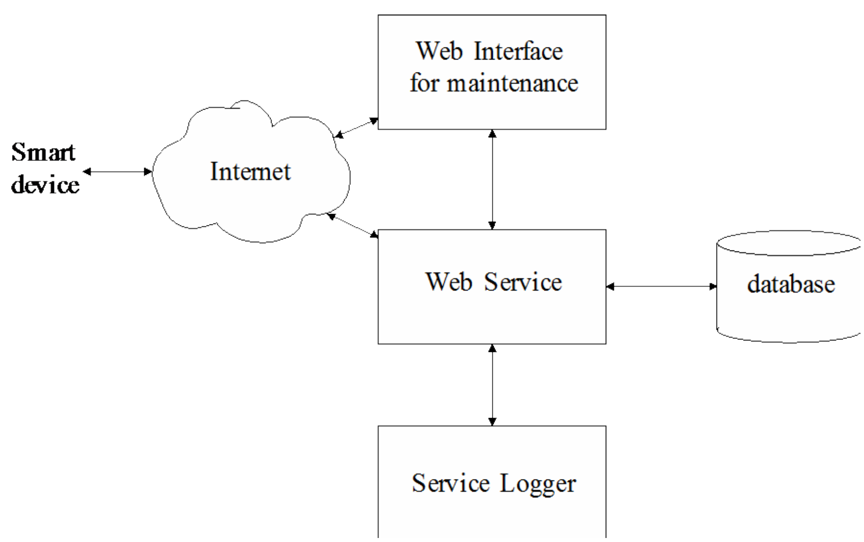

Figure 2. Implementation Model

5. Conclusions

User location information is the key information to provide location-based user-customized services. Among many different methods to obtain location information, the BLE beacon are frequently used for indoor positioning of users. Many studies have been conducted not only on the measurement of proximity of a user's device but also on the calculation of the distance between a user's device and a beacon through the received signal strength of the device. However, the provision of user-customized services through indoor positioning and all types of environmental information from beacons has a disadvantage has a problem that devices need to have the preliminary knowledge of beacon-related information. In the cases of large-scale spaces such as shopping centers and exhibition centers, the spaces can be subdivided into subspaces according to their purposes. If a number of beacons are installed and operated in such subspaces, it is difficult for a service operator to preload information regarding each beacon in user devices.

To resolve this problem, the present study proposed the indoor positioning and service framework providing beacon-related information through beacon signals that a user's device receives when he/she enters a certain space. This framework provides a user's device with information about indoor positioning technology using BLE beacons, information to access environmental information from BLE beacons, and information to control BLE beacons, and thereby, supports the provision of effective location-based user-customized services. In addition, this framework basically uses user location information to provide beacon-related information for devices. For this reason, the appropriate beacon-related information can be provided according to spaces where a user stays, without the preloading of beacon-related information in a device.

The framework proposed in this study provides beacon-related information for a user's device. Thus, this framework may contribute to the improvement of the accuracy of indoor positioning using such information, and to the development of new types of location-based user-customized services because it facilitates the service provision that is independent from manufacturers, types, and models of BLE beacons. A fruitful direction for further research is to establish a system a laboratory level by using the implementation model and to develop related services, so that new problems can be identified and better solutions can be made.

6. Acknowledgments

This was supported by Korea National University of Transportation in 2016.

7. References

[1] C.P. Yoon, C.G Hwang, "Efficient indoor positioning systems for indoor location-based service provider," Journal of the Korea Institute of Information and Communication Engineering, Vol. 19, No. 6, pp. 1368-1373, Jun. 2015.
[2] R. Faragher, R. Harle, "An analysis of the accuracy of Bluetooth low energy for indoor positioning applications," in Proc. of the 27th International Technical Meeting of the Satellite Division of the Institute of Navigation (ION GNSS+'14), Sep. 2014.
[3] J. Park, J. Kim, and S. Kang, "BLE-BASED ACCURATE INDOOR LOCATION TRACKING FOR HOME AND OFFICE," Computer Science & Information Technology(CS&IT), CSCP 2015, pp.173-182, 2015.
[4] X. Zhao, Z. Xiao, A. Markham, N. Trigoni, and Y. Ren, "Does BTLE measure up against WiFi? A comparison of indoor location performance," European Wireless 2014, pp. 263-268, May. 2014.
[5] D. Nam, H. Han, "Indoor Positioning System Using Fingerprinting Technique," Journal of The Korea Institute of Intelligent Transport Systems, Vol. 7, No. 1, pp. 1-9, Feb. 2008.
[6] S. Lee, K. Kim, and Y Shin, "Interference Avoidance for Beacon Based Indoor Wireless Localization," in Proc. of The Korean Institute of Communications and Information Sciences, Nov. 2015.

[7] H. Cho, J. Ji, Z. Chen, H. Park, and W. Lee, "Accurate Distance Estimation between Things: A Self-correcting Approach," Open Journal of Internet of Things, Vol. 1, Issue 2, pp. 19-27, 2015.