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Analysis of Positioning Accuracy Corresponding To the Number of BLE Beacons in Outdoor Positioning System

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ABSTRACT: In these days, a technology that utilize of Bluetooth Low Energy (BLE) beacon, has been attracted attention to provide variety of convenience services. Especially, not limited to the service that can assist to people directly such as public safety, healthcare, proximity-based service, mobile payment, etc., a technology that can provide convenience indirectly such as asset tracking has also been proposed. Most of all, the indoor location awareness using BLE beacon is the essential technique that can realize these services, it is expected to be more focused if the more BLE beacon is spread in the future. iBeacon uses Bluetooth low energy proximity sensing to transmit a universally unique identifier picked up by a compatible app or operating system. The identifier and several bytes sent with it can be used to determine the device's physical location, track customers, or trigger a location-based action on the device such as a check-in on social media or a push notification. One application is distributing messages at a specific Point of Interest, for example a store, a bus stop, a room or a more specific location like a piece of furniture or a vending machine. We focused on the relationship between the number of installed beacon and its positioning accuracy in this paper.

KEYWORDS: Outdoor Positioning, Bluetooth Low Energy, Positioning Accuracy, Practical Path Loss Model, Radiomap-based Positioning

I. INTRODUCTION

The continued spread of smartphones and Wi-Fi infrastructures have resulted in remarkable development of various Information and Communications Technology (ICT) industries. Most of all, indoor positioning technology has been grown up to support other variety of convenient services as a fundamental technology. Recently, after iBeacon appeared, attempts to recognize the position by utilizing Bluetooth beacon is increasing. Compared with Wi-Fi, since Bluetooth is designed for low power operation, it is running on coin battery generally and easy to install. On the other hand, there are shortcomings that a large number of beacons should be installed for attenuation of the signal is relatively large, and it does not spread widely compared to the Wi-Fi network. However, since such BLE beacon services in cooperation with mobile payment are being continually spread, in the near future, it is expected to be utilized in various services. In this project, we first analyse the characteristics of the Bluetooth low energy signal in order to take advantage of the indoor location estimation. Then, by configuring a virtual radiomap and location estimation simulation, we verify the feasibility of BLE beacon-based indoor location technology. The rest of our paper is organized as follows. In Section II, we briefly investigate the Bluetooth low energy technology. In Section III, we describe the practical signal characteristics of BLE by obtaining through experiments in office environment. In Section IV, we verify the relationship between the number of beacon installed and its positioning accuracy by creating a virtual radiomap using the obtained BLE path loss model, Section V summarizes our work and concludes this paper.

II. BLUETOOTH LOW ENERGY TECHNOLOGY

Bluetooth low energy (BLE) technology is a new standard for wireless personal area network technology developed by Bluetooth Special Interest Group (SIG). BLE, as known as Bluetooth Smart, is a part of Bluetooth 4.0 standard, however, it has other differentiated various functions with compared to classic Bluetooth[1]. Both Bluetooth

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and BLE technology operates on frequency of 2.4GHz and employs same modulation scheme – Gaussian Frequency Shift Keying. Also, both techniques use profile concept, and support service discovery function.

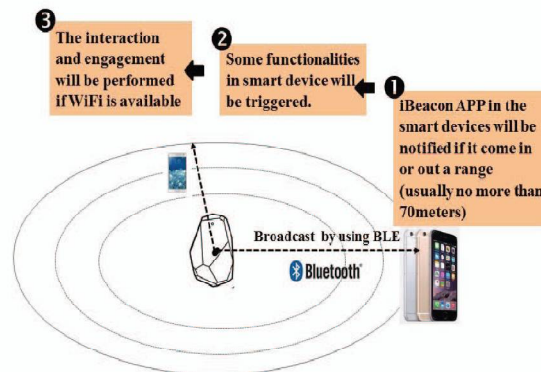


Fig1.1. Bluetooth energy technology

On the other hand, BLE devices have relatively short signal reachable distance, which is depended on the power usage policy. Theoretically, application throughput of the BLE is around 300kbps, which is up to seven times smaller than the classic Bluetooth. Due to the low transmission capacity, BLE also does not support the voice transmission. Whereas, BLE may operates with a low power of up to 100 times, depending on the use case. Applications of BLE or Bluetooth Smart that are commonly discussed are as follows: health care, sports and fitness, car electronics, generic sensors, proximity sensing, wearable devices.

III. BLE SIGNAL CHARACTERISTIC ANALYSIS FOR INDOOR LOCALIZATION

In this section, we investigate the BLE signal attenuation according to a distance, and obtain practical path loss model in order to determine the effectiveness of BLE-based indoor localization.

A. Experimental Environment

For the experiments, we use two types of BLE beacons commercially available in the market, as two each respectively. One is a 'pebble' beacon which is released by SK telecom and the other is released by 'Estimote'. Both products are operated by coin-typed battery, and the signal transmission power is 4dBm equally. We installed additional two Wi-Fi access points in order to compare the signal attenuation with the BLE and Wi-Fi. Each signal was measured during one minute at each reference distance from 1m to 13m with 2m interval. We employed LG Nexus5 and Samsung Galaxy Note3 devices to signal collection for considering device heterogeneity.

B. BLE Path Loss Model

In general, it is known that Log-distance path loss model can reflect well the trends of radio propagation of wireless devices[2]. Following equation (1) is a briefly re-written formulation for Log-distance path loss model Since we collected a lot of received signal data, the noise term $X(\square\square)$ can be omitted. From the equation (1), P indicates the strength of received signal at the reference distance, 1m. 0

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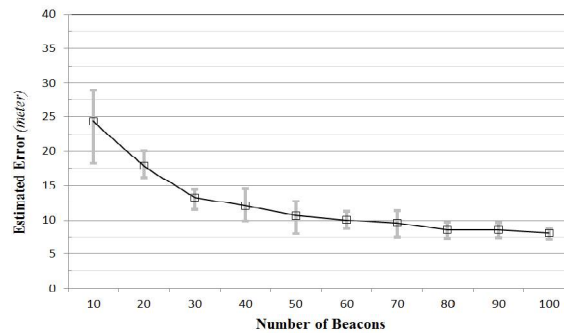


Fig 2.1(a) Min/Average/Max RSSI on LG Nexus5

A Variation of Received Signal Strength from 'BLE(1)'

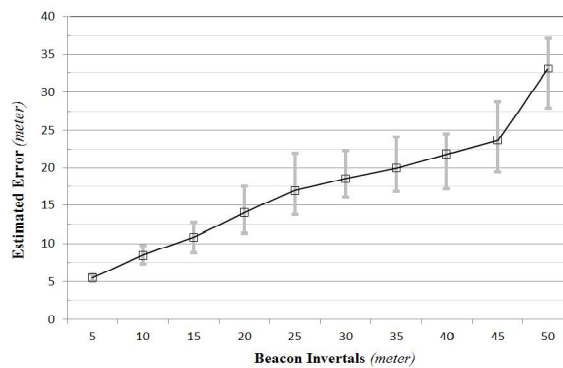


Fig 2.2(b) Min/Average/Max RSSI on Samsung Galaxy Note3

IV. INDOOR LOCALIZATION USING BLE BEACONS

In this section, we configure the BLE signal radiomap which is from virtually generated BLE beacons. Then, based on this signal radiomap, we predict the accuracy of the BLE-based indoor location estimation algorithm. Breaking down the iBeacon format, there are five parts: fixed iBeacon prefix; the proximity UUID: an identifier used to distinguish your Beacons from others, such as your stores or a museum; the major number can group a related set of beacons in an organization, such as a floor in a store or an exhibition hall in a museum; the minor number can be used to identify individual beacons in a specific area because each Beacon has a different minor number, by which we know where the customer is exactly; TX power, is used to determine how close you are to a beacon. It can be presented either as rough information (immediate/far/out of range) or as a more precise measurement in meters. An iBeacon can be placed around an item (goods, art works, or some places of a shop or institution) or a special area, like the lobby or the hallway between two exhibition halls or between the exhibition hall and other area. In addition, iBeacon technology is not an Apple's monopoly. Android devices can also support it. iBeacon technology will be used widely in our social lives for its low cost, low energy consumption and the tiny shapes.

As an indoor positioning system, iBeacons are popular in commercial fields. Push information about what's on sale. With an iBeacon, the software in a smart device or smartphone, can find where they are, and get notifications from the items nearby that are on sale. Even more, customers can pay at the "point of sale (POS)" without touching their credit cards or wallets at all. Control the shoppers' behaviors via recommending services automatically by iBeacons. In a store, the retailer can sense shoppers' interests via the calculation of time a shopper is in front of a specific item in the store, and then, the software in shopper's smartphone will show the other color or style of this item, or even let shopper access to the online shop to compare the price and style at real time. If the shopper does not buy an item, they will get

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some advertisements or coupons relevant to this item later. Promote O2O commercial actions. The retailers can gather shoppers behavior info, for instance, the shopper have ever seen the same goods in the other store of the same chain online or onsite with iBeacon technology. And then, push the good coupons info at the store, meanwhile, show the shopper this goods in their online shop, so as to guide shoppers make purchase online or offline. iBeacon technology brings many chances for the retailers to keep broadcasting the items/events info automatically by smartphone APP of users; to tracing users interests or potential demands; to contextualize shoppers' purchase tendency. All these, no doubt, will be great help in commercial fields. And it also can be worked well in other scenarios, take museum for instance.

A. Deploying BLE Beacons

For the simulation, we have assumed a space of 100m x 100m to deploy virtual BLE beacons. The strategy for deploying beacons can be classified into two: in random or grid-based. We deployed from 10 to 100 beacons randomly in the random topology. Also, we placed BLE beacon at 1m to 50m intervals with grid manner. In each simulation, we employed the path loss model which is received in Nexus5 from the 'BLE(1)' obtained previously, and the noise term was applied as normal distribution with $\sigma=2.74$ which is from experimental data. In consideration of the effects of randomness of the beacon placement and the impact of the noise term, each simulation was performed 10 times in each beacon topology, and we employed kNN fingerprint method [4].

B. Simulation Results

We described our simulation results in the figure 3. Figure 3(a) shows a variation of the positioning accuracy on the number of beacons deployed in the random topology. The more beacons make more accurate result, however, the certain level or less, the result shows similar performance. Figure 3(b) depicts simulation results for the grid topology. It makes relatively remarkable performance in denser case.

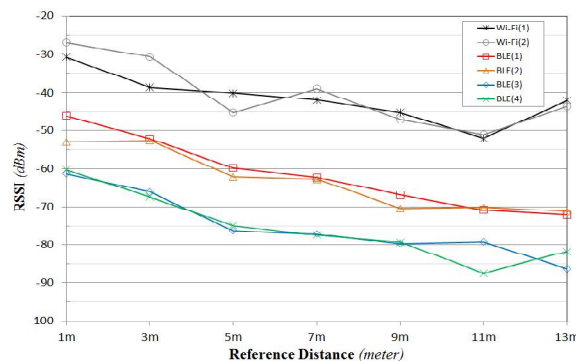


fig 3.1(a) Received Signal Strength on LG Nexus5

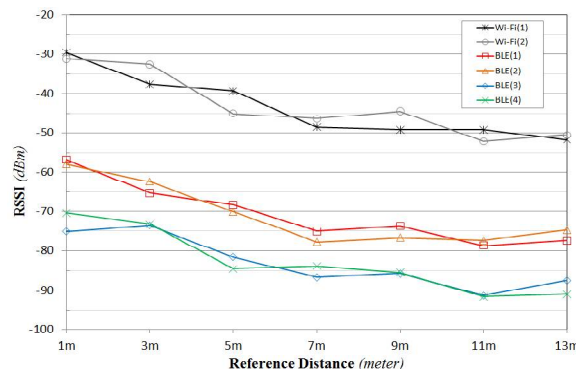


fig 3.2(b) Received Signal Strength on Samsung Galaxy Note3

Experimental Results of Received Signal Strength for Wi-Fi and BLE

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V. ACCESS VISITORS TO COLLECTION VIA IBEACON IN MUSEUM

Pushing notifications on iOS and Android devices can be triggered by an App according to the advertising from an iBeacon simply. If there is a content management platform that smartphone APP can access to, there will be a large space for museums to push history knowledge by multiple media or guide visitors to learn individually or cooperatively. Thus, more local history culture and intangible cultural heritage will be carried on and forwarded. We would like to analyze the practicability of iBeacon application in museum scenario.

3.1 Practicability of iBeacon's application in museum

The museum halls have several superiorities to distribute Beacons. Firstly, Beacons can be placed nearby or behind a collection, or be put at a specific place, take the lobby between different exhibition halls easily. Secondly, the majority of visitors have little idea about local culture or background knowledge relevant to a certain collection or exhibition in a museum. Most of them go to a museum for travelling or leisure. Therefore, when the visitors entered a museum hall, they will be lost, and do not know where to begin with. Of course, they will not come to a museum regularly. An automatic guidance or notification based on iBeacons will be very helpful to them to start their trip inside a museum. Thirdly, auto-notification and ---recommendation will support visitors' personal learning well, thereby facilitate interactions between collections and visitors via museum contents platform. In short, iBeacon technology will make the exhibition an enjoyable, life-affirming experience for the visitors. It is a good choice to protect and broadcast local cultures and histories.

Interaction between visitors and collections based on iBeacons

Thence there are many superiorities if iBeacon utilized in museum hall. We designed an interactive knowldge pushing system based on iBeacon. In this system, there a three points should be paid more attention to.

1) How to take advantage of iBeacon's data packets ---to identify differnet objects of a museum.

- ☐ ☐ The proximity UUID: identify the museum.
- ☐ ☐ Major: present different museum hall;
- ☐ ☐ Minor: identify different artworks in a museum hall;
- ☐ ☐ TX power: measure the distance.

2) Judgement of collection notification As you know, there are so many collections in a musuem hall with iBeacons. When it comes to how to judge which collection should be notified automatically on visitor' smartphone, the distance between visitor and colleciton, and visitor retention time in front of a collection ought be put into considered.

3) How to judge the interests of a visitor, and then push more details relevant to a collection? Beased on retention time; and visitors history behaviors recorded by the system.

The architecture of knowledge pushing system based on iBeacon.Only the notificaiton of the nearest collection will bounced on the screen of visitor's smart device in musuem hall. smart device in museumhall.

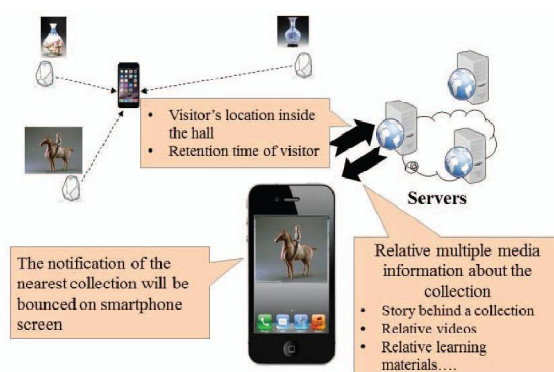


Fig 4Interaction between visitors and collection based on ibeaconsin museum hall

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The system will judge visitors' interests to an artwork mainly by two criterions: the retention time and visitors location indoor.

V. CONCLUSION

In this paper, we analysed the characteristics of the BLE signal and obtained practical path loss model by conducting with two types of BLE beacons. Because of the BLE operated in low power, the overall received signal strength is clearly low compared to the Wi-Fi, and the signal attenuation coefficient was relatively small. We also analysed on the relationship between the number of installed beacon and its positioning accuracy.

REFERENCES

- [1] *Bluetooth, Core Specification v4.1*, Bluetooth Special Interest Group, Dec. 2013.
- [2] T.Rappaport, *Wireless Communications-Principles and Practice*. Englewood Cliffs, NJ: Prentice-Hall, 1996.
- [3] M Ji, J.Kim, Y.Cho, Y.Lee, S.Park, "A Novel Wi-Fi AP Localization Method Using Monte Carlo Path-loss Model Fitting Simulation," in *Proceedings of IEEE 24th International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC)*, Sep. 2013.
- [4] V. Honkavirta, T. Perala, S. Ali-Loytty, and R. Piche, "A Comparative Survey of WLAN Location Fingerprinting Methods", Workshop on Positioning, Navigation and Communication, Mar. 2009