

Analysis of Positioning Accuracy corresponding to the number of BLE beacons in Indoor 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. In this paper, we first analyse practical path loss model of BLE signals with compared to that of Wi-Fi signals in order to take advantage of the BLE beacon for indoor positioning. To estimate the practical path loss model, we employed four BLE beacons (each two beacon is the same manufacturer) and two of Wi-Fi AP. Each signal was measured during one minute at each reference distance from 1m to 13m (with 2m interval) in a Line-of-Sight (LOS) environment. The calculated path loss model was used to generate a BLE signal virtually, we applied the model to configure the BLE radiomap and generate positioning measurement data in our simulation. Since BLE signal has relatively lower tx power compared to Wi-Fi APs, it requires much more beacons to achieve comparable positioning accuracy. We focused on the relationship between the number of installed beacon and its positioning accuracy in this paper.

Keywords— Indoor 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.

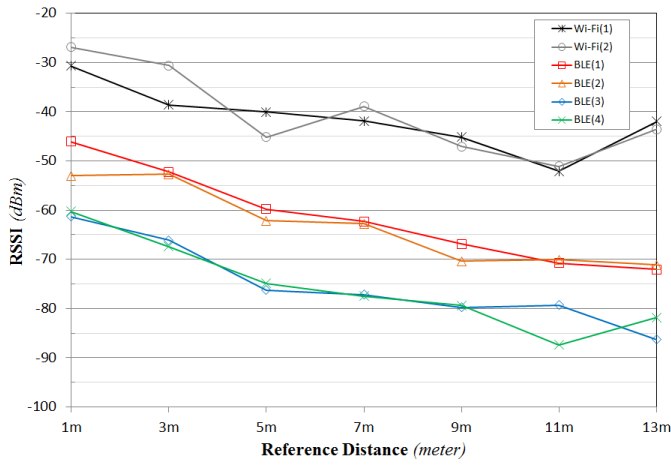
In this paper, we first analyse the characteristics of the Bluetooth low energy signal in order to take advantage of the indoor location estimation. Then, by configuring a virtual radiomap and location estimation simulation, we verify the feasibility of BLE beacon-based indoor location technology. The 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

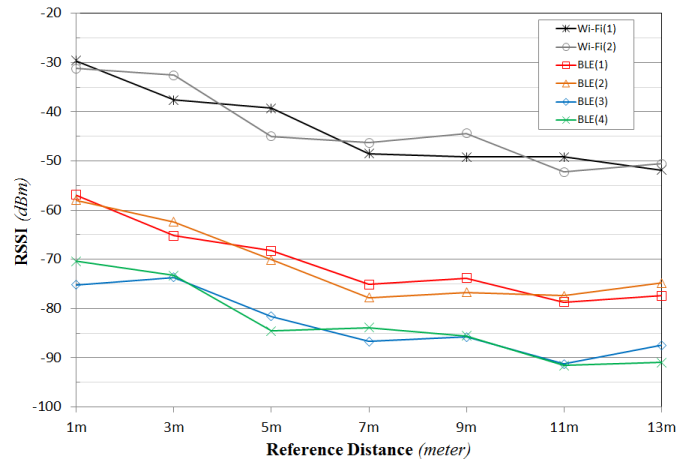
Bluetooth low energy (BLE) technology is a new standard for wireless personal area network technology developed by Bluetooth Special Interest Group (SIG). BLE, as known as Bluetooth Smart, is a part of Bluetooth 4.0 standard, however, it has other differentiated various functions with compared to classic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

Both Bluetooth 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.

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

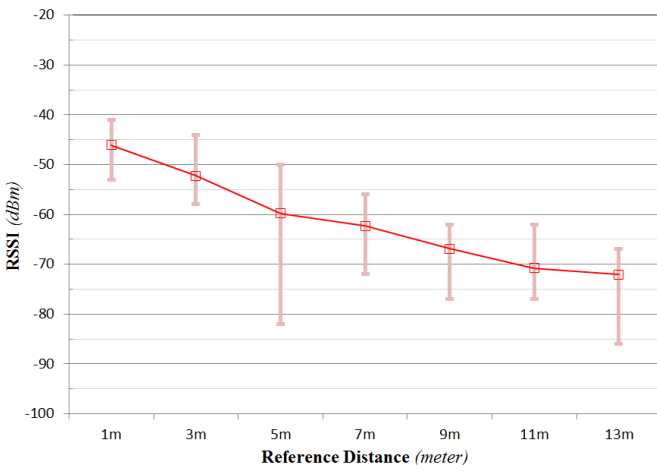


(a) Received Signal Strength on LG Nexus5

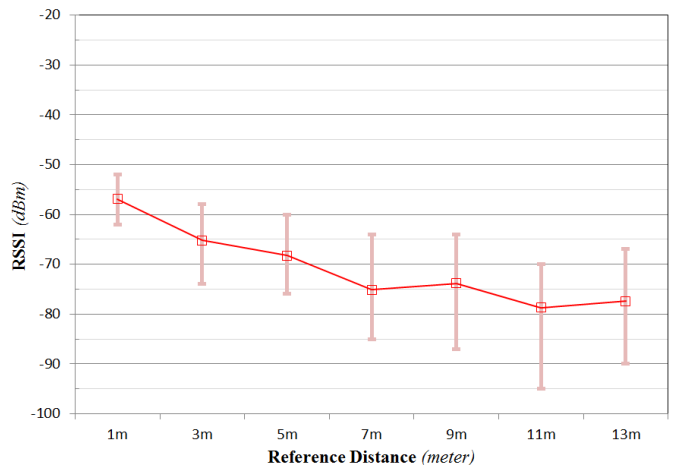


(b) Received Signal Strength on Samsung Galaxy Note3

Figure 1. Experimental Results of Received Signal Strength for Wi-Fi and BLE



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



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

Figure 2. A Variation of Received Signal Strength from 'BLE(1)'

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.

The experimental results are shown in figure 1 and 2. Figure 1 shows the average received signal strengths of Wi-Fi APs and BLE beacons from two kinds of smartphone. Figure 2 is shown with the Min/Max RSSI values in addition to the averaged received signal strength of 'BLE(1)'.

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.

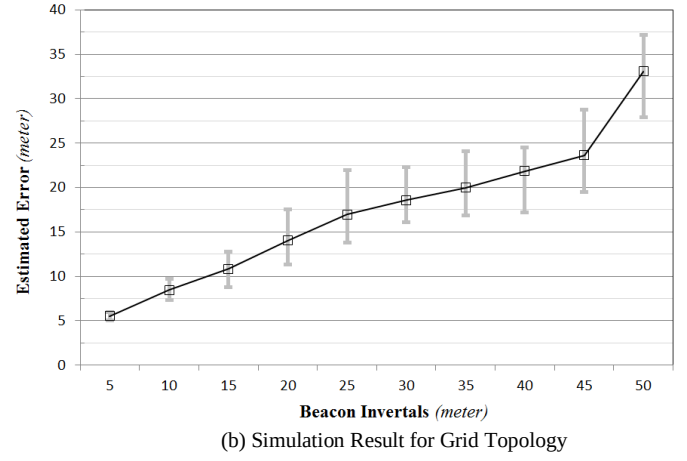
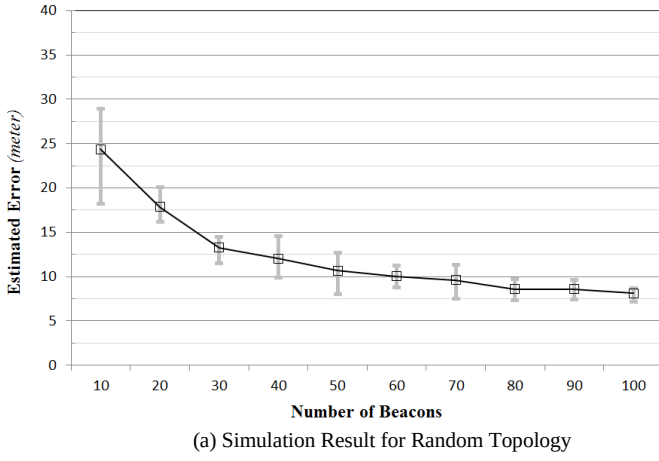


Figure 3. Simulation Result

$$P_r = P_0 - 10\alpha \log d + X(\gamma) \quad (1)$$

Since we collected a lot of received signal data, the noise term $X(\gamma)$ can be omitted. From the equation (1), P_0 indicates the strength of received signal at the reference distance, 1m. P_0 and α can be obtained by calculating the matrix equation, by substituting from the experimental result as we depicted in Figure 1[3]. As a result, estimated path loss model parameter is as following table 1.

TABLE 1. ESTIMATED SIGNAL PATH LOSS PARAMETERS FOR BLE

	LG Nexus5			
	BLE(1)	BLE(2)	BLE(3)	BLE(4)
P_0	-43.6	-48.8	-59.8	-59.0
α	1.05	0.83	0.87	0.95

	Samsung Galaxy Note3			
	BLE(1)	BLE(2)	BLE(3)	BLE(4)
P_0	-56.3	-57.4	-72.1	-68.1
α	0.85	0.80	0.63	0.85

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.

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.

V. CONCLUSIONS

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.

ACKNOWLEDGMENT

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Ju-il Jeon received the B.S and M.S. degree in information and communication engineering in 2009 from Chungbuk National University. He is currently researching at positioning & navigation technology research section in Korea Electronics and Telecommunications Research Institute. His research interests include video coding, video streaming technology, image recognition and indoor localization.



Youngsu Cho received his B.S., M.S. degrees in department of Mechanical and Aerospace Engineering from Seoul National University, Republic of Korea in 2000, 2002, respectively. He had worked as a full-time instructor in the department of Aerospace Engineering from Korea Air force Academy from 2002 to 2005 and has been a member of senior researcher at positioning/navigation technology research section in ETRI (Electronics and Telecommunications Research Institute), Republic of Korea, since 2005.

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