PERFORMANCE EVALUATION OF RANGING-BASED IBEACON POSITIONING IN INDOOR STRAIGHT PASSAGE

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ABSTRACT

Recently, there are various radio-signal based indoor positioning systems with a triangulation-based approach (Needham, 1986) using some transmitters with ranging techniques. When we focus on cheap transmitters, positioning stability, accuracy and availability are required to be improved in some actual environments. Thus, our study is aimed to evaluate the positioning accuracy and availability of the Bluetooth Low Energy in straight passages in indoor environments. In our study, we focused on the triangulation based positioning using iBeacon transmitters and receivers (Mubaloo Ltd, 2014). In our experiment, we applied a triangulation using ranging results with a constraint based on straight passage knowledge. Through our experiments, we confirmed that our approach can estimate with several meter accuracy along a straight passage.

1. INTRODUCTION

The majority of urban activities are in the indoor environment. Therefore, in order to support urban activities, it is necessary to acquire technologies position information in indoor. Recently, there are various radio-signal based indoor positioning systems, such as Wi-Fi, Radio-Frequency Identification (RFID), Bluetooth Low Energy (BLE), Ultra Wide Band (UWB), Indoor GPS, and, Indoor Messaging System (IMES) (Manandhar, 2008). These systems estimate position data with a triangulation-based approach using some transmitters with ranging techniques. When we focus on cheap transmitters, positioning stability, accuracy and availability are required to be improved in some actual environments, such as straight passages and crowded spaces. Thus, our study is aimed to evaluate the positioning accuracy and availability of the BLE in straight passages in indoor environments.

In our study, we focused on the triangulation based positioning using iBeacon transmitters and receivers. Firstly, we evaluated the stability using the iBeacon. In our experiment, the strongest signal was selected among received signals from all transmitters to identify the closest transmitter from a receiver. Secondary, we evaluated a conventional ranging technique based on the received signal-strength indication using the iBeacon in an indoor environment. Thirdly, we evaluated a ranging-based positioning performance using the iBeacon.

2. METHODOLOGY

There are Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA), and Received Signal-Strength Indication (RSSI) positioning, as typical indoor positioning methodologies (Golden, 2007). In actual indoor environment, the ToA, TDoA, and, AoA are sensitive to multipath effects in the radio wave propagation. On the other hand, the RSSI positioning is more robust than other methodologies. Moreover, because a precise synchronization between transmitters is not required in the RSSI positioning, cheap transmitters, such as iBeacon, can be used in RSSI positioning. Recently, many researches focus on fingerprint positioning (Khodayari, 2010). The fingerprint positioning is a positioning technique to correspond received signals with a database prepared in advance of the radio measurement. A radio wave propagation environment is not changed after a database preparation, accurate and stable position data can be estimated. However, an actual environment is generally changed after the database preparation. From these technical backgrounds, we focus on the RSSI positioning using iBeacon in this study.

Each signal from iBeacon transmitters has a non-overlapping identification number. Therefore, a signal from all transmitters can be received. Moreover, the closest transmitter from a receiver can be detected with identification of the strongest signal. The distance between transmitter and receiver can be calculated using the following equation based on the Friis transmission formula (Shaw, 2012) (1):

$$\text{The distance between a transmitter and receiver} = 10^{((\text{TxPower - RSSI}) / 20)} \quad (1)$$

The TxPower is the RSSI value at the position of 1 m from an iBeacon transmitter. By using the distance measurement results between the transmitter and the receiver two or more, position data can be estimated based on a triangulation. Although two intersections are estimated as position data candidates with two transmitters, an actual position is selected from the two candidates with a restriction, such as a mobility area mask, based on indoor environment knowledge, as shown in Figure 1.

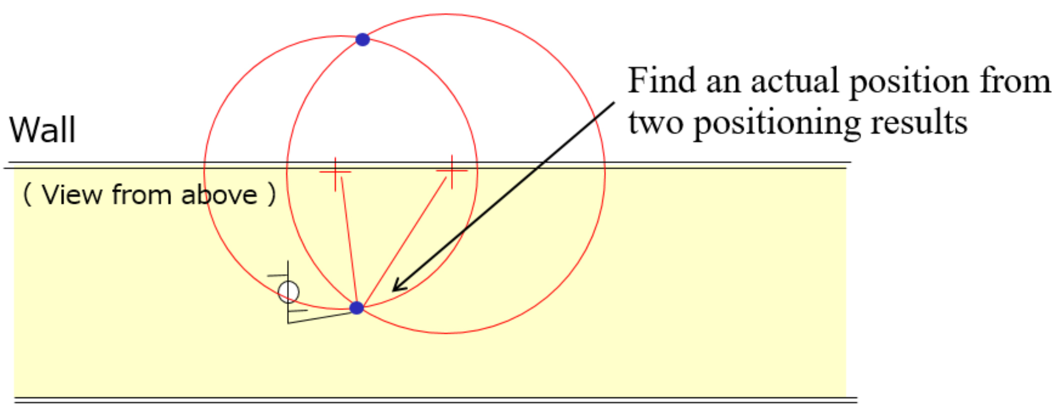

Figure 1. Position estimation with two transmitters in a corridor

3. EXPERIMENTS

3.1 Experiment environment

A corridor in our campus was selected in our experimental environment, as shown in Figure 2. This corridor consists of a 97.2m length of the corridor (width 2.0m, and ceiling height of 2.8m).

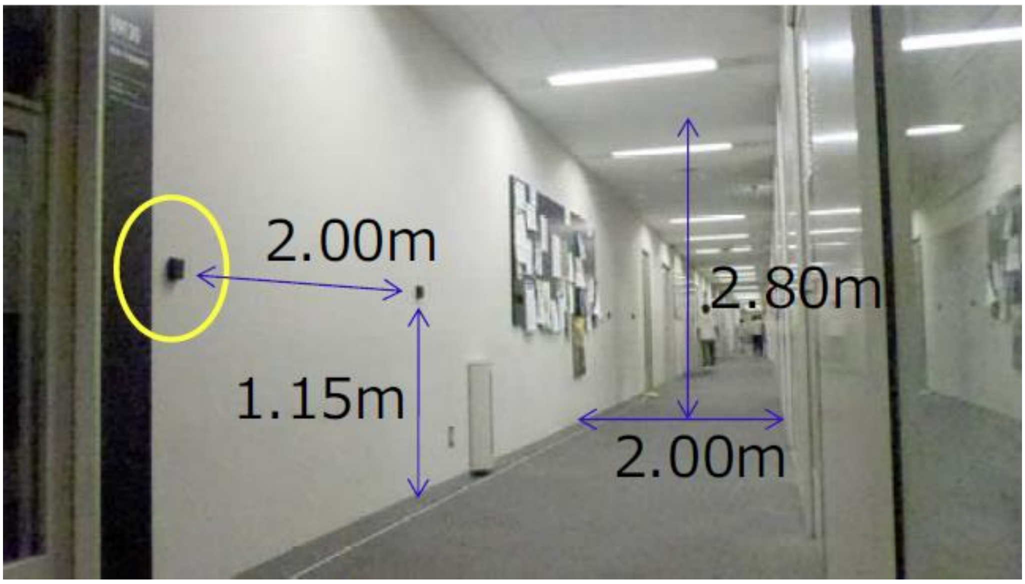

Figure 2. Experiment environment

We conducted three kinds of experiments. The first and second experiments were conducted to verify that iBeacon positioning can be available in the corridor. The third experiment was conducted to verify the stability in the corridor. In the first experiment, six iBeacon transmitters (MyBeacon MB004 Ac , Aplix) were set 1.15 m from the floor and every 2 m along a wall. All transmitters were assigned the same major identification numbers and unique minor identification numbers. In addition, each TxPower value was obtained in our iBeacon transmitter calibration experiment. We used a laptop PC (MacBook Air, Apple) with bleacon Node.js library was used as an iBeacon receiver and antenna. We recorded signals from all transmitters within approximately 1 Hz along the corridor with the laptop PC at the height of the iBeacon transmitters. In this experiment, we acquired signals with several walking patterns.
In the second experiment, eight iBeacon transmitters were set along the ceiling edges and every 3 m along the wall. In this experiment, we also acquired signals with several walking patterns.
In the third experiment, ten iBeacon transmitters were set at a 1.15 m from the floor and every 3 m along the wall. In this experiment, we stopped in the middle and record signals for 1 minute.

3.2 Calibration

Even if we use the same types of iBeacon transmitters, TxPower values of transmitters are not same. Thus, TxPower calibration works are required. Firstly, we set iBeacon transmitters at the same position. Next, we received signals from each transmitter at 1 m distant, as shown in Figure 3. Then, each average RSSI value was calculated. Finally, the each calculated value was used for TxPower value of each iBeacon transmitter.

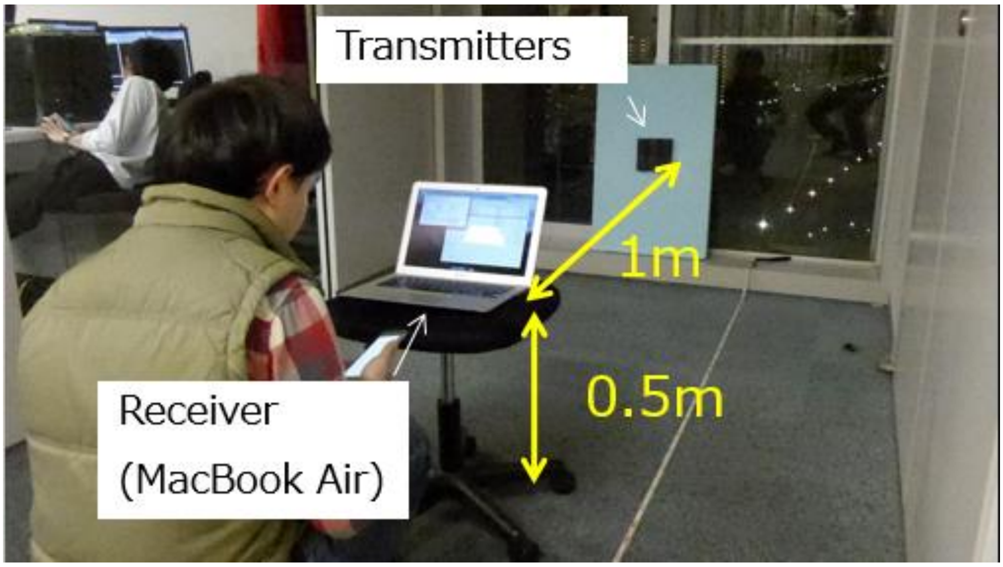

Figure 3. Calibration

We conducted four times for calibration works. The first time and second calibrations were carried out for 30 seconds in a corridor. Third calibration was conducted for 10 minutes in the same corridor. The forth calibration was conducted for 10 minutes in a room.

4. RESULTS

Table 1 shows RSSI values obtained in our calibration works. The average results in our calibration are as shown in Figure 4. The vertical axis indicates RSSI values, and the horizontal axis indicates signal received time. Even if same types of transmitter were used, TxPower values of transmitters were different before calibration works. However, we confirmed that TxPower were approximately adjusted after our calibration

Table 1. Received RSSI values (dB) from 10 transmitters in iBeacon calibration

Transmitter ID	1	2	3	4	5	6	7	8	9	10
First	-59.0	-55.0	-52.5	-49.0	-57.0	-54.5	NULL	NULL	NULL	NULL
Second	-55.0	-55.0	-62.0	-54.0	-56.5	-63.0	-55.0	-55.0	NULL	NULL
Third	-55.0	-55.5	-58.0	-54.0	-55.0	-53.5	-61.0	-53.0	-54.0	-63.0
Fourth	-55.0	-53.5	-56.0	-53.0	-58.5	-60.0	-58.0	-58.0	-56.5	-61.5

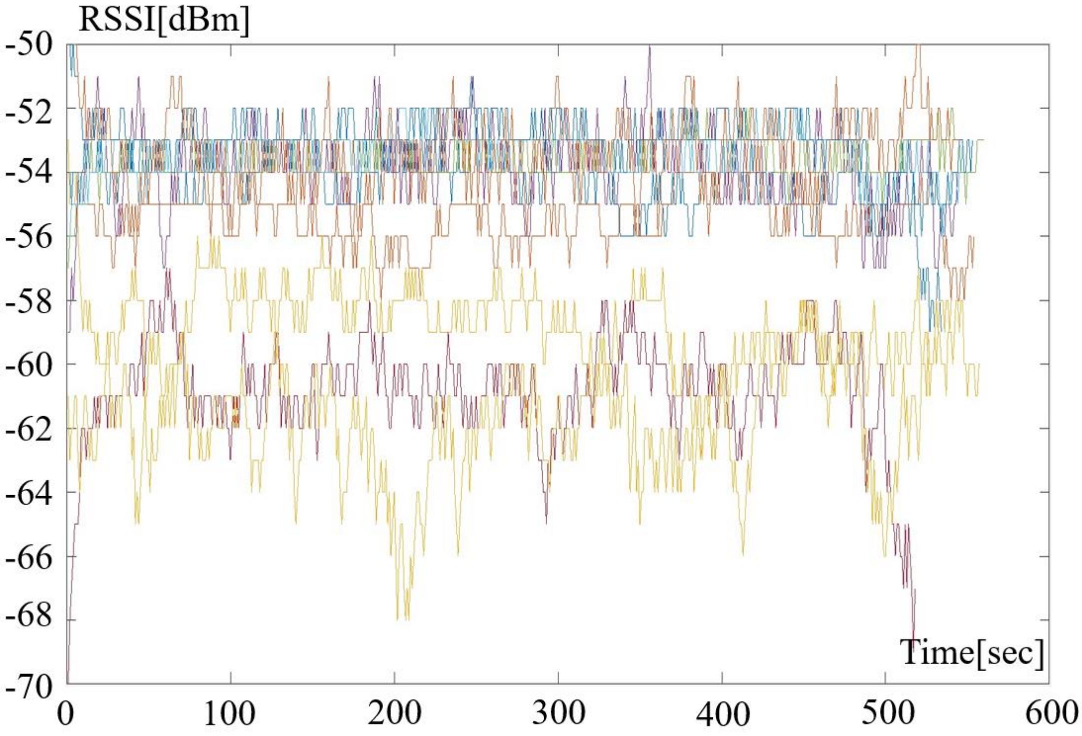

Figure 4. Average results of calibration

Figure 5 shows results in the first experiment by using the first calibration data. Red dots indicate distances from the receiver to the closest transmitter. This figure shows that the movement receiver was estimated continuously. The vertical axis indicates the distance between receiver and transmitters, and the horizontal axis indicates time.

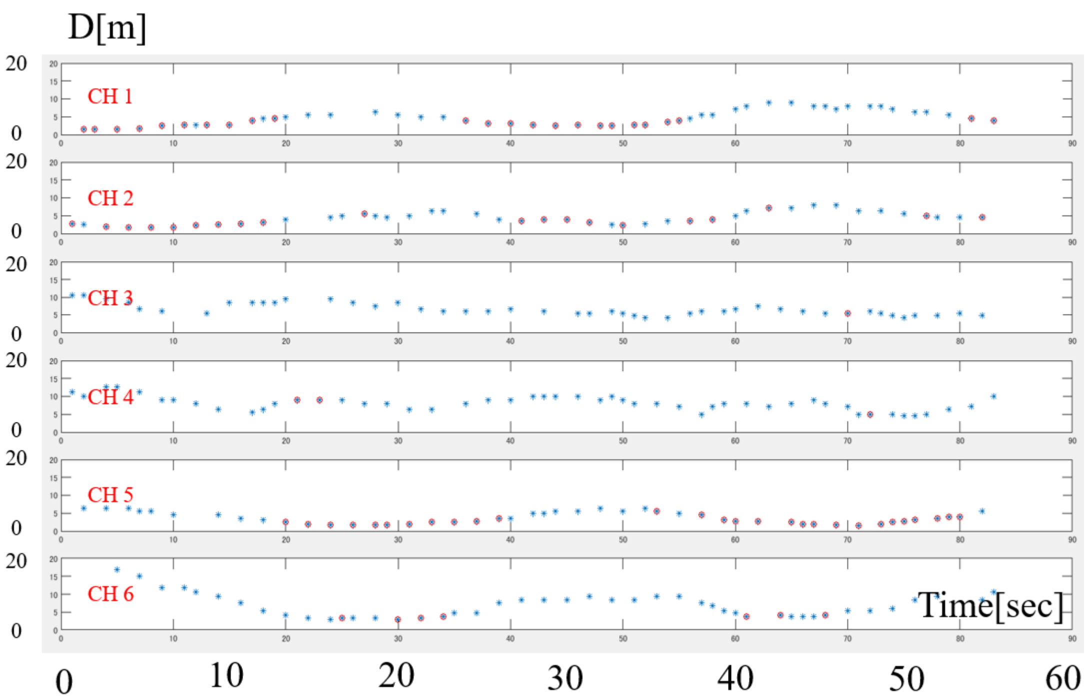

Figure 5. Results in our first experiment

Figure 6 shows results in the second experiment by using the second calibration data. Red dots indicate distances from the receiver to the closest transmitter. Moreover, this figure also shows that wider intervals of transmitters were better to recognize the closest transmitter from the receiver.

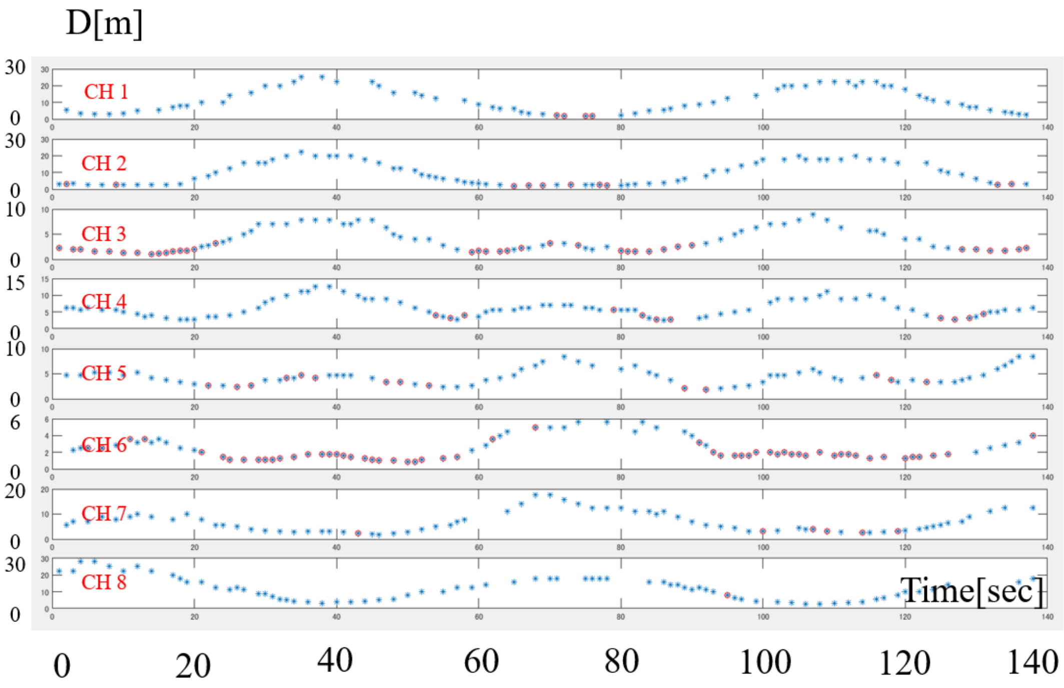

Figure 6. Results in our second experiment

Figure 7 shows our results in the third experiment with calibration data obtained in the third calibration work. This figure shows that we could estimate we stopped to receive signals at the position between iBeacon transmitter No.4 and No.5.

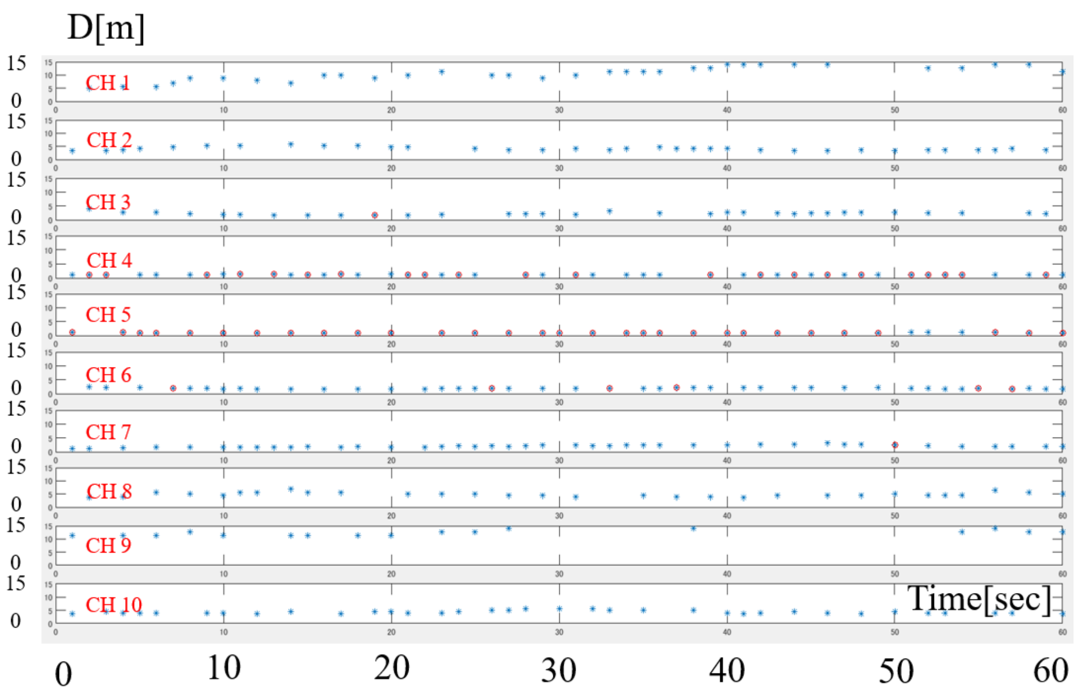

Figure 7. The third experiment results (1)

Figure 8 shows our results in the third experiment with calibration data obtained in the fourth calibration data. This figure shows that we could estimate we stopped to receive signals at the position between iBeacon transmitter No. 5 and No.6.

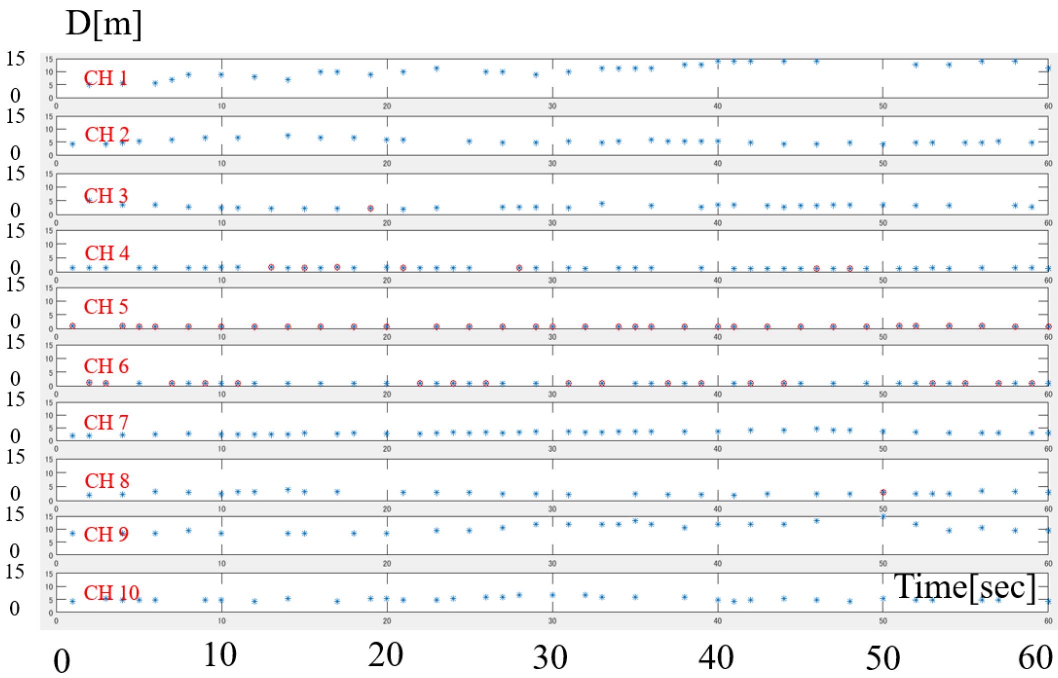

Figure 8. The third experiment results (2)

Through our experiments, we confirmed that position data were approximately estimated in real time in indoor environment. However, calibrated signals were unstable in the third experiment. There was also positioning error (approximately, 6 m) in the second experiment. In our future work, we would improve our calibration methodology to improve the stability of iBeacon ranging in indoor environments. Moreover, we would integrate iBeacon with the additional techniques, such as an inertial navigation using a gyro sensor.

5. SUMMARY

In our study, we focused on the triangulation based positioning using iBeacon transmitters and receivers. Firstly, we evaluated the stability using the iBeacon. In our experiment, the strongest signal was selected among received signals from all transmitters to identify the closest transmitter from a receiver. Secondary, we evaluated a conventional ranging technique based on the received signal-strength indication using the iBeacon in an indoor environment. Thirdly, we evaluated a ranging-based positioning performance using the iBeacon. In our experiment, we applied a triangulation using ranging results with a constraint based on straight passage knowledge. Moreover, we conducted several experiments related to user behaviors and passage environments. Through our experiments, we confirmed that our approach can estimate with several meter accuracy along a straight passage.

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