DOD-Based Indoor Localization Using BLE Beacons

Kota Kikuchi
Iwate University
4-3-5 Ueda, Morioka, Iwate
Japan
t0313038@iwate-u.ac.jp

Ryota Tazawa
Iwate University
4-3-5 Ueda, Morioka, Iwate
Japan
t2316029@iwate-u.ac.jp

Naoki Honma
Iwate University
4-3-5 Ueda, Morioka, Iwate
Japan
honma@iwate-u.ac.jp

Hiroto Minamizawa
Embedded Resource Integration, Inc.
3-8-44, Kamido, Morioka, Iwate
Japan
minamizawa@erii.co.jp

Atsusi Miura
Embedded Resource Integration, Inc.
3-8-44, Kamido, Morioka, Iwate
Japan
miura@erii.co.jp

ABSTRACT

This paper presents a BLE-based localization method suitable for the indoor smartphone geolocation service. In this method, a triangulation technique using Direction-of-Departure (DOD) information from the multiple BLE beacons is used for localization, where they are calculated only from the Received Signal Strength Indicator (RSSI). The outline of the proposed localization system and the experimental results of estimating locations are presented. The experiment reveals the proposed method can estimate the location with 0.54 m accuracy (50 percentile).

Keywords

RSSI, DOD, BLE, Localization

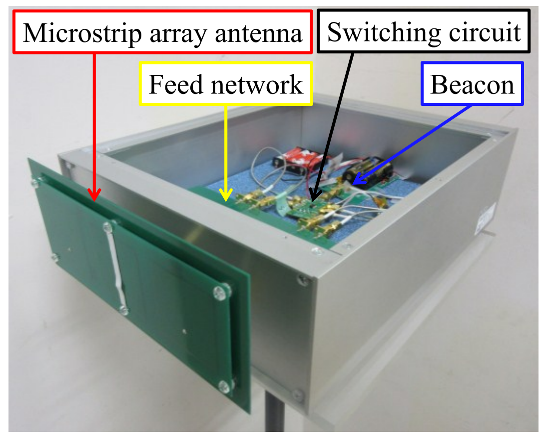


Figure 1: Transmitter used in the proposed localization system

1. INTRODUCTION

Currently, various kinds of localization techniques have been proposed for geolocation services. Especially, a challenge for an indoor localization is a key issue since GNSS signal is not available. By considering commercialization, an inexpensive and feasible technique is required, where the commercially available devices are used.

Localization system using Bluetooth Low Energy (BLE) beacons has been considered, and BLE-based system is generally inexpensive, low-power consumption, and easy-to-install. The important feature is the signal can be received by the most of the currently available smartphones without any hardware modifications. However, only the Received Signal Strength Indicator (RSSI) of the beacon signal is available at the receiver, and this obscures the important information for localization.

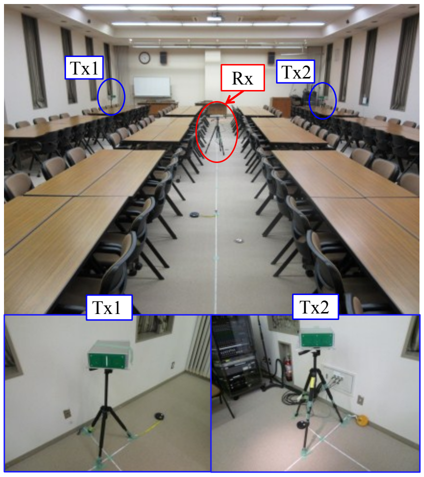
The authors have studied a Direction-of-Departure (DOD) based localization technique using only BLE signals [1]. Although DOD estimation requires the phase information, which is not available from RSSI, it is reconstructed by comparing four beacon signals, each of which has the radiation pattern different to others. Our system has features; (1) Off-the-shelf receivers (smartphones, PCs, etc.) can be used, (2) no pre-learning is required. In the following part of this paper, overview of this system and some experimental results demonstrating the localization accuracy are presented.

2. PROPOSED LOCALIZATION SYSTEM

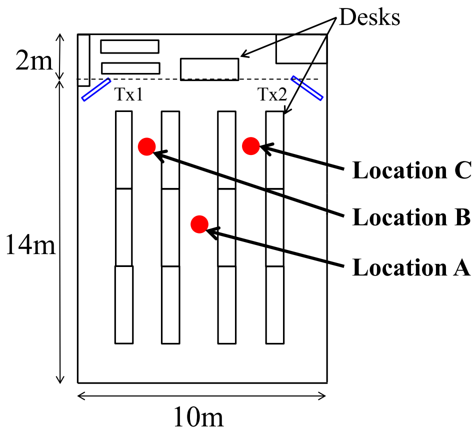
Figure 1 shows a beacon transmitter used in our localization system. The transmitter consists of three-element microstrip array antenna, feed network, switching circuit and BLE beacon. The beacon signal is distributed to the array antenna through the feed network comprising several 90-degree and 180-degree hybrids, and this circuit generates four different radiation patterns that are sequentially transmitted by switching RF circuit.

The signal transmitted from the transmitter is observed at the receiving terminal and the RSSI of the propagation channel is measured. At the receiver, the phase information of the channel between the beacon transmitter and receiving terminal is reconstructed by comparing the RSSI differences among four radiation patterns transmitted from the beacon array antenna. After that, DOD is calculated by using MUSIC (MUltiple SIgnal Classification) method and the receiving terminal determines self-position by using triangulation technique using DODs from multiple beacons [2].

The estimation is performed only at the receiving terminal, and this means no feedback from the system is necessary.



(a) Photo of environment



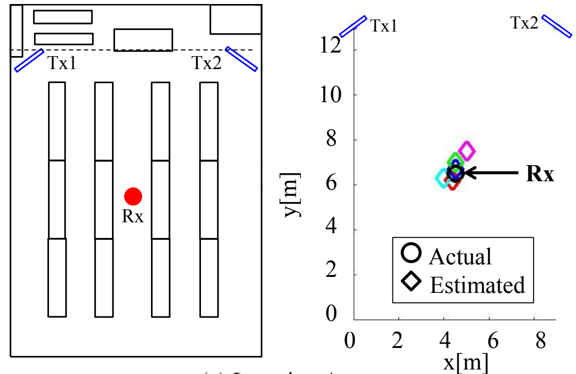
(b) Top view

Figure 2: Experimental

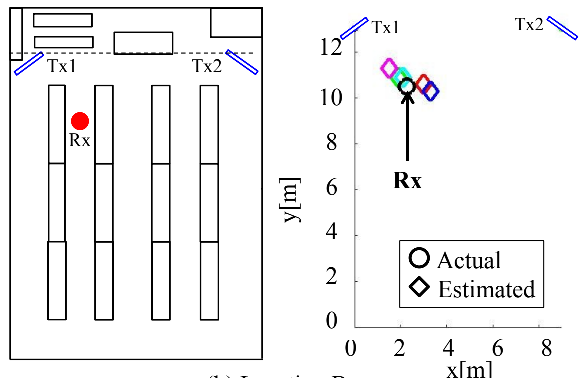
3. MEASUREMENT CONDITIONS AND EXPERIMENTAL RESULTS

Figure 2 shows experimental environment. This experiment was carried out in an indoor environment, where the size of the tested area was 14 m × 10 m. The beacon antenna arrays (Tx) were located at the two corners of the room as shown in Figure 2, and directed to the center of the tested area. Each of the Tx has three-element patch antennas, where the inter-element spacing was a half wavelength. As the BLE receiver (Rx), a laptop PC was used. The receiving terminal is located at 3 locations shown in Figure 2. The location of the receiver was estimated and the location estimation error was calculated at each of 3 measurement locations. Measurement was carried out 15 times in total, that is, 5 times at each of 3 measured locations, where the measurement time for each trial was 5 seconds. The operating frequency was 2.402, 2.426, and 2.480 GHz that corresponds to the BLE-Advertising channels, #37, #38, and #39, respectively.

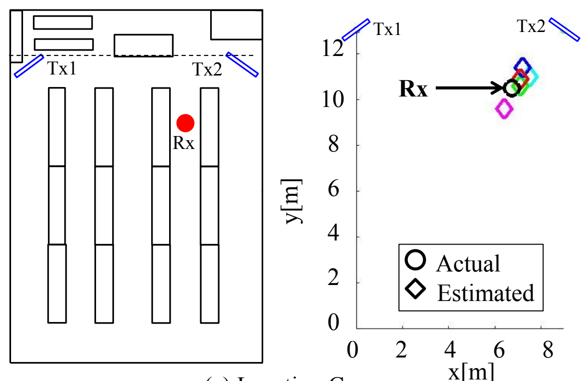
Figure 3 shows the result of estimating the location at three measurement locations. The location estimation errors at 50 percentile were 0.50 m, 0.76 m, and 0.90 m at the locations A, B, and C, respectively. The allover location error for this experiment campaign was 0.54 m at 50 percentile.



(a) Location A



(b) Location B



(c) Location C

Figure 3: Experimental results: estimated receiver

4. CONCLUSION

This paper has presented an RSSI-based indoor localization system using BLE beacons. This method uses the multiple beacons, and the location of the receiving terminal is estimated by the multiple DOD information calculated from RSSIs. The experiment results showed the overall estimation error was only 0.54 m at 50 percentile, which is significantly accurate compared with that of the currently available GNSS.

5. REFERENCE

[1] R. Tazawa, N. Honma, A. Miura, and H. Minamizawa, "Improving accuracy of RSSI-based indoor localization using three-element array," 2016 International Symposium on Antennas and Propagation, POS1-26, pp.336-337, Oct. 2016.