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The iBeacon Signal Optimization Methods for Improving the Reliability of Indoor Positioning Systems

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Abstract: The recent location based services have been focusing interest in indoor location based services in which the signals used in outdoor services such as GPS cannot be used and the research on the indoor positioning system using BLE (Bluetooth Low Energy) iBeacon as foundation technique has been expanded. However, RSSI (Received Signal Strength Indicator) information of iBeacon used to acquire distance information required for positioning becomes low in reliability due to the signal distortion problem caused by environmental factors such as obstacles from its characteristic of radio waves and accompaniment of the signal delay problem caused by diffused reflection. This study suggests a technique to verify and optimize iBeacon signals for the reliable indoor positioning system.

Key words: BLE iBeacon, indoor positioning systems, location-based services, characteristic of radio waves, technique to verify

INTRODUCTION

The late utilization fields of location based services using the location information of users are quite diverse and the demand of related services has been quickly increasing. The basic information used for positioning in the location positioning system means important information to induce reliable positioning results through the calculation process according to requests. Like this, the basic information for positioning becomes the essential information for location based services and means important information most versatile as application service. But the location information provided on the basis of GPS and mobile network has technical limits and cannot be used in the indoor positioning system (Sichitiu and Ramadurai, 2004).

BLE based iBeacon technology as a technology to calculate the distance between beacon and user's terminal based on wireless signal technology and predicts location was paid a big attention in the indoor positioning technology field. However, it is not easy to collect reliable distance values due to various environmental problems such as signal interference of the characteristic of wireless signals in the collection process of distance information as the basic information for positioning (Kotanen *et al*., 2003; Organero *et al*., 2012).

In general, the indoor positioning system using iBeacon is composed of three parts: the distance information collection process required for positioning to acquire reliable location calculation results, the process to calculate indoor locations based on distance information and the process of mapping the calculation results with the indoor map (Yoon and Hwang, 2015). At this moment, beacons as important information and the distance values of the user's terminal are quite important information to calculate positioning and provide services. iBeacon uses this information and acquire RSSI values. By the way, signal distortion and signal reduction that can occur due to environmental problems such as the location of an obstacle and signals between beacon and terminal bring about low reliability. This study suggests a technology to suggest reliability verification of distance information and an optimization technology of distance information through reliable iBeacon signal collection required for indoor positioning.

Literature review: The indoor positioning system using iBeacon uses the distance information of the beacon and the terminal as the basic value for positioning and acquires distance information by calculating TX Power included in the beacon frame and the RSSI values that express received signal strength. Accordingly, since it transforms the RSSI value expressing signal strength and uses, the reliability of the RSSI signal is very important (Oksar, 2014; Hightower and Gaetano, 2001). But beacons also, have the problems of signal distortion and

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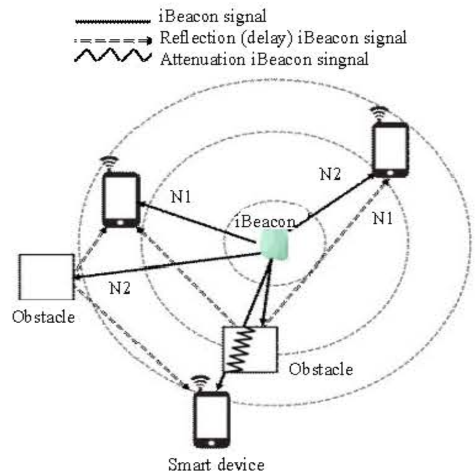

Fig. 1: iBeacon signal delay and attenuation

interference by the characteristics of wireless signal (Kim *et al*., 2015; Bobek *et al*., 2015). This distortion can be largely divided into two problems of signal delay and signal distortion.

Signal delay: The delay problem of the iBeacon signal is the distortion phenomenon caused by the signal's diffused reflection by obstacles located around. This is the problem that occurs due to absence of order information received at random without order information when advertised wireless signals are received by a terminal. Like this, received signals delayed in the process of diffused reflection due to interference of surrounding obstacles are the signals that add distorted distances according to the original distance information and reflection. That is as signal strength reduced information it is inappropriate for basic information. Of course, even though as for the distance for positioning, the maximum transmission level of TX power is used or signal correction is performed for improving accuracy through RSSI filtering, it cannot be the fundamental solution.

Signal filtering: Generally, the distance value between iBeacon and terminal using RSSI values confirm a distance with four status of immediate (0~2 cm) Near (20 cm ~2 M), Far (over 2 M) and Unknown (no meaning). In theory, it is able to calculate exact distances by using iBeacon but different distance values are measured even in the same distance. It is because the signal becomes reduced by the obstacles located between iBeacon and terminal and generates a distorted signal. Like this, distortion is created and the reduced RSSI value has inappropriate distance information to be used for a distance signal and in case that it is used for indoor positioning, positioning reliability becomes very low. Figure 1 shows the delayed receipt and reduced reception of the iBeacon signals caused by signal delay and reduction. This study suggests a technique to verify and optimize the reliability of iBeacon distance information in order to enhance the reliability of the received signals in the problem.

MATERIALS AND METHODS

Proposed the iBeacon signal verification methods. The suggestion is the technique to verify the reliability of the distance value of the beacon and terminal acquired from the RSSI signal received from the user's terminal and finally gain an improved distance information. This is divided into the following three courses. First, it corrects iBeacon information to include order information in the iBeacon signals without order and confirm the order information of the received signals. Second, distance information is corrected by using information advertised by the surrounding terminal. Last, the distance values acquired through the above courses are optimized by using Kalman filter.

Sequence data of ibeacon frame: iBeacon is composed of 47 bytes advertising data and order information is recorded in 9 bytes ibeacon prefix included in the data field of PDU (Protocol Data Unit) and transmitted and the signal order received by the positioning terminal is confirmed for filtering delayed distortion signals.

The data structure of iBeacon is changed for the purpose to store the sequence number of 2 bytes of company ID value of iBeacon prefix. Then, the values are established as the unit of millisecond to show the order of the beacons transmitted per second. Hexadecimal number was used for the 2 bytes to divide each byte into second and millisecond. The positioning terminal performs the filtering course for the data order that is received as the suggested data structure. Delayed received packets are removed and only significant information for real-time positioning is used.

Distance information sharing: Because the distance values filtered by the order information of the suggested technique have information in which some information is partly omitted it is not sufficient to be used for accurate distance information calculation. Therefore, an additional course to improve the reliability of distance information is required. For this, the terminals used for positioning were composed for sharing mutual distance information. In this course, each terminal is designed to have the AP (Access Point) function and additionally calculate the distance information between terminals. Each terminal includes the distance information of its value and iBeacon in the beacon frame of its wireless AP advertising information and advertise. At this moment as the technique to measure distance using Wi-Fi, surrounding terminals calculate distance with AP terminals. Furthermore, positioning terminals based on the information shared with surrounding terminals predict the distance between users and iBeacon and verify the inclusion of offset signals to user's received distance signals by obstacles. Figure 2 shows the data collection status for the verification course.

Extended Kalman filter: SSI values include irregular information and many studies use EKF algorithm to utilize it as significant values. Like this when the course to reduce deviation by using EKF is performed, the error scope is reduced. As a result, it can gain results with a higher reliability. However, as EKF algorithm is also

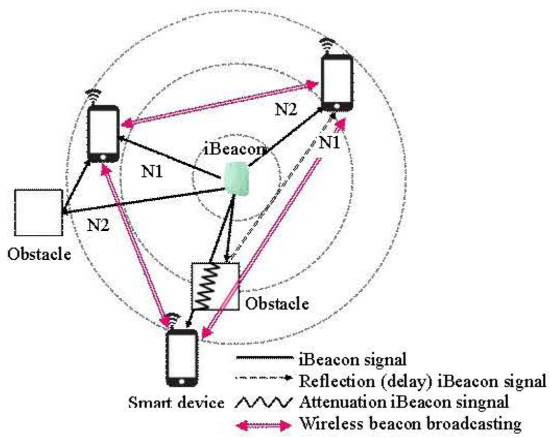

Fig. 2: Attenuation signal verification

performed based on the original data when original data of distance information with large deviations is used, results with deviations can be gained. Accordingly, this study used significant information after filtering through filtering and the suggested technique of distance information sharing as original data of EKF algorithm and improved the reliability distance.

RESULTS AND DISCUSSION

Experiment and analysis: The RSSI signal information to be used as distance information shows differences even in the same distance measurement. Moreover, the signal strength scope of TX Power of iBeacon and the signal transfer distance shown by signal range is enabled up to 70 m in theory but in reality, valid information is within 3 m. This means that the error of the RSSI values sharply increases over 3 m and it is mostly useless as actual distance information.

RSSI signal optimization with proven reliability: The experiment using the suggested technique filtered the order information of the RSSI signals in order to gain reliable distance values and performed correction by using information shared with surrounding terminals. In addition, it performed filtering through EKF algorithm based on the filtered values and did an optimization procedure to reduce deviations.

Figure 3 shows optimal results through EKF algorithm after filtering of the suggested technique based on the experiment data for the optimization of distance values between short (within 1 M) and middle (within 3 M) distances. Here, optimized RSSI values of

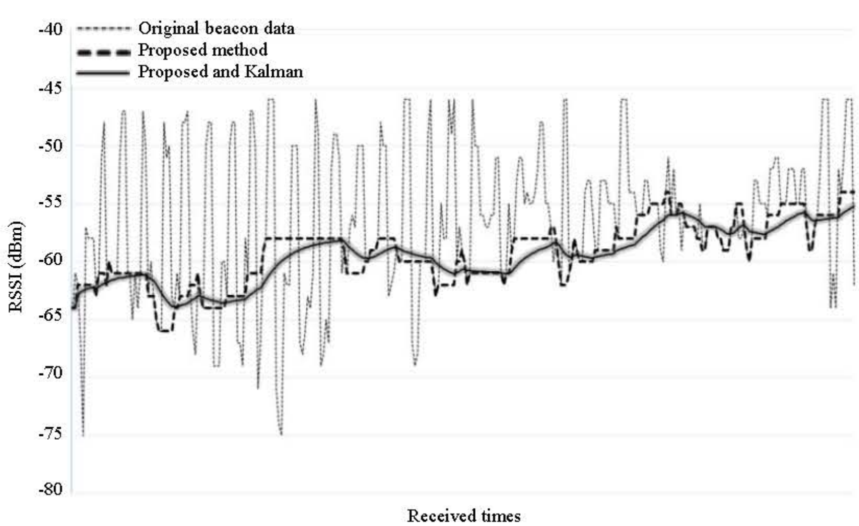

Fig. 3: Proposed RSSI sequence filtering

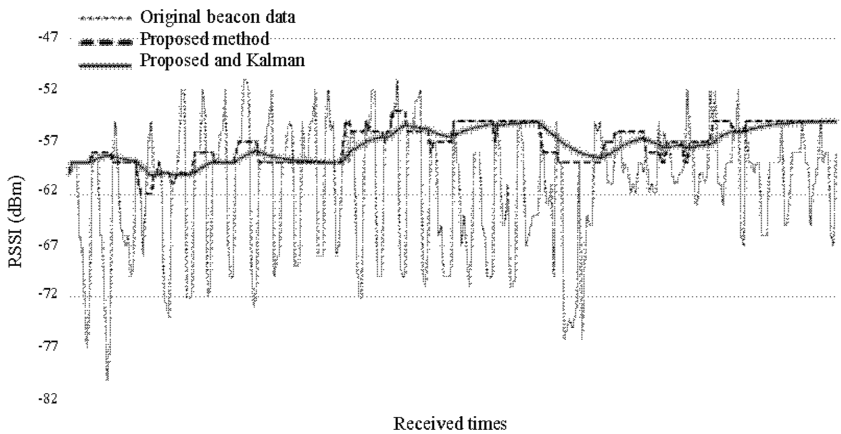

Fig. 4: The status of repeatedly reversed RSSI signal

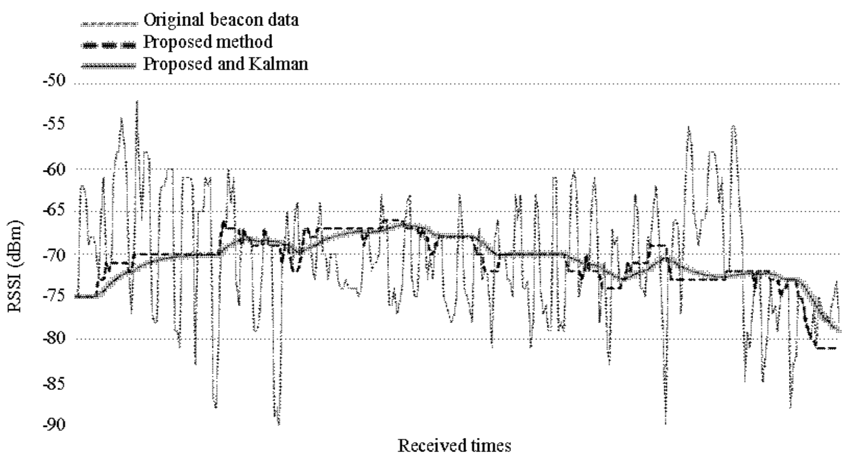

Fig. 5: Proposed RSSI filtering

dispersed source RSSI values can be found and reliability enhancement of RSSI signals can be confirmed through EKF algorithm.

However, in case that consecutive signal information is extremely few and the reversed order is repeatedly received, only the filtering process of the suggested technique can perform optimization but it becomes a wrong result that shows the distance values shown by RSSI signals are shorter than the original ones.

Figure 4 is the case that signal delay occurs and the order is repeatedly reversed, it shows the experiment result that the differences of RSSI values are extremely big. This means big interference by surrounding obstacles and as a result, it cannot be used as distance information. Therefore, correction was performed through distance information sharing of the surrounding terminals of the suggested technique.

Figure 5 shows the optimized results as well as reliability improvement through the suggested technique and EKF algorithm by using 3 M distance experiment data. In conclusion, the result values gained by performing EKF algorithm based on the data corrected by filtering the original data and sharing distance information through the suggested technique can reduce the scope of dispersed values and the deviations of RSSI signal values and finally gain reliable signal distance values.

CONCLUSION

This study suggested the optimization course of RSSI signals to verify reliability to distance information for improved positioning of the indoor positioning system. The suggested technique has verified the reliability of signals to solve the distortion problems of iBeacon signals and the process has verified RSSI signals based on the two distortion phenomena. First, order is applied to beacon signals and filtering was performed to the delayed reception signals and second filtering was performed to the verification and collection process of reception signals through information exchanges with surrounding terminals participating in positioning. In addition, the optimal process applying EKF algorithm was performed, so as to supplement the problems in which the values of reception signals swiftly change due to environmental factors. As a result, it was confirmed that reliability on the distance information of iBeacon and positioning terminals was improved through the signal verification and optimization of the suggested technique. The future research issue is to expand and optimize shared data of surrounding terminals as well as the optimization of the filtering technique of distorted RSSI signals.

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