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Facilities Navigation & Patient Monitoring System Using Ibeacon Technology

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***Abstract*—To increase the efficiency in the emergencyroom, the goal of this research is to implement a mobile-based indoor positioning system using mobile applications (APP) with the iBeacon solution based on the Bluetooth Low Energy (BLE) technology. We use the Received Signal Strength (RSS) based localization method to estimate the patients' locations. Our positioning algorithm achieves 97.22% (95% Confidence Interval = 95.90% − 98.55%) accuracy of classification. As the result, our mechanism is reliable enough to satisfy the need for medical staff to track the locations of their patients.**

Key words: Indoor positioning, mobile application, Bluetooth Low Energy.

I. Introduction

Location positioning systems are increasingly becoming popular for wide-ranging applications such as navigation and monitoring. The growing popularity using location-tracking system leads to a large amount of studies about positioning technology [1]. In recent years, the hospital emergency room overcrowding is common in countries around the world [2]. Because of the limitation of human resources and beds, patients will undoubtedly spend a lot of time waiting. While the patients are waiting, their locations are always not fixed as they might move around in the hospital, so the medical staff might spend much time to find them. Such a state will reduce the efficiency in the emergency room. Therefore, knowing the locations of patients in the emergency room is very important.

Numerous mobile applications (APP) are currently making use of positioning technologies such as the Global Positioning System (GPS), which could detect the position of the users. However, due to the signal attenuation caused by the construction materials of buildings, positioning systems cannot rely on this technology. The Bluetooth [3] is a wireless technology standard for exchanging data over short distances. Also, it is widely used in wireless personal area networks and becomes a popular technology among mobile devices [4]. The Bluetooth has been used for indoor localization since it is a cost effective and easy-to-deploy solution [5], [6]. With the progress and development of telecommunication technologies, a recently proposed technology called iBeacon [7] that is used especially in indoor positioning field using Bluetooth Low Energy (BLE) technology is adopted in this study.

The iBeacon is the Apple's implementation of BLE wireless technology to create a different way of providing location-based information services to mobile devices. It acts as an emitter continuously broadcasting Bluetooth signals, which each signal contains a Universally Unique Identifier (UUID) and a Received Signal Strength Indicator (RSSI), etc. In this research, we used an RSS-based algorithm as our major location-estimation method because it is simple to obtain the RSSI data from iBeacon without requiring any specialized hardware, compared to other localization methods such as time of Arrival (TOA), Angle of Arrival (AOA), and Time Difference of Arrival (TDOA) [8].

To increase the efficiency in the emergency room, the goal of this research is to implement a mobile-based positioning system using mobile applications with the BLE technology.

II. Method

A. *System architecture and flow-chart*

Our system architecture can be divided into four major components: iBeacon deployment, patients' mobile applications (APP), system server side and the monitoring side. These four components aggregate the patients' medical information, their location information and medical staff's information (Figure 1.).

The system flow-chart is illustrated in Figure 2. In the preparatory phase, we configured and calibrated iBeacon, and then carefully observed the tracking area in order to optimize iBeacon deployment.

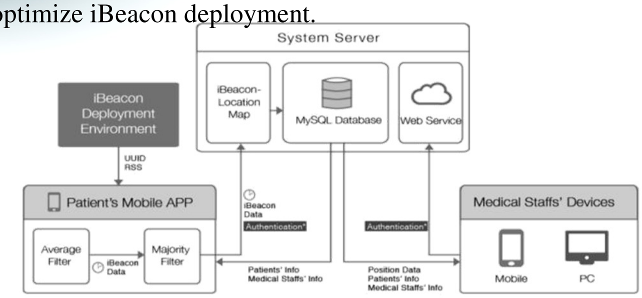

Figure 1. System Architecture

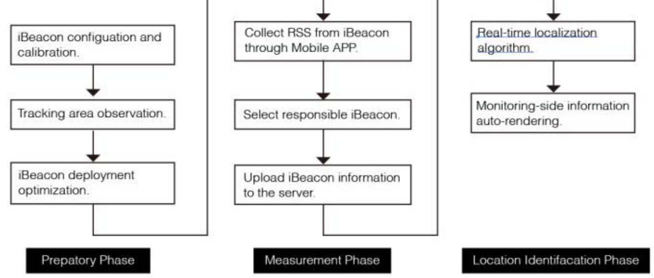

Figure 2. System Flow-chart

In the measurement phase, the indoor positioning APP is installed in patients' mobile devices after they registered. The APP automatically starts to extract the BLE signal in the background. The mobile application utilizes the calculated RSSI to select the nearest beacon and uploads the beacon information onto the system server. In the Location identification phase, patients' real-time locations are estimated based on the detected iBeacon signals and the beacon-location mapping table stored on the server side. The medical staff, which are the monitoring side, can access patients' locations through web browsers or mobile devices.

B. iBeacon deployment

The first component is the iBeacon deployment. The device we used is shown in Figure 3. We choose iBeacon technology because it is lighter, cheaper and easier to deploy than other wireless technologies. Many mobile devices in the market already have the BLE interface.

iBeacon is a small transmitter that sends Bluetooth signal packets following a strict format. The range of the signal is about 30 meters, and thanks to its low energy consumption it is estimated to be working normally for more than a year with two AA batteries. Hence, to change the batteries of iBeacon every year is necessary. We configured the frequency of the beacon to one packet per second in the beginning. Mobile devices are responsible for localizing by receiving the packets from the beacons. The relationship between mobile devices and iBeacons is a good way for privacy protection and data security since the positioning process is a one-way, independent process. Handshaking is not required between the mobile devices and beacons, which means the privacy of users are also maintained. Besides, to minimize the cost of the establishment, our goal is to accomplish the localization in visual range by using as less iBeacons as possible in this study.

Because iBeacon is a low energy device, the signal can be muted by interior such as human bodies. Therefore, the deploying positions of the iBeacons are important for keeping the accuracy. In order to track mobile devices, a fixed architecture of BLE beacons is necessary. We avoid putting the beacons in the positions around metal items, cement walls and etc.

The tracking area is composed of hallways and rooms. In the beginning, the tracking area was divided into subareas, which are named as A_i, $i = 1, 2, \ldots, n$ where n is the total number of the subareas need to be tracked. Also n is the total number of the iBeacons. Each subarea has a beacon placed in the center of the ceiling in the area. Because the range of the signal is about 30 meters, we need to make sure that each beacon is 10 meters away from one another.

Figure 3. The iBeacon device

C. The patients' mobile APP and the iBeacon selection

For the patients' side, our system provides them with a mobile APP, which could be installed after their registration in the emergency room. This APP accesses the patients' information such as the medical record, and their doctors and nurses from our server, and the information will be displayed on the patient's mobile phone. At the same time, it automatically collects the Bluetooth signals from the iBeacon in the background and selects the nearest beacon. Finally, the APP uploads the beacon information to our system server. All the data are transmitted through https protocol to ensure the security.

TABLE I. Parameters of beacon selection method

Name	***Parameter***	***Definition***
Subarea	A_i	A subarea of the tracking area.
Beacon node	B_i	An iBeacon with fixed position in the center of the subarea A_i.
RSSI	*B*	A RSSI value sent by Bi at the time t.
Average RSSI	*B*	An Average RSSI value of B_i from time t-4 to t.
Nearest iBeacon		An estimated nearest iBeacon per second based on the Bi that has the maximum .
Estimated iBeacon	E^t_{Bi}	An estimated nearest iBeacon in five seconds based on the majority of.
Estimated Subarea	E_{Ai}	An estimated subarea based on E^t_{Bi} .

The measurement phase included three stages. Since our localization method is RSS-based, we mainly utilize the RSSI values of the beacons to estimate the location. The first stage is signals collection. The APP collects the RSSI from several beacons $\{B_1, B_2, \ldots, B_n\}$, where n is the total

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number of both beacons and subareas and stores them into a database file.

The second stage is the selection of the nearest beacon, which we use two filters to select the nearest beacon. Let B be the measured RSSI per second emitted from B_i. In

order to deal with the RSSI variation, we firstly use the average filter [9], as shown in Eq. 1. The refers to the average RSSI during the time t-4 to t from B_i. is the estimated nearest beacon per second based on at time t, as Eq. 2.

With the filter above, we can obtain the nearest beacon. The beacon information will be saved in the database in the mobile device.

D. The server side

The server side application deals with data saving, reading and mapping. It not only plays the role of a bridge between the patient side and monitoring side but also maps the estimated nearest beacons sent from patient side with the locations of the correspondent subareas.

Location identification phase is performed on the server side. The Mapping table of beacons and locations is stored in the system server for the purpose of mapping the real locations. The system server synchronizes with the patients and monitoring side every five minutes to make both sides consistent. It is also easy to maintain by accessing the system with web service architecture.

E. Monitoring side

The last component is the monitoring side, which medical staff can access the location information of patients through a web browser or mobile device. We built the monitoring side as a web-based application, which is beneficial for cross-platform.

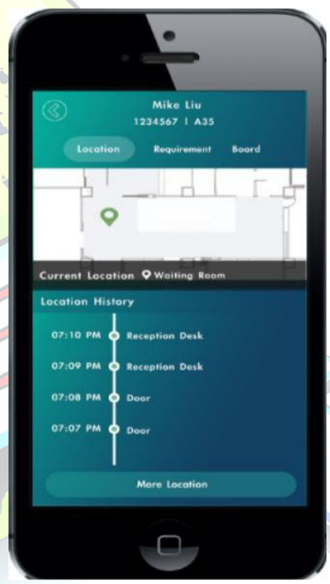

Figure 5. The interface of monitoring side

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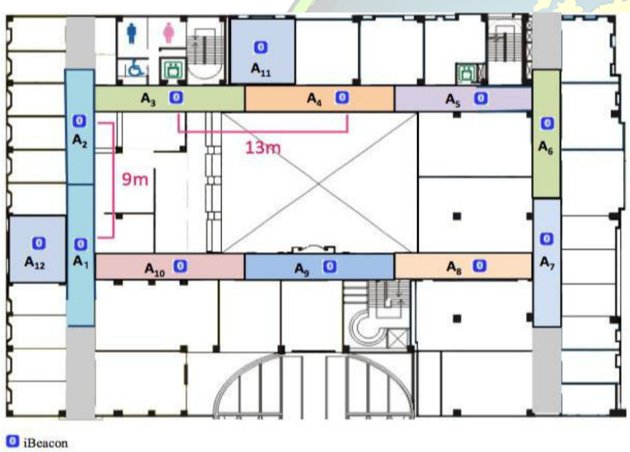
F. Experiment

In order to evaluate the proposed localization approach, several experiments were conducted in the experimental test-bed. The experimental test-bed was located in the third-floor of the CSIE building at National Taiwan University. The tracking area is divided into 12 subareas (A_1 - A_{12}), including two rooms and 4 hallways. The dimension of the rooms (A_{11}, A_{12}) is 7m x 6m x 3m, the horizontal hallways (A_3 - A_5, A_8 - A_{10}) is 40m x 3m x 2.5m, and the vertical hallways (A_2, A_3, A_6, A_7) is 8m x 3m x 2.5m. Twelve beacons are separately deployed on the center of the ceiling of the subareas, as shown in Figure. 4. Besides, we used the HTC ONE M8 as our mobile device.

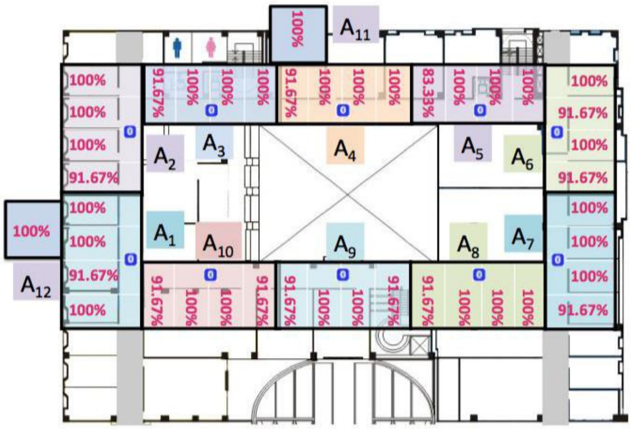
The frequency of iBeacon transmission is 1 packet/second, and our proposed algorithm generates an estimated location every 5 seconds. In order to verify the fault tolerance, we divided each subarea into four blocks, and stood in one point in each block with mobile phone hold in hands for one minute. Therefore, we got 48 estimated locations from each subarea. A total number of 576 estimated points were generated in 48 minutes through the experiment.



RESULT

To test the performance of the proposed algorithm, the accuracy (ACC) is adopted for evaluating the results. An accurate classifier will have a higher ACC value. The formula of ACC is the sum of correct predictions divided by total predictions, as shown in Eq. 4.

The mean ACC of classification is 97.22% (95% Confidence Interval = 95.90% — 98.55%). The minimum of ACC is 83.33% [10 out of 12]. The localization error is between 3 and 5 meters, which might be affected by the obstacles and walls in the tracking areas.



V. CONCLUSION

In the study, we implement a mobile indoor positioningsystem to help doctors and nurses finding their patients in anefficient way. Furthermore, this system is designed for not only the medical staff but also for the patients, both f themcould gain the benefits though using it.

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