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Date	:	…….

IBEACON-INTEGRATED INDOOR EMERGENCY ROUTE NAVIGATION SYSTEM IN HEALTHCARE INDUSTRY

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A report submitted in partial fulfillment of the requirements for the degree of Electrical Engineering (Control, Instrumentation & Automation)

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I declare that this report entitle “IBEACON-INTEGRATED INDOOR EMERGENCY ROUTE NAVIGATION SYSTEM IN HEALTHCARE INDUSTRY” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Indoor localization system is one of the solutions that can provide a better care giving service to the people in a healthcare facility. The main function of an indoor localization system is to get the real-time location of a target and to guide a person along a certain direction. Despite the importance of this system, there is no existing product that is fully suitable for the healthcare industry. All the existing products have their own disadvantages. To overcome this problem, a new approach is needed. This project is to develop an indoor emergency route navigation system by using a new technology called iBeacon for the healthcare industries. This system makes use of the location information of a person and guides him or her along the evacuation path to the exit. iBeacon is used in this project because it is a Bluetooth Low Energy (BLE) based indoor proximity device and it works the best in indoor situation. The procedure to complete this project is divided into two major parts. The first part is the development of the coding algorithm for the iBeacon interaction and the system operation. The next part consists of the analysis of the system to check on its reliability towards the operating distance and sensing ability of the iBeacon so that improvements can be made. From this research, it is concluded that the "near" range distance is optimum in terms of the beacon's operating distance and sensing ability. For the beacon setup, all beacons must be placed with a 6.0m distance from each other for it to perform effectively. However, the problem regarding to the disturbances that is affecting the Bluetooth signal has yet to be solved and future recommendation is suggested.

ABSTRAK

Sistem Penyetempatan Dalaman adalah salah satu penyelesaian yang boleh memberikan perkhidmatan penjagaan yang lebih baik kepada pengguna di industri kesihatan. Fungsi utama Sistem Penyetempatan Dalaman adalah untuk mendapatkan lokasi sasaran yang sebenar dan untuk membimbing seseorang itu ke arah yang tertentu. Walaupun sistem ini penting, tidak ada produk sedia ada yang sesuai sepenuhnya untuk industri kesihatan. Semua produk yang sedia ada mempunyai kelemahan mereka sendiri. Untuk mengatasi masalah ini, pendekatan baru diperlukan. Projek ini adalah untuk menghasilkan satu sistem navigasi laluan kecemasan dalaman dengan menggunakan teknologi baru yang dipanggil iBeacon bagi industri kesihatan. Sistem ini menggunakan maklumat lokasi bagi seseorang dan membimbing seseorang tersebut di sepanjang jalan kecemasan untuk mencapai zon selamat. iBeacon digunakan dalam projek ini kerana ia adalah satu Tenaga Rendah Bluetooth (BLE) berasaskan peranti berdekatan dalaman dan ia berfungsi terbaik dalam keadaan tertutup. Prosedur untuk menyiapkan projek ini dibahagikan kepada dua bahagian utama. Bahagian pertama ialah pembangunan algoritma pengekodan untuk interaksi iBeacon dan operasi sistem tersebut. Bahagian seterusnya terdiri daripada analisis sistem untuk memeriksa kebolehpercayaan ke arah jarak operasi dan keupayaan penderiaan daripada iBeacon supaya penambahbaikan dapat dilakukan. Dari kajian ini, kesimpulannya ialah bahawa jarak julat “near” adalah optimum dari segi jarak operasi beacon ini dan kemampuan penderiaan. Untuk penempatan beacon, semua beacon mesti diletakkan dengan jarak 6.0m antara satu sama lain supaya sistem ini beroperasi dengan berkesan. Walau bagaimanapun, masalah berhubung dengan gangguan yang menjejaskan isyarat Bluetooth ini masih belum dapat diselesaikan dan cadangan masa depan telah dicadangkan.

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CHAPTER 1

INTRODUCTION

1.1 Background

Healthcare is one of the most important industries in the world. By knowing this, many researches and engineers are focusing on building a more effective care giving system that can maximize the comfort for both the patients and personnel of that industry. Indoor localization is one of the ways to achieve that target [1]. Localization can be explained as the necessity to acquire the position of a person or object. If this event happens under a roof or inside a building, it is known as indoor localization [2]. Indoor localization is a more complex system when compared to the normal, outdoor localization since it takes account of several factors such as the environment, building structure, room's layout and type of construction materials [3]. It is important for healthcare facility to get a user-friendly localization system since it mostly involves sick or elderly patients [2]. The idea of implementing this system in healthcare facilities is not new and it is popular because the location information obtained from it can result in a lot of useful applications in healthcare services, tracking and navigating purposes [1], [3], [4]. The application that is emphasized on is its tracking and navigating function. By utilizing information acquired from an indoor localization system, it is possible to build an indoor navigation system.

There are a lot of commercial indoor localization systems in the market for the time being but none of them is really suitable for a healthcare industry. The systems are either low in performance or high in terms of cost [1]. Most of the current indoor localization systems come with their own drawbacks and some of the examples of these existing systems are radio frequency based (RFID), ultrasonic-based and active infrared based systems but these systems require a person to carry certain hardware (receiver or transmitter tag) [2]. Some of the more new and advance systems are the Zigbee system and the WiFi-fingerprinting system [5, 6].

The aim of this project is to apply a new technology, iBeacon, in developing an indoor navigation system for emergency situations in healthcare industries. This proposed system will be using the location information of a person and guide that person along the correct evacuation path to a safe area or the exit. iBeacon is a Bluetooth Low Energy (BLE) based indoor proximity technology can works with both iOS and android system [7]. It acts as a transmitter that continuously emits Bluetooth signals and every signal emitted contains a Universal Unique Identifier (UUID) and a Received Signal Strength Indicator (RSSI) [4]. With the strategically placed iBeacons and specially designed mobile apps, the location of a particular person or object can be determined with a significantly high accuracy. The most significant advantage of this approach is that it operates more effectively in indoor locations [8]. This makes it more suitable for the task for indoor emergency route guidance. The reason why this technology is chosen for this project is because it is cheaper, lighter and easier to activate than other wireless technologies [4]. The implementation of this indoor emergency route navigation system can surely assist the healthcare facility in making sure that their patients and hospital personnel are always safe.

1.2 Problem Statement

During an emergency situation in a healthcare facility, patients and hospital personnel are expected to be panic and scared [9]. Even though there are a lot of emergency evacuation plans or procedures to aid people during these situations, for example emergency signboards and alarms, it is hard to focus and utilize it when people are in panic mode. To top it off with low visibility during an emergency that involved smoke or electricity cut-off, it is almost impossible to evacuate people safely to a safe area or exit [10].

Also, most of the current indoor localization systems nowadays are having their own disadvantages. For example, radio frequency based (RFID) system, camera-based system, WiFi fingerprinting system and so on [2, 6]. The disadvantages of these current products usually involve costs, accuracy, scalability and robustness [5]. Hence, there is a need to find a new system to overcome all the drawbacks.

An indoor emergency route navigation system that utilizes iBeacons is a good solution that can overcome all the existing drawbacks. Other than that, this system also provides an extended application of indoor localization system which is to utilize the location information of a person and guide that particular person along the correct path to successfully reach a safe area or exit during an emergency in healthcare facility.

In Europe and United States, some companies have already come up with products that utilize iBeacon in a couple of specific fields (retail, healthcare, tourism), but this technology has yet been fully utilized in Malaysia. It is a good opportunity to implement this technology to developing countries like Malaysia as to reduce the technology gap between developing and more advanced countries.

1.3 Objectives

The main objectives of this project are:

1. To develop a coding algorithm that is able to interact with iBeacon.
2. To apply algorithm to an indoor emergency route navigation system.
3. To analyse and optimize the reliability of the iBeacon-integrated system in terms of its operating distance and sensing ability.

1.4 Scope

The implementation of this project only targets the application of an indoor emergency route navigation system for healthcare facilities. The LightBlue Bean, an iBeacon product from Punch Through Design is used for the entire project. Furthermore, the development of the coding algorithm for this project is done using the Xcode IDE.

To analyse the reliability of the iBeacon-integrated system, several tests are done by running the developed algorithm in an iOS device (iPad) to test the Received Signal Strength Indicator (RSSI) and the estimated distance given by the iBeacon. This is to determine the system's optimum reliability in terms of its operating distance and sensing ability.

1.5 Significance of Study

iBeacon provides a lot of opportunity and improvement for several different fields such as retails, tourism and healthcare. By implementing an indoor emergency route navigation system to the healthcare industry, it may reduce evacuation difficulties, for example, having people heading to a wrong direction during emergencies. This insurance will provide a safe and comfortable environment for everyone in the hospital. A patient does not need to worry about safety issues in the hospital and hospital personnel can fully concentrate in carrying out their duties.

On the other hand, this project can also reduce the technology gap between advanced countries and developing countries like Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 Emergency Evacuation

Emergency evacuation is defined as an urgent or immediate movement of people away from a threat. These threats are usually nature or man-made hazards. Some of the examples of these hazards are earthquakes, floods, fire, or building collapse. Because of these occurrences, a plan to deal with emergencies is crucial to save lives and property [11]. A solid emergency evacuation plan should be carefully planned out to avoid fatalities and to reduce property damages. In these scenarios, emergency personnel need to make sure that the public is safe during an emergency or an accident. Moreover, a good emergency evacuation plan helps to promote safety awareness among the society. Conversely, the absence of an emergency evacuation plan may cause heavy losses in terms of both casualties and financial/property collapse [11].

2.2 Indoor Localization System

Localization is defined as the necessity to acquire the position of a person or object. If this event occurs under a roof or inside a building, it is known as indoor localization [2]. Indoor localization system is more complex when compared to a normal, outdoor localization system since it takes account of several factors such as the environment, building structure, room's layout and type of construction materials [3]. A general indoor localization system should consider the following criteria [2]:

- Comfort – The system should be user-friendly.
- Accuracy – The system should have a certain degree of accuracy to track location and movements.
- Installation Effort – The installation of the system should be hassle-free.
- Cost – The expenditure of the system should be low.
- Acceptance – The system should be built under the consideration of its user.

To achieve a better indoor localization system that is specialized for healthcare facilities, other criteria should also be considered. Figure 2.1 shows the list of criteria and constraints for an indoor localization system in healthcare industries.

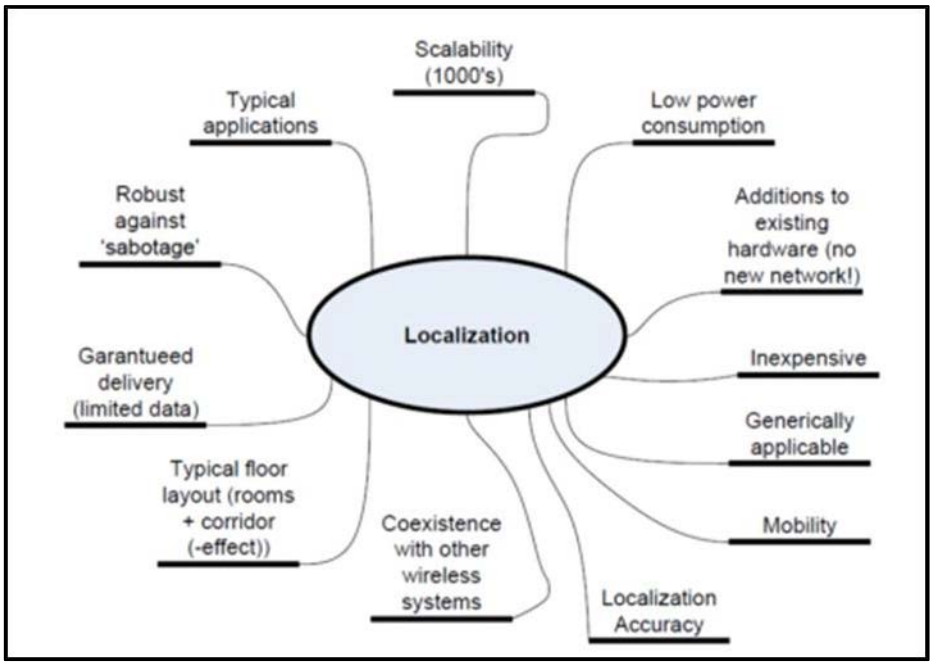

Figure 2.1: Indoor Localization Criteria and Constraints in Healthcare Industry [5]

There are a lot of commercial indoor localization systems in the market for the time being but none of those systems is highly suitable for a healthcare facility. The systems are either having a bad performance for a cheap price, or a very good performance system that comes with a hefty installation and maintenance cost [1]. Most of the current systems come with their own drawbacks and these drawbacks are usually related to the installation/maintenance costs, localization accuracy, scalability or robustness [5]. Some of the examples of existing indoor localization system are radio frequency based system (RFID), ultrasonic-based system, active infrared system and also camera-based system [2].

2.3 Related Works

There exists a lot of different system for indoor localization in the market nowadays. All of these systems are built to achieve and solve certain criteria and constraints coming from an indoor localization system. Nevertheless, most of the existing systems have their own disadvantages.

The current indoor localization systems are:

- **Radio-Based Systems**

  There are a lot of systems that use this method but the main drawback is that its accuracy is easily affected by multipath propagation or physical disturbance. Another disadvantage for this system is the targeted person or object is required to carry/wear a tracking hardware [2].

- **Ultrasonic-Based Systems**

  This system uses two signals to locate objects, an ultrasonic signal and an RF signal that travels faster than the ultrasonic signal. The RF signal is used to measure the propagation time of the ultrasonic signal. For this system, the cost of initial hardware is low but the installation and maintenance costs are significantly high. Other than this, not only does this system need hardware, but the accuracy of the system drops drastically for moving objects [2]. This makes it unsuitable for tracking down a person.

- **Camera-Based Systems**

  Camera-Based system is one of the most common and popular indoor localization systems. The benefit of this system is that no extra hardware is needed. On the other hand, the main drawbacks of this system is the privacy violation and the light condition dependency [2].

- **Others**

  Some of the more advance systems are the Zigbee method and the WiFi-Fingerprinting system. Zigbee method is defined as a patient-monitoring method where it uses a mesh network to send vital signs to the hospital personnel. This method can also provide location updates. Due to its high network traffic-ing, this method raises scalability matters [5].

  WiFi-Fingerprinting system provides localization on the scale of tens of meters and its algorithms are proximity-based. This means that it relies on a short range of WiFi transmitters and a signal survey [6]. The drawback for the WiFi-Fingerprinting system is similar to the Ultrasonic-Based system which requires high system installation cost [5].

2.4 iBeacon

Figure 2.2: iBeacon Product from Punch Through Design

iBeacon is a new technology that is introduced by Apple in 2013 [12]. The only protocol for iBeacon is to be a transmit-only device. It acts as a broadcaster that sends periodic packets that contain information used by the receiver [13]. iBeacon is described as a low power, low cost and short range transmitter that is able to push notification or information to a smart mobile [14]. iBeacon uses Bluetooth Low Energy (BLE) to transmit data, usually an identification number and a measured power, and any device that has a BLE-Chip can receive it [12]. The advantage of this new device is that the receiving device does not need to pair itself with the iBeacon to use it [7]. Thanks to this technology, people can communicate with their physical environments (Shopping mall, museum, hospital) digitally [14].

Every iBeacon transmits its own, unique signal identifier. With this, a device can receive more signals simultaneously. This unique identifier is called the Proximity Universally Unique Identifier (UUID) and it is used to distinguish one iBeacon from the others. The only way to communicate with an iBeacon is by configuring its UUID [12]. Figure 2.3 shows the general data format for an iBeacon Proximity UUID.

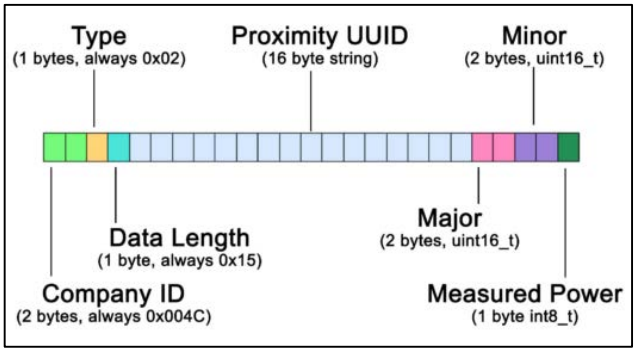

Figure 2.3: iBeacon Proximity UUID Data Format [12]

iBeacon has two functions. The first one is the region monitoring function. This function basically creates a region around the iBeacon and triggers a push notification to whichever device that enters or leaves that specified region. The next function is to calculate the proximity distance between the iBeacon and the receiving device. In this function, the distance is determined by calculating the Received Signal Strength Indicator (RSSI) that is emitted from the iBeacon itself. This function is perfect for the application of indoor localization system [12]. Figure 2.4 shows the basic operation for iBeacon. When a device sense an iBeacon's UUID, a push notification will be triggered and at the same time, information will be retrieved from the network cloud and shown in the device.

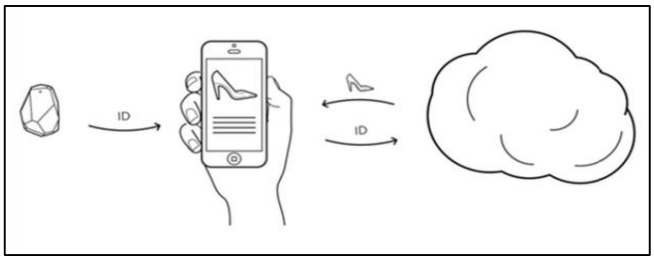

Figure 2.4: Basic Operation of iBeacon [7]

An iBeacon transmits its current position to all devices in a range from a few inches to around 70 meters [7]. Apple provides a property called “accuracy”, which is an estimation of the proximity to the beacon by measuring the signal strength (RSSI). This means that the proximity to the beacon is more accurate when the signal is stronger [15]. Apple called it “accuracy” instead of “distance” is probably to avoid its use as a direct distance measuring tool. To compensate and filter the “accuracy” to get a better proximity estimation to the beacon, Apple provides another property, “proximity” to sort the distance into three groups, which are “immediate”, “near” and “far” [16].

All these estimation of the distance can have a significant degree of uncertainty and there are a lot of factors that can lead to these variations, such as radio noise, reflection of the signal, position of both the beacon and the device, or maybe obstacles in between them that eventually disturbs the signal. With all these disturbances, for a beacon that is 5 meters away from the device, the estimation of the distance can fluctuate up to around 2-10 meters. That is the reason to conclude that a device which is nearer to the beacon can provide a better estimation when compared to a device that is further away [16].

2.5 Comparison between iBeacon and Other Existing System

Table 2.1 shows the comparison between iBeacon and other existing systems on their cost, accuracy and user acceptance. It is shown that all existing systems have their own drawbacks and when compared, iBeacon has a better overall advantage. iBeacon-based system is a low cost system with good accuracy in proximity distance. It also has a high user acceptance since it does not require any tracking hardware and it does not violate user privacy.

Table 2.1: Comparison between iBeacon and Other Systems on their Characteristics [2, 5]

	Cost	**Accuracy**	**Acceptance**
iBeacon	Low	Good in proximity distance	High
RFID	Low	Easily affected by physical disturbance	Low because a tracking hardware is needed
Ultrasonic	High	Bad for moving objects	Low because a tracking hardware is needed
Camera	Low	Good but dependent on light condition	Low because of violation of privacy
WiFi-Fingerprinting	High	Good in proximity distance	High

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Overview

Generally, this project involves the development of an indoor emergency route navigation system that utilizes iBeacon. This project consists of two main parts. The first part is the development of a coding algorithm that is able to interact with iBeacon and the reliability test of the iBeacon-integrated system using an iOS device application. The next part presents the analysis of the system on its reliability towards the beacon's operating distance and sensing ability. Figure 3.1 shows the flowchart of the project for better understanding.