International Journal of Smart Home
Vol. 9, No. 7 (2015), pp. 161-168
http://dx.doi.org/10.14257/ijsh.2015.9.7.16

An iBeacon-based Indoor Positioning Systems for Hospitals

Jingjing Yang[1], Zhihui Wang[2] and Xiao Zhang[3]*

School of Information Science and Engineering, Hebei North University, Zhangjiakou, Hebei, China
[1]r78z-yang@126.com, [2]iowzh@126.com, [3]yjr78z@gmail.com

Abstract

How to help patients find their departments or wards is an issue that needs to be solved by hospitals urgently. This paper presents an iBeacon-based indoor positioning system for hospitals. It firstly analyzes the advantages of iBeacon compared with the common indoor positioning technologies; then designs the indoor positioning system for hospitals based on the three-layer architecture of Internet of things to have message-push-service through clients. Finally, the shortest distance algorithm Floyd is used to recommend the nearest department or ward to patients. Shown as result of the experiment, indoor positioning for hospitals can be realized by the system.

Keywords: *Indoor Positioning Systems for Hospitals, iBeacon, Internet of Things, Floyd*

1. Introduction

Even though there are floor distribution maps and guide signs in outpatient department floors of most hospitals, many patients are still worried about that they may spend much time finding the department or ward when seeing a doctor. In recent years, with the development of computer technology and short-range wireless communication technology, the concept of intelligent medicine [1] emerges. Intelligent medicine refers to the use of the most advanced technology - Internet of things [2], to make possible interaction between patients, medical personnel, medical institutions, and medical equipment and finally to achieve the informatization. We can provide, through the advanced concept and technology about intelligent medicine, indoor positioning for patients, thus improving their treatment experience.

At present, indoor positioning technology [3] is increasingly perfect. It is commonly used in large and medium-sized shopping malls and famous museums while rarely used in hospitals [4-5]. Indoor positioning is realized via WLAN, Bluetooth or radio frequency identification technology [6]. Wireless local area network can realize the goal of positioning, monitoring and tracking target in a wide range. Self-location of network nodes is the basis and prerequisite for most applications. The Bluetooth technology is to locate object by measuring the signal strength. It has some merits. The greatest one of them is the small volume of the device, which makes it easier to be integrated in PDA, PC and mobile phone. Thus its popularization is easier. But it has some disadvantages. First, the devices and equipment of Bluetooth are expensive. Second, in the complex space environment, the Bluetooth system is unstable and vulnerable to be interfered by noisy signal. Radio frequency identification technology is to use radio frequency to achieve the goal of recognition and positioning by non-contact two-way data communication. On the one hand, it has advantages of big transmission range, low cost and getting information about the location in a few milliseconds. On the other hand, it has the disadvantages of short effect distance, and lack of the communication ability. Besides, it is also difficult to be integrated into other systems.

ISSN: 1975-4094 IJSH

In this paper, iBeacon-based indoor positioning systems for hospitals are introduced. It has merits of both Internet of things and mobile internet and achieves the goal of indoor positioning within hospitals [7]. It has the advantages of low power consumption, fast response, and accurate positioning, thus bringing great convenience to patients.

2. The iBeacon Technology

The iBeacon is a piece of equipment for indoor positioning issued by Apple Corp in September 2013 [8]. Its working mechanism is that a communication device equipped with low power Bluetooth (BLE) sends, by using BLE technology, its own ID, and after receiving that ID, a mobile Internet device will take some actions according to it [9]. SIG formulate standards for Bluetooth technology. It put forward low power Bluetooth technology, referred to as BLE, when the standard 4.0 began to be used. This low power Bluetooth technology, compared with the traditional one, has advantages of lower cost and lower power consumption, as can be evidenced by an example that a button cell can allow low power Bluetooth devices to operate for up to a year to two years [10]. The Bluetooth LE protocol is significantly more power efficient than Bluetooth Classic. Several chipsets makers, including Texas Instruments and Nordic Semiconductor now supply chipsets optimized for iBeacon use. Power consumption depends on iBeacon configuration parameters of advertising interval and transmits power. A study on 16 different iBeacon vendors reports that battery life can range between 1–24 months [11].

An iBeacon deployment consists of one or more iBeacon devices that transmit their own unique identification number to the local area. Software on a receiving device may then look up the iBeacon and perform various functions, such as notifying the user. Receiving devices can also connect to the iBeacons to retrieve values from iBeacon's GATT (generic attribute profile) service. iBeacons do not push notifications to receiving devices (other than their own identity). However, mobile software can use signals received from iBeacons to trigger their own push notifications.

Table 1. Comparison of Three Kinds of Common Indoor Positioning Techniques

	WiFi	RFID	iBeacon
Coverage	50m	10m	50m
Cost	high	Low	A little high
power consumption	high	low	low
Bandwidth	1.8G	250kb	1M
Battery life	Several days	1-2 years	1-2 years
Positioning accuracy	2m-3m	1m-2m	1-2m

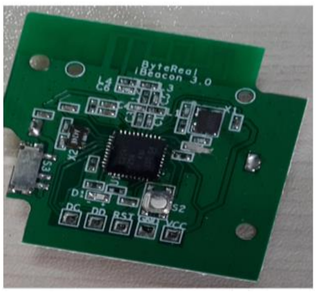


Figure 1. iBeacon Module

Table 2. All Kinds of Compatible Devices of iBeacon

Mobile phone operating system	Compatible devices
IOS devices	IOS devices with Bluetooth 4.0 (iPhone 4S and later, iPad (3rd generation) and later, iPad Mini (1st generation) and later, iPod Touch (5th generation).
Android	Android 4.3+ (e.g. Samsung Galaxy S3/S4/S4 Mini, Samsung Galaxy Note 2/3, HTC One, Google/LG Nexus 7 2013 version/Nexus 4/Nexus 5, HTC Butterfly, OnePlus One).
Windows Phone	Windows Phone devices with the Lumia Cyan update or above.

Table 1 shows differences between iBeacon and another two kinds of indoor positioning techniques. Compared with those two techniques, iBeacon has the advantages of low cost, accurate positioning, large coverage, and long battery life. Manufacturers can design their own iBeacon equipment based on the specifications. Theoretically, any kind of low-power Bluetooth development board can deal with the work of iBeacon. Table 2 shows all kinds of compatible devices of iBeacon, which contains almost common market mainstream phone.

In this paper, we used iBeacon produced by Byte real Technologies, as shown in Figure 1. It is based on the TI BLE SOC CC2541, and can meet the requirements of iBeacon-based indoor positioning systems.

3. The iBeacon-based Indoor Positioning Systems

3.1. System Architecture

The iBeacon-based indoor positioning systems for hospitals was designed based on three-layer architecture of Internet of things [12], as shown in Figure 2.

The network layer: A high-performance router was chosen as hardware bearing, because direct communication between server and client, such as mobile phone, and tablet, is completed, through the indoor WiFi, 3G, or 4G.

The perceptual layer: First iBeacon was configured. Then, iBeacon's ID and the region where it locates were put into database server by technical staff and iBeacon was set in a certain place. When a user enters this place, iBeacon will automatically send the specified information to the client, and the client forward it to the server. The server determines the location of the user according to information from the pre-configured iBeacon, and then sends the information processed back to the client.

Application layer: It includes server and client. Server is responsible for processing information, while client is responsible for interacting with users. The client should be designed to meet the requirement of humanity.

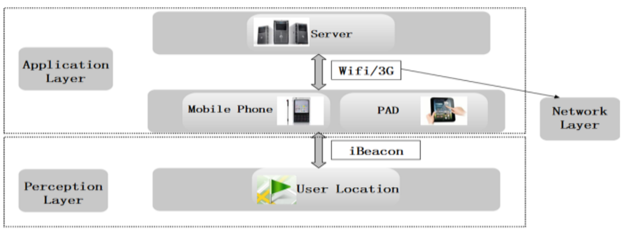


Figure 2. The Composition of the System

3.2. Functional Architecture of Application Layers

As shown in Figure 3, the application layer is divided into three functional modules: the message pushing module, the indoor navigation module and the data (about department visitors) collecting module. The message pushing module consists of hospitals' broadcasting message pushing, introduction of departments and dynamic pushing. The navigation module can be subdivided into positioning and position marking, target department, pharmacy, ward navigation as well as empty-bed recommendation.

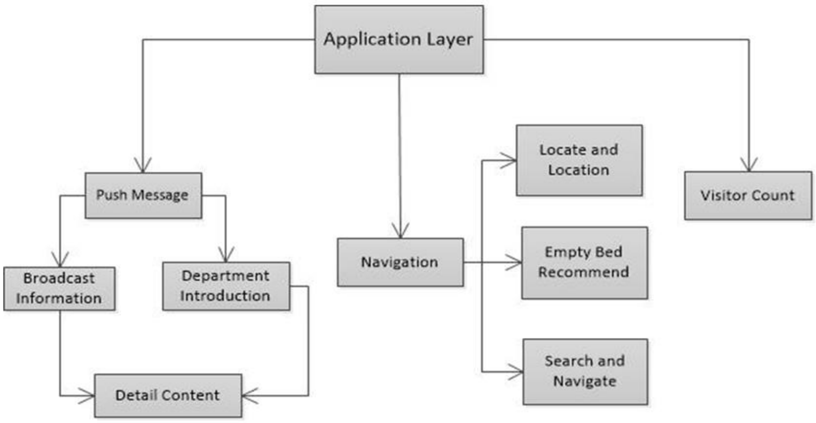


Figure 3. Architecture of Application Layers

3.2.1. Message Pushing

Message pushing service of client refers to the real-time delivery of information from server to directed mobile phone [13]. It differs from the common polling mode mainly in two aspects: long networking and real-time delivery.

Message pushing is long networking, with message delivered to client at a delay of 0.1-0.5 seconds, while polling mode is not long networking, with message delivered to client at a delay of 1-10 minutes according to varying polling modes, even 1 hour or a day. The process of message pushing is as follows:

Step1. Client sends a request of http long connection, and then waits for response from the server. This request is asynchronous.

Step2. After the server receives the request, it does not immediately send the data, but hold this connection. This process is none blocking, so the server can continue to process other requests.

Step3. Only when the server has new data, the server takes the initiative to push out these new data, through good connections established before, to the client.

Step4. The client receives data returned which can be processed and then gives a new request of long connection again.

When a patient enters an area covered by the iBeacon signal, client of the device which this patient carries will receive iBeacon's ID, under the condition that the device's wireless network, 3G or 4G is opened. Client gives ID received to the server, and the server will compare the received ID with data put into database by technical personnel. If it exists, this patient's location will be gotten.

When a patient approach target department, the client will determine the distance between iBeacon module and user terminal. When this distance is less than a specific value, the client will take the initiative to request the server to push dynamic message of the Department, including the number of people queuing before this department, and registration fee. Furthermore, the client also can push detailed introduction of the range of the department. Patients can judge whether their illness is in the range of department through the client. Figure 4 is the flow chart of message pushing.

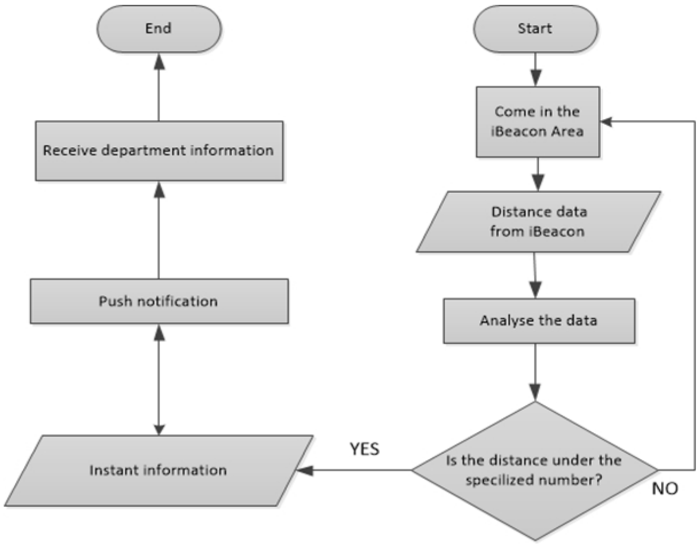


Figure 4. The Flow Chart of Message Pushing

3.2.2. The Shortest Distance Algorithm

The location of users can be reflected by iBeacons. The position of iBeacosn is relatively fixed. So we only need to calculate the shortest path between each two iBeacons. In this paper, the shortest distance algorithm Floyd was used. The Floyd algorithm uses the idea of dynamic programming. Its core idea is to determine the shortest path between two vertices i and j. That is, all the nodes are used as intermediate points to find the minimum value. The improved algorithm is as follows:

Step1. Distribution of iBeacons can be taken as an undirected graph. Starting from an arbitrary Beacon, if it is adjacent to another one, the weight between them is d, and if not, the weight is infinite.

Step2. For each pair of iBeacons i to j, whether there is an iBeacon k that makes the distance from i to k to j shorter than the route known is figured out. If there is a k like that, update the formula 1.

$$d^{(k)}_{ij} = \begin{cases} w_{ij} & if\ k = 0 \\ \min(d^{(k-1)}_{ij}, d^{(k-1)}_{ik} + d^{(k-1)}_{kj}) & if\ k >= 1 \end{cases} \quad (1)$$

When patients open function interface of navigation, the client will get the current position of the user from server according to ID sent by the iBeacon. After information about the user’s position is gotten, it will be displayed on plane map. Besides, patients can search the target department, pharmacy and ward according to their need. Finding empty beds is used as an example. In navigation process, using the shortest distance algorithm, the system calculated empty bed which was the nearest to patients according to their current location, and then directs patients to quickly arrive at the destination in clinic. The flow chart of recommending the nearest bed is shown in Figure 5.

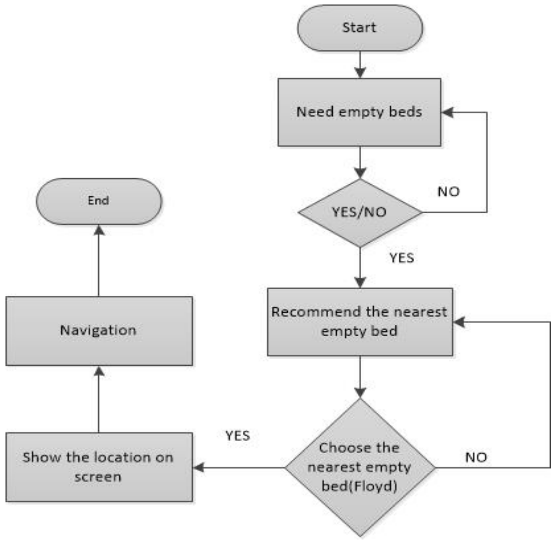
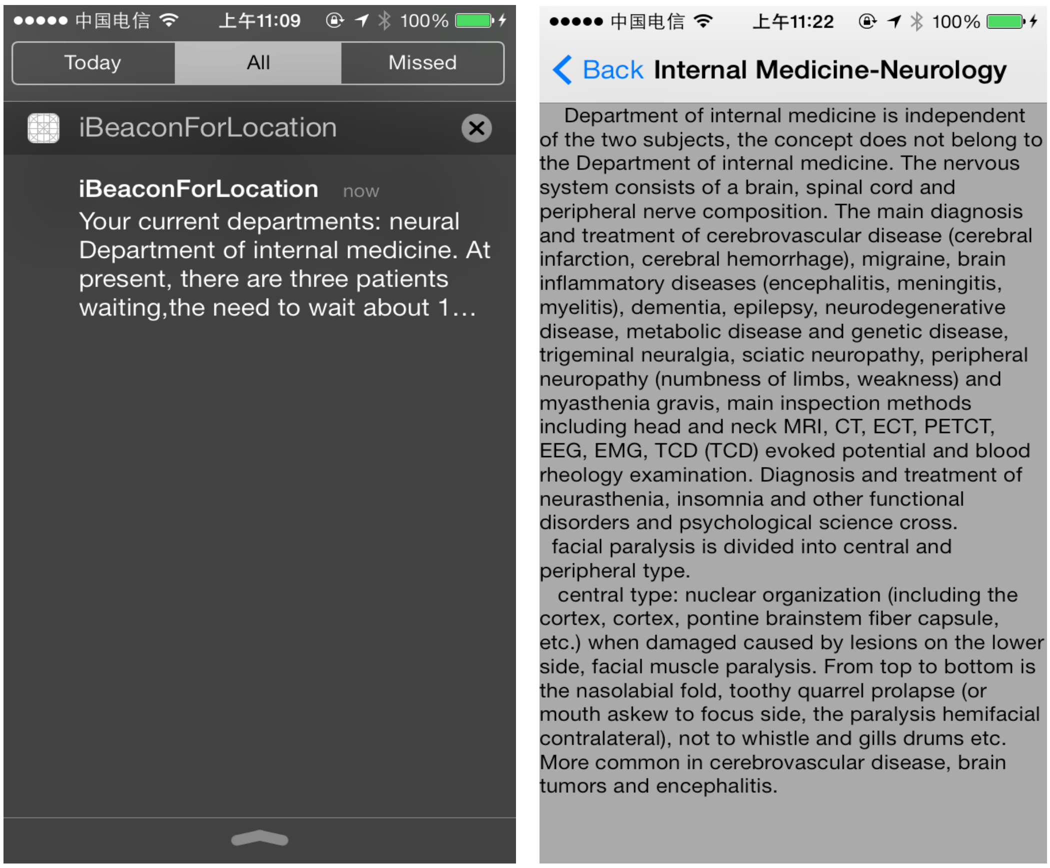


Figure 5. The Flow Chart of Recommending the Nearest Bed

4. The Experiment

Local LAN built by wireless router was used as the network layer, PC was used as the application layer server, Xcode6.1.1 was used as the development tool of client, iPhone5s mobile phone with IOS8.0 system was used as test platform of the application layer, and iBeacon produced by Byte real Technologies was used as the equipment of the sensing layer to construct iBeacon-based indoor positioning systems for hospitals. The experimental results are shown in Figure 6.



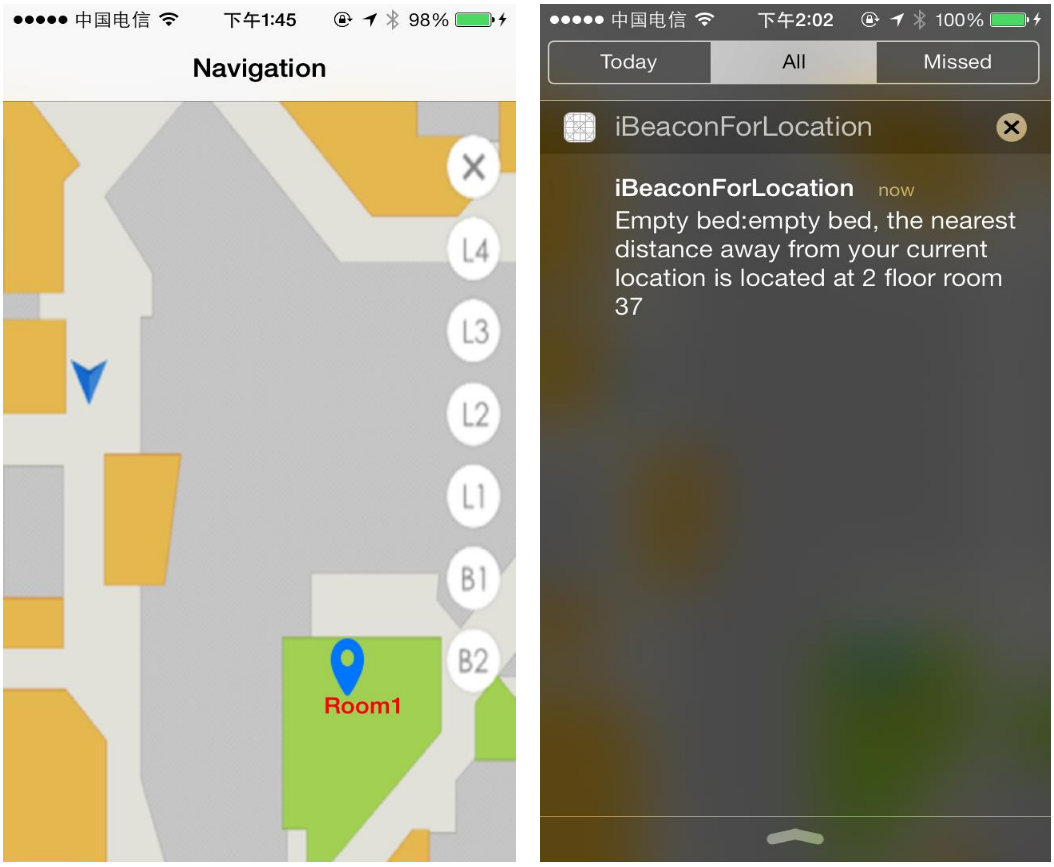


Figure 6. The Experimental Results

The first picture of Figure 6 is the illustrations of visitors' status of the target department displayed in client when patients approach it. The second picture is the details of the target department. The third picture is a map displayed in client where the patient's current position is marked. The fourth picture is the nearest empty bed for the user recommended by the system.

5. Conclusions

In this paper, iBeacon-based indoor positioning systems for hospitals are introduced. First, system was designed based on three-layer architecture of Internet of things and the shortest distance algorithm Floyd was used to recommend the nearest department or unit to patients. Finally, experiments were conducted to verify the feasibility of the system. Such a study on iBeacon-based indoor positioning systems for hospitals is of great importance, as its application can save time for patients and save manpower, and material resources for hospitals.

Acknowledgements

This work was supported by Hebei North University (No.Q2014002, No. ZD201301, No. ZD201302, No .ZD201303, No. Q2014005, No. Q2014008) and the Education Department of Hebei Province (No.QN2014182).

References

[1] B. Michelberger, "iCare: Intelligent Medical Information Logistics", Proceedings of International Conference on Information Integration and Web-based Applications & Services. ACM, **(2013)**.
[2] H. Kopetz, "Internet of things", Real-time systems, Springer US, **(2011)**, pp. 307-323.

[3] R. Mautz, "Overview of current indoor positioning systems", Geodezija ir kartografija, vol. 35, no. 1, **(2009)**, pp. 18-22.
[4] M. B. Kjærgaard, "Indoor positioning using GPS revisited", Pervasive Computing, Springer Berlin Heidelberg, **(2010)**, pp. 38-56.
[5] R. Tesoriero, "Using active and passive RFID technology to support indoor location-aware systems", Consumer Electronics, IEEE Transactions on vol. 54, no. 2, **(2008)**, pp. 578-583.
[6] R. Mautz, "Overview of current indoor positioning systems", Geodezija ir kartografija, vol. 35, no.1, **(2009)**, pp. 18-22.
[7] A. Ghose, A. Goldfarb and S. P. Han, "How is the mobile Internet different? Search costs and local activities", Information Systems Research, vol. 24, no .3, **(2012)**, pp. 613-631.
[8] P. Martin, "An iBeacon primer for indoor localization demo abstract", Proceedings of the 1st ACM Conference on Embedded Systems for Energy-Efficient Buildings, ACM, **(2014)**.
[9] N. Newman, "Apple iBeacon technology briefing", Journal of Direct, Data and Digital Marketing Practice, vol. 15, no. 3, **(2014)**, pp. 222-225.
[10] C. Gomez, J. Oller and J. Paradells, "Overview and evaluation of bluetooth low energy, an emerging low-power wireless technology", Sensors, vol. 12, no. 9, **(2012)**, pp. 11734-11753.
[11] J. Kahn, http://9to5mac.com/2014/11/03/best-ibeacon-hardware-stress-test-battery-life/, **(2014).**
[12] A. Gluhak, "A survey on facilities for experimental internet of things research", Communications Magazine, IEEE vol. 49, no. 11, **(2011)**, pp. 58-67.
[13] D. Namiot, "Local Area Messaging for Smartphones", International Journal of Open Information Technologies vol. 1, no. 2, **(2013)**, pp. 8-11.

Authors

Jingjing Yang, a lecturer in the School of Information Science and Engineering, Hebei North University, China. His research interests are in the field of medical information and internet of things.

Zhihui Wang, a lecturer in the School of Information Science and Engineering, Hebei North University, China. His research interests are in the field of medical information and internet of things.

Xiao Zhang, a Professor in the School of Information Science and Engineering, Hebei North University, China. His research interests are in the field of medical information and internet of things.

