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Research Article

BLE-based Indoor Positioning System for Hospitals using MiRingLA Algorithm

Le Van Hoang Phuong, Truong Quang Vinh*

ABSTRACT

Over the past decades, locating and navigating to the departments and wards in a large hospital have never ceased to draw public attention. A large number of human-based efforts and solutions have been given to deal with the difficulty in location and navigation in a large hospital. However, the problem is still existing, which urges human to take technology into account seriously. In this context, an indoor positioning system comes into play, it can not only tackle the trouble but also act as a prospective platform to build other applications on top of it. Nonetheless, the ever-changing environment and the heavy dependence on installation stage have precluded many state-of-the-art methodologies from practice. In this paper, we present an indoor positioning system based on Bluetooth Low Energy and applied to hospitals, which is easy-deployed, robust in the noise-rich, obstacle-rich environment. The system provides 3 principal functions like new medical examination registration, patient's in-app schedule management, and navigation. We implemented a web application to realize the first function. Besides, an Android application was developed to put ability up for patients to manage schedules and find ways. Moreover, we proposed a positioning method that is a modification to inter Ring Localization Algorithm (iRingLA), called MiRingLA. It utilizes 3 rings and Least Squares Estimation to deal with the drawback of the iRingLA. In addition, we applied a Kalman filter to reduce noises from received signals. The proposed method was experimented in a practical environment and achieved the mean localization accuracy of 0.91 m. Moreover, we performed comparisons between our proposed method and some of the others. Our proposed scenarios were experimented and proved to be feasible and suitable for a real application.

Key words: Indoor Positioning System, Bluetooth Low Energy, iRingLA, iBeacon, Received Signal Strength Indicator

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INTRODUCTION

In recent years, the demands on medical services have been increased. People give more needs for easy medical procedures, patient monitoring, navigation, etc. Therefore, an indoor positioning system is a promising approach to satisfy their needs and enhance the quality of hospitals. Indoor positioning systems help locate objects in a closed area such as a house, building where the Global Positioning System (GPS) does not work precisely as designated. In fact, GPS signals vary rapidly when propagating through these areas, therefore, some other types of signals have been researched to alternate GPS.

Typically, there are three kinds of signal used for positioning, namely Wi-Fi, Ultra-wide Band (UWB) and Bluetooth Low Energy (BLE)[1]. Each of them has its own good features and well-performing contexts.

Wi-Fi has been widely used in many indoor positioning systems. Triangulation, trilateration and fingerprinting are well-known approaches. N. Pritt[2] implemented a system for indoor navigation running on a smartphone or tablet utilizes Wi-Fi signals. Wi-Fi networks and devices are available in many such places as schools, shopping malls, and supermarkets. Moreover, Wi-Fi signals have large coverage. Nonetheless, they consume much power and depend on infrastructures. In fact, Wi-Fi signals are sensitive to environments and easy to be interfered by others in signal-rich environments. In Saab (2010)[3], the authors offered an indoor positioning system based on Radio Frequency Identification (RFID). It consists of a network of readers and numerous passive tags and yields the average of the absolute position errors of 0.1 m. The advantages of the systems based on this technology are reliability and high accuracy. However, the common problem is the requirement of numerous tags and readers which are not cost-efficient. Turan Can Artunç, Müştak Erhan Yalçin[4] carried out a study on a UWB-based indoor positioning system, in which the server received distances from anchors via Wi-Fi and estimated positions by using trilateration. Their experiments showed that the system achieved the accuracy of 1.55-8.4 cm. The advantages of UWB-based

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systems are high accuracy, low energy, and high immunity to the multipath fading. Nevertheless, it is not cost-efficient and causes interference to other RF signals. Bluetooth Low Energy is a new technology that has been focused on recently. It is an alternative to traditional technologies such as Wi-Fi, UWB. Nowadays, BLE is ready for many devices such as smartphones and beacons which offer a new approach to indoor positioning. BLE Beacon is a kind of BLE-enabled devices that continuously broadcasts BLE signal following a specific protocol. iBeacon [5] is a well-known protocol developed by Apple, Inc. that is widely used in many BLE beacons. In Chen *et al.* (2015) [6], the authors presented a framework of combining the Pedestrian Dead Reckoning (PDR), iBeacons, and a particle filter. Their real experiments achieved the accuracy of 1.2 m. The authors of Li *et al.* (2016) [7] built a newborns localization and tracking system in hospitals using iBeacons. Of the deployment patterns and numbers of iBeacons, 5 beacons placed in the middle area gave the best performance with the localization accuracy of 1.29 m.

In this study, we mainly focused on a solution to a hospital's existing demands, specifically in locating and navigating. We performed a study of a positioning method, MiRingLA, which was made up of iRingLA, LSQ, and a Kalman filter. Furthermore, we researched to provide automatic floor detection and Dijkstra-based multi-floor navigation. A real experiment was also carried out to evaluate the performance of our system.

The rest of the paper is organized as follows. The next section will present the proposed system. Section **Positioning Method** describes the positioning method, followed by experimental results in section **Experimental Results**. Finally, we draw some conclusions in section **Conclusion And Future Work**.

PROPOSED SYSTEM

With a view to realizing a practical positioning system applied in hospitals, we consider the system's mobility, easy maintenance, low energy, and persistence. We suppose to use BLE beacons which meet above concerns and MiRingLA positioning method. BLE beacons are the tiny devices that broadcast BLE signal periodically and continuously. They are straightforwardly stuck on walls and well-known for their lifespan and low power consumption. MiRingLA makes the system first-rate for its effortless preparation.

Figure 1 describes the model of the proposed system which includes 3 principal parts: a web server, smartphones, and BLE beacons. Web server is the center of the system, it acts as a database server and takes up providing smartphones with maps' information and patients' schedules. Moreover, it provides nurses and doctors with abilities to register new patients and update their medical records. RSSI denotes Received Signal Strength Indicator which is the received signal strength measured by smartphone. The Android application (IPSHApp) runs by smartphones is designed to show patients' schedules and directions to the assigned rooms. The positioning method is comprehensively executed by smartphones that requires 3 RSSIs of 3 separate BLE emitters to find the patients' positions.

POSITIONING METHOD

Radio Wave Propagation Model

Many localization methods are mainly based on the Received Signal Strength Indicator (RSSI). Bluetooth signal is one of the electromagnetic waves that significantly depend on environments. Recent research [8–10] has led to the conclusion that radio waves vary according to types of environment, distances between transmitters and receivers, etc. Some path loss models have been introduced to predict the propagation loss in environments. In this study, we apply the Log-distance Path Loss model [8] due to the characteristics of a hospital environment mentioned:

$$PL = P_{TxdBm} - P_{TxdBm} = PL_0 + 10nlog\left(\frac{d}{d_0}\right) + X_g \quad (1)$$

$$RSSI\,(d) = RSSI\,(d_0) - 10nlog\left(\frac{d}{d_0}\right) \quad (2)$$

where d is the distance between the transmitter and receiver d_0 is the reference distance, usually 1m. n is the path loss exponent that depends on transmission mediums, usually 2 in offices. FromEquation (2), the path loss exponent can be expressed as:

$$n = \frac{RSSI\,(d_0) - RSSI\,(d)}{10log\left(\frac{d}{d_0}\right)} \quad (3)$$

Trilateration and iRingLA

In this section, we review the trilateration [11] and iRingLA [12–14] approaches that are the foundation of our proposed method.

Trilateration is a classical geometry approach to determine a point's coordinates using a set of 3 circles (**Figure 2a**). When we have coordinates of three beacons and three average distances from them to the receiver respectively, the position is the root of a set of three circles' equations:

$$\begin{cases} (x-x_1)^2 + (y-y_1)^2 = d_1^2 \\ (x-x_2)^2 + (y-y_2)^2 = d_2^2 \\ (x-x_3)^2 + (y-y_3)^2 = d_3^2 \end{cases} \quad (4)$$

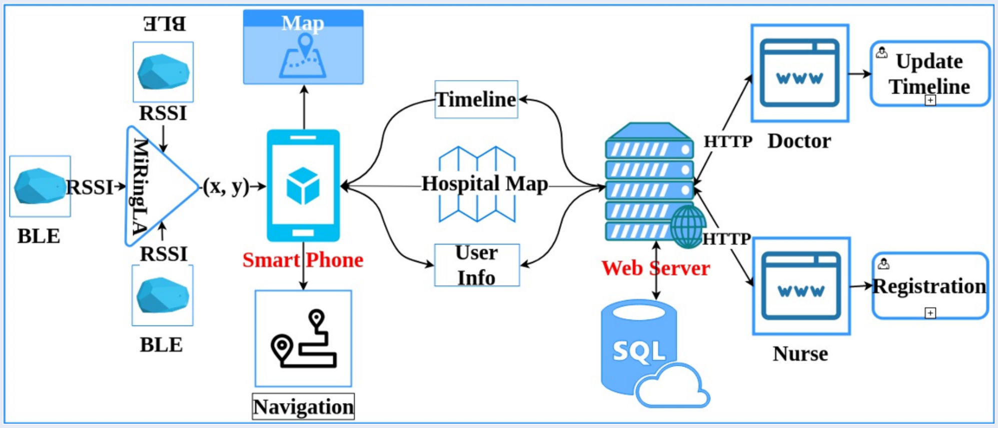


Figure 1: **The proposed system's architecture.**

Figure 2a indicates that we can only find the exact position if three circles intersect at one unique point. Due to all the reasons mentioned in section Radio Wave Propagation Model, we cannot obtain exact RSSIs as well as distances from a beacon to a receiver so three circles do not intersect either at only one point or at all (**Figure 2b**). This means we cannot obtain a unique root from Equation (4) by using a normal solving method.

iRingLA, a new localization method based on trilateration has been introduced and researched that helps resolve the problems. Instead of using only three circles, iRingLA draws rings around the three anchors (beacons) (**Figure 3**). Each of them is made of an inner and outer circle whose radii are expressed as:

$$\begin{cases} R_i = R_{ave} - E \\ R_{out} = R_{ave} + E \end{cases} \tag{5}$$

where E is the error of a specific environment attained from experiments. The desired point is the centroid of the common area of 3 intersected rings.

Modified iRingLA (MiRingLA)

In our work, the targeted place is a hospital. Distances become further and the characteristics of the environment change continuously, signals may be diminished by walls and obstacles, which causes iRingLA may neither perform accurately as it designated nor give any positions at a specific point of time. **Figure 3b** depicts a case in which the 3 rings do not have any points in common. In this case, iRingLA cannot locate the object and the system does not work properly.

We propose a modification to the iRingLA that helps the object always be positioned. When the 3 rings do not intersect at all, we apply the Least Squares Estimation (LSQ) [15] into 3 average-radius circles to estimate the position. The LSQ is to minimize the square error and with given the estimated distances $d_i$and known positions $(x_i, y_i)$of the i^{th}transmitter, the position of a receiver can be estimated by finding $(\widehat{x}, \widehat{y})$satisfied this equation:

$$(\widehat{x}, \widehat{y}) = argmin \sum_{i=1}^{3} [d_i - \sqrt{(x-x_i)^2 + (y-y_i)^2}]^2 \tag{6}$$

Let:

$$A = \begin{bmatrix} 2(x_k - x_1) & 2(y_k - y_1) \\ 2(x_k - x_2) & 2(y_k - y_2) \\ 2(x_k - x_3) & 2(y_k - y_3) \end{bmatrix} \tag{7}$$

$$B = \begin{bmatrix} d_1^2 - d_k^2 - x_1^2 + x_k^2 - y_1^2 + y_k^2 \\ d_2^2 - d_k^2 - x_2^2 + x_k^2 - y_2^2 + y_k^2 \\ d_3^2 - d_k^2 - x_3^2 + x_k^2 - y_3^2 + y_k^2 \end{bmatrix} \tag{8}$$

Then the estimated position is the result of this calculation:

$$X = \begin{bmatrix} x_0 \\ y_0 \end{bmatrix} = (A^T A)^{-1} A^T B \tag{9}$$

Figure 5 shows a brief overview of our proposed MiRingLA. **Figure 4** is a geometric illustration of the grid-based computation method proposed to find a receiver's position:

1: Clusters $\{C_1, C_2\} \leftarrow$ ring1 $\cap$ ring2
2: $for\ each\ C_i\ do:$
3: $R_i \leftarrow$ the rectangle best wraps C_i
4: divide$R_i$intom^2equal cells
5: $R_i \leftarrow [(m-1)^2 + 4)$ points
6: $for\ each\ R_i\ do:$

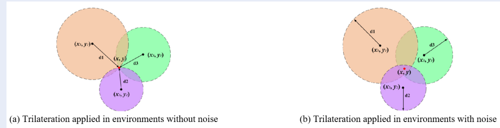


Figure 2: **Three circles intersect at (a) a unique point (b) many points.** The pictures are taken from [10].

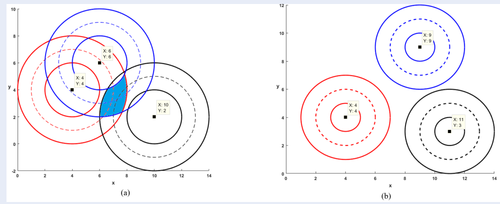


Figure 3: **iRingLA: inter Ring Localization Algorithm**. Three rings (**a**) intersect at one cluster (**b**) do not intersect at all

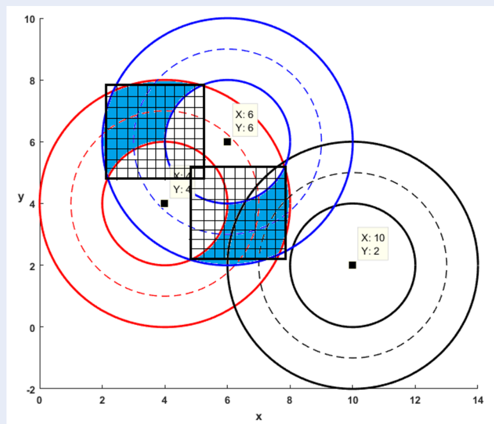


Figure 4: **Illustration of the grid-based computation of iRingLA.**

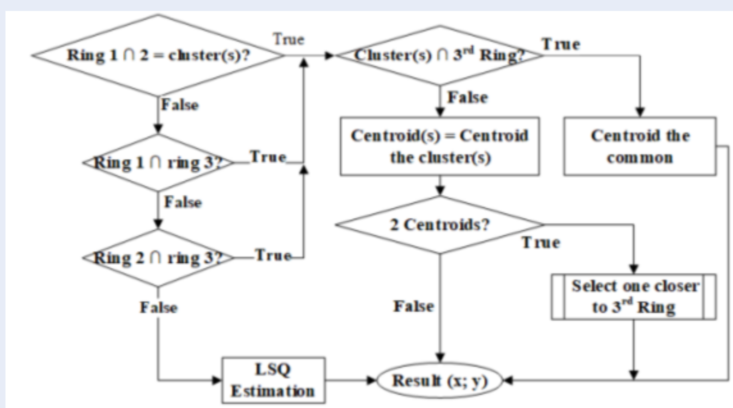


Figure 5: **Summary of MiRingLA**.

7: $S_i \leftarrow \{(x,y) \in R_i | (x,y) \in \text{ring}\,1, (x,y) \in \text{ring}\,2\}$.
8: $for\ each\ S_i\ do$:
9: $S_i \leftarrow \{(x,y) \in S_i | (x,y) \in \text{ring}\,3\}$
10: $if\ S_i \neq \varnothing\ then$:
11: position $(x,y) \leftarrow average\ (S_i\}$

Kalman Filter

RSSI may be affected by noise in indoor environments, thereby receivers using the RSSI may not achieve accurate distances. Averaging these values is a common solution but it also continuously changes over time. These unwanted average RSSIs will significantly diminish the accuracy of either iRingLA or MiRingLA. There are various filters able to eliminate a large part of noise from signal. The authors of[16] applied a Kalman filter effectively to remove noise from RSSI. In order to deal with the noise problem, we also apply a Kalman filter to refine received signal, thereby making the received signal strengths more reliable. The performance of the Kalman filter was denoted in **Figure 7**.

Kalman filter mainly consists of two distinct phases: prediction and correction and can be written in short as follows:

• Prediction phase:

$$\begin{cases} \widehat{X}_k = AX_{k-1} + Bu_k + w_k \\ \widehat{P}_k = AP_{k-1}A^T + Q_k \end{cases} \tag{10}$$

• Correction phase:

$$K = \widehat{P}_k H (H \widehat{P}_k H^T + R)^{-1} \tag{11}$$

$$Y_k = CX_{kM} + Z_k \tag{12}$$

$$\begin{cases} X_k = \widehat{X}_k + K \left(Y_k - H\widehat{X}_k \right) \\ P_k = (I - KH)\,\widehat{P}_k \end{cases} \tag{13}$$

where X - state matrix ($\widehat{X}$: predicted), P - process covariance matrix ($\widehat{P}$: predicted), U - control variable matrix, W - predicted state noise matrix, Q - process noise covariance matrix, Y - measurement of state, Z - measurement noise, R - measurement covariance matrix, H - conversion matrix, I - identity matrix, A - state transition matrix, B - control matrix, C - transformation matrix, K - Kalman gain, k denotes the k^{th} sample.

In our physical model, we assume that in each step of measurement, the device does not move and the position is also static. A and C are set to identity matrices as we assume the state is static (*i.e.* $X_k = X_{k-1}$ and the state is modeled directly (*i.e.* we assume $Y = X_{kM}$. B is set to 0 due to no control. Q is typically set to a small value (e.g. 0.008). R is set to the variance of measurements σ^2(*e.g.* 4) shown in **Figure 6**.

EXPERIMENTAL RESULTS

Web server

Being the center of the system, the web server is responsible for providing Android applications hospital maps' information and patients' schedules. Moreover, it provides nurses and doctors with abilities to register new patients and updating their medical records. We developed the server based on the SailsJs MVC framework. **Figure 8a** is a nurse-customized interface contains tables of patients' information, history and new examination registrations. **Figure 8b** is a picture of a doctor's website which includes patients' information, history of treatments, prescriptions and schedules. After registering a new patient (**Figure 9a**), the nurse will assign him to a specific room for later medical procedures by creating a new invoice using the table shown in **Figure 9b**. An item will be automatically added to the patient's schedule. The doctor is in charge of that room will see the assigned patient's information, and he can provide treatments or appoint him to another room to take some extra tests (**Figure 10**). After all treatments are completed, the doctor will mark that patient as done to finish his medical tests.

Android Application (IPSHApp)

The actual position of a device as well as a patient is estimated using its RSSIs and our proposed positioning method. Navigation is powered by the Dijkstra[17] algorithm. There are 5 main steps to take to attain a position and a route presented as follows:

1) Create lists of beacons along with their corresponding filtered RSSIs and the average RSSIs.
2) Select the three greatest average RSSIs of three beacons.
3) Use MiRingLA to compute the position (x,y)
4) Create a Dijkstra graph made up of the map's vertices, edges, and the current position.
5) Determine the destination then execute the Dijkstra algorithm to find the shortest path from the current position to the destination.

On starting, the application continuously scans all iBeacon packets broadcasted by beacons, then selects the greatest RSSI and send it to the server to identify the floor that the patient is currently in. After that, the application will download the map of the floor accompanied by all of its information including physical dimension, points, and edges of Dijkstra graphs from the server via WLAN or the Internet. The map is used for displaying the patient's position and navigation information. **Figure 11** provides the way we applied the Dijkstra algorithm to find a route. The

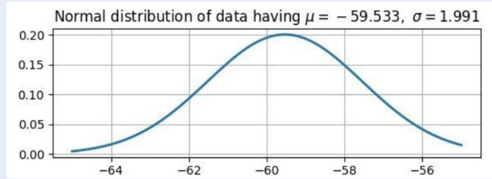


Figure 6: **Normal distribution of RSSIs in raw form**.

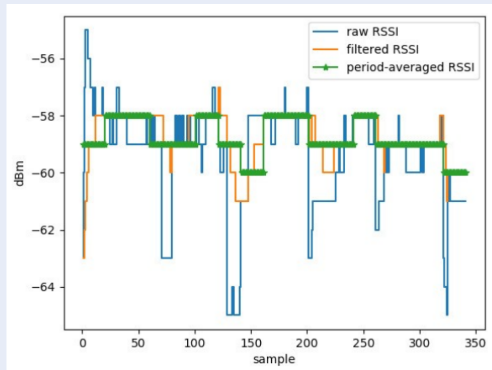


Figure 7: **Raw, filtered and period-averaged RSSIs at distance 1m from an emitter**. The final average RSSI at 1m was −59dBm and attained by computing mean of these values. The Kalman filter significantly removed noise from signal.

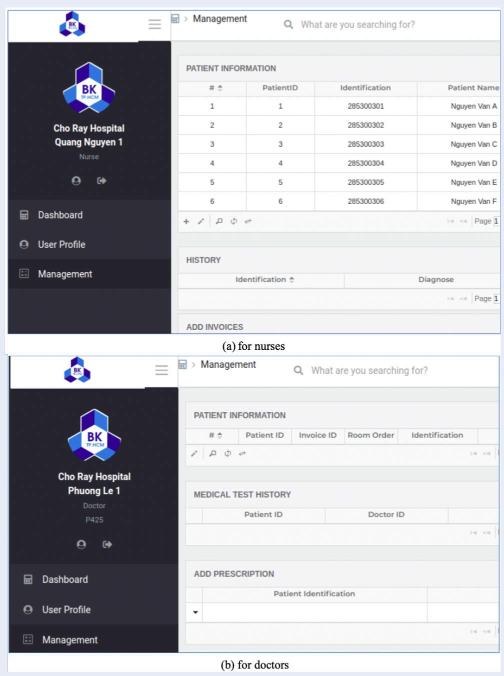
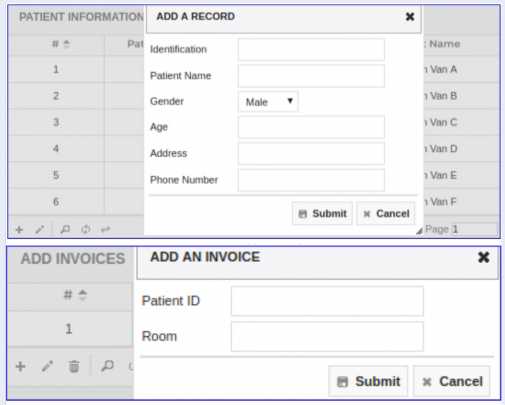


Figure 8: **Website**.



(b) Nurses add a new invoice

Figure 9: Patient management.

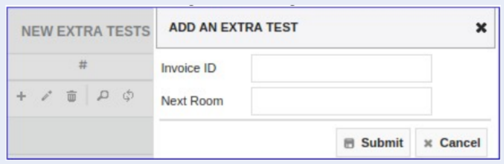


Figure 10: Doctors ask patients to take extra tests in another room.

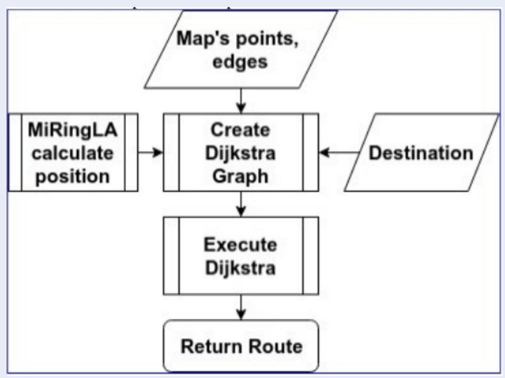


Figure 11: Finding a route from current position to the destination.

points and edges are used to construct Dijkstra graphs for finding routes to the destinations. Points are such predefined locations on a map as rooms, exits represented by red dots. A red dot in **Figure** 12 denotes a vertex of a Dijkstra graph. An edge consists of 2 red dots and the distance between them. On detecting a new beacon, the application will identify whether the patient is on another floor or not and update the map.

BLE Beacon

We use the Proximity Beacons [18] because of their such good features as small sizes, long-term use and built-in BLE enabled. For deployment, we need to choose suitable positions for these beacons with some concerns. As introduced, MiRingLA inherits trilateration which means 3 beacons form a shape of a triangle. A smartphone in this triangle is given more accurate positions. Furthermore, the further distances, the less reliable RSSIs so we do not keep a beacon far from the receiver. **Table** 1 shows the configurations of our

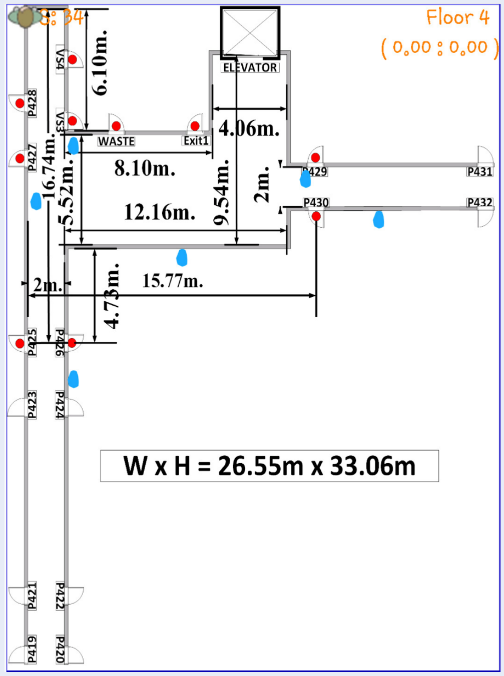


Figure 12: **Beacon deployment**.

beacons and their visual positions on the map are illustrated by **Figure** 12. As the shorter broadcast intervals, the more stable BLE signals, we configure it as small as possible, namely 100 ms.

Deployment

The experiments are conducted on the 4^{th}floor of Bach Khoa Dormitory, 497 Hoa Hao Street, District 10, Ho Chi Minh City, Vietnam. The area under testing is a half of the floor with dimensions of 26.55 m x 33.06 m and is shown in **Figure** 12. The area includes 9 rooms, 1 exit illustrated by their labels and 2 corridors. The dimensions of the vertical and horizontal corridors are 2m x 16.74m and 15.77m x 5.52m respectively. Blue shapes represent the beacons, and they are stuck on the walls and 1.2m above the ground. The device involved in these experiments was Samsung Galaxy Note 5.

In this phase, we conducted some measurements to evaluate our system performance and accuracy. $RSSI_{d_0}$, n, $E$are the three most important parameters of the MiRingLA. In our test, as can be seen in **Figure** 7, $RSSI_{d_0}$is$-59dBm$ To find out the value of n, we take several RSSI measurements at different distances d, then compute their corresponding path loss exponents using **Equation** (3)**.** The final value of n can be obtained by averaging those computed path loss exponents which are summarized in **Table** 2. After possessing $RSSI_{d_0}$, n we perform estimation using this equation:

$$d = 10^{\frac{-59 - RSSI(d)}{10x2.295}} \tag{14}$$

In the next step, doing the same measurements as above, and then we compute estimated distances using **Equation** (14). The environment error E is the difference between an actual and estimated distance. E is 0.57m and shown in details in table III. **Equation** (5) gets:

$$\begin{cases} R_{in} = R_{ave} - 0.57 \\ R_{out} = R_{ave} + 0.57 \end{cases} \tag{15}$$

and will be used to draw a ring for each beacon whereR_{in}, R_{out}, R_{ave} are respectively the inner, outer radius and the average distance estimated using **Equation** (14)**.**

Evaluation and Discussion

Figure 13 shows the trajectories of an experiment. We walk along the lines connecting dots at normal speed, each step takes about 60 cm and is marked as a dot. The stars and their line connectors represent the estimated positions and estimated walking path respectively. The positioning error is the Euclidean distance

Table 1: BEACON CONFIGURATION

No.	Major	Minor	$T_x(dBm)$	Broadcast Interval (ms)
1-6	421	1-6	0	100
UUID = B9407F30-F5F8-466E-AFF9-25556B57FE6D				

Table 2: PATH LOSS EXPONENT n

$RSSI_d(dBm)$	$d(m)$	n	$RSSI_d(dBm)$	$d(m)$	n
-52	0.25	1.16	-74	4.00	3.52
-55	0.50	1.33	-76	5.00	3.56
-59	1.00	1.00	-77	6.00	3.16
-61	1.25	2.06	-79	7.10	3.15
-64	1.5	2.84	-80	8.20	3.08
-67	2.00	2.66	-81	9.10	2.96
-74	2.50	3.77	-84	10.1	2.41
-73	3.00	2.93	-86	13.6	2.38
$\overline{\overline{n}} = 2.295$					

between the user's true physical position and the estimated one. In this scenario, our proposed approach achieves the mean localization accuracy of 0.91 m. When m is set to 100, the average execution time of MiRingLA on our phone is 112 ms, and the smaller the value of m, the less computation time. Each time of finding a route takes around 10 ms. The values show that our application can provide a position in each step.

Figure 14 denotes a patient's schedule including the information of room, doctor, turn, specialty, and his status. The route from the current position to the destination is depicted in Figure 15. It consists of some short parts along with their distances. Moreover, the application is able to find a route not only within a floor but from the current position to a location on another floor. This thanks to the automatic area detection which makes our application context awareness, especially when patients move to another area or the destination is not in the same area.

Table 4 provides the localization accuracy of some approaches. The author of the study[6] presented a framework tested in an office zone. By applying a combination of PDR and a particle filter, they attained the accuracy of 1.2m. Given the same area, their method is fairly effective than ours in terms of the number of iBeacons, however, it is less accurate and more complicated. The author of the study[7] established an in-room newborns localization system in hospitals with some deployment patterns and numbers of iBeacons. They led to the conclusion that 5 iBeacons in the middle area performed best with the mean accuracy of 1.29m. They also compared the performance of the reality path-loss model and Estimote iBeacon model by the cumulative distribution function of distance measurement error. However, their system achieved less accuracy than ours, their path-loss model may work only in light-of-sight situations, and no promise that the model would work in a real hospital have been given. In[19] the authors applied iRingLA and performed experiments in an empty 4m-by-4m room which yielded the accuracy of 0.41m when it comes to the distance measurement error. However, a small empty room is an ideal place without obstacles, walls, furniture, and they did not guarantee their approach would perform as-is in larger and more complex areas like ours. In our work, the contribution of the Kalman filter and MiRingLA method helped together enhance the overall performance of the system. The real experimental results[20] conducted in our test-bed (section deployment) show that the methodology is simple but effective and useful, the accuracy is 0.91 m which is reliable enough to locate patients and providing navigation.

CONCLUSION AND FUTURE WORK

In this paper, we have introduced a Bluetooth Low Energy-based Hospital Positioning System made up of 3 parts: a web server, smartphones, and BLE beacons. The system provides new medical examination

Table 3: **ENVIRONMENT ERROR**

d_{actual} (m)	$d_{MiRingLA}$ (m)	E (m)	d_{actual} (m)	$d_{MiRingLA}$ (m)	E (m)
0.25	0.395	0.145	3.00	3.684	0.684
0.50	0.606	0.106	4.00	4.633	0.633
0.80	1.00	0.2	5.00	4.203	0.797
1.70	2.018	0.318	6.00	6.826	0.826
2.00	2.218	0.218	7.00	6.084	0.916
2.55	2.927	0.377	8.00	8.943	0.943
			9.00	10.25	1.25
$\overline{\overline{E}} = 0.57$					

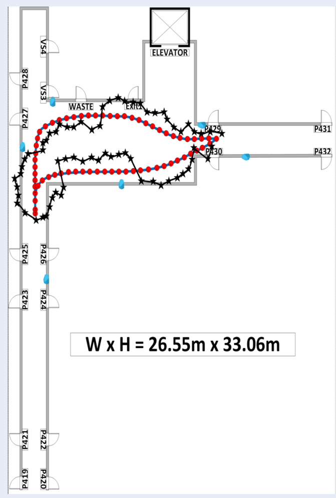


Figure 13: **The trajectories of a specific experiment**. The line connecting dots represents the walking path of a user at normal speed, each step takes 60cm and is marked as a dot. The stars and their line connectors represent the estimated positions and estimated walking path respectively

Table 4: **THE MEAN ERRORS OF DIFFERENT SYSTEMS**

Study	Environment	Method	Error
[5]	47.3mx15.9m office zone	PDR, particle filter	1.2m
[6]	a room, 5 iBeacons	Triangulation, LSQ	1.29m
[7]	a 4m x 4m empty room	iRingLA	0.41m (1D error)
Proposed	corridors of a dormitory's floor	Kalman filter, MiRingLA	0.91m

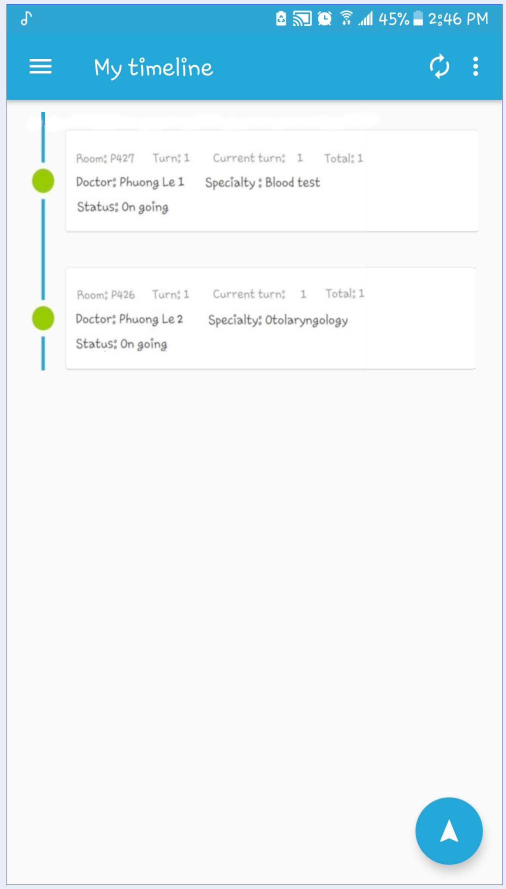


Figure 14: **IPSHApp displays a patient's schedule including the information of room, doctor, specialty, turn, and status**.

registrations, treatments, in-app schedule management, and navigation. We also proposed a positioning method, MiRingLA, which is a combination of iRingLA and Least Square Estimation, which yielded the accuracy of 0.91m. Furthermore, a Kalman filter is also applied to improve the reliability of RSSIs. The navigation is developed based on the Dijkstra algorithm getting along with automatic current area detection, which provides multi-floor navigation.

The big advantage of our proposed system is effortless deployments which are an ideal solution to the practice. The beacons are small, long-lasting and easy to be stuck on walls and relocate, which gives mobility. Besides, by applying MiRingLA, there are no longer needs for measurements and calculations for the parameters in the same environment when the deployments are changed.

Some improvements are intended to be conducted in the future. We are researching on improving the stability of patients' positions on moving by utilizing a particle filter along with compass, accelerometer and gyroscope sensors integrated in available modern phones. For navigation, current routes are fairly tough and broken due to the lack of dots in **Figure** 12 and the positions of them. We will define more points and apply other algorithms. Besides, IPSHApp is mainly tested on a Samsung mobile phone. Some experiments on Nokia3 carried out show that the parameters $RSSI_{d_0}$, n, Ehave small differences compared to the Galaxy Note5 which proved that the accuracy slightly varied. Instead of using the same MiRingLA's parameters for all sorts of smartphones, we divide them into groups based on their models and the application will get their corresponding parameters from the server on starting.

LIST OF ACRONYMS

GPS: Global Positioning System

UWB: Ultra-Wide Band

BLE: Bluetooth Low Energy

RFID: Radio Frequency Identification

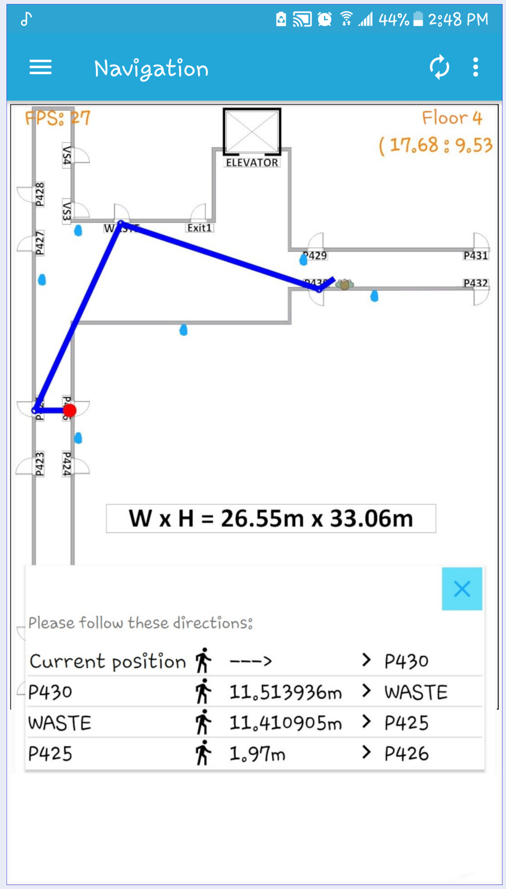


Figure 15: **IPSHApp displays the patient's current position and the route from the current position to the destination.**

PDR: Pedestrian Dead Reckoning
LSQ: Least Squares Estimation
IPSHApp: Android Application
RSSI: Received Signal Strength Indicator
MVC: Model View Controller
WLAN: Wireless Local Area Network
IRingLA: inter Ring Localization Algorithm
MiRingLA: Modified inter Ring Localization Algorithm

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

AUTHORS' CONTRIBUTIONS

Phuong Le Van Hoang conducted the theoretical study, worked out almost all of the technical work including implementing the algorithm, web server, and Android application; devised experiment scenarios, performed experiments, and wrote the manuscript in consultation with Vinh Truong Quang. Vinh Truong Quang thought up conceptual ideas, involved in planning and supervised the work, contributed to the design of the system architecture, and the final manuscript. All authors discussed the results, provided comments and helped shape the research, analysis, and manuscript.

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Tạp chí Phát triển Khoa học và Công nghệ – Kĩ thuật và Công nghệ, 2(1):46-59

Bài Nghiên cứu

Hệ thống định vị trong nhà trên nền tảng BLE sử dụng phương pháp định vị MiRingLA

Lê Văn Hoàng Phương, Trương Quang Vinh*

TÓM TẮT

Trong những năm gần đây, việc bệnh nhân biết mình đang ở đâu và đi như thế nào để đến các phòng khám trong một bệnh viện lớn đã và đang thu hút sự quan tâm của công chúng. Nhiều nỗ lực và giải pháp dựa vào con người đã được đưa ra để giải quyết sự khó khăn trong định vị và tìm đường đi ở các bệnh viện lớn. Tuy nhiên sự khó khăn ấy vẫn đang tiếp diễn, điều đó thúc giục con người phải xem xét đến yếu tố công nghệ một cách nghiêm túc. Trong bối cảnh này, hệ thống định vị trong nhà sẽ giúp ích, nó không chỉ đáp ứng được nhu cầu trên mà còn là nền tảng công nghệ đầy tiềm năng để xây dựng các ứng dụng hữu ích khác. Tuy nhiên, sự thay đổi liên tục của môi trường bệnh viện và sự phụ thuộc đáng kể vào giai đoạn lắp đặt hệ thống khiến cho nhiều hệ thống định vị hiện đại khó được áp dụng vào thực tiễn. Trong bài báo này, chúng tôi trình bày một hệ thống định vị trong nhà dựa trên Bluetooth Low Energy áp dụng cho các bệnh viện, dễ triển khai, thích ứng cao trong môi trường nhiều nhiễu, nhiều chướng ngại vật. Hệ thống này có 3 chức năng chính: đăng ký khám bệnh, bệnh nhân quản lý lịch trình khám bệnh trên điện thoại và chỉ đường cho bệnh nhân đến các phòng ban. Để thực hiện được chức năng đăng ký khám bệnh, chúng tôi đã xây dựng một ứng dụng web, bên cạnh đó, một ứng dụng Android được phát triển nhằm hiện thực 2 chức năng còn lại. Chúng tôi đề xuất một phương pháp định vị dựa trên phương pháp iRingLA, gọi là MiRingLA. Nó là sự kết hợp của 3 vành khăn và phương pháp xấp xỉ bình phương tối thiểu để khắc phục nhược điểm của phương pháp iRingLA. Ngoài ra, bộ lọc Kalman được sử dụng để giảm bớt nhiễu cho tín hiệu nhận được. Phương pháp này được thử nghiệm trong môi trường thực tế và đạt độ chính xác 0.91m. Hơn nữa, chúng tôi thực hiện phép so sánh để thấy sự tương quan giữa phương pháp được đề xuất và một số phương pháp khác. Những thí nghiệm được thực hiện đã chứng minh rằng hệ thống này khả thi và phù hợp với một ứng dụng thực tế.

Từ khoá: Hệ thống định vị trong nhà, Bluetooth năng lượng thấp, giải thuật iRingLA, giao thức iBeacon, chỉ số cường độ tín hiệu nhận được

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