A Real-Time Indoor Navigation Scheme Exploiting Wi-Fi Access Points

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***Abstract*— In recent years, smart phones and wireless internet usage are remarkably increased. It is known that citizens reside in indoors more than 80 percent of daily life. The indoor positioning technologies have been recognized as the core technology for their safety, management, and location-based service. Most shopping complex have installed Wi-Fi access points (APs) for providing internet service to the customers. In this paper, an implementation of real-time indoor positioning scheme based on radio signal strength (RSS) value of Wi-Fi AP is presented and the issues of implantation are discussed with the experiment results. Although there is estimation error, the estimated position of the smart phone can be displayed on the smart phone in real-time.**

***Index Terms*— Wi-Fi; Indoor Navigation; Positioning; Lateration.**

I. INTRODUCTION

It is known that people reside indoors more than 80 percent of their daily life. In recent years, most of the shopping complexes have installed Wi-Fi access points (APs) to provide internet service to customers. The indoor positioning technologies have been recognized as the core technology that provides a location-based service, while at the same time ensuring the convenience and safety of the customers. Global positioning system (GPS) is a well-known system for outdoor navigating, but the GPS technology does not work well indoors. Thus, indoor positioning technique has been developed to overcome the limitation of GPS. However, it is not widely used and there are various technologies, which are developed in progress [1].

In this paper, an implementation of real-time indoor positioning scheme based on radio signal strength (RSS) value of Wi-Fi AP is presented and the issues of implantation are discussed with the experiment results. For the implementation, a lateration method, which uses three circles of APs are considered as this method is simple and easy to implement for indoor positioning scheme [2]. In the lateration method, the RSS values from all existing APs are gathered and the RSS values from the APs are converted to the distance from the respective APs by using log-normal shadowing model [3, 4]. Despite of this advantage, there has been very limited real-time indoor positioning service that utilizes RSS value. This instance is due to the limitation of handheld device as an indoor navigation system.

Nowadays, various smart phones equipped with Wi-Fi module have been introduced, and these phones can handle the application for indoor navigation. For the purpose of this research, an Android application is developed for a real-time positioning. The performance of the presented scheme is provided and the issues of implantation are also discussed with the experiment results.

II. THEORETICAL BACKGROUND

To estimate the position of a smart phone, a server is needed to compute the estimated position with three measured distance information between the APs and the smart phone. In this section, we discuss how to measure the distance and estimate the position of the smart phone.

A. RSS Characteristics

Propagation of wireless signal can be affected with signal attenuation, shadowing, scattering, multipath, and diffraction [5]. The RSS value diminishes during propagation. As a result, the distance can be measured by using this characteristic. In this paper, the log-normal shadowing model [3, 4] is utilized and its mathematical expression is described as follows:

$$P[\text{dBm}] = P_{ref} - 10 \cdot k \cdot \log\left(\frac{Dis}{D_m}\right) \tag{1}$$

where Dis is the distance, P_{ref} is the RSS value at a reference point, D_m is 1 m as a reference point, and k is the loss coefficient which depends on indoor environment [4]. The signal Power, P, is measured at the receiver. Equation (1) can be transformed to the distance as follows:

$$\text{Dis} = \text{D}_m \cdot 10^{\left(\frac{P_{ref} - P}{10 \times k}\right)} \tag{2}$$

Therefore, the estimated distances can be calculated with Equation (2).

B. Lateration Method

Generally, the lateration method means the tri-lateration method. Figure 1 shows an example of tri-lateration method based on three reference APs.

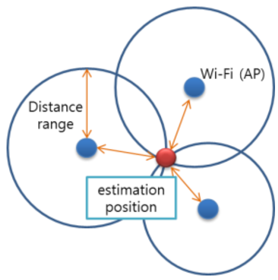

Figure 1: Example schematic of tri-lateration method

As shown in Figure 1, the intersection of three circles is considered as the estimated position of the target. Note that the measured distance between an AP and the smart-phone is used as the radius of each circle. The mathematical equation and its matrix form are expressed as follows [1, 6]:

$$H\hat{x} = b \tag{3}$$

where:

$$H = \begin{pmatrix} x_2 - x_1 & y_2 - y_1 \\ x_3 - x_1 & y_3 - y_1 \\ \vdots & \vdots \\ x_{n-1} - x_1 & y_{n-1} - y_1 \end{pmatrix} \tag{4}$$

$$b = \frac{1}{2}\begin{pmatrix} x_2^2 + y_2^2 - d_2^2 - (x_1^2 + y_1^2 - d_1^2) \\ x_3^2 + y_3^2 - d_3^2 - (x_1^2 + y_1^2 - d_1^2) \\ \vdots \\ x_{n-1}^2 + y_{n-1}^2 - d_{n-1}^2 - (x_1^2 + y_1^2 - d_1^2) \end{pmatrix} \tag{5}$$

where $\hat{x}$ is the estimated position of the smart phone, n is total number of APs, (x_1, y_1), (x_2, y_2) and (x_3, y_3), are the coordinate of APs that sends the first, second and third strongest RSS value.

For the estimated position, the above equation can be rewritten as follow:

$$\hat{x} = (H^T H)^{-1} H^T b \tag{6}$$

III. Description of Implementation

Based on the theoretical background of the previous section, the related equations are transformed into codes. The smart phone built in Wi-Fi module has a function that can search surrounding Wi-Fi signals. The RSS value can be measured by the smart phone by this function. The flow of system is as follows: Firstly, the smart phone scans the RSS value of AP and the RSS value is sent to the web server. Secondly, the web server ranks the RSS values and brings the position data of APs successively from the database. Thirdly, each of distance and positioning coordinate is calculated on the web server by using Equation (2) and (3). Finally, the information of the coordinate is accessed and is displayed on the smart phone. Thus, the user can check his/her position with the estimated position of smart phone in real-time. Figure 2 shows the signal flow of the implemented indoor navigation scheme.

A. *Android Application*

An Android application was developed for the implementation. This application is not only widely used OS but it is also easy to be developed by anyone who knows Java language. We utilized the embedded Wi-Fi module in the smart phone. By pushing the Wi-Fi scan button, the smart phone searches every channel of 2.4GHz and 5GHz bands of the surrounding APs. The APs can be distinguished by the service set identifier. The sorted RSS value of APs is sent to the web server by the POST method.

Note that Android is a Java-based operating system. Java has two data transfer methods, namely the SOCKET and HTTP. A SOCKET is bound to a port number so that the data are destined to be sent to [7]. Meanwhile, HTTP transfers data by a uniform resource locator (URL). Although there are several advantages and disadvantages, we selected HTTP because of easy to use [8]. What is needed is to install the Apache program. HTTP also has two methods, which are the POST and GET. POST uses the simplified and encoded URL for security. On the other hand, GET uses full URL. It can avoid overload by removing the encoding process. After the value is posted, the smart phone receives a return value, which contains the estimated coordinate, from the web server and it is displayed by the WEBVIEW function that displays the web page. Figure 3 shows the developed Android application.

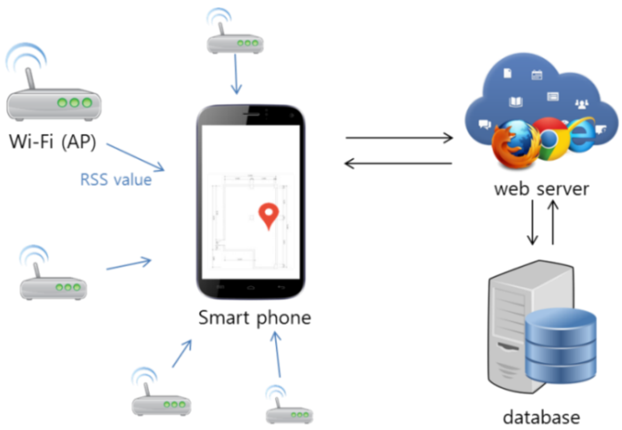

Figure 2: Signal flow of the implemented indoor navigation scheme

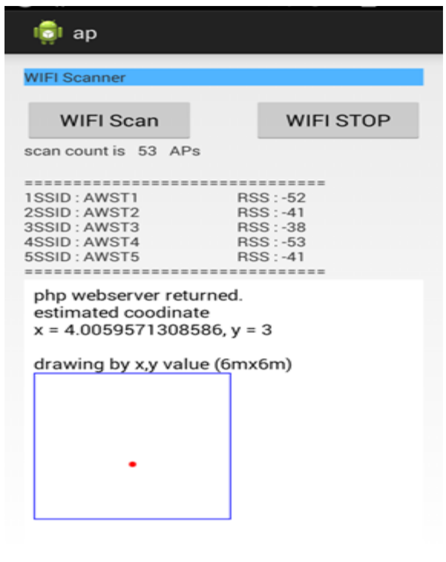

Figure 3: Developed Android Application

B. *Web Server*

Apache is a service program that constructs the web server or web page by using HTTP protocol through number 80 port. To make a desktop to a web server, Apache HTTP server and PHP programs are installed. It is known that both programs are the simplest, fastest, lightest and most stable. We used 5.3.29 of PHP and 2.2.25 of Apache version, respectively. The RSS values of APs are sorted in sequence of signal strength from the Android smart phone. The web server commands to get information of location of the selected three APs from database and calculates the distance between the smart phone and the AP. The coordinate of the estimate position can be acquired by calculating Equation (5). Finally, the estimated position is displayed on the smart phone. To show current position on smart phone, a web page is made by canvas function of HTML5, which is Javascript. Database is constructed for MySQL installed version of community-5.6.22.0 and it contains the location information of APs.

IV. Experimental Results

A. Measured Log-Normal Shadowing model

On the 6th floor of a general office building of our university, the RSS values were measured at an interval of 0.5 m to gain the RSS characteristics of AP as the distance between the AP and the receiver is increased. Figure 4 shows the comparison of the log- normal shadowing model, the measured RSS values, and the average value of APs in terms of distance. It is shown that the average value is similar as log-normal shadowing model until a distance of 3 m is reached. Note that P0 and N set to -36, 0.7, respectively.

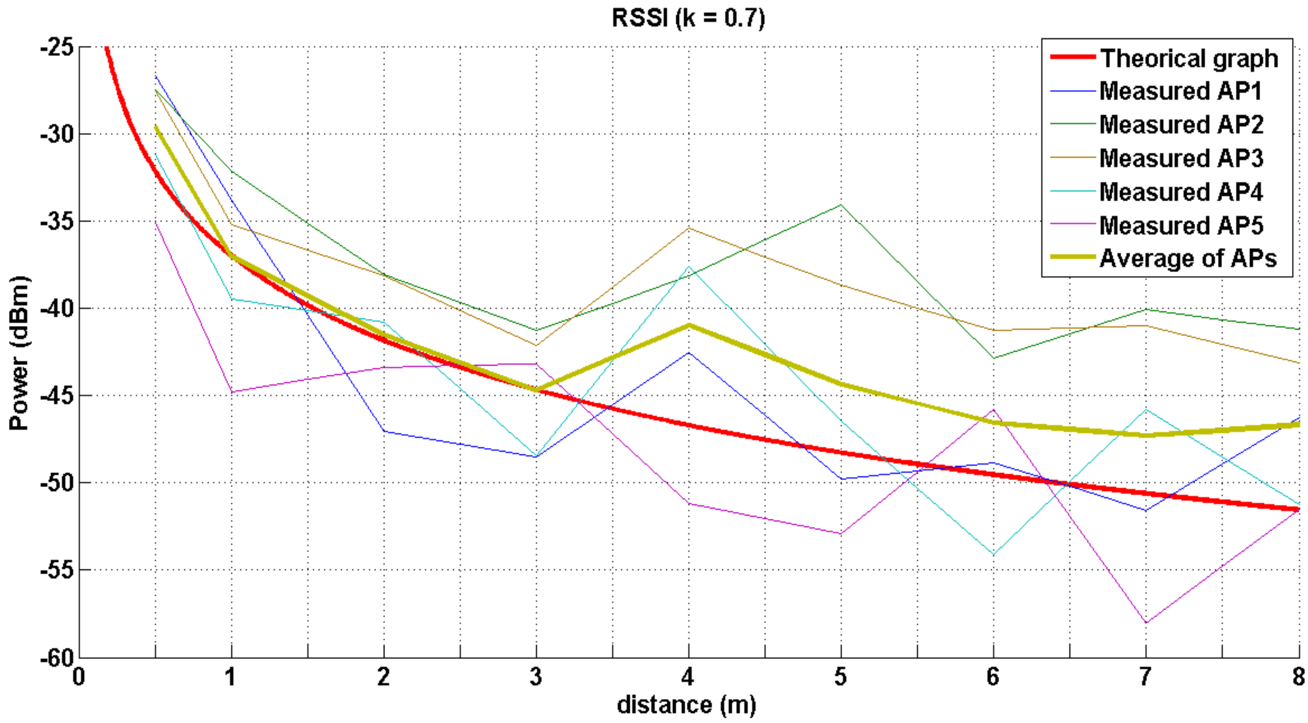

Figure 4: Comparison of the log- normal shadowing model, the measured RSS values, and the average value of APs in terms of distance(m)

B. Position Estimation by Tri-lateration method

The experiment was performed at a corridor on the same floor. The dimensions of the test bed are 6 m by 6 m in wide corridor and its area of 36 m^2. The smart phone was a S4 model of G series of S company. The APs was a ZIO-AP1500N with a frequency scope of 2.4~2.4835GHz. The wireless method of 802.11b/g/n WLAN was utilized with the same channel. All the devices were installed at a 1m height from the floor for the experiment in the LOS environment. We repeated every measure 25 times for each point. Figure 5 shows the experimental results and Table 1 shows the average of error and the variance.

Table 1
Average error and variance

Unit (m)	Error	Variance
1	5.98	9.30
2	5.85	8.16
3	4.18	11.53
4	3.37	0.16
Total	4.84	7.29

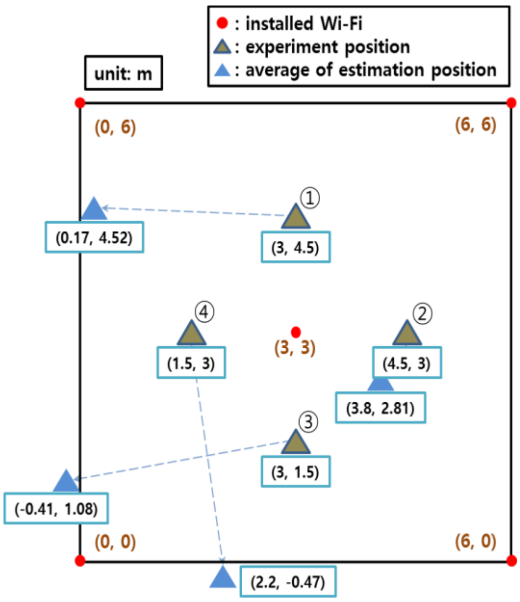

Figure 5: Result of experiments

V. Conclusion

In this paper, an implementation of real-time indoor positioning scheme based on RSS value of AP is presented with the experiment results. As shown in the experimental result, the application of smart phone worked properly, but its performance has estimation error. There are several reasons. First of all, the RSS values are different from every angle. Secondly, although the RSS values were measured from the same AP, there was fluctuation, which can lead to the error of distance estimation. To solve these issues, we should know all the characteristics of APs including the information of RSS value from every angle. In practice, several factors may affect the radio signal propagation as well as the RSS value. Therefore, filtering techniques are recommended as one of performance enhancing techniques. Further, the required RSS scanning time is almost 4 seconds and it is critical problem for a real-time indoor navigation scheme. However, the required RSS scanning time can be reduced by changing the setting of smart phones. As the future works, it is needed to find a way to mitigate the fluctuation of RSS values and to evaluate the performance of scheme with reduced RSS seeking time.

Acknowledgment

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References

[1] Liu, H.,Darabi, H., Banerjee, P.,and Liu, J. 2007. Survey Of Wireless Indoor Positioning Techniques And Systems. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews. 37(6): 1067-1080.

[2] Izquierdo, F., Ciurana, M., Barceló, F., Paradells, J., and Zola, E. 2006. Performance Evaluation of a TOA-Based Trilateration Method to Locate Terminals In WLAN. 1st IEEE International Symposium on Wireless Pervasive Computing. 1-6.

[3] Seidel, S.Y. and Rappaport, T.S. 1992. 914 MHz Path Loss Prediction Models for Indoor Wireless Communications in Multifloored Buildings. IEEE Transactions on Antennas and Propagation, 40(2): 209–217.

[4] Rappaport, T. S. 2002. Wireless Communications: Principles and Practice. Prentice Hall: NJ.

[5] Figueiras, J. andFrattasi, S. 2010. Mobile Positioning and Tracking.WILEY: NJ

[6] Jeon, H., Jo, U., Jo, M., Kim, N., and Kim, Y. 2013. An Adaptive AP Selection Scheme Based on RSS for Enhancing Positioning Accuracy. Wireless Personal Communications. 69(4): 1535-1550.

[7] What is a Socket?. (n.d). Oracle The Java Tutorials. Retrived from. https://docs.oracle.com/javase/tutorial/networking/sockets/definition.html. [Acessed on 1 May 2015].

[8] Steven Chan , F.M. Jun 17, 2009. Which is Better?. Retrieve from https://blogs.oracle.com/stevenChan/entry/which_is_better_forms_servlet_or_socket_mode.[Acessed on 2 May 2015].