A Novel RSS-Ratio Position Estimation Scheme for Wi-Fi Networks

Nammoon Kim and Youngok Kim*
Department of Electronic Engineering of Kwangwoon University, Seoul, Korea
*Corresponding author

***Abstract*—the importance of location based service has been addressed frequently in various fields and the interest about core technique of various positioning scheme for indoor has been increased. The positioning scheme based on Wi-Fi is widely used because the infrastructure is already set up in many indoor spaces. The fingerprinting and the lateration schemes are typical techniques for Wi-Fi based positioning. However, these schemes have some problems for actual execution, such as hard-works for building data base and the time-varying characteristics of wireless signal. In this paper, a novel received signal strength (RSS)-ratio based positioning is proposed to mitigate the problems of conventional schemes. The performance of proposed scheme is evaluated in normal office environment according to various number of selection APs. According to the experiment results, the positioning error of proposed scheme is reduced about 82% than that of conventional RSS lateration scheme.**

Keywords-positioning; Wi-Fi positioning; received signal strength (RSS); RSS ratio

I. INTRODUCTION

Recently, the importance of location based service (LBS) is increasing in order to provide service of user-centered in a various application such as online-to-offline, fin-tech, guidance, indoor navigation. Global Navigation Satellite System (GNSS) has been studied and used in various fields. However, GNSS is a useless in indoor spaces because line of sight (LOS) for receiving a satellite signal is not ensured.

To solve this problem, the various method is applied for indoor positioning such as Wi-Fi, Ultra-wideband, Bluetooth, Inertial Measurement Unit, and RFID [1-6]. The Wi-Fi is most preferred method because there are many AP in indoor for communication. Therefore, it is possible to minimize the cost of additional infrastructure installations. There are some method for position estimation method using Wi-Fi such as fingerprinting that use pre-collected training data and lateration that uses a triangular positioning scheme. For this method, Wi-Fi communication module of user, Access Points (AP), and server with database is required.

Fingerprinting scheme estimate the position of user by comparison of real-time received signal strength (RSS) and pre-collected training data in database. Therefore, this scheme requires a lot of preliminary works, and cannot flexibly respond according to change in the environment. On the other hand, lateration scheme estimate the position of user without prior perform using the position of APs. Therefore, it is possible to flexibly cope with environmental change. However, sometimes the intersection of triangulation positioning is not exists because of the characteristic of wireless signal, and the error of estimated position is generated [1].

In this paper, we proposed a novel positioning scheme based on RSS-ratio to mitigate the problem of lateration scheme and to reduce complexity of lateration scheme due to matrix operation. The performance of the proposed scheme was evaluated through experiments in the normal office environment by Wi-Fi transmit module of user, AP for indoor.

The rest of the paper is organized as follows. In section Ⅱ, the system description about positioning based on Wi-Fi is expressed with typical schemes. In section Ⅲ, the proposed scheme is described. In section Ⅳ, the proposed scheme is evaluated and reviewed. Finally, out conclude remarks are summarized with future works in section Ⅴ.

II. SYSTEM DESCRIPTION

A. Positioning Based on Wi-Fi

The system architecture of Wi-Fi based position estimation method is shown in Fig. Ⅰ. The subject of the positioning can be divided two methods. First, the user device receives the transmitted signal from a peripheral APs and collected RSS is transmitted to database for the position estimation calculation. Another one is the opposite of previous case. In this system, user device transmit the signals and surrounding APs receive the transmitted signal. And this case also transmit RSS to Database. In the first case, even though problem of user devices with different transmission power can be mitigate, operating time of user device is decrease because of limited battery capacity in the service for users. However, the second case can reduce the load of the user device because APs are always supplied power. The user position is estimated by the collected data in the database with position of installed APs and pre-defined parameters.

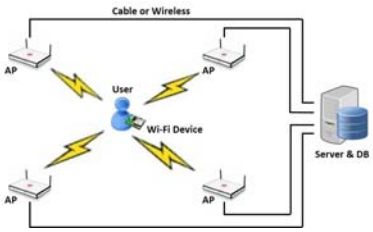

FIGURE I. SYSTEM DESCRIPTION

B. *Fingerprinting Scheme*

Fingerprinting scheme is a method most commonly used. This method consists of two phase: offline and online. In the offline phase, the database is built base on training data. Training data is collected at reference position that is located at a constant grid interval. The positioning accuracy is decided by interval of grid. High grid density is required to obtain high precision, which need more collection time. In the online phase, the position of user is estimated through the comparison of the training data in database with the real-time RSS of user. However, the drawback of this scheme is reliability of training data. The reliability of collected training data is decrease according to the change in the environment such as movement of structure, change of building structure, and the density of floating population. Because of this reasons, the training data should be re-collect. In order to solve this problems, various studies have been proceed. In spite of this drawback, installed APs can use without re-install for positioning. Thus, it applied to most of commercial techniques.

C. *Lateration Scheme*

The lateration scheme is commonly used in the RSS based positioning method. Even though the position of installed APs affect performance of positioning, this scheme can cope with environment change because it does not require collection process for training data. The lateration scheme is a position estimation method via triangulation based on RSS f user. The matrix of lateration is expressed as follows [7] :

$$\mathrm{HX} = \mathrm{B}, \tag{1}$$

where,

$$H = \begin{pmatrix} x_2 - x_1 & y_2 - y_1 \\ x_3 - x_1 & y_2 - y_1 \\ \vdots & \vdots \\ x_n - x_1 & y_n - y_1 \end{pmatrix},$$

$$B = \frac{1}{2}\begin{pmatrix} (d_1^2 - d_2^2) + (x_2^2 + y_2^2) - (x_1^2 + y_1^2) \\ (d_1^2 - d_3^2) + (x_3^2 + y_3^2) - (x_1^2 + y_1^2) \\ \vdots \\ (d_1^2 - d_n^2) + (x_n^2 + y_n^2) - (x_1^2 + y_1^2) \end{pmatrix},$$

and x_n and y_n are the coordinates of AP_n and d_n is the distance between the AP and the user device. Therefore, the least-square solution of (1) is given by

$$X = (H^T H)^{-1} H^T B,$$

and the position of receiver X, which is coordinates of x and y, can be estimated.

In the above equation, distance is estimated by log normal shadowing model. The log normal shadowing model is used for modeling RSS [8]. This equation is described as follows:

$$RSS[dBm] = P_0 - 10 \cdot N \cdot \log(\frac{D}{D_0}), \tag{2}$$

where D_0 means 1m as a reference distance and P_0 is the RSS value at reference distance. Equation (2) is transformed for distance estimation as follows:

$$D = D_0 \cdot 10^{(\frac{P_0 - RSS}{10 \cdot N})} \tag{3}$$

In this paper, x_1 is applied strongest AP among used APs.

III. PROPOSED SCHEME

A. *RSS Ratio Based Position Estimation*

As shown in fig. Ⅱ, lateration scheme have a problem that is an intersection because there is no intersection because of characteristic of wireless signal. This problem makes the ambiguity and big error in the positioning. This is a reason to use fingerprinting in the commercial application. However, as mentioned in the section Ⅱ, fingerprinting scheme is not suitable because of much time for training data collection according to environment change. In this paper, RSS ratio based positioning scheme that have a low complexity is proposed.

Figure Ⅲ represents flowchart of proposed scheme. RSS is collected from around APs for a time T in order to prevent the impact of the change characteristic of wireless signal. collected RSS from APs is saved in the database and the average RSS of each AP is calculated. AP is sorted based on average RSS in descending order to select an AP because the reliability of strongest AP is high than lower AP due to the signal attenuation. The APs for positioning are selected in sorted APs according to pre-defined number. Three of more AP is to be selected for triangulation. There are two selection method for positioning: fixed and dynamic selection. In this paper, however, selection method is not included.

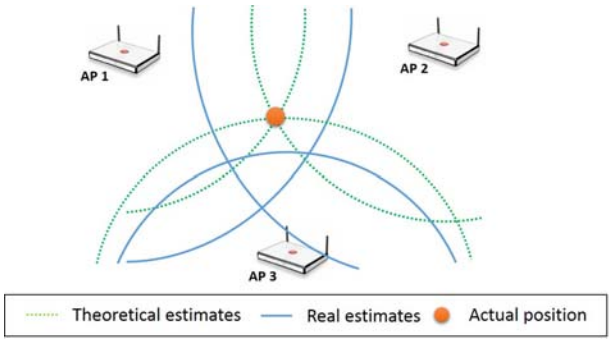

FIGURE II. PROBLEM OF RSS BASED POSITIONING SCHEME

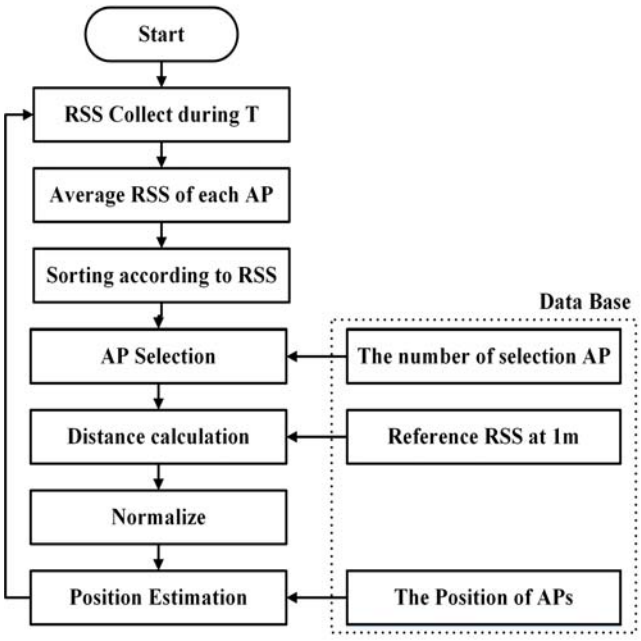

FIGURE III. FLOWCHART OF PROPOSED SCHEME FOR RSS RATIO BASED POSITIONING

Since the strength of a radio signal is inversely proportional to the distance squared, RSS is converted into the distance for linear analysis by (3). P_0 use the pre-measured power of each AP. The process up to date is same with lateration scheme. Therefore, the problem of the intersection is still present. In order to solve this problem, the weight of each AP is decided based on converted distance as follow:

$$W_{AP_k} = (\sum_{k=1}^{M} dis_k) / dis_k \,, \tag{4}$$

where, W_{AP_k} is weight of k-th AP among selected APs. M is the number of selected APs for positioning. dis_k is converted distance of k-th AP.

Normalized weight are expressed as follow:

$$Nor\_W_{AP_k} = W_{AP_k} / \sum_{k=1}^{M} W_{AP_k} \,. \tag{5}$$

Finally, the position of user is estimation by the position of APs and normalized weight of each AP as follow:

$$Est.Pos = \sum_{k=1}^{M} AP\_Pos \cdot Nor\_W_{AP_k} \,, \tag{6}$$

where, *AP_Pos* is installed position of AP.

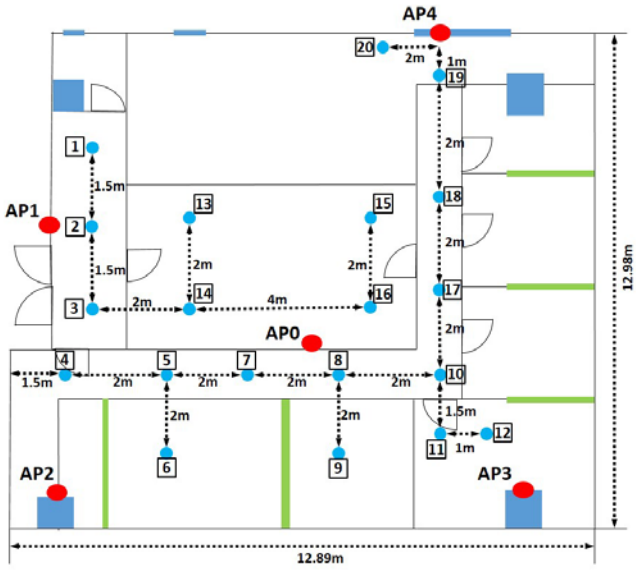

FIGURE IV. EXPERIMENT ENVIRONMENTS WITH POSITION OF MEASURED AND APS

TABLE I. REFERENCE RSS OF EACH AP AT 1M

	AP0	*AP1*	*AP2*	*AP3*	*AP4*
RSS at 1m (dBm)	-40.94	-49.85	-39.93	-42.85	-39.05

IV. EXPERIMENT RESULTS

A. *Environments*

The experiment was performed in a normal office environment. The dimension of the office are 12.89m by 12.98m with an area of about 167m^2 as shown fig. Ⅳ. The Wi-Fi transmit module used 802.11 b/g and communication channel auto selection. All APs is installed on the wall of about 2.5m height from the floor. RSS of transmit module is collected at 5 APs from 20 reference position for 30 sec. Each AP collected about 65 average sample from reference points. The transmit module is located on the neck as necklace. The reference signal power of each AP is applied as shown in table Ⅰ. RSS of each AP is collected in 1m.

B. *Result of Experiments*

The performance of proposed scheme is performed with conventional scheme that is lateration according to the change the number of AP for positioning.

Figure Ⅴ shown the position error of proposed scheme that is RSS ratio based positioning with conventional scheme at 20 position. As shown figure, the accuracy is greatly improved. The accuracy of the 3, 4, and 5 selection AP case is increase from 19.03m to 3.37m, from 14.42m to 2.71m, and 13.93m to 2.43m. It is performance increase of about 82.3%, 81.2%, and 82.6%. And we can show the increase of performance with increase of the number of selection AP. The result of performance evaluation is given table Ⅱ.

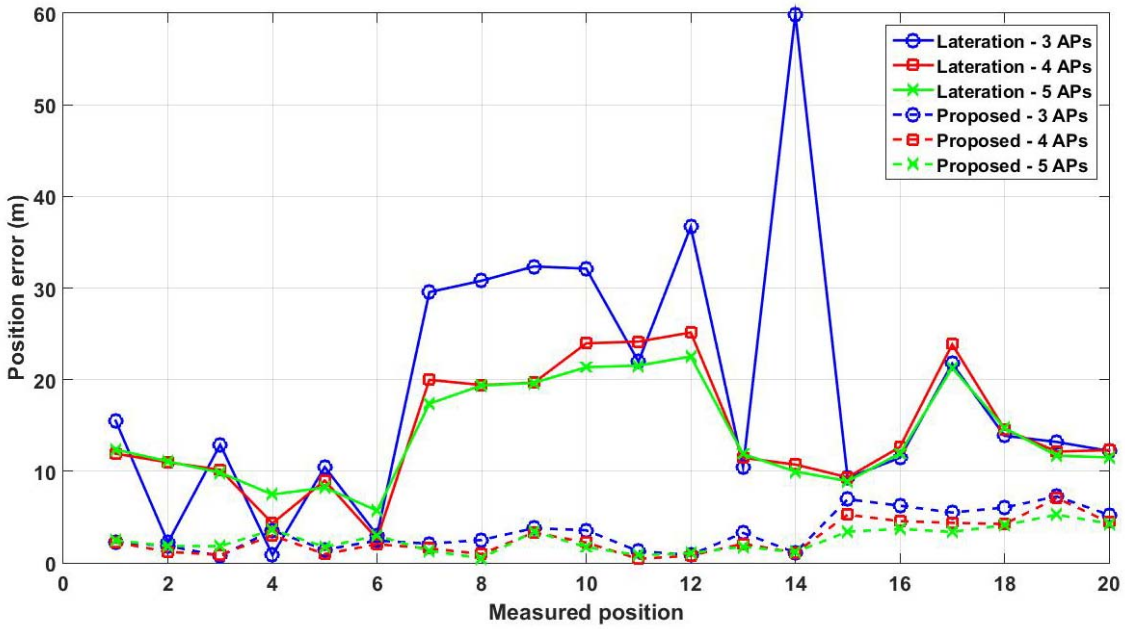

FIGURE V. PERFORMANCE EVALUATION OF PROPOSED SCHEME WITH CONVENTIONAL SCHEME

TABLE II. AVERAGE POSITION ERROR WITH THE NUMBER OF APS

	3 APs	*4 APs*	*5 Aps*
Conventional (m)	19.03	14.42	13.93
Proposed (m)	3.37	2.71	2.43

V. CONCLUSIONS AND FUTURE WORKS

In this paper, the position estimation scheme, which is based on RSS-ratio of Wi-Fi, is proposed, and the performance of proposed scheme is evaluated with various the number of APs in normal office environment. The experiment was implemented with transmit module that is located on the neck as necklace and AP to use indoor. In contrast to the high complexity of conventional scheme through the complex matrix operation, the proposed scheme has a low complexity through simple operation. Also, the estimated position is located in target space always without map information because the position of user is estimated based on distance weight and position of APs.

However, the accuracy of proposed scheme is decided by the position of APs and LOS. We will study about performance analysis according to the position of APs and decision method for optimal AP position.

ACKNOWLEDGMENT

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF), funded by the ministry of Education (NRF-2013R1A1A2005157).

REFERENCES

[1] M. A. Al-Ammar, S. Alhadhrami, A. Al-Salman, A. Alarifi, H. S. Al-Khalifa, A. Alnafessah, and M. Alsaleh, “Comparative Survey of Indoor Positioning Technologies, Techniques, and Algorithms,” Cyberworlds (CW), 2014 Int. Conf. on, pp.245-252, Oct. 2014.

[2] J. Hightower and G. Borriello, “Location system for ubiquitous computing,” Computer, vol. 34, Issues 8, pp.57-66, Aug. 2001.

[3] P. Bahl and V. N. Padmanabhan, “Radar: An in-building RG-based user location and tracking system,” in Proc. 9th Annu. Joint Conf. IEEE Comput. Commun. Soc., vol. 2, pp775-784,Mar. 2000.

[4] L. M. Ni, Y. Liu, Y. C. Lau, and A. P. Patil, “Landmarc: Indoor location sensing using active RFID,” Pervasive Computing and Commun. 2003 (PerCom 2003), Proceeding of the First IEEE Int. Conf. on, pp.407-415, Mar. 2003.

[5] A. Kotanen, M. Hannikainen, H. Leppakoski, and T. D. Hamalainen, “Experiments on Local Positioning with Bluetooth,” Info. Tech.:Coding and Computing [Conputers and Commun.],2003. Proceedings. ITCC 2003. Int. Conf. on, pp297-303, Apr. 2003.

[6] R. J. Fontana and S. J. Gunderson, ”Ultra-wideband precision asset location system,” Ultra Wideband Systems and Technologies, pp.147-150, May 2002 [Digest of Papers. 2002 IEEE Conf. on].

[7] H. Lui, H. Darabi, P. Banerjee, and J. Liu, “Survey of Wireless Indoor Positioning Techniques and System,” Systems, Mand, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, vol. 37, Issue 6, pp.1067-1080, Nov. 2007.

[8] Z. Jianwu and Z. Lu, “Research on distance measurement based on RSSI of ZigBee,” Computing, Communication, Control, and Management, 2009. CCCM 2009. ISECS International Colloquium on, vol. 3, pp.210-212, Aug. 2009.