Enhanced Indoor Positioning Method based on IEEE 802.11 RSSI Considering DOP in Building Environments

Jun Gyu Hwang, Giovanni Escudero, Jingjing Wang, Joon-Goo Park
School of Electronics Engineering
Kyungpook National University
Daegu, Republic of Korea
email: cjstk891015@naver.com, gioescudero@gmail.com, wjj0219@naver.com, jgpark@knu.ac.kr

Kwang Eog Lee
Agency for Defense Development
Daejeon, Republic of Korea
email: kelee@add.re

***Abstract*—The demand for Location Based Service (LBS) is increasing in the development of communication and mobile technologies. Moreover, location determination technologies especially for indoor environments are getting a lot of attention. Most indoor positioning methods just make use of Received Signal Strength Indicator (RSSI) measurements that generate from the same floor. However, usually RSSI measurements are available from different floors. In that case, we have to consider the Dilution of Precision (DOP) used in satellite positioning systems. With this in mind, we can choose a better Access Point (AP) configuration than that of when using only APs in the same floor. In this paper, to improve the accuracy of indoor positioning, we propose an indoor positioning method that includes APs placed in different floors and takes into consideration the DOP.**

Keywords-LBS; DOP; RSSI; Indoor Positioning; Wi-Fi.

I. INTRODUCTION

Positioning technologies can be separated into two groups, that is, outdoor positioning and indoor positioning. In outdoor positioning, Global Positioning System (GPS) [1] is a common example of such technologies. In indoor positioning, several methods, WLAN, Bluetooth, ZigBee, etc., have been developed depending on the situation [2]. However, WLAN measurement based indoor positioning methods are becoming a strong candidate for positioning in such environments.

The existing methods for indoor positioning that we evaluate, usually, take advantage of the properties that the received signal strength has, to determine the distance from an AP to a mobile station, in order to obtain its location [3].

Usually, indoor positioning methods based on IEEE 802.11 WLAN information only make use of RSSI measurements that generate from the same floor. However, in regular indoor environments such as commercial or office buildings, RSSI measurements from APs in different floors can be detected, and dilution of precision can be used to increase the accuracy of these measurements [4].

Given this, in the following paper, we propose an indoor positioning method that considers APs in different floors in order to increase the accuracy of the positioning system.

This paper presents in its second section descriptions for the RSSI penetrated channel model and for dilution of precision. The third section introduces the proposed positioning method using DOP and an overview of the simulation parameters and results. In section four, we present our conclusions.

II. RSSI PENETRATED CHANNEL MODEL AND DOP

A. RSSI Penetrated Channel Model

The RSSI defines a measurement of the RF energy and its unit is dBm. The RSSI decreases exponentially as the distance from the AP increases. Because of these characteristics, in this paper we use an RSSI attenuation model given by [5]

$$\mathrm{RSSI[dBm]} = -10\mathrm{n}\log_{10}\frac{d}{d_0} + A \tag{1}$$

$$\mathrm{d[m]} = 10^{\frac{\mathrm{RSSI-A}}{-10\mathrm{n}}}. \tag{2}$$

In (1), n is the attenuation factor, parameter A is the offset which is the measured RSSI value at a reference point (usually 1 meter) from the AP. And d is the distance from the AP to the point of measurement. d_0 is the reference point distance. These parameters reflect the indoor propagation environment. Because RSSI is a sensitive parameter, it is affected by the environment significantly.

In practical situations, many factors that can affect the RSSI value exist, such as furniture, walls, and people. These factors can produce signal scattering and multi-path effects. They can also result in positioning errors. In order to reduce positioning errors, proper parameter determination is necessary.

The penetrated channel model shows the RSSI when measured through an additional layer. Figure 1 shows a schematic of the penetrated channel model.

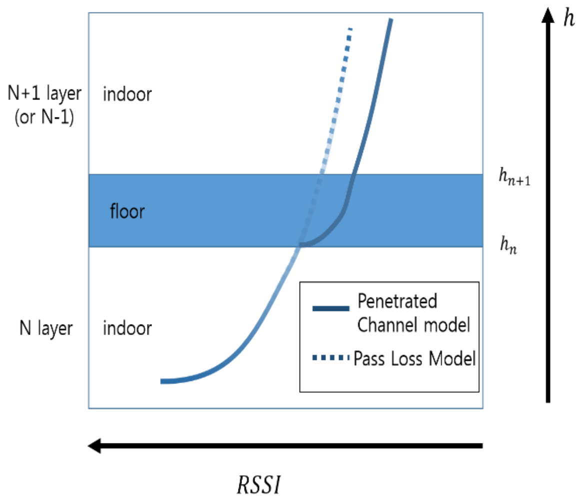

Figure 1. Penetrated Channel Model.

Each layer is separated by the floor. The floor has an attenuation factor which is different from the indoor environment. Also, the reference point changes from d_0 to h_n. Therefore the penetrated channel model equation in the floor is as follows:

$$\mathrm{RSSI[dBm]} = -10n_f \log_{10}\frac{d}{h_n} + (-10n\log_{10} h_n + A). \quad (3)$$

In (3), n_f is the attenuation factor in the floor, height h_n is the distance between the floor layer and the ceiling layer. When an RF signal passes through the floor the attenuation factor comes back to n and the reference point changes to h_{n+1} which is the distance between one floor layer and the next. So, the penetrated channel model equation in the next layer is

$$\mathrm{RSSI[dBm]} = -10n\log_{10}\frac{d}{h_{n+1}}h_n + \left(-10n_f\log_{10}\frac{h_{n+1}}{h_n} - 10n\log_{10} h_n + A\right). \quad (4)$$

By defining the penetrated channel model, even APs that are located on a different layer are available for positioning.

B. DOP(Dilution of Precision)

The effect of satellite geometry is quantified in the measure called Dilution of Precision, or DOP. DOP does not depend on anything that cannot be predicted in advance. It only depends on the positions of the GPS satellites relative to the GPS location of the receiver. The satellite position is known in advance, and GPS position is also fixed, thus the DOP of a GPS system can be calculated even without using the GPS system.

The problem of defining if the DOP is poor or good due to satellite geometry remains. When satellites are located at wide angles relative to each other, this configuration minimizes the error in position calculations. On the other hand, when satellites are grouped together or located in a line the geometry will be poor.

DOP is often divided into several components which are listed below [6]:

- VDOP: Vertical DOP
- HDOP: Horizontal DOP
- PDOP: Positional DOP
- GDOP: Geometric DOP

These components are used due to the variation of accuracy of the GPS system. The PDOP is most used among other components. The positioning error of PDOP is calculated from the data of GPS receiver multiplied by range error which is given by

$$\text{Positioning Error} = \text{Range Error} * \text{PDOP}. \quad (5)$$

A DOP of 2 means that whatever the range error was, the final positioning error will be twice as big.

For example, if the User Estimated Range Error (UERE) is 10 meters and the PDOP is 2, the final positioning error will be 20 meters.

1) Computation of DOP: As a first step of computing DOP, consider the unit vectors from the receiver to satellite *i* [6]

$$\left(\frac{x_i - x}{R_i}, \frac{y_i - y}{R_i}, \frac{z_i - z}{R_i}\right) \quad (6)$$

Where:

$R_i = \sqrt{(x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2}$

x, y, z: position of the receiver

x_i, y_i, z_i: position of the satellite

The formula (6) in matrix form is given by

$$A = \begin{bmatrix} \frac{x_1 - x}{R_1} & \frac{y_1 - y}{R_1} & \frac{z_1 - z}{R_1} & -1 \\ \frac{x_2 - x}{R_2} & \frac{y_2 - y}{R_2} & \frac{z_2 - z}{R_2} & -1 \\ \frac{x_3 - x}{R_3} & \frac{y_3 - y}{R_3} & \frac{z_3 - z}{R_3} & -1 \\ \frac{x_4 - x}{R_4} & \frac{y_4 - y}{R_4} & \frac{z_4 - z}{R_4} & -1 \end{bmatrix} \quad (7)$$

The first three elements of each row of A are the components of a unit vector from the receiver to the indicated satellite. Since the number of APs is three, the minimum number of APs required, we assume the fourth vector to have an infinite value and thus set every element to -1.

Formulate the matrix, Q, as

$$Q = (A^T A)^{-1} = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} & \sigma_{xz} & \sigma_{xt} \\ \sigma_{xy} & \sigma_y^2 & \sigma_{yz} & \sigma_{yt} \\ \sigma_{xz} & \sigma_{yz} & \sigma_z^2 & \sigma_{zt} \\ \sigma_{xt} & \sigma_{yt} & \sigma_{zt} & \sigma_t^2 \end{bmatrix} \quad (8)$$

From Q, the DOP can be calculated as

$$PDOP = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2} \quad (9)$$

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III. Proposed Positioning Method and Simulation

A. Proposed Positioning Method

We propose a method that is divided into two steps. First, we scan APs. Then, we measure the received signal strength indicator and determine on which floor the AP is located.

Next, we compute the DOP of each combination of APs. Then, a combination of three of the APs with the best DOP is selected and we use this combination for positioning.

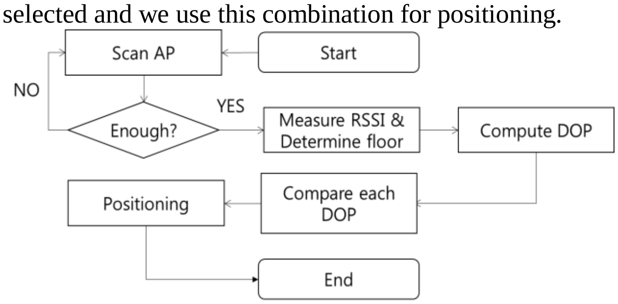

Figure 2. Proposed Positioning Algorithm

Figure 2 is a representation of the proposed positioning algorithm used in our method.

B. Simulation

We conducted experiments in Kyungpook National University's IT-1 building. This building's h_n is 2.57m, h_{n+1} is 3.74m, and the attenuation factor n is 2.9, n_f is 7.02.

We used IpTIME N3004 model APs, Broadcom laptop embedded wireless network cards, and software for collecting the RSSI.

Figure 3 shows the Cumulative Distribution Function (CDF) for both the existing method and the proposed method. Ninety percent of the proposed method's CDF is less than 1.2m. However, ninety percent of the existing method's CDF is less than 2.2m.

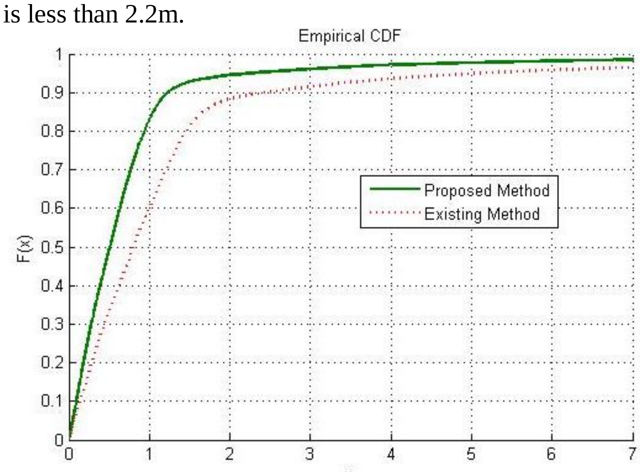

Figure 3. Proposed positioning algorithm results

TABLE I. Simulation Result

	Existing Method	Proposed Method
Average Error	1.56 m	1.24 m

As shown in Table 1, the positioning error of the proposed method is less than that of the existing method by 0.32 meters. The existing method uses an RSSI attenuation model in a WLAN environment without taking the DOP into consideration.

IV. Conclusions

This paper proposes an indoor positioning method using IEEE 802.11 WLAN RSSI measurements considering the penetrated channel model. In order to enhance indoor positioning accuracy, we use different layer APs. The proposed method in this paper can enhance the positioning accuracy in multilayer-buildings and wall-through indoor environments. The simulation results show that the positioning error of the proposed method is less than that of existing method by 0.32m.

In the future, an integrated model is necessary to consider penetration as well as diffraction. Also, when a positioning error occurs there is RSSI error as well. Given this, a filter for correcting the RSSI error should be developed.

V. Acknowledgments

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