Enhanced Positioning Method using WLAN RSSI Measurements considering Dilution of Precision of AP Configuration

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***Abstract*–With the development of mobile internet, requirements of positioning accuracy for the LBS (Location Based Service) are becoming more and more higher. The LBS is based on the position of each mobile device. So, it requires a proper acquisition of accurate user's indoor position. Thus, indoor positioning technology and its accuracy is crucial for various LBS (Location Based Service). In general, RSSI (Received Signal Strength Indicator) measurements are used to obtain the position information of mobile unit under WLAN environment. However, indoor positioning error increases as multiple AP's configurations are becoming more complex. To overcome this problem, an enhanced indoor localization method by AP (Access Point) selection criteria adopting DOP (Dilution of Precision) is proposed. The proposed method can raise the positioning performance according the status of AP distribution.**

Keywords-Indoor positioning; Wireless LAN; RSSI; Dilution of Precision (DOP).

I. INTRODUCTION

Positioning technology is divided into two parts, which are indoor positioning and outdoor positioning respectively. In outdoor positioning, dominant technology is existed such as GPS (Global Positioning System) [1], however, in indoor environments cannot be carried out effectively by it. In recent years, WLAN (Wireless Local Area Network) is widely used to locate in an indoor environment.

Positioning in Wireless Local Area Network (WLAN) based on IEEE802.11 [2] is considered. Generally, received signal strength indication (RSSI) is used in the WLAN Location Based Server (LBS) as the location information provider. However, positioning error usually occurs in indoor environment. Because the access points are set very concentrated and complex in indoor environment. To overcome this problem, in this paper, an enhanced indoor positioning method by access point (AP) configuration selection criteria adopting dilution of precision (DOP) is proposed.

There are a number of existing location systems which utilize a variety of sensing technologies and system architectures. These systems have varying characteristics, such as accuracy, scalability, range, power consumption and cost. Infrared has been popularly used for containment-based location systems [3]. Infrared location system can suffer in strong sunlight an under fluorescent tube lighting as both of these are sources of infrared light. The method that uses RSSI for localization is called fingerprinting. This technique is based on the specific behavior of radio signals in a given environment, including reflections, fading and so on, rather than on the theoretical strength-distance relation. Cricket [4] is an indoor location system developed at MIT and utilizes Radio Frequency (RF) and ultrasound using static transmitters and mobile receives. The Dolphin system [5], developed at the University of Tokyo, utilizes Radio Frequency (RF) and ultrasound to create a peer-to-peer system, providing co-ordinate based positioning. The Dolphin team has created a system which can propagate locations with 10-15cm of accuracy from four stationary reference nodes.

There have been several studies about indoor positioning method adopting dilution of precision (DOP). Ziari et al. [6] present a mathematical approach of a new version of the known GPS dilution of precision and also present a model that allows to estimate the precision based on criteria other than the geometric one only. Lemelson et al. [7] has implemented an algorithm that computes a GPS-like DOP value based on the geometry of access points. In A.G. Dempster [8], positioning using Angle-of-arrival (AOA) and an expression for dilution of dilution of precision (DOP) has been derived for angle-of-arrival positioning systems which allows the quality of an Angle-of-arrival (AOA) position to be determined. Indoor positioning error increases as multiple access point's configurations are becoming more complex. To overcome this problem, in this paper, we propose an indoor positioning method that selects the AP combination adopting DOP due to access point (AP) geometry. That means the selected access point (AP) combination not only has high RSSI but also has good configuration to enhanced positioning precision.

The remaining paper is organized as following. In Section II we discuss general characteristics of DOP and RSSI measurements. Proposed positioning method considering DOP is stated in Section III. In Section IV, the result of experiment is described. Finally, in the Section V, we give conclusion of this paper.

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II. CHARACTERISTICS OF DOP AND RSSI MEASUREMENTS

A. Dilution of Precision (DOP)

The effect of satellite geometry is quantified in the measure called Dilution of Precision, or DOP [9]. DOP does not depend on the 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 GPS system can be calculated even without using the GPS system.

How can we define the DOP is poor or good due to satellite geometry? 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 [10]:

VDOP: Vertical DOP
HDOP: Horizontal DOP
PDOP: Positional DOP
TDOP: Time 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 as:

$$\text{Positioning Error} = \text{Range Error} * \text{PDOP} \qquad (1)$$

A DOP of 2 means that whatever the range error were, the final positioning error will twice as big. For example, if the user estimated range error (UERE) is 20 meters and the PDOP is 2, the final positioning error will be 40 meters (20 x 2).

B. Computation of DOP

As a first step of computing DOP, consider the unit vectors from the receiver to satellite i [11] :

$$\left(\frac{x_i - x}{R_i}, \frac{y_i - y}{R_i}, \frac{z_i - z}{R_i}\right) \qquad (2)$$

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 satellite

The formula (2) in matrix form is given by:

$$A = \begin{bmatrix} \frac{x_1 - x}{R_1} & \frac{y_1 - y}{R_1} & \frac{z_1 - z}{R_1} & -1 \\ \frac{x_2 - x}{R_2} & \frac{y_2 - y}{R_2} & \frac{z_2 - z}{R_2} & -1 \\ \frac{x_3 - x}{R_3} & \frac{y_3 - y}{R_3} & \frac{z_3 - z}{R_3} & -1 \\ 1 & 1 & 1 & -1 \end{bmatrix} \qquad (3)$$

The first three elements of each row of A are the components of a unit vector form the receiver to the indicated satellite. The elements of the fourth row when consider the fourth satellite. Since the number of AP is three for indoor positioning, thus we assume the fourth AP at the infinite and set every element to 1.

Formulate the matrix, Q, as:

$$Q = (A^T A)^{-1} = \begin{bmatrix} d_x^2 & d_{xy}^2 & d_{xz}^2 & d_{xt}^2 \\ d_{xy}^2 & d_y^2 & d_{yz}^2 & d_{yt}^2 \\ d_{xz}^2 & d_{yz}^2 & d_z^2 & d_{zt}^2 \\ d_{xt}^2 & d_{yt}^2 & d_{zt}^2 & d_t^2 \end{bmatrix} \qquad (4)$$

From Q, the DOP can be calculated as:

$$\text{PDOP} = \sqrt{d_x^2 + d_y^2 + d_z^2} \qquad (5)$$

C. RSSI Measurements

The RSSI (Received Signal Strength Indicator) is defined in IEEE 802.11 standard, which is the ratio of transmitter power and received power present in dBm unit. The RSSI has the characteristic that it can decrease exponentially according to the increase of distance. Because of these characteristics, in this paper we used RSSI attenuation model and is given as [12]:

$$\text{RSSI[dbm]} = -(10n \log_{10} d - A) \qquad (6)$$

$$\text{distance[m]} = 10^{\frac{\text{RSSI}-A}{-10n}} \qquad (7)$$

In (6) the parameter A is the offset which is the measured RSSI value at 1m point apart from AP. And the parameter n is the attenuation factor. This parameter reflect indoor propagation environment. Because the RSSI is a sensitive parameter, it is can affected by environment significantly. In Figure 1 that shows RSSI attenuation as distance.

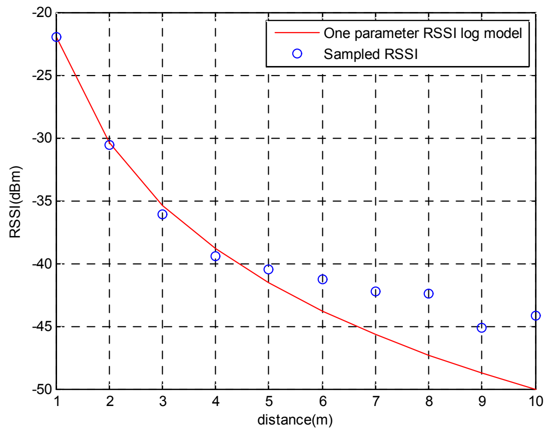

Figure 1. RSSI attenuation according to the elapsed distance.

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

III. PROPOSED POSITIONING METHOD CONSIDERING DOP

First of all, we should understand the relationship of positioning error between RSSI measurements and DOP, separately. High RSSI value and low DOP can potentially increase the positioning accuracy. Thus, according to above statement, if we can select the AP combination that can produce RSSI value which is high and DOP value is low, then we can get a higher positioning accuracy. However, it is difficult to satisfy all conditions simultaneously. In order to overcome the problem, we consider the appropriate Trade-off between RSSI measurements and DOP. So, we should establish the relationship of positioning error between RSSI and DOP.

In order to get a lower positioning error, we will select the AP whose RSSI value size just be considered in descending order. As shown in Figure 2, we use wireless network card on notebook computer, and inSSIDer software to receive the RSSI from AP1, AP2, AP3, AP4, separately. We use the (5) to calculate the DOP for every AP. The received RSSI values from inSSIDer software are shown in Table 1 as follows:

TABLE 1. Received RSSI value(dBm)

	RSSI value
AP1	-51
AP2	-52
AP3	-70
AP4	-73

When visible access points (APs) are close together or located in a line , the distribution of AP is said to be weak and the DOP value is high, when far apart, the distribution of AP is strong and the DOP is low. As shown as Figure 2, AP1,AP2, and AP3 are located in a line, the DOP value of range A is high, howerver, the DOP of range B is low because the access points (APs) are far from each other.

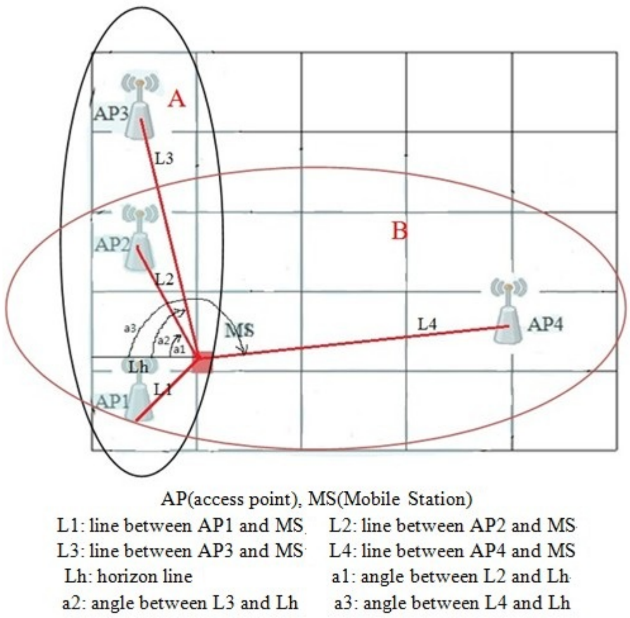

Figure 2. AP selection criteria (1).

However, there are many different configurations of access point (AP) combination, such as combination A of AP1, AP2 and AP3, combination B of AP1, AP2 and AP4 or combination C of AP1, AP3 and AP4 and so on. In general, if don't consider the DOP, the best AP selection is that every access point (AP) has a relative high RSSI value. The Table 1 shows that the RSSI of AP3 is just a little greater than AP4. So, that we should select the combination A to locate can get a higher positioning precision than selecting the combination B. But, according to the description of DOP, we can know that APs are grouped together or located in a line the geometry will be poor and located at wide angles relative to each other, this configuration minimizes the error in position calculations. So if adopting DOP, we should select combination B to locate because the RSSI value of AP4 approximate AP3 and configuration status of AP4 is better than AP3. Why do not select the combination C to locate? In Figure 2, the angle a2 is a little larger than angle a1, so the DOP value of AP3 is a little lower than AP2's, but the Table 1 shows the RSSI value of AP2 is much higher than AP3's. In other words, the difference of DOP between AP2 and AP3 is not high, but the difference of RSSI value between AP2 and AP3 is very high. In this case, it is better that select the AP2 to locate. Finally, we can determine that positioning accuracy B is higher than A. As shown as Figure 3.

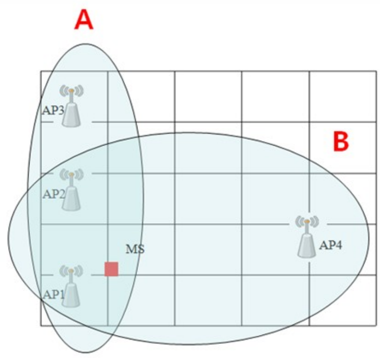

Figure 3. AP selection criteria (2).

Through the analysis of the positioning error, we can find the relationship between RSSI differences and DOP differences. So, we can decide the new AP combination set compared with that of the existing AP set which decided only by RSSI differences.

In Figure 3, because the RSSI value of AP4 approximate AP3, so the RSSI differences between the AP3 and AP4 are not high, and configuration status of AP4 is better than AP3. Namely, the DOP value of AP4 is lower than AP3. Say it again, if we select the AP which is affected by the ratio of RSSI differences and DOP differences, that means the AP has high RSSI and low DOP, then we can get a good positioning result. The relationship between RSSI differences and DOP differences can be given by:

$$\frac{(RSSI\,3 - RSSI\,4)}{(DOP3 - DOP4)} > \alpha > 0 \qquad (8)$$

RSSI3, RSSI4: The RSSI of 3rd and 4th AP

DOP3, DOP4: the DOP of 3rd and 4th AP

α : Threshold value which is determined by environments

According to (8), if the ratio of RSSI differences and DOP differences is greater than the threshold value which is determined by environments, we will select the new AP to compare, otherwise, using the existing AP to locate.

The algorithm is shown as follows:

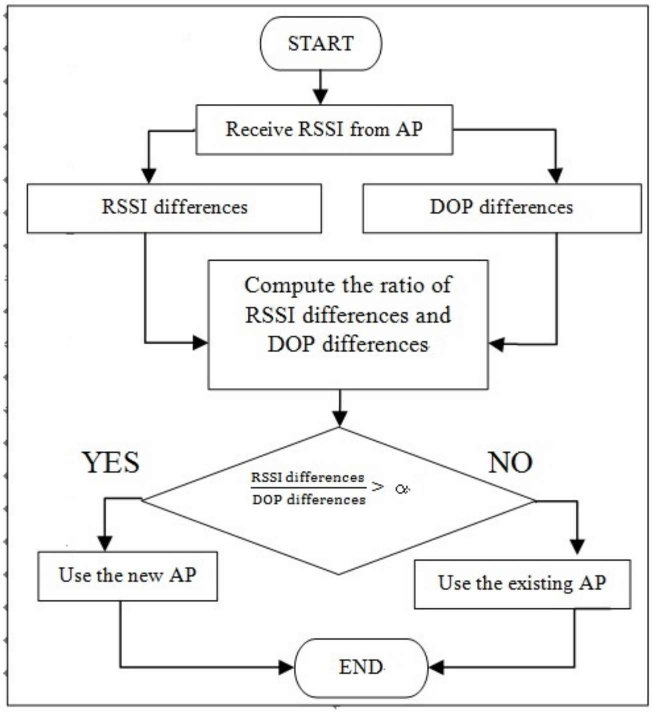

Figure 4. The proposed positioning algorithm.

IV. EXPERIMENTAL RESULT

We verify the result by experiment in indoor half-open environment. In this experiment, the threshold value α is 1.8.

In Figure 5. (a), it shows the distribution of access points (APs) which are set arbitrarily and the path of mobile station (MS). In Figure 5. (b), it can easy find that the positioning error of MS1 adopting DOP is better than the positioning error without adopting DOP. The same situation occurs in MS2 and MS3. But in the adopting DOP and without adopting DOP case, the result is almost the same.

In Figure. 5 (a), we can find that the access points (APs) around the MS1, MS2, MS3 are very concentrated. If we do not adopt DOP to calculate the position of MS1, MS2 and MS3, we certainly select the combination of AP1, AP2 and AP3, because the RSSI value of AP1, AP2 and AP3 are better than others. If we adopt DOP to calculate the position of MS1, MS2 and MS3, we will select the combination of AP1, AP2 and AP5 to calculate the position of MS1, and that calculate the position of MS2 will select the combination of AP2, AP3 and AP4. According to the result, if the access points are set very concentrated and complex in indoor environment, the positioning error of adopting DOP is lower than without adopting DOP.

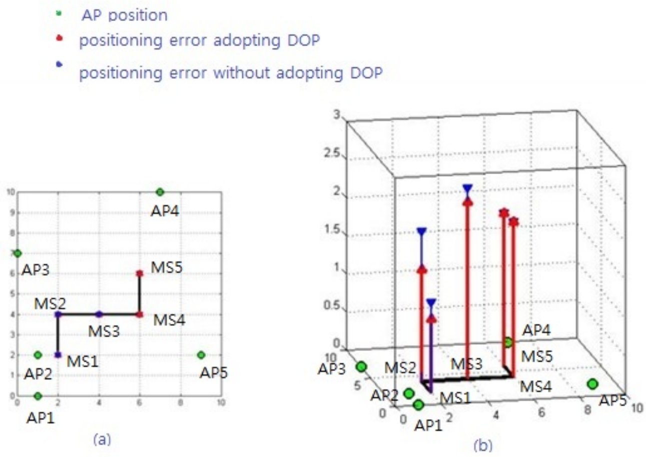

Figure 5. Experiment result comparison: (a) MS path and AP position distribution. (b) Comparison of positioning error adopting DOP and positioning error without adopting DOP.

As shown as Table 2, the positioning error of proposed method is less than that of existing method by 9.3%. The existing method using RSSI attenuation model in WLAN environment.

TABLE 2. position error experiment result (m)

	Existing Method	Proposed Method
Average error	1.93	1.75
Minimum error	1.18	0.96
Maximum error	2.50	2.32

V. CONCLUSION

This paper described a method for indoor positioning use the RSSI attenuation model in WLAN environment. In order to enhanced indoor positioning accuracy, we adopt DOP (Dilution of Precision). That we can analyze the ratio relationship between RSSI differences and DOP differences of each AP to select the AP combination with high RSSI and low DOP. That is, it can raise the positioning performance according the status of AP distribution. Positioning error usually occurs in indoor environment. Because the access points are set very concentrated and complex in indoor environment. In this paper, proposed method can raise accuracy in access point distribution concentrated and complex indoor environment. The experimental result shows that the positioning error of proposed method adopting DOP is less than that of existing method only use RSSI attenuation model by 9.3%.

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