Design and Implementation of Indoor Position Estimation System using Drone for Industrial Security

Sanghoon Lee, Seonki Jeon, Myeong-in Choi, Byeongkwan Kang ,and Sehyun Park,

School of Electrical and Electronics Engineering
Chung-Ang University
Seoul, Republic of Korea
e-mail: leessan0, junsk0108, auddlscjswo, byeongkwan, shpark@cau.ac.kr

***Abstract*—Indoor Position Estimation System (IPES) via RSSI and Trilateration using three fixed nodes is method to identify the location of the moving node in the building. The location of the moving node can be estimated within a range of relatively small error by using the three fixed nodes. This paper suggests that replacing one of the three fixed nodes with the drone located outside can be used to estimate the location of the moving node in the building. And finally, it is proved that the person could be scanned by a drone that is outside the building.**

Keywords-LBS; Indoor Positioning; RSSI; Trilateration; Drone

I. INTRODUCTION

Current Location-Based Services (LBSs), about Outside Position Estimation, are available because of GPS technology. It came with a lot of development in the present, and now that is applied to the majority of the smart phones or mobile devices. On the contrary, Indoor Position Estimation cannot use GPS technology because of interference from buildings. Therefore, Indoor Position Estimation uses the Wireless LAN (WLAN), WiBro, RFID, Zigbee, and etc. Among them, the utilization of indoor position estimation using the WLAN is better than the others. One of the best thing among the WLAN infrastructure components is WiFi, because WiFi is continuously developing new versions, so WiFi`s data transfer rate was gradually improved. It can be used valuably for inside position estimation.

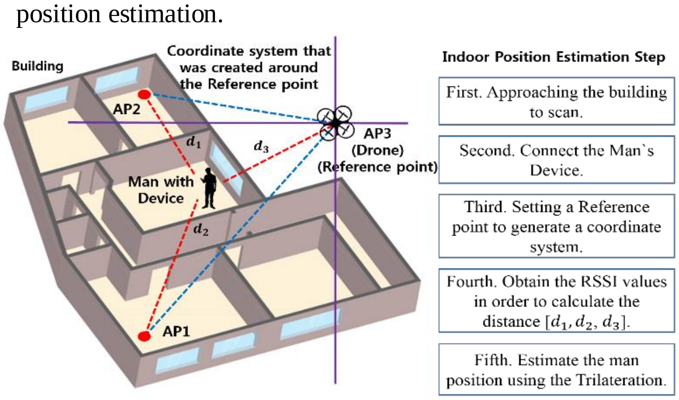

Figure 1. Method of scanning the inside of the building using the drone.

In this paper, two indoor fixed nodes and the third indoor fixed nodes are replaced by a drone from outside, and these fixed nodes are possible to estimate the location of the moving nodes in a building. To do this, three fixed nodes and one moving node are connected to the WiFi, and Signal loss calculated by the Friis formula using the signal intensity got via RSSI. After then, the mobile device estimates the distance from each fixed nodes to moving node. Finally, drone estimates the location of the moving node based on the position of the three fixed nodes using the trilateration.

This paper is organized as follow. In Section 2, it presents a method for estimating the location using the moving node in three fixed nodes and one moving node through the existing RSSI method. In Section 3, we introduce the test bed to experiment with one fixed node replaced with a drone and test procedures. In Section 4, we present the experimental values obtained from our experiments on the test bed in tables and graphs. Finally, in Section 5, using the drone of the outside would conclude it possible to scan for devices inside the building by analyzing the values obtained in the experiment.

II. INDOOR POSITION ESTIMATION SYSTEM

A. RSSI measurement

RSSI denotes the received signal strength, and the units of RSSI using ‘dB’. This is the same in WiFi. And, the high value of RSSI expressed as a negative number is clear signal intensity. As the moving distance of the signal is long, the strength of signal is weakened. With this feature, the signal strength received from the AP is used to estimate the distance from AP. The accuracy of position estimation using the RSSI is dependent on the high accuracy RSSI value and the environment of the measurement. Therefore, Position estimation method using the RSSI is showing relatively low reliability in an accuracy and a stability. Nevertheless the position estimating method using the RSSI uses widely, because the number of places WiFi Access zone has increased than before.

An important feature of wireless signal transmission is that the signal strength decreases as the distance increases. The value of the distance measurement of the RSSI is determined by changing of the signal intensity corresponding to the moving distance of the signal. It will obtain a moving distance between the respective nodes from the change of the RSSI value according to the moving distance of the signal. Researchers have done some effective researches about signals in different transmission environment [1], and conclude some good empirical formula.

$$L_d = L_1 + 10 \times \rho \times \log d + v \quad (1)$$

$$L_1 = 10 \log G_1 G_r (\frac{c/f}{4\pi})^2 \quad (2)$$

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G_t is Transmitting antenna gain, G_r is Receiver antenna gain, c is thr velocity of light, f is carrier frequency, ρ is Channel attenuation coefficient (value 2~6), v is the Gaussian random variable which considered the shadow effect, then v ~ $N(0, \delta^2)$, d is the distance, L_d is the channel loss after the distance d. In practice, we get the relation between RSSI and the distance through the measurement showing the relation for transmission power and receiving power by the following formula [2].

$$P_R = \frac{P_T}{r^n} \quad (3)$$

After conversion was

$$P_R(db) = A - 10 \times n \log r \quad (4)$$

P_R is the receiving power of the wireless signal, P_T is transmission power, n is the Propagation factor, r is the distance between Transceiver Unit. A is the receiving signal power when the signal transmit 1 meter. The numerical value of constant A and n determined the relation between receiving signal strength and signal transmission distance.

B. Trilateration.

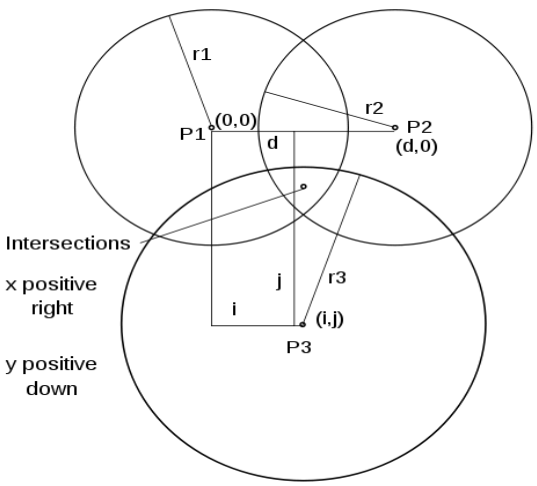

Figure 2. Trilateration.

The Trilateration is a method to obtain the relative position of the object using the triangular geometry as with triangulation. Unlike Triangulation, using one of the sides and two included angles of a triangle, Trilateration need two or more reference points, the distance between the target and the respective reference point to find the location of the target [3]. Only using Trilateration requires at least three reference points in order to accurately determine the relative position of the two-dimensional surface. In Fig. 2. The plane z = 0, shows the three sphere centers, P1, P2, and P3; their x, y-coordinates; and the three sphere radii, r1, r2, and r3 [4]. The two intersections of the three sphere surfaces are directly in front and directly behind the point designated intersections in the z = 0 plane.

The intersections of the surfaces of three spheres is found by formulating the equations for the three sphere surfaces and then solving the three equations for the three unknowns, x, y, and z. To simplify the calculations, the equations are formulated so that the centers of the spheres are on the z = 0 plane. Also, the formulation is such that one center is at the origin, and one other is on the x-axis. It is possible to formulate the equations in this manner since any three non-collinear points lie on a unique plane. After finding the solution, it can be transformed back to the original three dimensional Cartesian coordinate system. Next three equations for the three spheres

$$r_1^2 = x^2 + y^2 \quad (5)$$
$$r_2^2 = (x-d)^2 + y^2 \quad (6)$$
$$r_3^2 = (x-i)^2 + (y-j)^2 + z^2 \quad (7)$$

C. Position estimation using the RSS I and Trilateration

After measuring the intensity of a signal through the RSSI, the distance is calculated by using the Friis formula between the mobile node and the fixed node. Friis formula is as follows.

$$d = \frac{c}{4\pi f} \times 10^{\frac{L}{20}} \quad (8)$$

Distance measurement method by the signal intensity is used to Friis formula above.

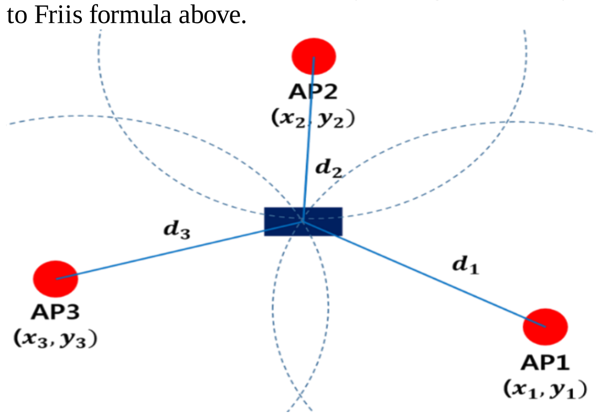

Figure 3. Overview of Position Estimation Method.

c is the Transmitting velocity, f is the frequency of the radio, L is the loss of the received signal. L is obtained by subtracting Intensity of the received signal at the reference point from Received signal intensity Fig. 3. The equations to obtain the distance from each AP as follows. [5]

$$d_1^2 = (x - x_1)^2 + (y - y_1)^2 \quad (9)$$
$$d_2^2 = (x - x_2)^2 + (y - y_2)^2 \quad (10)$$
$$d_3^2 = (x - x_3)^2 + (y - y_3)^2 \quad (11)$$

The using of RSSI values measured at the location with no obstructions is calculated as the actual value. The error between the actual distance and the calculated distance becomes large if the RSSI value is measured from the wrong environment. [6]

III. IMPLEMENTATIONS AND EXPERIMENTS

A. Implementations

Fig. 4 shows a test bed. Test bed was installed in the laboratory. Fig. 4. (a), The starting point in the Test bed is (a) Starting point (0,0) in Fig. 4 (a) ,which is given coordinate of (0,0). Based on the starting point, 1 o`clock is meant the x-axis and 9 o`clock is meant the y-axis. Fig. 4. (b), Test bed`s cell size is 45cm. Fig. 4. (a), In the rest of the sequence, (b) is separated into 6 cells in the x-axis based on the starting point and is given coordinate of (6,0). (c), based on the start point, is located in the 6 cells in the x-axis direction and 7 cells in the y-axis direction and is given coordinate of (6,7). (d), based on the start point, is located in the 7 cells in the y-axis direction and is given coordinate of (0,7). (e) is an Access point 1 and AP channel is 'ISRC_PYD'. (f) is an Access point 2 and AP channel is 'ISRC-5G'. (g) is moving node, and (g)`s coordinate is not fixed.
The total size of the test bed is '6x7'. And that is '270cm x 315cm'.

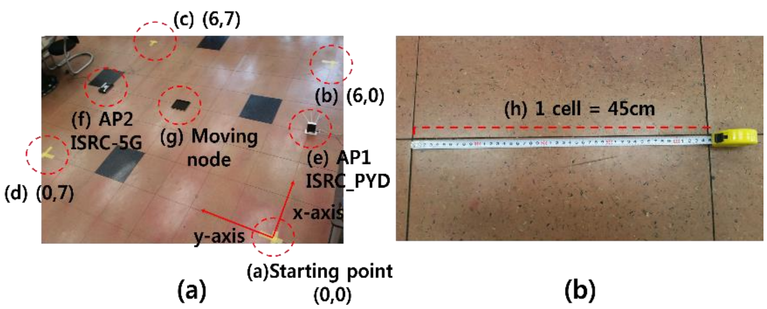

Figure 4. Implementation: (a) test bed, (b) test bed`s cell size.

Fig. 5 shows an AR Drone which has a WiFi module to connect another WiFi AP. This AR Drone will carry out the AP3 outside of the laboratory`s test bed. In this experiment, the AR Drone will be 3m in height from the ground. And AR Drone`s coordinate is not fixed. In addition, the glass wall exists between the AR Drone and moving node. The actual building will exists a cement walls or glass walls between the moving node in the building and AR Drone. This glass wall will interference communication with the AP and AR Drone. This position minimizes the disturbance factors than the actual environment. And This Drone`s AP Channel is 'ardrone2_096244'.

Figure 5. AR Drone, role of AP3.

B. Experiments

Fig. 6 expresses the test bed as a picture. AP1 is located at the starting point (0,0), AP2 is located at (3,7). AP3 is AR Drone, AR Drone exists outdoors a distance 110cm to the minus x-axis direction from the position of the test bed (0,5). And glass wall exists between the AR Drone and moving node. Moving node was defined as a device that can measure the RSSI value for each APs. And this moving node is located at a (3,4). This experiment was performed as follows.

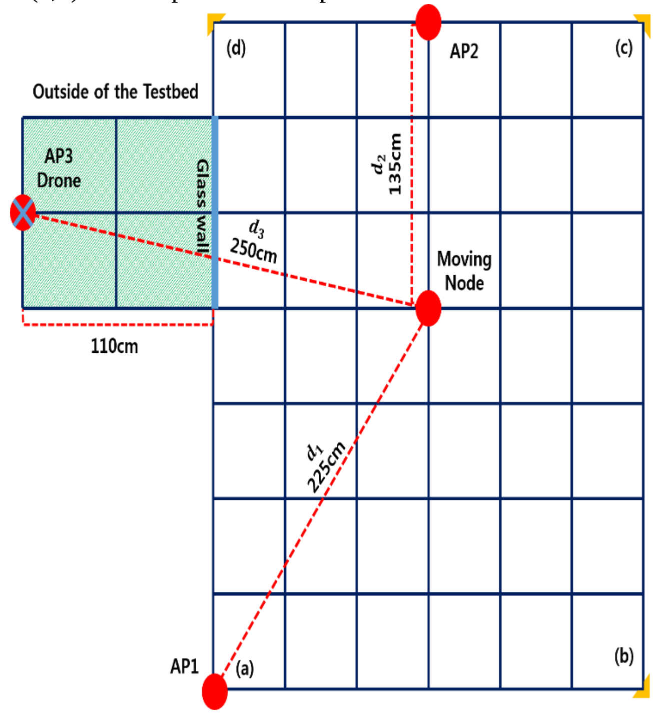

Figure 6. Illustrates of the test bed.

First, each AP is set on the coordinates of the test bed. And then, the actual distance is calculated from between APs and the moving node. As a result,

- Distance between AP1 and moving node is measured 225cm.
- Distance between AP2 and moving node is measured 135cm.
- Distance between AP3 and moving node is measured 250cm.

Then, RSSI values for each of the AP is measured in (3,4) located at the moving node in the test bed. As a result of the measurement,

- AP1 RSSI value is -54 dB
- AP2 RSSI value is -56 dB
- AP3 RSSI value is -62 dB

And, RSSI values for each of the AP is measured in (0,0) located at the moving node in the test bed. As a result of the measurement,

- AP1 RSSI value is -59 dB
- AP2 RSSI value is -57 dB
- AP3 RSSI value is -63 dB

In Section 4, the distance is calculated between the AP and moving node by using the RSSI values. Since then, comparing the calculated distance with the actual distance is determined by the accuracy of the calculation.

IV. EXPERIMENTAL DATA ANALYSIS

A. *Analysis results*

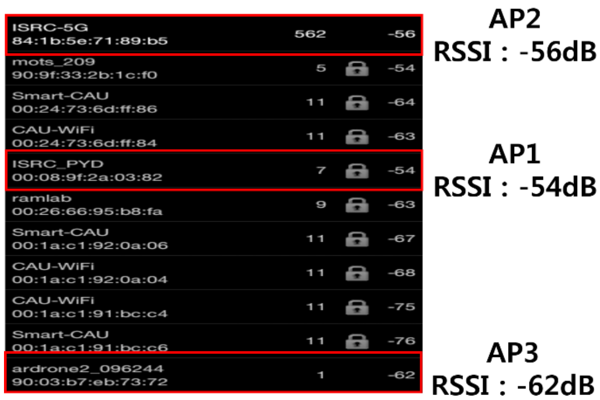

Figure 7. AP`s RSSI values measured at (3,4)

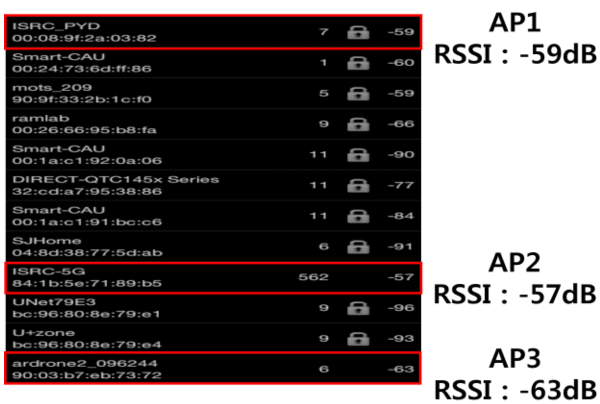

Figure 8. AP`s RSSI values measured at starting point (0,0)

Fig. 7 is AP`s RSSI values measured at (3,4). Each value is measured that AP1 RSSI value = -54 dB, AP2 RSSI value = -56 dB, AP3 RSSI value = -62 dB. Fig. 8 is AP`s RSSI values measured at starting point (0,0). Each value is measured that AP1 RSSI value = -59 dB, AP2 RSSI value = -57 dB, AP3 RSSI value = -63 dB.

Before calculating the distance between the AP and the moving node by the RSSI values using the (8), c is propagation speed, and this value is set to '3×10^8', and the frequency of AP1 is 2.4Ghz, the frequency of AP2 is 5Ghz, the frequency of AP3 is 2.4Ghz. Calculating the (8) have this values, it is as follows.

- $d_1^{`} = \frac{3\times10^8}{4\times\pi\times2.4\times10^9} \times 10^{\frac{(-54+59)}{20}} \cong 176\text{cm}$
- $d_2^{`} = \frac{3\times10^8}{4\times\pi\times5\times10^9} \times 10^{\frac{(-57+56)}{20}} \cong 42.5\text{cm}$
- $d_3^{`} = \frac{3\times10^8}{4\times\pi\times2.4\times10^9} \times 10^{\frac{(-63+62)}{20}} \cong 88\text{cm}$

The actual distance between AP and the moving node in Fig. 6. As follows,

- $d_1 = 225\text{cm}$, $d_2 = 135\text{cm}$, $d_3 = 250\text{cm}$

Analysis of the error between the calculated distance with the RSSI value and actual distance is as follows.

- Distance difference (AP1 and Moving node between the actual distance) and (distance calculated as the RSSI value) is (225cm – 176cm = 49cm), and the error rate is 27.8%.
- Distance difference (AP2 and Moving node between the actual distance) and (distance calculated as the RSSI value) is (135cm – 42.5cm = 92.5cm), and the error rate is 217%.
- Distance difference (AP3 and Moving node between the actual distance) and (distance calculated as the RSSI value) is (250cm – 88cm = 162cm), and the error rate is 184%.

B. *Error Anlaysis*

The most significant error was calculated between d_2 and $d_2^{`}$, the error between $d_1$ and $d_1^{`}$ was the least. First, an analysis of the largest error that occurred in AP2. The difference between the RSSI value of the Fig. 7 and RSSI value of Fig. 8 hardly occurs because the moving node and AP2 are close. Errors in AP1 showed a relatively appropriate amount to 27.8%. Lastly, an analysis of the error that occurred in AP3. Error has occurred since AP3 is located in the outdoor, so signal is interfered by the wall when the signal transmitted.

The way to reduce the above error is as follows. In order to reduce the error arising from the AP2, the distance between the AP and the moving node has to be ensured over a certain distance. In order to reduce the error that occurred in AP1, RSSI values measured several times, it is possible to reduce the error by using the average value of these values.
Lastly, in order to reduce the error that occurred in AP3, the position of the drone moves to less radio interference place [7].

V. CONCLUSIONS AND FUTURE WORKS

In this paper, we confirmed that it is possible to scan a person by a drone that is located outside the building and connected with AP inside of the building. If a mobile device has the appropriate distance between the mobile device and the AP and the little signal interference, we can efficiently estimate the indoor position of the mobile device. If this tracking function is developed, we will quickly find people who need help a help in a disaster area.

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REFERENCES

[1] L. Girod and D. Estrin, “Robust Range Estimation Using Acoustic and Multimodal Sensing,” Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems, Maui, pp. 1312-1320, 29 October-3 November 2011.

[2] L. Giord, V. Bychovskiy, J. Elson and D. Estrin, “Locating Tiny Sensors in Time and Space: A Case Study,” In: B. Werner, Ed., Proceedings of the IEEE International Conference on Computer Design: VLSI in Computers and Processors, Freiburg, pp. 214-219, 16-18 September 2002.

[3] Lee, Jung-Kyu, YoungJoon Kim, and Jong-Ho Lee and Seong-Cheol Kim, “An Efficient Three-Dimensional Localization Scheme Using Trilateration in Wireless Sensor Networks,” IEEE Commun. Lett., vol. 18, pp. 1591-1593, 2014.

[4] Zheng Yang and Yunhao Liu, “Quality of Trilateration: Confidence-Based Iterative Localization,” IEEE Trans. Parallel Distrib. Syst., vol. 21, pp. 631-640, 2010.

[5] P.K. Sahu, E.H.-K. Wu, and J. Sahoo, “DuRT: Dual RSSi Trend Based Localization for Wireless Sensor Networks,” IEEE Trans. Parallel Distrib. Syst., vol. 13, pp. 3115-3123. 2013.

[6] Anindya S. Paul and E.A. Wan, “RSSI-Based Indoor Localization and Tracking Using Sigma-Point Kalman Smoothers,” IEEE J. Sel. Top. Signal Process., vol. 3, pp. 860-873, 2009.

[7] A.H, Wong, M.J. Neve, and K.W. Sowerby, “Antenna selection and deployment strategies for indoor wireless communication systems,” IET Communications, vol. 1, pp. 732-738, August 2007.

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