Indoor Localization Improvements Based on Average RSS Samples

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Abstract. There are some constraints and challenges in the big building, hence, the Global Positioning Systems (GPS) doesn't work so well. To address this problem, indoor localization systems carried out based on methods like the Receive Signal Strength (RSS) and Time of Arrival (ToA). However, harsh indoor environments still a big challenge due to the impact of other signal sources or movements of people into the building. Subsequently, the test of signal changeable with time under several conditions. To overcome those problems, Average samples of RSS (ASRSS) proposed in this paper by measure the 63 samples. The Net Spot software was experimental software to measure RSS values in a continuous way with time. The final reference RSS measurements resulting in an average of 63 samples. In the simulation side, Wireless Insite Package (WIP) used to design a Three-Dimensional (3D) case study building. The results of RSS based on the ASRSS technique confirm that the RSS in simulation and experimental sides so close to estimation calculations. The enhancements of estimate RSS lead to estimate accurate position with average errors equal to (0.098m).

1. Introduction

Recently, the new technologies have been played main role by increase demand on those of technologies. Indoor localization (ILs) is one of those technologies that developed by the researchers and received immense attention, owing to its pertinence in human's safety and security issues. Indoor localization can be used to find persons inside buildings such as, train stations, airports, and hospital, or monitoring human's healthy in addition to tracking of someone for security aspects. The popular system to estimation position is Global Position System (GPS). However, there are limitations and constrain inside building [1], therefor, indoor localization systems have been designed to address those problems. Many systems designed depending on signal characteristics such as, Time of Arrival (ToA), Time Deference of Arrival (TDoA), Angle of Arrival (AoA), and receive signal strength [2]. Furthermore, combination methods have been used such as, RSS and ToA [3], TOA and AoA [4]. The position can be estimate by using smart devices like mobile phone or laptop. Wi-Fi is ubiquitously everywhere, therefore, a lot of indoor localization system constructed based on Wi-Fi like in [5]. However, indoor environments are complex, therefore, there are challenges and constrains that impact on systems accuracy. The pattern of propagation is play main role on measurements in case of Non-Line of Sight (NLoS), this phenomenon happens when objects separate senders and receivers. Therefore, the received signal reach receiver from walls or others objects, hence, the TOA is deference from link to another. The other impact is attenuation when weak signal arrives receivers, therefore, the estimation of correct position depending on this signal will be difficult [1]. To address those challenges, the researchers proposed several solutions to enhancement the performance of system by mitigate the impact of NLOS and other constrains. One of those solutions are NLOS identifications [6], or to estimate accurate RSS value, the fingerprint technique proposed in many researches such as
in [7]. However, the fingerprint techniques basically apply based on data base of RSS measurements measured on offline phase. Therefore, those measurements are different from real environments due to many impacts lead to inaccurate Reference RSS. To address this problem, Average Samples of RSS (ASRSS) will propose in this paper. The proposal aims to measure RSS values under many scenarios to deal with real environments. The obtained RSS measurements will use to carry out Indoor Localization System (ILS) based on optimum data and this one of main objective of this research.

2. Related works
There a lot of indoor localization systems constructed based on Wi-Fi technology. The authors in [8] have been studied ILS under specific conditions. The main issue is the propagation behaviours in indoor environments. Two algorithms were presented to mitigate the impact of NLOS, ML in addition to Bayesian have been applied as mathematical solution to address the regressive measurements. In Bayesian method, the results confirm that the performance is more accurate than ML estimator. The authors in [9] have been proposed new algorithm to deal with indoor environments, such algorithm has been tried to mitigated the impact of NLOS in indoor localization. In this approach, two level of last square method was suggested to implemented accurate positioning system. Such proposed system designed based on radio signal which transmit from based station that deployed to mobile. This kind of signal especially in indoor environments causes an error in measurements hence inaccurate system. Therefore, GLE algorithm presented in this study which took in consideration those affectations. To show the effeteness of proposed approach, RMS was used to measure the percentage of error, the results confirm that the performance of systems is increase in both TOA and AOA methods. After summarized many researches related to this study, clearly noted that the complexity in measure accurate signals is main challenge. In addition, Wi-Fi technology is preferring due to availability and simplicity.

The authors in [10] evaluated ILS based on Wi-Fi technology. They proposed new algorithm to address the NLoS impact subsequently, improve system accuracy. To utilize indoor positioning based on both ToA and RSS, they applied their algorithms based on couple area. The idea of selected two areas is to obtain the accurate measurements from each geometric area which selected. By substitute the enhance data into Triangle Centroid algorithm, the localization system will be carried out. The results show the better performance and the error range was less than another algorithm. The authors in [11] applied ILS model based on ToA. In their research, they used 2.4 GHz frequency in addition to IEEE 802.15.4 technologies. By using suggested method and technologies, the authors tried to implemented reliable system. Both scenarios LoS and NLoS signal propagation have been taken in considerations. The obtaining results in experimental measurements confirm that in LoS scenario, the UWB is prefer to distance under 11m. However, 2.4 GHz is recommended in distance above 11m. In NLOS scenario, UWB is suitable for distance under 10m while 2.4 GHz is prefer above that distance. The authors in [12] have been constructed ILS based on Wi-Fi approach. One of several methods to improve localization especially in indoor environments is deep learning. Basically, in localization there are online phase in addition to offline phase. In offline phase, there is data base which built based on RSS measurements. According to that, they built fingerprint data based on couple of algorithms, cross entropy in addition to mean squared. In online phase, the algorithm matching the real measurements with data base to adopt those measurements. The optimum measurements which obtained after enhancements using data base show significantly decrease in error, therefore, system will be more accurate based on proposed algorithm compared with previous work. The authors in [13] implemented ILS based on Wi-Fi technology as a prefer indoor wireless communication. Wi-Fi technology proliferate and that encourage developers to use this kind of technology. The researchers benefited from APs that deployed inside building to estimate positions based on RSS methods. To achieve stability, ROC curve was presented to overcome dimensionality problem. In addition, they doing some manipulate the second-order discriminant function in order to increase simplicity. All those procedures led to more accuracy according to their results.
According to the results in table 1, that obtained by the authors in [14], the select of Wi-Fi technology is better than other technologies according to performance and availability.

Table 1. The comparison between some wireless technologies

| Environments | Average error (m) in distance (1-5m) based on RSS |
|--------------|-----------------------------------------------|
|              | Wi-Fi | BLE | Zigbee | LoRaWAN |
| 1            | 0.843 | 0.661 | 0.882 | 0.846 |
| 2            | 0.486 | 0.844 | 0.911 | 1.534 |
| Overall      | 0.6645 | 0.753 | 0.896 | 1.190 |

3. Indoor localization

To measure the required distances, there are a number of methods like RSS and TOA. The harsh indoor environments and NLOS phenomenon as shown in figure 1 should take in account.

\[ a_i = \sqrt{(x - x_i)^2 + (y - y_i)^2} \]

\[ i = 1, 2, ..., k \] (1)

where \( x \) and \( y \) are estimate coordinate, \( x_i \) and \( y_i \) are reference coordinate. To make equation (2) more practical, there are addition parameters will add to modify it and can written as following [15, 16]:

\[ d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2} + \beta_i + m_i \] (2)
where $\beta_l$ is equal to zero in LOS and greater than zero in NLOS, $m_l$ is noise value.

In RSS method, path loss propagation model will present to measure the distance as following [15]:

$$\text{PL}(d) = Plo - b_l - 10\gamma\log_{10}\frac{|r-x_i|}{d_o} + Q$$

(3)

where $Plo$ path loss in reference distance, $b_l$ is positive bias, $\gamma$ is path loss exponent, $Q$ is the log normal shadowing. By theoretical way, RSS can measure by [17]:

$$RSS = p_o - 10\alpha \log(d) - S$$

(4)

Where $p_o$ is receive power in reference distance that recommended in one meter, $\alpha$ is path loss gradient which different depending on environments that system designed for. Generally, $\alpha$ value is 2 in LOS and 6 in NLOS [1], $d$ is the distance between reference point such as APs and targets, $S$ is shadow fading.

The distances between TXs and RXs can be calculated as following [15]:

$$(d_i)^{RSS} = 10^\frac{p_o-p_i-b_{max}}{10\gamma}$$

By used integrate system, the authors in [15] obtained better performance after improve other works. However, there are range of errors still due to instable in measurements between estimated and real measurements. Therefore, this paper will improve the system by overcome the variation in measurements based on ASRSS technique. Then, measure the distance based on equations (5) to carry out optimum system.

4. Case Study Building

To implement the proposal, campus of electrical engineering technical building selected to carry out the indoor localization system. Such system implemented in simulation and experimental scenarios; the simulation side was done based on Wireless Insite Software (WIS). Such software has hug ability to measure required parameters will discuss in simulation side section. Whereas, the experimental data obtained by using Wi-Fi Meter software (WMS), the details of RSS measurements will depict in experimental side section.

A- Simulation Side

Three-dimensional (3D) building designed based on WIS taking in consideration real geometric measurements. To measure RSS, eight position was selected to deploy the receivers in addition to three positions for transmitters as show in figure 2.

Figure 2. The case study building
In WIS, there is ability to set up the properties of transmitters and receivers to match the experimental devices so the selected properties of both TXs and RXs listed in Table 2 assigned based on that. The operating frequency is 2.4 GHZ, in addition both TXs and RXs antennas is Omni-Directional to correspond with experimental one.

**Table 2.** The characteristics of antennas

| Antenna properties | TX          | RX          |
|--------------------|-------------|-------------|
| Antenna type       | Omni        | Omni        |
| Input Power (dBm)  | 13.5        | -           |
| Gain (dBi)         | 7.3         | 1.3         |
| E-Plane HPBW       | 10°         | 90°         |
| Waveform           | Sinusoid    | Sinusoid    |
| Tem. (k)           | 295         | 295         |
| Polarization       | V           | V           |
| Received Threshold (dBm) | -140     | -140        |

One of important features in WIS is setup the permittivity and conductivity of all materials to deal with real ones. To apply that, there are constant parameters as listed in Table 3 and Table 4. The conductivity and permittivity for each material calculated depending on some parameters. According to [18], the conductivity denoted by \( \sigma \), can be determine as following:

\[
\sigma = c \times f^d
\]  
(6)

The constant \( c \) and \( d \) are illustrating in Table 2. The permittivity \( (\eta) \) is determine as following:

\[
\eta = a \times f^b
\]  
(7)

The constant \( a \) and \( b \) are related to each material used to construct the chosen building which are listed in Table 3, [18].

**Table 3.** The constant \((c \text{ and } d)\) that used in (6).

| Material type | c    | d   |
|---------------|------|-----|
| Concrete      | 0.0326 | 0.8095 |
| Brick         | 0.038 | 0.8 |
| Wood          | 0.0047 | 1.0718 |
| Glass         | 0.0043 | 1.1925 |

**Table 4: The constant \((a \text{ and } b)\) that used in (7).**

| Material type | a    | b |
|---------------|------|---|
| Concrete      | 5.31 | 0 |
| Brick         | 3.75 | 0 |
| Wood          | 1.99 | 0 |
| Glass         | 6.27 | 0 |
As mentioned, 2.4GHz frequency used in this research, based on equations (6) and (7). Table 5, depicts the permittivity and conductivity for mention frequency. The values in table 4, will setup in WIP for the materials use in building construction.

**Table 5. The Permittivity & Conductivity for 2.4GHz frequency**

| Material type | Conductivity | Permittivity |
|---------------|--------------|--------------|
| Concrete      | 0.0926       | 5.31         |
| Brick         | 0.1079       | 3.75         |
| Wood          | 0.0134       | 1.99         |
| Glass         | 0.0122       | 6.27         |

**B- Experimental Side:**

In experimental side, Net Spot software as shown in figure 3, used to measure RSS values in interested areas. The selected position to measure RSS values deal with simulation one for compression issues later. In eight locations 63 samples are measure under different scenarios with take in consideration the type of environments.

![Net Spot software interface](image)

**Figure 3. The Net Spot software interface**

By taking different places in case study building represents different environments increases the reliability of measurements to deal with practical measurements in the whole building. In the environment of lab1, four points deployed to measure RSS experimentally with 63 samples for each one. These measurements with the other measurements in the other four places stored in database.
Finally, MATLAB software presented to convert the optimum data was stored in database to distance lead to location by using trilateration method.

5. Results & discussions

The estimated distance was done based on RSS measurements; therefore, accurate RSS measurements will lead to accurate distance estimation. Figure 6a-h depicts the eighth position was selected to measure reference RSS based on 63 samples on each position. The RSS values unstable due to several impacts such as other signals and movements of peoples who use smartphone. All those affections will lead to difference values in each time, by take a lot of samples which includes each scenario. The average of those samples will be the reference RSS which use to estimate distance between the TXs and RXs.

![Figure 4a. Measure samples in first position](image1)

![Figure 4b. Measure samples in second position](image2)
Figure 4c. Measure samples in third position

Figure 4d. Measure samples in fourth position

Figure 4e. Measure samples in fifth position
Figure 4f. Measure samples in sixth position

Figure 4g. Measure samples in seventh position

Figure 4h. Measure samples in eighth position
The obtaining results show the effeteness of AS technique, table 5 show the result that obtain in both experimental and simulation scenarios compared with theatrical results. In table 6, there are 8 RSS values in each scenario, the results in experimental side is the average of 63 samples measured base on Wi-Fi Meter software as mentioned. In simulation side, the RSS values obtained from WIP after deploy 8 points in same place with real scenario. Moreover, theoretical aspect was done based on equation (4) to find required RSS based on interested distance taking in consideration the noise aspect was defined as \( n \) in equation (4).

**Table 6.** The measurements of RSS(dBm) in difference scenarios.

| Target index | Theoretical RSS | Simulation RSS | Experimental RSS |
|--------------|----------------|---------------|-----------------|
| 1            | -52.8          | -54.4         | -53.9           |
| 2            | -55.1          | -56.2         | -55.3           |
| 3            | -61.8          | -62.5         | -63.7           |
| 4            | -63.5          | -65.15        | -64.7           |
| 5            | -64.2          | -65.1         | -64.8           |
| 6            | -68.5          | -68.9         | -69.5           |
| 7            | -71.9          | -72.3         | -72.7           |
| 8            | -72.8          | -73.2         | -73.7           |

After measure accurate RSS based on ASRSS technique, the distance between TXs and RXs calculated based on equation (5). Table 7 illustrates the measure distance compared with real distance and the difference between them depict the error percentage.

**Table 7.** The distance error in eight positions

| position | Real distance (m) | Estimate distance (m) | Error (m) |
|----------|-------------------|-----------------------|-----------|
| 1        | 22.51             | 22.42                 | 0.09      |
| 2        | 24.34             | 24.21                 | 0.13      |
| 3        | 15.81             | 15.69                 | 0.12      |
| 4        | 33.63             | 33.52                 | 0.11      |
| 5        | 28.48             | 28.35                 | 0.13      |
| 6        | 19.75             | 19.68                 | 0.07      |
| 7        | 16.31             | 16.29                 | 0.02      |
| 8        | 17.25             | 17.15                 | 0.1       |
6. Conclusions

In this research, a proposed ASRSS technique is carried out with RSS method in order to find locations of targets in 8 positions deployed in a selected building. Such building has been designed based on WIP to measure RSS and TOA. Three transmitters based 2.4 GHz were deployed in a suitable place within case study building. In experimental side Net Spot software used to measure RSS in 8 locations with 63 samples for each of one. The results confirm that a significantly decreases in error (which calculated as the differences between the theatrical, simulate and experimental RSS) are obtained using the proposed ASRSS and WIP. After obtained optimum data, the location of 8 receivers estimated and the results show that such error has been enhanced from (0.136m) in previous work to (0.098m) using the proposed ASRSS. By measure RSS close from simulate and theoretical measurements in addition to estimate accurate targets location, the objective of this study was done. It is worth to mention that the RSS measurements based on single sample will lead to high error according to complexity inside crowded building. Also, should mention that the estimated RSS by theoretical way is difficult without some parameters represented noise and other impacting. By applied propose ASRSS, the suitable parameters for each environment recorded to use in theoretical issues.

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