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Improving Indoor Localization System Using a Partitioning Technique Based on RSS and ToA

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Abstract

Designing a localization system for an indoor environment faces more challenges because of multipath and interference problems. In this field, the most important techniques used for such environment, are RSS and ToA which need to be improved especially from more interference because of the huge multipath problems. In this paper, a case study of a selected building is chosen in order to apply the proposed technique of this research. Such proposal is based on the PT of the area in the case study into MZ. Each zone is allocated special values for the parameters used to estimate the target positions. WI package is used to simulate the case study area and apply such proposal based on RSS and ToA. The results confirm that the estimated locations are close to the real locations by the average error of (2.8) meter and (0.192) meter for ToA corresponding one zone and four zones respectively. In contrast, the results of our experiment show that the accuracy is improved from an average error of (2.4) meter and (0.217) meter for RSS corresponding one zone and four zones respectively. Such results confirm that dividing the case study area into more zones leads to more accuracy.

Keywords: Indoor localization; RSS; ToA; WI; MZ; PT; GPS; AoA.

1. Introduction

Indoor localization gains attention and is a common topic for researchers recently to find the person and the other object. Indoor localization was created to correspond with the crowded building to trace the kids, patient movements, monitoring, and security. The common technique widely accustomed to realize the location is GPS. However, GPS is convenient in outside environments and their square measure is constrained and limited, which leads to obscured GPS service just like the position within high buildings [1, 2]. During this state of affairs, indoor localization systems square measure is accustomed to estimate the position in any space that GPS does not work. For every setting, many ways are used like; ToA [3, 4], TDoA [5], AoA [6], and RSS [7] are preferred techniques for indoor environments. Also, hybrid methods like ToA/AoA [8], RSS/ToA [9], and TDoA/RSS [10] are used to address the weakness of someone by tacking the corresponding potential points. In general, signal characteristics are used to construct the indoor localization systems in most cases to estimate the gap between RPs and targets [11]. However, the indoor wireless communications system suffers from many constraints and challenges that influence its responsibleness. The widely known development impact on system accuracy known as multipath that happens in NLoS environments once obstacles separate transmitters and receivers [1]. Moreover, time synchronization and time measure square measure are common issues in inferring location victimization ToA [12]. To deal with those issues, several researchers projected many techniques and algorithms like [13], whose projected NLOS identification technique to alleviate the impact of multipath.

Also, WLS is formulating for indoor localization [14]. To boost position systems supported RSS, LAN fingerprint conjointly has already been projected in [15]. One of the most important parts of the localization system is to axis points that are used in the target areas in order to achieve full coverage required for building a localization system. So, the existence of a wireless system will degreed the performance of the localization system. To address these problems a PT is proposed in this paper to improve the average localization techniques.

Nomenclature			
RSS	Received Signal Strength	ToF	Time of Flight
ToA	Time of Arrival	ITU	International Telecommunication Union
PT	Partitioning Technique	**Symbols**	
MZ	Multi Zones	d_i	distance between both the transmitter and th receiver (m)
WI	Wireless InSite	Y_i and X_i	receiver coordinate
GPS	Global Position System	X, and Y	transmitter coordinate
TDoA	Time Deference of Arrival	PL_0	path loss
AoA	Angle of Arrival	γ	exponent of path loss
NLoS	Non-Line of Sight	d_0	reference distance (m)
RPs	Reference Points	d	distance between the coordinator and the mobile node (m)
WLS	Weighted Least-Squares	$X\sigma$	Gaussian random variable
HALPA	Hybrid Wi-Fi Access Point-based Localization Algorithm	PT	transmitter's power (dBm)
HIL	Hybrid Indoor Localization	C	speed of electromagnetic waves in vacuum space
MSCM	Multidimensional Scaling Classical Metric	k	variable value
LED	light-emitting diode	η	relative permittivity
		σ	conductivity

The idea is to highlight the benefits of increasing the number of partitioning from one zone to multi zones and monitor the effect of increasing the number of partitions on the accuracy of positioning. The content of this paper is structured as follows. Section two provides a survey of the related work, then, the theory background is presented in section three. In section four details of the case study area are presented. The results of the proposed approach are presented in section five and the results are discussed in Section six. Finally, the conclusion is given in section seven.

2. Related work

There are several indoor localization networks developed based on Wi-Fi technology. The authors in [16] studied recent advances in methods and applications for indoor wireless localization. There is a review of different technical technologies for wireless indoor positioning and navigation. Current technologies do not cope with the level of output needed by critical applications. The goal of the paper is to provide a deeper understanding of state-of-the-art technology and inspire new research initiatives. Several current Wi-Fi-based indoor localization algorithms were studied by the authors in [17] depending on wireless APs, i.e. hotspots, which have been easily affected by NLOS conditions and multipath influence. There are also many other challenges, including stability of positioning and blind spots, which would cause precision to deteriorate at certain positions or even loss of positioning. The HAPLA can flexibly choose various positioning techniques to achieve high positioning accuracy. In [18], the authors use three phases in a HIL to increase the accuracy of WiFi-based localization. This analyses the distances between each pair of peer resources across acoustic ranges. The MSCM approach is applied to the distances used. Our experimental findings show that the average HIL position error is approximately 1 meter. WiFi-based solutions are realistic, but their low-precision outcomes do suffer. This article presents a new indoor localization method, HILL, that uses the measured distances between adjacent mobile devices and the localization effects based on WiFi.

Our experimental results demonstrate that HIL leads to a position error of around 1 meter, while a 3 to 4 meters' error results from traditional WiFi-based systems. The authors in [19] enforced an indoor positioning system by using Wi-Fi technology. to try and do that path loss propagation was used to measure the desired distance. Space should be measured between the known points known as reference points and also the targets. They recommended the trilateration technique to estimate the final estimation supported the distance was measured. The authors in [20] enforced a localization system based on TOA for a smartphone. The conception of the proposed system is built to rely on a LED. During this system, the smartphone acknowledges the light additionally to sound waves that emit from transmitters. During this case, the measurements of TOF are used to estimate the position. The authors during this study applied their system using multitrilateration which supported obtained measurements. The large challenge in estimating location supported TOA is synchronization, to deal with this drawback, reference time that is transmitted to synchronize with recoveries. At an equivalent time modulated led was proposed to alleviate the synchronization challenge. moreover, they examined the ability of VLC time synchronization in positioning. Finally, 100mm was the being deviation in three-dimension positioning in a dark space that is suitable in sensible aspects. The authors in [21] made localization system supporting the Wi-Fi approach. One of the many strategies to enhance localization particularly in indoor environments is deep learning. Basically, in localization, there's an online introduce an addition to the offline phase. within the offline phase, there is info built based on RSS measurements. consistent with that, they built fingerprint information based on some of the algorithms, cross-entropy, in addition, to mean squared. within the online phase, the algorithm matching the real measurements with a database to adopt those measurements. The optimum measurements obtained after enhancements using the database shows a major decrease in error, therefore, the system is highly correct supporting the proposed algorithm compared with the previous work.

3. Theory Background

Wireless network localization is a method of location determination in the entire region or in a given part of the region. The approximate location or region that is achieved by using a certain localization strategy is the outcome of the localization process [22]. To measure the actual distance (d_i) between both the transmitter and the receiver, it has been started with Euclid's equation.

$$d_i = \sqrt{(X - X_i)^2 + (Y - Y_i)^2} \tag{1}$$

Where Y_i and X_i are the ith receiver coordinate, X, and Y are the transmitter coordinate. Assuming one transmitter affects the receiver.

3.1. Log-Normal Path Loss Model-Based RSS

Measurements are based on the principle that the greater distance between two nodes, the lower the relative signal received by them [23]. Since the landscape differs considerably from place to place, gathering RSS data at points with defined coordinates within the area is the best way to locate the RSS relationship and the distance from the transmitter to the receiver. Despite this easy learning technique, it relies on the orientation of the signal propagation line and details of the area such as walls, furniture, and others. For certain reasons, this process should be done. For estimating the distance between the receiver and the transmitter, there is a log-normal path loss model ($PL(d)$) [24]:

$$PL(d) = PLo + 10\,\gamma \log_{10}\left(\frac{d}{do}\right) + X\sigma \tag{2}$$

Where PL_0 is the path loss at reference distance d_0 (1 meter), which can be calculated from the Friis equation or field measurements and is recommended for many types of research like [25]. Also, γ is the exponent of path loss which relies on the relevant propagation environment, and if barriers occur, the value will become greater, d is the distance between the coordinator and the mobile node in meters and $X\sigma$ is the Gaussian random variable is zero-mean (in decibels) deviation. A parameter of the d_0, γ, and $X\sigma$ describe the model of loss of path that has a fixed distance for receiving and transmitting. The platform is capable to be used to develop and evaluate general wireless networks.
The RSSI in dBm of the mobile node at the coordinator node can be calculated as follows [26]:

$$RSSI = PT - PL(d) \tag{3}$$

Where PT is the transmitter's power in dBm, the RSSI at the coordinator node will be:

$$RSSI = PT - PL_0 - 10\,\gamma \log_{10}\left(\frac{d}{do}\right) + X\sigma \tag{4}$$

The WiFi module's RSSI can be obtained from actual measurements and the $X\sigma$ can be obtained from curve fitting. The distance (d_i) between the node and the coordinator node can also be calculated according to [27]:

$$d_i = d_0\, 10^{-\left(\frac{RSSI - PT + pl_0 - X\sigma}{10\gamma}\right)} \tag{5}$$

In this work, the values obtained of PL_0 is 35 dBm (provided from the Friis equation for 2.4 GHz) [28], the path loss exponent γ depends on the setting and in the range of (2-6) for indoor environments. [29], and the standard deviation $X\sigma$ can take the range of (2-14) [28].

3.2. ToA Method

The distance from the measurement device to the target is directly proportional to the propagation time. ToA measurements must be made with respect to signals from at least the reference points in order to facilitate 2-D placement. The one-way propagation distance (d_i) is estimated for ToA-based systems as [30]:

$$d_i = (time_{send} - time_{receive}) * C + k \tag{6}$$

where C is the speed of electromagnetic waves in vacuum space ($C = 3*10^8$ m/s), k is the variable value. Assuming one transmitter affects the receiver like in this paper.

4. Case Study Area

The second floor of the laboratories building is selected within the campus of Electrical Engineering Technical College related to Middle Technical University. The model of the selected area is applied as a case study by the WI package. Fig. 1 illustrates the case study model. To apply our experiment, thirty receivers and three transmitters are deployed in the case study area. The height of transmitters and receivers were 2 meters and 1 meter respectively. The deployment of transmitters was in a suitable location as shown in Fig. 2 to get convenient coverage.
The type of antennas for each transmitter and receiver was omnidirectional with a frequency of 2.4GHz and all characteristics can be seen in Table 1. In order to, create a simulation model deal with real case study building, the WI software takes into account the relative permittivity (η) and conductivity (σ) for each material as recommended by ITU as shown in Table 2 [31]. In order to evaluate the signal propagation model, the RSS and ToA data are collected for each receiver, which means that 90 readings for each RSS and ToA.

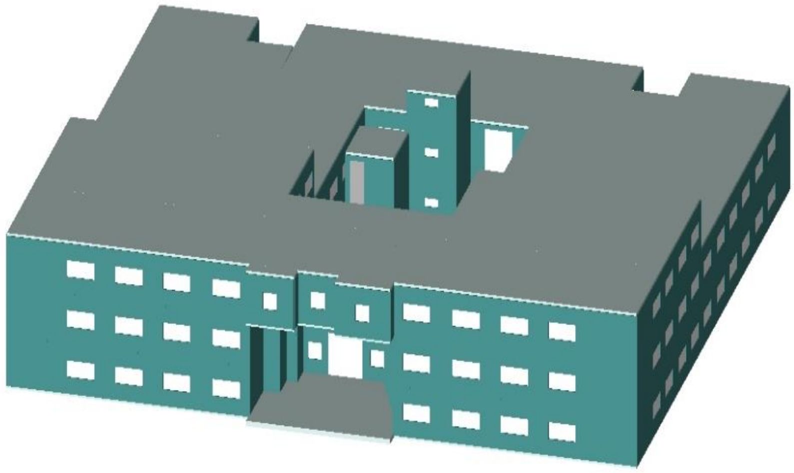

Fig. 1. The case study building

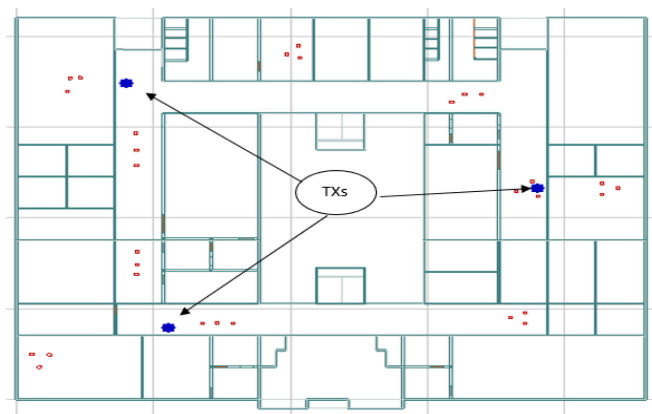

Fig. 2. The deployment of transmitters

Table 1. The characteristics of antennas

Properties of antennas	TX	RX
Antennas type	Omni.D.	Omni.D.
Input Power (dBm).	12.5	-
Gain (dBi).	7.5	2.2
E-Plane HPBW	13˚	94˚
Waveform	Sinusoid	Sinusoid
Temp. (k)	296	296
Polarizations	V	V
Received Threshold (dBm)	-150	-150

Table 2. The calculations of relative Permittivity &Conductivity for 2.4GHz

Material type	σ	η
Concrete floors	0.0931	5.21
Brick walls	0.1079	3.75
Wood doors	0.0136	1.99
Glass windows	0.0121	6.37

5. Results

The simulation measurements were performed in several settings during the construction of the case study. The three transmitters were installed in the specified locations and using WI software, RSS, and ToA metrics were measured using equations (5) and (6) for RSS and ToA respectively. The measurements are converted into distances metric between transmitters TXs and receivers RXs. To highlight the effect of the proposed model depending on partitioning the case study area as the following procedure:

In the first step, we take all of the working areas as one zone shown in Fig. 3. In order to, summarize a large number of results, the average error of all 30 receivers is listed in Table 3 which illustrate the average error for determining the location related to 3 TXs. We mean by the word "error" is the difference between the actual location and estimated location calculated by equations (1) and (6) respectively

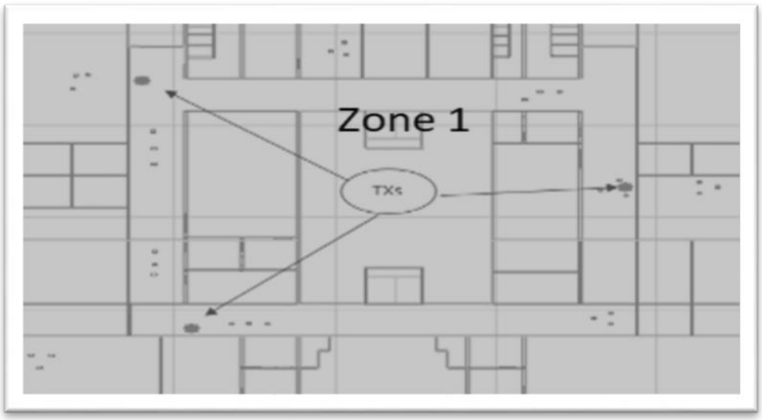

Fig. 3. A case study area with one zone

Table 3. The result of the average error of RSS & ToA for the one zone

Variable values			ToA method			RSS method		
$X\sigma$	γ	k	Error(m) (TX1&RXs)	Error(m) (TX2&RXs)	Error(m) (TX3&RXs)	Error(m) (TX1&RXs)	Error(m) (TX2&RXs)	Error(m) (TX3&RXs)
10	4	1.5	2.8	1.9	2.5	2.3	2.4	1.5

In the second step, the case study area has been divided into two zones as shown in Fig. 4. All values of $X\sigma$, γ, and m for each zone and its corresponded resent are listed in Table 4. It is worth to mention, that such parameters take different values for each zone. The result shows the average error for all 30 RXs related to 3TXs corresponding to ToA and RSS.

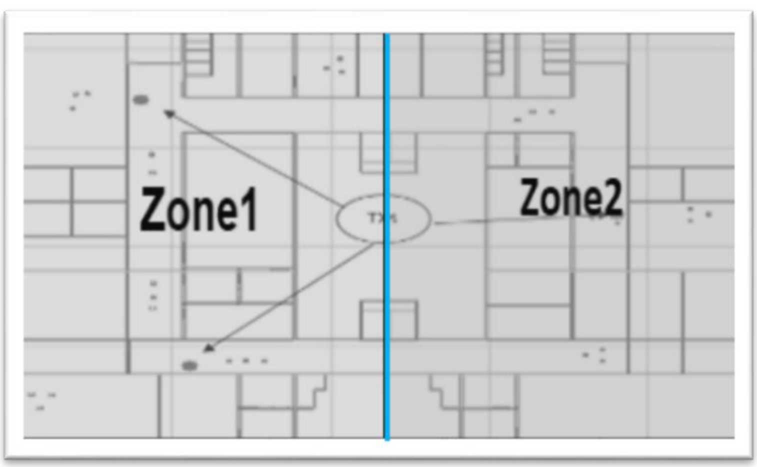

Fig. 4. A case study area with tow zone

Table 4. The result of the average error of RSS & ToA for the two-zone

Zone	Variable values			ToA method			RSS method		
	$X\sigma$	γ	k	Error(m) (TX1&RXs)	Error(m) (TX2&RXs)	Error(m) (TX3&RXs)	Error(m) (TX1&RXs)	Error(m) (TX2&RXs)	Error(m) (TX3&RXs)
1	10	4	1.5	0.912	1.151	0.825	0.721	0.791	1.126
2	8	2	1.2	1.234	0.871	0.974	1.133	0.875	0.821

The third step is to apply the same scenario of the second step but with four zones as shown in Fig. 5, and repeat the same procedure of the previous step. All results are listed in Table 5. Note that the parameters $X\sigma$, γ, and m is different in each zone which leads to a precisive results.

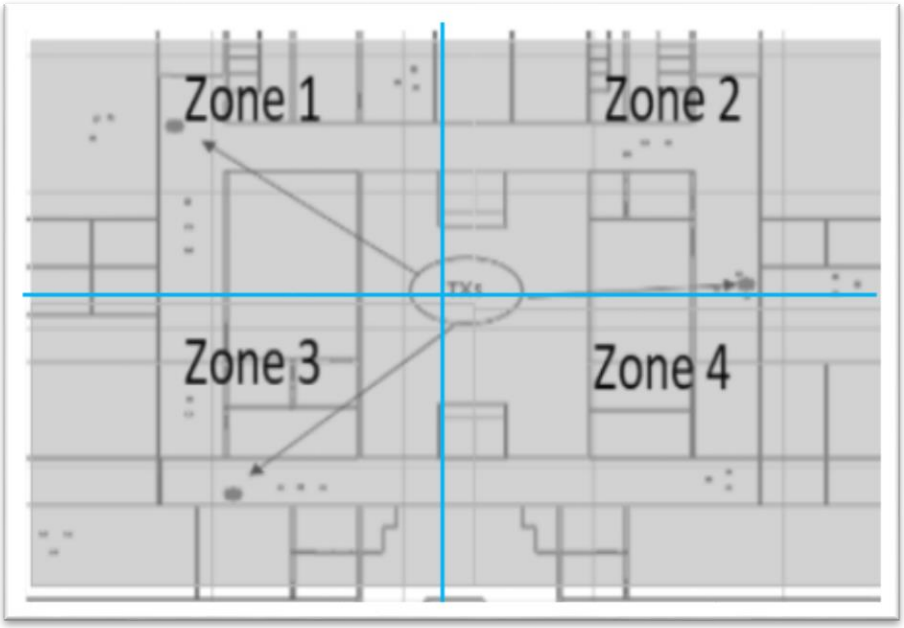

Fig. 5. A case study area with four-zone

Table 5. The result of the average error of RSS & ToA for the four-zone

Zone	Variable values			ToA method			RSS method		
	$X\sigma$	γ	k	Error(m) (TX1&RXs)	Error(m) (TX2&RXs)	Error(m) (TX3&RXs)	Error(m) (TX1&RXs)	Error(m) (TX2&RXs)	Error(m) (TX3&RXs)
1	10	4	1.5	0.221	0.235	0.271	0.312	0.321	0.335
2	8	2	1.7	0.252	0.312	0.318	0.297	0.311	0.279
3	12	6	1.2	0.221	0.218	0.248	0.311	0.256	0.314
4	10	4	2	0.314	0.364	0.192	0.257	0.341	0.217

6. Discussion

For one zone area of the case study, the result listed in Table 3 confirms that the average error in the ToA method ranged from (1.9 to 2.8) meters and between (1.5 to 2.4) meters in the RSS method.

On the other hand, when the case study is divided into two zones, the results become better than step one as listed in Table 4. Now, the range of errors for RSS and ToA are (1.234 to 0.974) meters and (1.151 to 0.912) meters respectively.

In addition, by dividing the case study area into four zones the results become more accurate as listed in Table 5 which is illustrates that the range of errors for RSS and ToA are (1.126 to 0.791) meters and (1.133 to 0.875) meters respectively.

7. Conclusions

From previous results, it can be concluded that the proposed system confirms that the accuracy of estimating the target position becomes more accurate by dividing the case study into MZ. The reasons for such improvement is related to the specific values of the parameters ($X\sigma$, γ, k) used in equations (5) and (6). Note that, each zone is constructed from a number of wales, doors, windows ………etc, which differ from zone to zone. So that using specific values from the mentioned parameters for each zone, will reduce the error significantly, as the results confirm such an idea. The results of our experiment show that the accuracy is improved from the average of error (2.8) meters to (0.192) meters for ToA corresponding to one zone to four zones respectively. In contrast, the results of our experiment show that the accuracy is improved from an average of error (2.4) meters to (0.217) meters for RSS corresponding to one zone to four zones respectively. Such results confirm that dividing the case study area into more zones leads to more accuracy. These results are compared with the research [32], where the researchers relied on the results achieved in their research, it was reported that ToA is better than the RSS method and that errors have been identified (0.48-1.52) m.

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