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Position Localization based Angle of Arrival for Indoor Environments

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Abstract - Position location for indoor environments an attractive subject for many researcher because of its importance for personal and object localization. In this research, a model of case study is constructed using Wireless InSite (WI) package and simulated. An algorithm of Angle of Arrival (AoA) is employed to estimate the location of fifteen targets deployed randomly in such building. Although AoA needs only one transmitter (TX) to estimate location, but we experience two and three TXs in order to increase accuracy. The results show that the position locations of our experiment are closed to actual locations with a minimum error of (0, 0.1). Also, the results confirm that accuracy is improved by increasing the number of TX device.

Keywords - Position location; Wireless InSite; AoA.

Research Methodology

In this research, we will study the location of buildings, flat lands, or people, taking into consideration the problems that may negatively affect the work, such as high noise, cellular communications, electrical systems, and the nature of the environment to be targeted. To address these problems and achieve accuracy, algorithms and access angles were used, the aim of which is to give us more accurate results and the least possible errors

Main results of this paper

Creating a model to locate people and objects using the Wireless InSite WI package)) using the Angle of Arrival (AoA) algorithm. A model of a building containing fifteen random targets was taken and the results showed that the error rate is low and is almost from (0) to (0.1) and the percentage of correctness and accuracy increases with the increase in the number of transmitters and receivers

1- Introduction

Indoor localization has become exceedingly important in various applications because a significant time is spent in large buildings for personal tracking and monitoring (e.g., hospitals, office buildings, shopping malls, airports, etc.) [1]. This made the demand for location-based services tracking persons or objects is increasing steadily to improve our life style in the fields of emergency services, healthcare, navigation, social networking, geofence, entertainment/gaming, asset tracking, etc. [2-7]. Unlike outdoor environments, the signal of Global Positioning System (GPS) is declined too hard and poorly received in indoor environments [8]. Therefore, how to achieve accurate indoor positioning based on commodity infrastructure become an urgent academic and industrial issue.

Angle of arrival (AoA) is one of active technique used for accurate position localization inside large buildings. AoA, or direction of arrival/orientation (DoA), measurement is a way for determining the orientation of propagated Radio Frequency (RF) wave incidence on an antennaarray or determined during antenna rotation from maximum signal strength [9]. AoA determines the direction based on the measurement of Time Difference of Arrival (TDoA) at individual elements of the array, from these delays the AoA can be estimated.

However, there are many challenges facing indoor localization such as huge multipath effect and large noise stem from other wireless communication like cellular system communication [10]. Inaccuracies in measurement of AoA can be related to the wireless communication channel, the measuring device/method, or both. The spatial features of the wireless channel have significant effect on the AoA detection [11].

In addition to other electric systems, many researchers were resolve this problem in many methods such as [12] where AoA were estimated by finding the mean received power and determine mean time of arrival (ToA) to obtain orientation and theta for butter localization in antenna array. In [8] AoA-based localization with two known access point 4800 Wi-Fi with 2.4 GHz to estimate the location for 10 unknown points were used for more accurate result and the localization error was less than 2.5 meter, about 80% of the time as the result showed in the Line of Sight (LoS) dominating environments. SpinLoc localization principle [13] used Channel State Information (CSI) in indoor environment with 20 degree median error, providing localization accuracies of 6.5 meter, with four access point, and up to five meter, with more access point localization. The researcher in [14] proposed localization system with one single LED lamp using Received Signal Strength (RSS)/AoA algorithm and demonstrate ~10 cm average position error is achieved in a 2m×2m×2.5m work area. Also, in [15] proposed Infrastructure for AoA estimation in Indoor environment, with potential accuracy better than 2 meter. The authors presented an indoor localization approach for the dynamic correction of Received Signal Strength Indication (RSSI) by deploying the Bluetooth gateway and the experimental results showed that this method can improve the accuracy of localization and meet the positioning requirements in indoor environment but some special positions like indoor cornersand complex electromagnetic regions were not considered [16]. In this research, one building of Electrical Engineering Technical College is selected as a case study to apply an experiment position location for many objects represented by receiver device (RXs). Also, number of transmitter device (TXs) is installed in a preplanned location in order to complete AoA requirements.

2- Position Localization Based AoA

The wireless indoor localization methods classified to: range-based and range-free methods [17-19]. Range-based methods to measure the distance between the target and Reference Points (RP) (at least three RPs) then the target's position location determined by triangulation method. Physical parameters obtained from wireless signals, include, (ToA), (TDoA), RSSI and Time of Flight (ToF). ToA, TDoA, and ToF are very sensitive to timing error [20-26]. Also, range-free methods which can be subdivided into proximity detection, Distance Vector hop (DV-hop), and AoA based methods [27-33]. Some researchers use combinations of these methods to increase accuracy in spite of its complexity and high cost.

AoA is defined as the angle between a reference direction which is known as orientation and the propagation direction of an incident wave. Orientation is a fixed direction against AoA are measured and represented in degrees in a clockwise direction from the north. AoA is absolute when the orientation is 0 or pointing to the north otherwise, it is relative [34]. It can be estimate the distance between TX and RX according to the speed of electromagnetic wave propagation, thedistance d is obtained by:

$$d = c \times t \tag{1}$$

Where c is speed of light (3×10^8) ms^{-1}, t is the propagation time in one way signal with maximum power received in LoS, but for indoor environment with multipath propagation the time is takes as $\bar{t}$ value of t can be calculated as:

$$\bar{t} = \frac{\sum_{i=1}^{N_p} P_i t_i}{P_R} \quad (2)$$

Where N_p is the paths number and P_i is the time averaged power in watts of the i^{th} path, P_R is total power receive, t_i is the ToA for each propagation path which can be calculated from:

$$t_i = L_i / c \quad (3)$$

Where L_i is the total geometrical path length [12]. The TX -RX separation distance can be utilized to determine the coordinates of the location of target which is represented as RX. Such location will be calculated with respect of TX location and bearing angle $\boldsymbol{\beta}$ between TX and RX which represented by the relation:

$$\beta = \alpha + \pi. \quad (4)$$

Where $\boldsymbol{\alpha}$ is direction of arrival in (phi) calculated by Wireless InSite (WI) package as a position coordination RX (X_{RX}, Y_{RX}) which can be estimated by:

$$X_{RX} = X_{TX} + d \times cos\,(\beta) \quad (5)$$

$$Y_{RX} = Y_{TX} + d \times sin\,(\beta) \quad (6)$$

Where (X_{TX}, Y_{TX}) represented the TXs known location, equations (5) and (6) are clear out in Fig. 1[35]

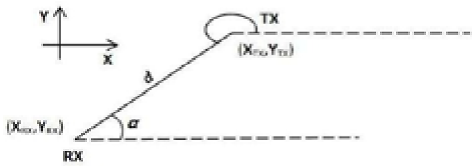


Figure 1: RX coordinates with respect to TX position.

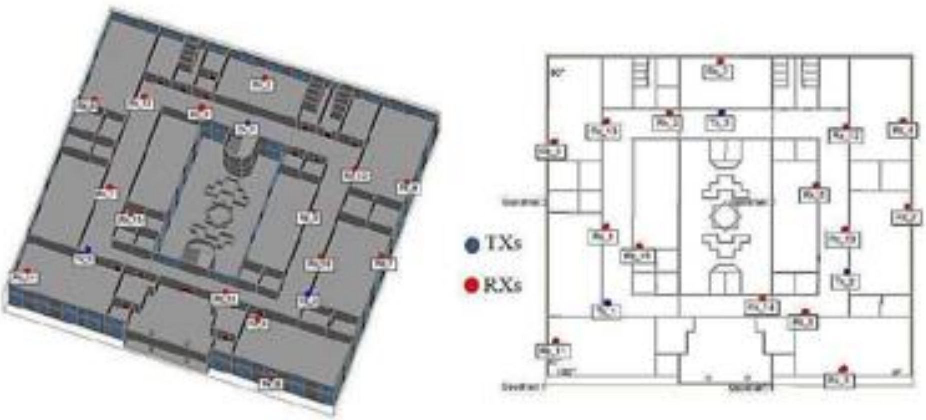
Also, d and α were calculated by mean ToA for Non Line of Sight (NLoS) and LoS in WI package**.[12]**

Estimating an accurate position using AoA technique leads to improve the location position inside large building in addition to track the personal moving by relative accuracy. The case study of this research is represented as a good chosen to apply the real experiment in order to obtain actual results useful for position localization system.

- Case Study

The 1'st floor of case study building, with a dimension of (47m×43m×3.5m) is chosen to apply our experiment. Firstly, the simulated building is designed using WI and loaded by specific instructions. The resultant building is illustrated in Fig. (2-a). Three different locations of TXs device with a height of 2m above floor are set up in a various location highlighted by blue color. On the other hand, fifteen RXs with 1.5m above floor are handled randomly in same floor of building shownas red color in Fig. (2-b). Also, all properties of both TX and RX are listed in Table I.

On the other hand, the impact of serious effects on wave propagation causes by different building materials (Brick, Wood, Glass, Concrete) with a frequency of 2.4GHz band and 1 MHz bandwidth. Such impacts was taken into consideration for the entire investigation, where eachmaterial thickness, conductivity (σ) and relative permittivity (η`) was determine based on the recommendation of International Telecommunication Union (ITU). The results of (σ & η`) calculations at a frequency of 2.4 GHz are listed in Table II.



(a) (b)

Figure 2: Simulation model of case study (a) 3D view
(b) Distribution of TXs and RXs

TABLE I. TX AND RX ANTENNA PROPERTIES

Antenna properties	TX Antenna	RX Antenna
Antenna type	Omni-Directional	Omni-Directional
Input Power (dBm)	30	-
Gain (dBi)	5	2
Waveform	Sinusoid	Sinusoid
Polarization	V	V
(VSWR)	1	1

Where (VSWR) is the Value for the antenna's voltage standing wave ratio.

TABLE II. MATERIAL THICKNESS, CONDUCTIVITY AND PERMITIVITY VALUES

Materials	Thickness (m)	σ	η`
Brick	0.125	0.038	3.75
Glass	0.003	0.012	6.27
Concrete	0.125	0.066	5.31
Wood	0.030	0.012	1.99

4Results and Discussion

As with previous explanation of section (3), location can be estimated by only one TX when depending on using equations (5) and (6), but for more accuracy, three TXs are deployed. The average value is adapted with three results of RXs. The accuracy can be evaluated by Error (*E*) which is known as the difference between actual RX position and the average estimated RX position obtained from all TXs as in the relation:

$$E = | A_{RX} - AVG_p | \tag{7}$$

Where A_{RX} is actual RX position, AVG_p is average estimated position.

The result of estimated location as compared with actual location for three TXs is shown in fig. 3.

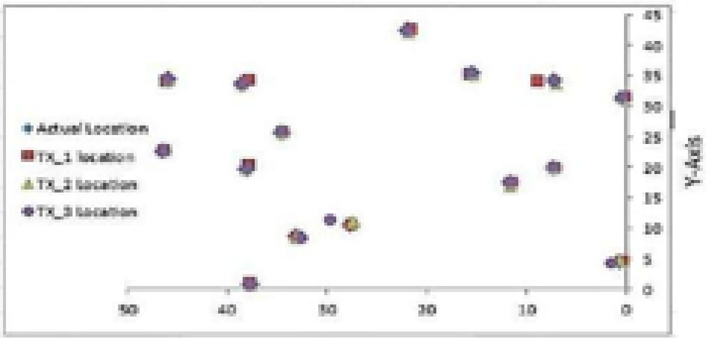


Figure 3: Represent the actual and estimated coordinates of RXs

Table-III SHOWS THE TX LOCATION ANE ESTIMATED RX LOCATION

RXs	TX_1 Location (7.5, 9.92)				Tx_2 location (35.5 , 14)				Tx_3 location (22.2 ,35.5)			
	d	ω	X	Y	d	ω	X	Y	d	ω	X	Y
Rx_1	10.1	272.05	7.14	19.92	31.83	349.39	7.21	19.86	21.42	45.68	7.22	19.98
Rx_2	28.62	252.36	15.56	35.28	31.39	317.6	15.31	35.17	6.745	359.74	15.40	35.33
Rx_3	35.45	246.72	21.51	42.40	32.75	300.76	21.75	42.14	6.99	271.79	21.98	42.26
Rx_4	45.46	212.19	45.97	34.13	21.06	250.26	45.81	34.36	23.72	177.93	45.91	34.44
Rx_5	31.14	210.39	34.36	25.67	12.32	289.01	34.49	25.64	15.68	142.05	34.5	25.9
Rx_6	25.49	176.9	32.94	8.54	7.73	45.13	33.04	8.52	28.89	111.01	32.55	8.33
Rx_7	40.87	198.13	46.34	22.63	11.70	227.34	46.42	22.6	27.34	152.24	46.39	22.56
Rx_8	31.50	163.49	37.7	0.94	13.34	66.67	37.72	0.68	37.93	114.17	37.73	0.69
Rx_9	22.74	289.05	0.07	31.41	41.91	335.37	0.41	31.46	22.14	50.19	0.4	31.36
Rx_10	32.02	198.76	37.81	20.21	5.66	274.15	38.09	19.64	22.29	135.61	37.90	19.73
Rx_11	8.67	37.68	0.36	4.62	38.92	13.71	0.58	4.77	37.47	56.25	1.38	4.14
Rx_12	38.97	218.79	37.67	34.33	19.64	270.02	38.49	33.63	16.37	174.18	38.48	33.64
Rx_13	24.27	267.87	8.82	34.17	37.24	327.93	6.94	33.77	15.06	4.34	7.18	34.10
Rx_14	28.01	181.75	27.5	10.53	11.45	14.56	27.41	11.12	25.37	109.32	29.59	11.36
Rx_15	6.51	242.04	11.48	17.43	27.10	353.66	11.66	16.96	20.79	59.33	11.59	17.41

TABLE -IV SHOWS ACTUAL RX LOCATION WITH AVERAGEESTIMATED LOCATION AND RANGING ERROR

RXs	Actual location		Average estimated location		Ranging error	
	X	Y	X	Y	X	Y
Rx_1	7.23	19.87	7.19	19.9	0.3	0.13
Rx_2	15.47	35.39	15.44	35.3	0.17	0.13
Rx_3	21.92	42.43	21.75	42.3	0	0.1
Rx_4	45.9	34.42	45.9	34.3	0.02	0.1
Rx_5	34.47	25.64	34.45	25.7	0.18	0.12
Rx_6	33.62	8.58	32.84	8.46	0.05	0.02
Rx_7	46.43	22.62	46.38	22.5	0.02	0.02
Rx_8	37.7	0.75	37.72	0.77	0.13	0.07
Rx_9	0.42	31.35	0.293	31.4	0.14	0.14
Rx_10	38.09	19.72	37.95	19.9	0.11	0.12
Rx_11	0.7	4.63	0.807	4.51	0.24	0.22
Rx_12	38.52	33.65	38.28	33.9	0.44	0.2
Rx_13	7.21	34.23	7.447	34	0.56	0.47
Rx_14	27.61	10.53	28.17	11	0.02	0.11
Rx_15	11.6	17.38	11.58	17.3	0.2	0.35

TABLE -V RANGING ERROR ESTIMATED FROM SINGLE TX

RXs	TX_1		TX_2		TX_3	
	X	Y	X	Y	X	Y
RX_1	0.9	0.03	0.02	0.1	0.01	0.11
RX_2	0.9	0.11	0.16	0.22	0.01	0.06
RX_3	0.41	0.05	0.17	0.29	0.06	0.15
RX_4	0.07	0.29	0.09	0.04	0.01	0.02
RX_5	0.11	0.03	0.01	0	0.03	0.26
RX_6	0.08	0.04	0.02	0.06	0.47	0.25
RX_7	0.09	0.01	0.01	0.02	0.04	0.06
RX_8	0	0.19	0.02	0.07	0.03	0.06
RX_9	0.35	0.06	0.01	0.11	0.02	0.03
RX_10	0.28	0.49	0	0.08	0.13	0.01
RX_11	0.34	0.01	0.02	0.14	0.68	0.49
RX_12	0.65	0.68	0.03	0.02	0.04	0.01
RX_13	1.61	0.06	0.27	0.46	0.03	0.07
RX_14	0.11	0	0.2	0.59	1.98	0.82
RX_15	0.12	0.05	0.06	0.4	0.01	0.03

As illustrated the range of error are limited between maximum value which is obtained at RX- 13 (0.56, 0.47) and minimum value (0, 0.1) at RX-3. Table III illustrates the detailed results of estimated

and actual locations. In addition, the error range between actual and average estimated location are listed in table IV for all fifteen RXs. In this paper, an experiment of position localization for 15 RXs was applied in a case study of large building. Three TXs are installed in a chosen floor of such building to increase the accuracy which approaches a minimum value of (0, 0.1). The detailed results of position estimation for each RX relative to each TX are summarized in Table V. While themaximum value of error using single TX reached (1.61, 0.06) from TX-1 in RX-13, (0.2, 0.59) from TX-2 in RX-14 and

(1.98, 0.82) from TX-3 in RX-14, the minimum value of error approach (0.11, 0) from TX-1 in RX-14, (0.01 ,0) from TX-2 in RX-5 and (0.01, 0.02) from TX-3 in RX-4, this result illustrated in Table V

3- Conclusion

In this paper, an estimation of position localization is applied for large building using AoA technique. Such building is chosen as a case study which represent as a part of college campus. Three TXs are installed in such area to experience the position location using AoA based on single TX, two TXs and three TXs. Fifteen RXs are deployed randomly in such case study which are represent the target objects to estimate their location. The result show that the estimated location is closed the actual position by minimum error of (0, 0.1). Also, the result show that estimated location is approach to the actual position when increasing the number of TX. But the payment and complexity will increased with increasing the number of TX.

<u>Suggestions for future work</u>

Some suggestions can be added that would increase the solidity of this work in thefuture, as follows :

-Increase the number of transmission units used

-Increase the number of reception units used

(As increasing the number of transmission and reception units is directly proportionalto the more accurate access angle)

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