



HYBRID ALGORITHM FOR INDOOR BASED LOCALIZATION

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Abstract

Localization algorithm plays a major role in different applications such as tracking, positioning, and monitoring. The general framework presented by localization approaches may not work well in practical environments, due to many reasons related to dealing with 2 Dimensional space only or having high computational costs. As a result, Hybrid Localization Algorithm (HLA) was proposed and presented in this paper based on the use of both Received Signal Strength (RSS) and Angle-of-Arrival (AoA). The algorithm has been tested in a 3 Dimensional indoor scenario, with considering the effects of different building materials. The obtained result indicate an effectiveness in localizing the received points by using 2 transmitters for more accuracy in positioning coordination with the average ranging error of less than 0.23m for both Line of Sight (LoS) and Non Line of Sight (NLoS) cases.

Keywords : AoA, RSS, Localization algorithm, indoor, hybrid

I. Introduction

The development of smart phones and wireless devices has resulted in a wide range of services. The most interesting service was indoor localization. Such process can be defined as the process of obtaining the location of the device or the user in an internal environment [IV]. The services based indoor localization has increased its significant recently [XVII]. Due to its uses in many applications for tracking and monitoring. Despite Global Positioning System (GPS) has been used for outdoor localization, it shows ineffectiveness in indoor environment [XIV]. Localization based Indoor scenario has suffered from many challenges as compared to outdoor.

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These challenges were due to its complexity and the presence of different objects in the indoor environment [I]. As a result, the need for low and accurate indoor positioning system has been increased in the last few years [XI, XXII].

Recently, the efforts of researcher academy and industry have resulted in contributing many approaches for both accurate and low cost localization methods for indoor environment [VI, XVI, III, XII]. One of the most interesting methods was based on the use of Angle of Arrival (AoA) measurement, where the orientation of radio frequency (RF) waves have been determined [X]. AoA has been utilized to obtain the direction by measuring the difference in time of arrival for elements individually of an array of points and by obtaining these delays the AoA can be estimated easily. Many researchers have focused on improving localization using AoA technique as in [XX] and by using directional antenna. However, their method has required extra time and cost. In addition, other researchers estimated AoA by finding the Mean Received Power (MRP) and determine the Time of Arrival (ToA) value to obtain the orientation and θ to achieve better estimation in indoor localization [VII]. Furthermore, in [X] localization based AoA has been presented by using two Access Point (AP) devices to estimate the location of 10 random unknown locations. However, their method shows inaccurate results where the estimation error for each location was about 2.5 meter. On the other hand, researcher in [XXI] uses channel state information for localization and by using four AP devices, the researchers could achieve an accuracy of 6.5 meter. While, by increasing the number of utilized AP devices such accuracy has been increased up to 5 meter. However, their method has been reported to be required many devices and the results didn't reach the required. In addition to that, an infrastructure for the estimation of AoA has been proposed in an indoor environment [II]. However, this method achieves accuracy of less than 2 meter. Meanwhile, great efforts have been made by researchers in [XXIV] to propose system for localization and based on using both Received Signal Strength (RSS) and AoA. Their presented algorithm could achieve about 10 cm average in localization error for a small area. However, the presented algorithm has not been tested for a large indoor environment.

In this work, a localization method based on the use of AoA and RSS has been presented and investigated. The presented algorithm used to locate several received points within the entire targeted building and with considering the multi-floor localization. Building materials effects have been considered with this work, and based on the use of Wireless In Site (WI) simulation software [XVIII]. The paper was divided into sections, section II described the localization based hybrid approach. Section III and IV presents the Hybrid localization algorithm and the case study respectively. The obtained results would be discussed in section V and finally the conclusion is listed in section VI.

II. Localization based hybrid method

Recently, the method of hybrid localization has gain higher emphasize by researchers due to reason of its higher accuracy and being used in a wide range of applications. Range based hybrid approach is one type of such localization, which can

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be any combination of ToA, TDoA, AoA and RSS [VIII, V]. The most interesting combination was the RSS-AoA based hybrid localization, which has a significant in improving the estimation accuracy at lower cost [V]. For that reason, the measurement of AoA has been used to achieve self-localization. While, RSS could be obtained easily with low accuracy in the harsh environment. Furthermore, such hybrid method doesn't require a time synchronization procedure as it required in ToA and TDoA [XXIII].

Angle of Arrival (AoA)

It can be defined as the angle between a reference direction known as orientation and the direction of path propagation of an incident wave. AoA is measured and presented in degree and it has an absolute value when the orientation is zero or pointing to the north. Otherwise, it would have relative value [XV]. AoA can be represented by two main values, which are $(\theta$ and ϕ). The representation of these two angles in the axis coordination can be seen in Figure 1.

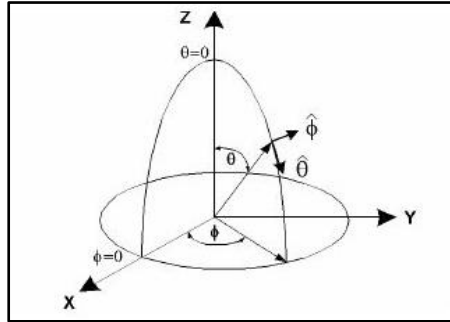


Fig. 1: The representation of theta and phi angle for AoA based method.

The calculation for the Direction of Arrival (DoA) depends on these two values and can be calculated based on equation 1[XVIII]

$$g_{\theta}(\theta, \Phi) = \sqrt{|G_{\theta}(\theta, \Phi)|} e^{j\psi_{\theta}} \quad (1)$$

Where G_{θ} the theta component of the receiving antenna is gain and ψ_{θ} is the relative phase of the θ component of the far zone electric field. For our scenario these two angles would be calculated via WI software.

Received Signal Strength (RSS)

It represents the indication for signal strength which measured the power value transmitted from an AP and received by the receiver or reference point (Rx) [XIV]. In recent localization approaches Received Signal Strength was one of the most significant aspects. This significant has been increased since most of the wireless AP devices provide direct access to the RSS measurement [XIII]. It is worth

noting that RSS represent the summation of the received power, total noise and interferences and as expressed in equation 2 [XVIII].

$$RSS = P_R + I_{Total} + N_{Total} \quad (2)$$

Where P_R represent the received power value obtained from the received point, I_{Total} represent the value of the total interferences and N_{Total} represent the total noise in the system. For our scenario, WI software will consider the value of P_R and calculate based on below equation 3 [XVIII].

$$P_R = \sum_{i=1}^{NP} \frac{\lambda^2 \beta}{8\pi\eta_0} |E_{\theta,i}(\theta_i, \Phi_i) + E_{\phi,i}(\theta_i, \Phi_i)|^2 \quad (3)$$

Where λ represents the wavelength, β is the spectrum overlapping, η_0 is the impedance of the free space, $E_{\theta,i}$ and $E_{\phi,i}$ are the components of theta and phi of the electric field of the i^{th} path at the receiver point, NP is the total number of paths and finally θ_i, Φ_i gives the direction of arrival.

III. Hybrid Localization Algorithm (HLA)

It has been designed a hybrid algorithm for the purpose of localization estimation for indoor environments. This algorithm has been designed by using Matlab program shown in figure 2. The flowchart of the algorithm has been drawn as seen in figure 3. The first step of the HLA is to prepare the database and collect the data from WI software based on both RSS and AoA parameters. The next step is to enter the AP coordination of XT_x and YT_x, which is supposed to be known for our localization algorithm. Then the algorithm would obtain the optimum path based on the values of RSS of each received point and from each AP device. Based on the previous step the several parameters of optimum path would be selected such as distance, theta (θ) and phi (Φ). The algorithm would calculate the angle between the AP and the received point $\beta_{AP, Rx}$ and based on equation 4. The final step includes calculating the values of x and y coordination for the received point or target within the indoor environment based on equation 5 and 6 respectively. Please follow this logic in writing the paper: first, briefly highlight the idea, then describe the methods for achieving the goal and the planned results, and only after that proceed to the detailed presentation. When reviewing the literature, you should not simply list the sources, but analyze them. You should explain with specific examples what has already been done by other scholars, what tasks are ahead, and in which direction you plan to move, that is, you have to introduce the reader to the research background and explain the place of your study in it.

$$\beta_{AP, Rx} = \alpha + \pi. \quad (4)$$

Where α is direction of arrival in phi (Φ) which has been obtained from WI software and for each received point.

$$X_{Rx} = X_{Tx} + d \times \cos(\beta) \quad (5)$$

$$Y_{Rx} = Y_{Tx} + d \times \sin(\beta) \quad (6)$$

Where (X_{Rx}, Y_{Rx}) represent the coordination of the targeted received point which represent the output of our presented algorithm.

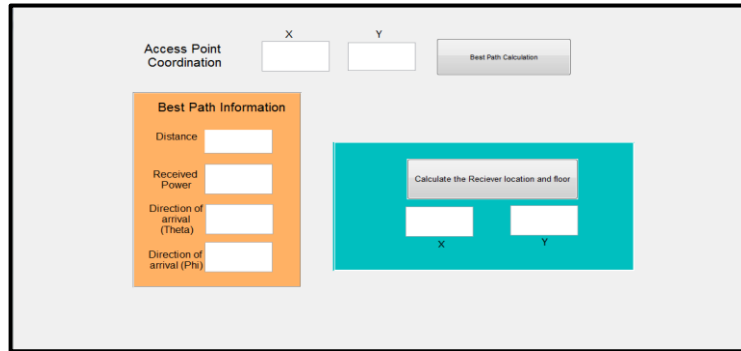


Fig. 2: GUI window for the Hybrid Localization Algorithm

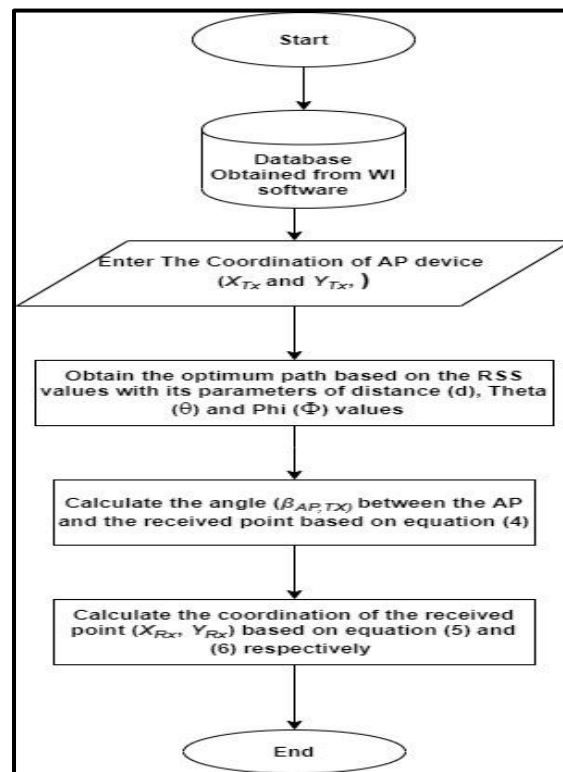


Fig. 3: Flowchart of our proposed localization algorithm.

IV. Case Study

The site intended for investigation in this work is the building of electrical department in university of technology which consists of ground and 4 floors. The case study has been designed, modelled and simulated using wireless In Site software and shown in figure 4. The floors selected for investigation were the 2nd and 3th floors, where it has been deployed two predefined transmitters per each floor. For the received point which will be considered as the target points for testing our presenting localization algorithm, it has been distributed 11 and 10 points for the two investigated floor respectively. Such distribution was based on the structure requirement of our targeted building. The distribution location of each AP and received point per each floor can be seen in figure 5. In addition, the properties of these devices were pictured in Table 1. In context, the serious effects of different building materials on propagation characteristics were taken into consideration by obtaining the value of Relative Permittivity (ϵ) and Conductivity (σ) as listed in table 2 and as recommended by International Telecommunication Union (ITU) [IX]. It is worth to mention, that the selected bandwidth is 20 MHz working with 2.4 GHz frequency.

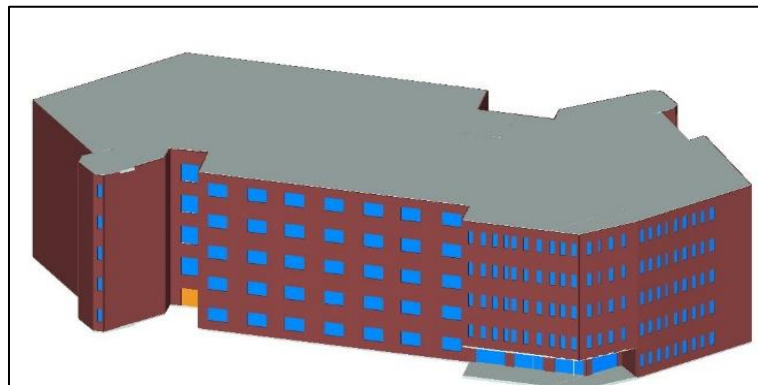


Fig. 4: The simulated model of the targeted building

Table 1: The antenna proprieties of AP and receivers.

properties	AP Antenna	Rx Antenna
Antenna type	Omni-Directional	Omni-Directional
Power (in dBm)	30	-
Antenna Gain (dBi)	9	2
E-Plane HPBW	90°	90°
Polarization	V	V

Table 2: Material values for each utilized material in our case study

Materials	Thickness (cm)	ϵ	σ
Concrete	30	5.31	0.066
Wood	4.5	1.99	0.012
Glass	0.3	6.27	0.012
Brick	28	3.75	0.038
Drywall	0.9	2.94	0.021

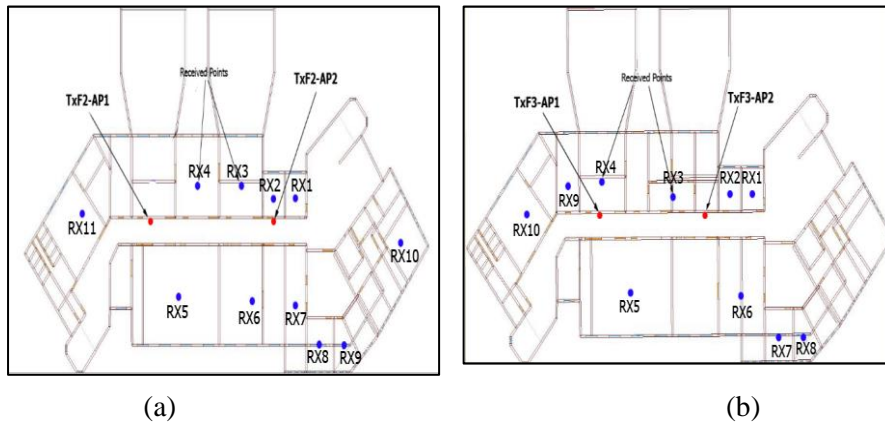


Fig. 5: The distribution of AP's and received points per (a) 2nd floor and (b) 3rd floor.

V. Result and Discussion

The previous displayed case study has been investigated using WI software. The result obtained from this software will form the database for our HLA. Result obtained from our proposed algorithm for localization estimation in both 2nd and 3rd floor can be seen in figure 6 and 7 respectively, where it can be notice that the estimated locations are very close to the actual locations, which verify the accuracy of the proposed algorithm. The values of all requested parameters such as Optimum Path (OP) RSS, distance, theta angle value and the estimated locations coordination from both Tx's have been listed in Table 3 and 4 and for both 2nd and 3rd floor respectively. It's worth to mention, that the obtained parameters and coordination represent the values for the optimum path based on RSS signal in each received point. They should be referred to in numerical order. Number the tables sequentially, according to their appearance in the text.

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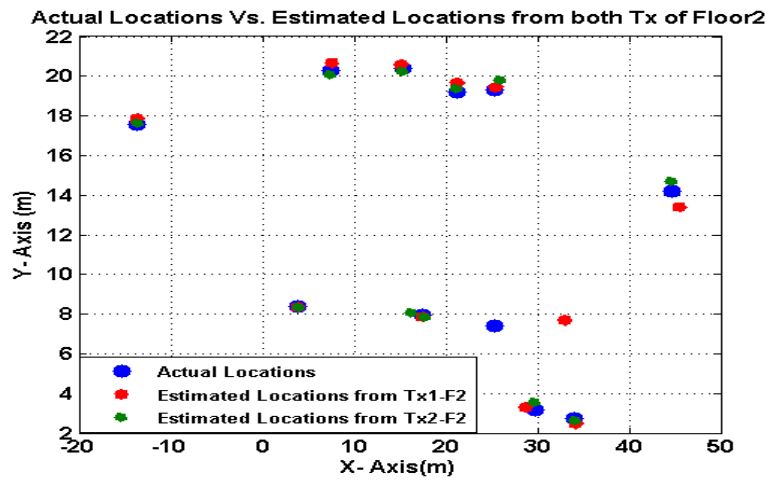


Fig. 6: The actual and estimated coordinates of RXs in the 2nd floor.

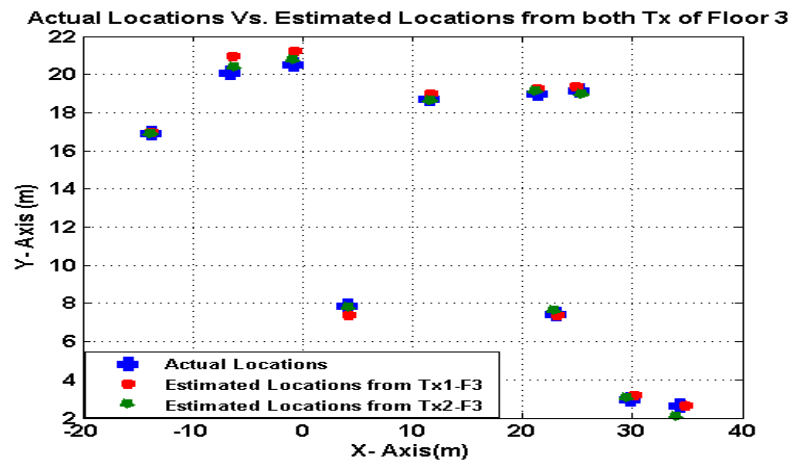


Fig. 7: The actual and estimated coordinates of RXs on the 3rd floor.

Furthermore, the average estimated coordination's has been compared with actual coordination's for each floor and as seen in figure 8 and 9. Where it can be seen that more accurate results have been achieved by taking the average values of the estimated coordination's from the two transmitters in each floor. As a result, the ranging error has been calculated for both scenarios and listed in Table 5 and 6 for the same two floors respectively. It can be seen that the coordination minimum error was (0.003, 0.018) m and the coordination maximum error was (0.618, 0.453) m for the second floor. While, for the third these values were (0.039105, 0.0143) m and (0.315, 0.584) m for minimum and maximum coordination errors respectively. Meanwhile, the average ranging error for positioning was (0.234, 0.193) and (0.103, 0.225) for 2nd and 3rd floor respectively.

Table 3: The Tx locations and estimated Rx locations for 2nd floor

Rx's	TX2 -F2 (21.4158,16.7108)					TX1-F2 (-1.0245,16.4809)				
	OP(RSS)	d	α	x	y	OP(RSS)	d	α	x	y
Rx1	-37.167	4.86988	214.07	25.4498	19.4389	-55.83	31.1692	344.49	26.0587	19.8158
Rx2	-21.049	2.9309	272.75	21.2752	19.6383	-55.832	23.5547	199.58	21.1682	19.3746
Rx3	-38.99	16.3588	212.83	15.1618	20.5797	-53.466	18.509	208.22	15.2845	20.233
Rx4	-52.82	16.4705	327.14	7.5806	20.6475	-40.235	12.0707	225.32	7.46296	20.0637
Rx5	-49.566	19.4376	25.49	3.87029	8.34578	-29.64	9.56916	121.41	3.96255	8.31401
Rx6	-29.443	9.68098	66.14	17.4998	7.85719	-37.157	20.6999	155.34	17.7876	7.84422
Rx7	-40.008	14.7112	142.04	33.0147	7.66179	-62.88	30.0468	125.19	16.2912	8.07471
Rx8	-54.633	16.1979	116.99	28.767	3.27711	-58.232	33.6516	155.92	29.6986	3.55065
Rx9	-32.6	22.3372	97.32	34.2618	2.44434	-81.557	37.854	158.5	34.1955	2.60736
Rx10	-68.026	24.3875	172.13	45.5736	13.3715	-67.506	45.7071	177.74	44.647	14.6785
Rx11	-42.235	35.5721	350.1	-13.627	17.8267	-26.972	13.9326	333.9	-13.536	17.6104

Table 4: The Tx locations and estimated Rx locations for 3rd floor

Rx's	TXF3-AP2 (17.1219,16.6987)					TXF3-API (-0.9786,16.6043)				
	OP(RSS)	d	α	x	y	OP(RSS)	d	α	x	y
Rx1	-37.864	14.4377	327.98	24.8807	19.3538	-55.28	27.1811	193.5	25.4515	18.9496
Rx2	-27.186	8.63125	240.64	21.3538	19.2213	-53.989	27.055	346.02	21.2322	19.1403
Rx3	-27.582	9.0765	306.53	11.7192	18.9921	-40.789	14.45	209.18	11.6376	18.6495
Rx4	-47.591	20.2016	331.97	-0.7101	21.1921	-22.678	4.1561	267.45	-0.7937	20.7563
Rx5	-42.056	15.954	35.86	4.19197	7.35274	-30.131	10.226	120.46	4.20533	7.78966
Rx6	-30.923	11.1191	122.89	23.1599	7.36181	-41.068	28.1767	147.93	22.8983	7.64374
Rx7	-47.346	18.8029	133.92	30.1646	3.15484	-54.119	36.284	147.14	29.4999	3.08297
Rx8	-34.722	26.612	98.03	34.8394	2.65237	-76.911	37.928	157.45	34.0496	2.05931
Rx9	-56.255	25.205	338.46	-6.3228	20.9527	-38.544	10.2189	300.68	-6.1927	20.3929
Rx10	-39.809	30.887	359.5	-13.764	16.9682	-32.235	12.84	358.61	-13.815	16.9158

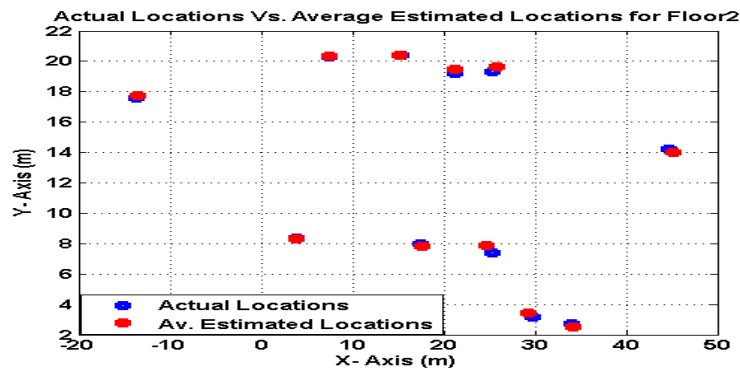


Fig. 8: The actual locations Vs. Av. estimated locations of floor2.

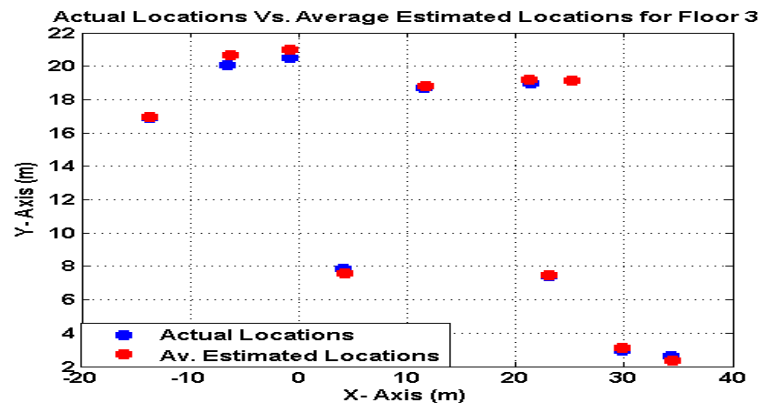


Fig. 9: The actual locations Vs. Av. estimated locations of floor3.

Table 5: Comparison between actual locations vs. Average estimated locations and

Rx's	Actual Location		Av. Estimated Location		Ranging Error	
	X	Y	X	Y	X	Y
Rx1	25.258	19.2997	25.75425	19.62735	0.49625	0.32765
Rx2	21.2941	19.2258	21.2217	19.50645	0.0724	0.28065
Rx3	15.3298	20.3874	15.22315	20.40635	0.10665	0.01895
Rx4	7.4859	20.2784	7.52178	20.3556	0.03588	0.0772
Rx5	3.9132	8.3904	3.91642	8.329895	0.00322	0.0605
Rx6	17.5344	7.9697	17.6437	7.850705	0.1093	0.119
Rx7	25.2715	7.4151	24.65295	7.86825	0.61855	0.45315
Rx8	29.6729	3.1792	29.2328	3.41388	0.4401	0.23468
Rx9	34.0779	2.7377	34.22865	2.52585	0.15075	0.21185
Rx10	44.6007	14.2229	45.1103	14.025	0.5096	0.1979
Rx11	-13.6221	17.5757	-13.5815	17.71855	0.0406	0.14285

ranging error for second floor localization.

Table 6: Comparison between actual locations vs. Average estimated locations and ranging error for third floor localization.

Rx's	Actual Location		Average estimated location		Ranging Error	
	X	Y	X	Y	X	Y
Rx1	25.13	19.14	25.17	19.15	0.039	0.014
Rx2	21.41	18.97	21.29	19.18	0.117	0.209
Rx3	11.60	18.68	11.68	18.82	0.077	0.142
Rx4	-0.81	20.48	-0.75	20.97	0.054	0.498
Rx5	4.15	7.88	4.20	7.57	0.053	0.311
Rx6	23.10	7.45	23.03	7.50	0.075	0.056
Rx7	29.87	2.96	29.83	3.12	0.042	0.155
Rx8	34.24	2.61	34.44	2.36	0.204	0.251
Rx9	-6.57	20.09	-6.26	20.67	0.315	0.585
Rx10	-13.73	16.91	-13.79	16.94	0.061	0.03

VI. Conclusion

In this work, it has been designed a Hybrid Localization Algorithm for both low cost and computational process. Algorithm works based on the use of RSS and AoA, where RSS is used to select the optimum path, which will select the desired parameters based on these paths for each tested received point. The localization estimation has been based on the use of direction angles of theta and phi for each optimum path in each received point. Obtained results indicate high accurate indoor localization estimation with average ranging error of less than 0.23 m for both LoS and NLoS cases and by only using two transmitters or Access points. For the future, the presented algorithm could be developed and tested for localizing multi-floor scenarios.

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