



AN ENHANCED STUDY ON LOCALIZATION OF WIRELESS SENSOR NETWORKS USING MOBILE ANCHOR NODES

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Abstract

Localization is done with many different sensors in many different applications. Outdoor localization in an extremely static WSN typically uses several static anchor nodes with well-known positions to assist the localization of the blind nodes. These static anchor nodes that self-using GPS usually are more expensive and this contributes to a higher system cost. Differences between localization from static anchors and mobile anchors are Path designing it should be pre-planned, or it may react to data from blind-nodes. Localization of nodes with range-based techniques involves estimating the distance between a transmitter and receiver by using features of the transmitted signal like a radio signal Strength Indicator (RSSI) as delineated in this paper. This paper explores the use of mobile anchor nodes moving through a sensor field to localize the nodes in an outdoor setting using multilateration technique.

Keywords : Localization, Sensor Networks, Mobile anchor nodes, Airborne anchors, Anchor node

I. Introduction

Wireless sensor networks (WSNs) are a significant category of pervasive computing environments. WSNs are delineated as one of the important technologies in the Internet of Things (IoT) as a new tool for gathering data on the natural world, extending the reach of our human senses. WSNs consist of networks of sensitive detector nodes that are deployed in real environments and they are typically small, low-cost devices with limited capability for processing. The applications of WSN are monumental, such as in military, civil, and environmental applications [I]. The sensors will detect scalar characteristics such as temperature or multimedia system features such as audio and video in environmental monitoring. In some cases where

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sensors are deployed remotely, the precise geolocation of sensor nodes is automatically determined when preparation is usually important to cover the origin of events in indoor and outdoor applications. Parenthetically, the place of a bushfire cannot be identified without the exact location of temperature readings in the forest. To date, several algorithms have been suggested to solve device localization problems. Many of the published algorithms are suitable for specific conditions, comparable to mobile phone indoor localization or outdoor localization using a small range of geo-located anchor nodes.

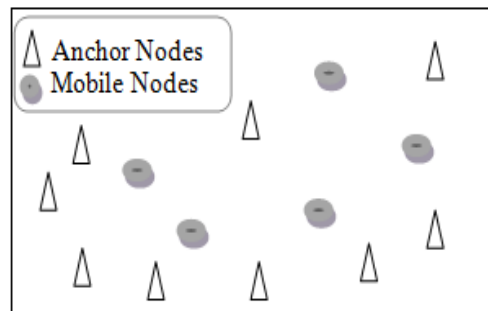


Fig. 1: Anchor vs Mobile Nodes

Localization requires finding the position of an item in place. Localization can be two-dimensional (2D), such as finding a position on a map, or 3-dimensional (3D) position, such as locating height, latitude, and longitude. Localization can also be 4D if the location includes tracking a moving object's positions over time. This paper deals with the 3D location of static items, in this case, WSN nodes, using a portable anchor, in this case, an unmanned aerial vehicle (UAV) can be presumed. My study focuses on one very narrow field of location, the localization of wireless sensor nodes, which determines their position based on wireless communication with other known position nodes.

Throughout this paper, the following terms are used;

1. An anchor node is a node with a well-known position that acts as a target reference node and transmits packets of beacons including its current position. There is also a fixed or mobile anchor node.
2. A mobile anchor node is a moving anchor node that transmits beacon packets regularly across the deployment region.
3. A blind node is a node with an unidentified location within the deployment region. It utilizes data for estimating its position in various beacon packets.
4. A static node may be a node whose position when deployed remains unchanged. All blind nodes are static nodes during this research.
5. A local anchor is a blind node initially. It serves as an anchor node for other blind nodes when it is located.

Localization starts with the acquisition of input data such as the location of the anchor nodes and their anticipated range signal as shown in Figure 1 based on these inputs, the altitude or angle between the anchor and the blind nodes will be determined, therefore determining the estimated position of the blind nodes will be calculated.

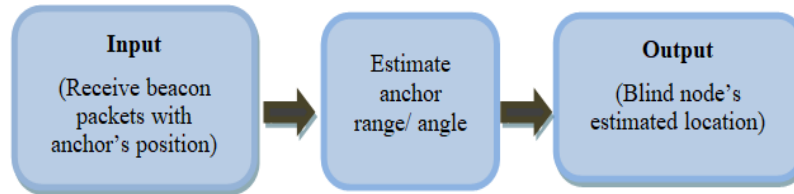


Fig. 2: Localization process in distance-based wireless Localization

II. Previous Work with Airborne Anchors

Kumar et.al. [XIV] used three beacon messages to locate a node dispersed by a GPS-equipped floating anchor. Calculation time is saved by the law and few bases are used. Yadav et.al. [XXI] though indicates that victimization over 3 beacon messages reduces the failure of location. In this case, the original research used an algorithm that separately endorsed the range-free sphere equation to calculate the node location. Using RSSI numbers of four anchor nodes, this job has been enhanced by implementing the complexity-reduced 3D-lateration localization approach (COLA). While it is a stronger price of computing, the algorithm offers greater precision of place.

Ssu et al. [XX] created a system for localization using the conjecture of geometry, that is, the chord's perpendicular bisector. If two chords are acquired, it is easy to calculate the place of the sensor node depending on the conjecture. In [II], instead of using complete RSSI numbers, comparing the recorded RSSI scores from the portable beacon to a sensor node, the horizontal junction (PI) uses the PI geometric relationship to calculate the node's location. Guerrero et al. [IX] intruded an azimuth-defined zone location (ADAL) method that uses a beacon node with a rotary directional antenna to periodically transmit messages in a determined azimuth and uses an unidentified node.

Table 1: Previous works with airborne anchors

Proposals (Refs)	Proposed Algorithms	Accuracy takes place	Strengths/ Weaknesses
Kumar et. al. [XIV]	Range free using three beacon message	+/- 1m	+Few anchors. +Reduce computation times. -Random waypoint/ random direction walk -Trilateration

Yadav et. al. [XX]	Range free/ Connectivity Range	No error if the beacon message is at the surface of connectivity range	+Reduce overhead +Reduce memory resource
Seo & Kim et. al. [XVIII]	COLA/ RSSI	+/- 2 to 4m	-Trilateration +Reduce computational cost by using typical trilateration for 3D trilateration
Chia-Ho & Kuo-Feng et.al. [VI]	RSSI Range-free Chord selection Scheme	+/- 1m	+ Few anchors. -Assumes a perfectly predictable range.
Abdi & Haghighat et. al. [I]	RSSI Neighbor Scheme/ Anchor Return Scheme/ Three Nodes Scheme	+/- 1.5m	-Only use three neighbor nodes + Improve average localization error and reduce average location error with a steeper slope

Numerous techniques of improvement comparable to chord selection and jittered beacon scheduling improve their node positioning. The algorithm requires into consideration the anchor's GPS errors and works fairly well in terms of positioning period and low noise beacon. This study, however, used a range-free algorithm that encompasses comparatively small precision of localization.

III. Multilateration Algorithm

The localization of range-based devices includes an estimation of the transmission range to the receiver by using characteristics similar to the Radio Signal Strength Indicator (RSSI) as defined in the prior section. Then, using a suitable localization method such as multilateration, the approximate range is used to determine the localization of the blind nodes. Multilateration is achieved in second by connecting at least three circles (trilateration) and in 3D space by intersecting at best four spheres centered on four anchors. Multilateration offers a statistical method error solution for more than the minimum range of spheres, followed by base bases. Multilateration as described in [XI] is an expansion to trilateration [IV] and the impact of distance error in positioning is usually inverted by extra bases. The algorithm distinguishes the position of the blind node, located at the intersection of the spheres centered on the anchors in Figure 2 where the anchors A1 to A5 are well-known or B is the blind node.

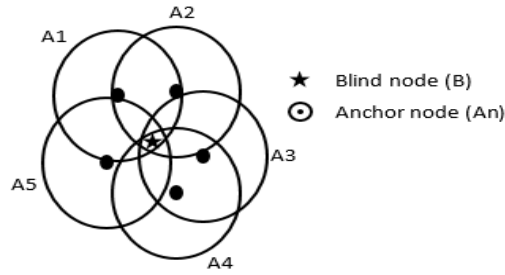


Fig. 3: Intersection points of spheres in Multilateration

The areas are described as in the above figure as ;

$$(x-x_i)^2 + (y-y_i)^2 + (z-z_i)^2 = d_i^2 \quad (i=1,2,\dots,nR) \quad (1)$$

Where, x , y and z are the blind node's location, x_i , y_i and z_i are the named anchor node locations from one to nR , and d_i is the range between the blind node and i . However, for calculating x , y , z , d_i parameters are used in the next section.

Deterministic Multilateration (DML):

This section in methodology reconstructs the equations and results used to define the DML algorithm. The DML algorithm range estimates will be focused on the Log-Normal Shadowing model. The path-loss equation for a specified range can be calculated using equation (2), reiterated here for convenience, to calculate the range estimation dx between the moving anchor node and the blind node.

$$dx = 10 * [(PL(dx) - PL(d_0)) / (10.n)] \quad (2)$$

Referring to Flip ambiguities in the literature review, multilateration solves the unknown position of node B, using n beacons, numbered 1 to n , at positions $[x_i, y_i, z_i]$ and at estimated distance r_i from node B. We can define a matrix A with $n-1$ rows of the form;

$$[(x_n - x_i) \quad (y_n - y_i) \quad (z_n - z_i)] \quad (3)$$

Where x_n , y_n , and z_n are the x , y , and z position of the mobile anchor beacon position and x_i , y_i , and z_i is the position of the i th blind node position.

We also can define a column range vector r , with each row of the form;

$$(1/2)((x_n^2 + y_n^2 - r_n^2) - (x_i^2 + y_i^2 - r_i^2)) \quad (4)$$

Then we solve for the blind node position;

$$x = [x \quad y \quad z]^T \quad (5)$$

By solving the matrix;

$$A x = r \quad (6)$$

$$\text{Giving} \quad x = A^\# r \quad (7)$$

$$\text{Where } A^\# \text{ is the pseudo inverse, } (A^T \cdot A)^{-1} \cdot A^T \quad (8)$$

If there are more beacons than are required for a solution, the least-square error solution is provided by this method.

IV. Results and Analysis

Three (3) distinct models with distinct topologies will be explored in addition to examine the relative efficiency of mobile versus fixed anchors, including the differences in the amount of mobile anchor nodes. For position estimation, deterministic localization will be used. The simulation is performed on three experiments;

- 1) The position of the blind node through the designated flight path.
- 2) Localization of the blind node using fixed static anchors. The limitations and the practicality to locate the blind node by using four fixed anchors in the viewing region will be explored.
- 3) Blind node localization through a combination of mobile and fixed anchor nodes. Different scenarios for RSSI variables are contrasted in these experiments: a low variability scenario (standard deviation of RSSI at a given range is 1dB), a medium variability scenario (3.4dB), and a high variability scenario (5dB).

Localization of the Blind Node Using the Designated Flight Path

The results of the fixed set of 12 anchors at a height of below 10 meters are shown in Figure 3 and Table 2. The model is clearer here and comparable to all variation levels. For the 4 simplest anchors the error is pretty massive; reduces because so many patterns are used until the RSSI variation of 5dB relates to 10 anchors. As the range of anchors increases, the error increases again as optional "poorer" anchors are used. This shows clearly that "more anchors are not always better to use continuously." There are a preferred number of anchors that provide the highest variability with a specified variation and normal variation: 8 anchors for small variation, 10 medium anchors, and 12 elevated dimension anchors.

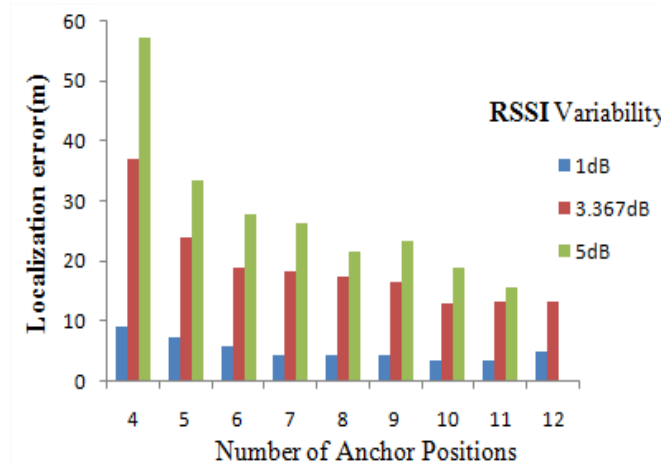


Fig 4: Average localization error for 12 mobile anchors with specified RSSI variability flight path positions.

Table 2:
Localization error for 12 different mobile anchor nodes at RSSI variability.

Standard deviation	Number of anchor positions								
	4	5	6	7	8	9	10	11	12
1	8.92	7.16	5.73	4.28	4.23	4.15	3.26	3.18	4.78
3.367	36.75	23.84	18.86	18.07	17.14	16.42	12.92	12.99	13.02
5	57.14	33.12	27.66	26.09	21.48	23.24	18.63	15.42	NA

Number of anchor positions

Localization of the Blind Node Using Fixed Static Anchors 1 3.367 5

Experiment 3 results with 4 fixed anchors at the ground level of the area at various places (20, 20, 0 and 40, 20, 0) are illustrated in figures 4 and 5. 4 fixed anchor results are higher than the best 4 mobile anchors in figure 4, with distinct RSSI variation in terms of the localization error. The localization error in Figure 4 is reduced to 3 and 9 meters, respectively. For 1dB and 3.367dB, the localization error is shown in the preceding Figure 3. The four fixed nodes are better placed to locate the blind node in the center of a region (20, 20, 0). Only low and medium variability nodes can be located in this simulation. Using a high RSSI localization variability, the receiver sensitivity limitation results in an unlocalized node. The localization error, for example, when the blind node is 40, 20, 0, may, however, be increased or not located concerning other layouts. The result shows an improvement in localization error in a certain layout using four fixed anchors. Therefore, the previous section examines another extension of the combination of these fixed anchors with the strongest mobile anchor node.

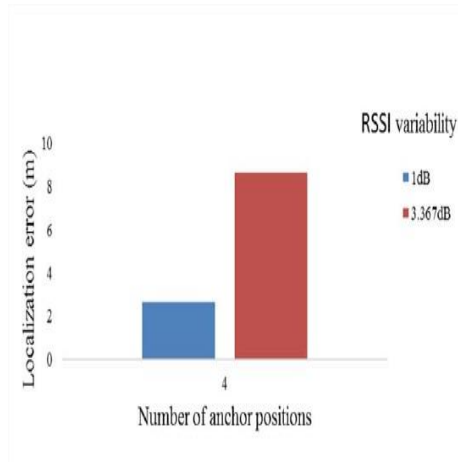


Table 3: Localization error using four fixed anchors

Standard deviation	Number of anchor positions
	4
1	3.64
3.367	9.65
6	NA

Fig. 4: Localization error with 4 fixed node anchors at 20,20,0.

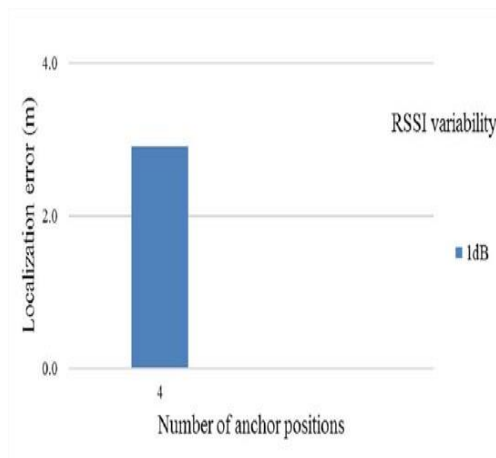


Table 4: Localization error using four fixed anchors

Standard deviation	Number of anchor positions
	4
1	3.91
3.367	NA
5	NA

Fig 5: Localization error using four fixed anchors only for the blind node at 40, 20, 0.

Localization of the Blind Node Using a Combination of Fixed and Mobile Anchor Node:

The results from combining the four fixed anchors and the 12 mobile anchor nodes on the flight path, and choosing the most efficacious N outcomes are presented in Figure 6 and Table 5. The graph shows only the 12 most simple anchor positions.

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When using anchor combination, the ideal amount of mobile anchor nodes is also around 6 to 10 positions. Localization using anchor node combinations shows no significant error corrections, as results for all factors are analogous to the results of mobile anchor nodes. These similarities are presented in depth in the following section.

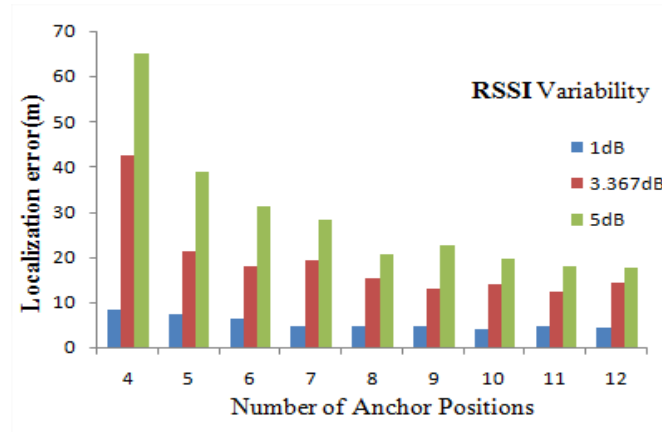


Fig. 6: Localization of fixed blind node on the ground using a combination of fixed anchor and designated position of the mobile anchor node

Table 5: Localization error for 16 anchors at different RSSI variability.

Standard deviation	Number of anchor positions								
	4	5	6	7	8	9	10	11	12
1	8.17	7.46	6.42	4.72	4.53	4.67	3.96	4.68	4.17
3.367	42.56	21.15	17.96	19.13	15.26	13.08	13.89	12.14	14.26
5	65.18	38.97	31.15	28.31	20.64	22.49	19.64	18.05	17.48

However, it may not always be easy to combine four fixed anchors with the highest mobile

anchors. In comparison to mobile anchors in this graph, most fixed points, for example, 0, 50, 0 have a long distance of 46 meters.

Comparison of RSSI Variabilities for Fixed, Mobile, and Combination Anchor:

Figure 7 and Table 7 compare the results of fixed (4 positions only), mobile (best 4 to 12) and fixed and mobile (best 4 to 12). Figure 7 shows low variability, figure 8 shows medium variability, while figure 9 shows high variability results. The error from the combination of anchors is adequate to or worse than the case of mobile anchor nodes solely, once more reflective that “more anchors aren't continually better”.

Table 6: New position of anchor nodes (fixed and mobile anchor) based on the shortest estimated distance in the meter.

Estimated distance (m)	Anchor position		
	X	Y	Z
3.95	34	34	7
6.75	32	32	6
11.24	24	34	6
18.56	43	35	8
19.68	14	25	6
23.72	45	20	9
28.56	10	0	10
32.67	50	0	0
39.09	50	50	0
47.99	0	0	10
55.07	5	50	9

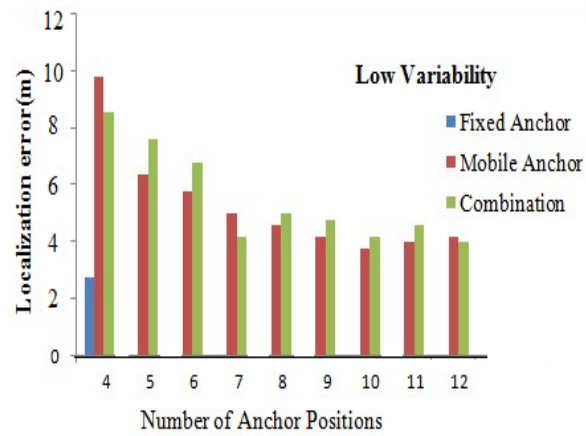


Fig. 7: Comparison of 4 fixed anchors, the best 4 to 12 mobile anchor node positions, and the best 4 to 12 combination of fixed and mobile anchor positions with low variability

Table 7: Localization accuracy for the different scenarios with low variability.

Scenario	Number of anchor positions								
	4	5	6	7	8	9	10	11	12
4 fixed anchor	2.68	NA	NA	NA	NA	NA	NA	NA	NA
4-12 mobile	9.93	6.23	4.72	4.25	3.20	3.12	3.49	3.92	4.13
4-12 Combination	9.18	6.49	5.48	3.74	3.49	3.65	4.15	4.74	4.66

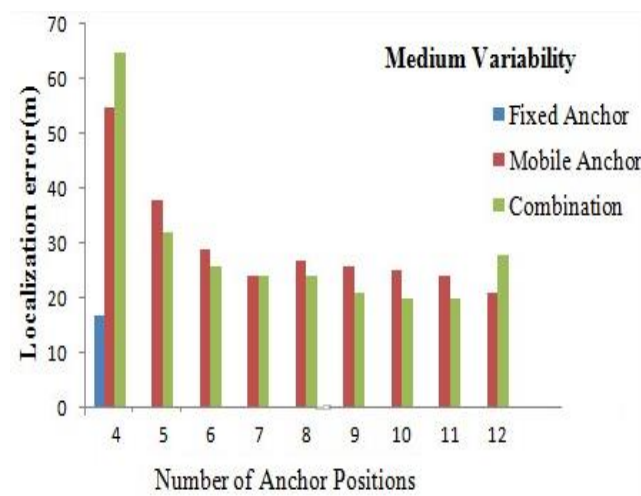


Fig. 8: Comparison of 4 fixed anchors, the best 4 to 12 mobile anchor node positions, and the best 4 to 12 combination of fixed and mobile anchor positions with medium variability.

Table 8: Localization accuracy for the different scenario with medium variability

Scenario	Number of anchor positions								
	4	5	6	7	8	9	10	11	12
4 fixed anchor	8.64	NA	NA	NA	NA	NA	NA	NA	NA
4-12 mobile	37.77	24.87	19.87	17.09	16.11	15.41	12.64	13.25	15.47
4-12 Combination	42.52	22.11	18.92	17.15	14.23	12.09	12.48	12.32	11.92

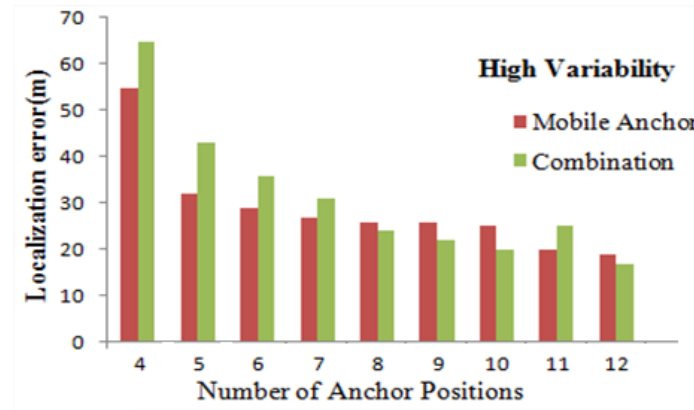


Fig. 9: Comparison of 4 fixed anchors, the best 4 to 12 mobile anchor node positions, and the best 4 to 12 combination of fixed and mobile anchor positions with high variability.

Table 9: Localization accuracy for the different scenarios with high variability.

Scenario	Number of anchor positions								
	4	5	6	7	8	9	10	11	12
4 fixed anchor	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-12 mobile	55.13	32.78	25.63	26.07	23.47	24.26	17.51	22.36	NA
4-12 Combination	64.22	38.97	31.15	25.23	22.71	22.46	15.97	16.58	16.36

In comparison to the predetermined and combination of fixed as well as Mobile anchor positions, random mobile anchor node positions provided greater precision. However, it is not easy to plan the mobile anchor trajectory, especially when several blind nodes are distributed somewhere else. There would be consistent results in smaller variables in RSSI readings. The normal localizing error in the RSSI variant was 3 m with 1dB variability, 13 m with 3.367dB variability, and approximately 12 m with a 6dB variant, for the simplest results. Therefore it indicates that RSSI variability can influence the accuracy of the location. Owing with its much higher geometry, but localization with only fixed anchors was not capable of a high RSSI variability, the fixed anchor situation yields higher results than the mobile anchor nodes compared to a low variability. Here, fixed anchors in the best areas to improve efficiency, but this is often not a very real situation wherever the node locations are uncontrolled. Surprisingly, due to the combination around poor anchor geometry, the combined set up of fixed and mobile anchor nodes did not make a substantial increase in precision.

V. Conclusion

This paper examined the location of wireless sensor nodes based on RSSI in a special bond with the motivating context of air-dropped sensors deployed through an airborne mobile anchor. The location accuracy relies on position whether the mobile anchor node points are geometrically arranged. The simplest anchors seem not to be the highest anchors. Therefore, anchor geometry is very important. To identify the blind nodes with insufficient beacon packets, the work will be improved on geometric sensitivity and mobile anchor trajectories with cooperative localization. Also, Cooperative localization can decrease the distance between the mobile anchor and the accuracy of the position.

Conflict of Interest :

Authors declared : No conflict of interest regarding this article.

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