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A RSSI Based Localization Algorithm for WSN Using a Mobile Anchor Node

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Abstract

Wireless sensor networks are attracting a great deal of research interest. One of the most interesting researches in these networks is localization of sensor nodes whose accurate is a strong requirement in many applications. In recent years, several techniques have been proposed for localization in wireless sensor networks. In this paper, we present a localization scheme using only one mobile anchor station with receiving signal strength indicator technique, which reduces average localization errors and execution time. The satisfactory simulation results and also comparison of localization errors and execution time between our scheme and similar previous schemes depicts the efficiency of proposed method against previous schemes.

Keywords: Average localization error, Localization, mobile anchor, received signal strength indicator, wireless sensor networks.

1. Introduction

A sensor network consists of a large number of sensor nodes which are placed within an area in an extensive and distributive manner to gather data and information about that place; location of these sensor nodes may not be known in advance and this characteristic makes it possible to use sensor nodes in inaccessible and very dangerous environments [1]. Manually configuring each node or equipping each node with a GPS (global positioning system) is not cost-effective at all due to low scalability, low energy and high costs. In most localization methods, a given number of nodes which are aware of their position are given reference or data guide roles [2].

Localization algorithms can be generally divided into two range-based and range-free parts. Range-based algorithms need distance or angle of nodes from each other to calculate position of each of them. Phase1 is estimating angle or distance and the second one is calculating position of nodes. All TDOA (time difference of arrival), AOA (angle of arrival), RSSI (received signal strength indicator) and TOA (time of arrival) methods which are used for estimating distance and Multilateration and Trilateration methods which are used for calculating the position are categorized in this node. Methods like Centroid, DV-Hop, Amorphous and several other algorithms could do positioning process using topology information,

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relationship between nodes and the number of steps between them. These methods have advantages such as low cost and not requiring additional hardware [3].

In this paper, a mobile anchor station was used by RSSI technique for estimating position of other sensor nodes. In Section2, the related works are studied; in Section3, the proposed algorithm is investigated. In Section4, the proposed method is evaluated and finally the conclusion and future works are discusses.

2. Related Works

In [4] a GPS-equipped mobile anchor(MA) was constantly circulating with unlimited energy and awareness about its position in a specified area while broadcasting its position information in a short distance. Other nodes which were considered to be fixed could estimate their positions by receiving this position information. When the mobile reference node entered radio radius of a fixed node, the fixed node received some beacon points (BP) that included current position of the mobile reference node and saved it in the list of visited (see Fig. 1).

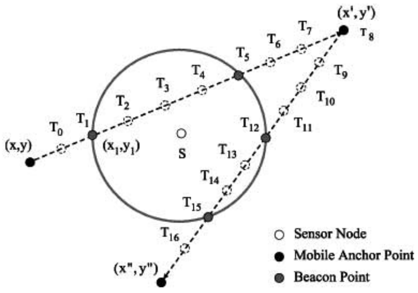

Fig. 1. Beacon point selection

From among the BPs in the MA moving path, the first and last ones were selected, only three of which were required for positioning. Location of the fixed sensor node was found by drawing two hypotenuses attached onto BP vertices, drawing their perpendicular bisectors and finding their section point.

Also, in [5] like in [4] algorithm, an MA broadcasted its location information and fixed nodes could estimate their position by receiving this information. So, the fixed node received some BPs; but, different BPs were selected and, for every BP, a separate receiving probablity was considered. In the first route, in which the mobile reference node passed through sensor node communication area, two BPs were selected from among the list of visited BPs; the first one at the entry time of mobile reference node by measuring strength rate of received signal and the second one by measuring the received signal strength with maximum rate of RSSIMax (see Fig. 2).

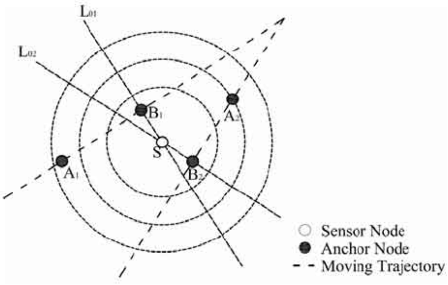

Fig. 2. Determination of sensor node location

In the second route of the mobile reference node from communication area of the sensor node, these two BPs were selected as mentioned above. After drawing hypotenuses passing these two BPs and the perpendicular bisector passing the second BP with RSSIMax and finding the cross section of the two inceptors, location of the sensor node was more precisely found in comparison to the previous algorithms. Guo's [6] scheme also utilizes the geometric relationship of a perpendicular intersection to compute node positions. To improve the localization accuracy of Ssu's scheme[4], an efficient scheme is suggested to estimate sensor locations from possible areas by using geometric constraints[7].

In [8] there was a change compared to previous algorithms; unlike previous algorithms, the reference node did not broadcast its location, but fixed sensor nodes periodically sent beacon messages with maximum power. The reference node calculated its distance from sensor nodes through receiving these messages using RSSI technique and the sensor node could position itself by receiving four different positions. MA movement plan was discussed and a general movement plan was recommended in [9]. Reference [10] introduce a methodological approach to the evaluation of localization Algorithms.

Selecting BPs was a bit different in [11], which presented its method as RGL. In the first passing of the reference node, two BPs were selected from the visited list; the first one was BP with maximum signal strength and the second one was the BP before maximum signal strength. These two selected points and the node itself formed a right triangle and two positions were considered for positioning the sensor by solving its formulations. In the second passing route of the reference node through communication area of the sensor node, another triangle like the above-mentioned one was obtained. Among these four points, two points with minimum distance were selected and average x and y values of these points were considered as spatial coordinates of the sensor node.

3. Proposed localization scheme

Here, there was only one mobile anchor node which estimated its distance from the sensor node using RSSI technique.

3.1. Assumption

- All sensor nodes are randomly distributed in the environment.
- Mobile reference node and other sensor nodes are fixed.
- Mobile reference node is equipped with a GPS and knows its position.
- Reference node has unlimited energy and is moving in the environment.
- A sensor node can only send or receive signal within its communication area.

Here, the reference node was moving directly, randomly and without any certain order in the environment and broadcasted its position with distance d. When the mobile reference node entered radio radius of a fixed node, the fixed node received BPs that included information about current position of mobile reference node and saved it in the visited list. By receiving each of BPs by the fixed sensor node, distance was also calculated by RSSI mechanism and saved in another list in sensor node memory.

Assume that the reference node enters radio radius of the sensor node and records n number of BPs with (xi, yi) spatial coordinates. The sensor node with (xu, yu) unknown coordinates knows its distance from each of the BPs recorded by the reference group with size ri. According to the Pythagorean Theorem:

$$\left(x_i - x_u\right)^2 + \left(y_i - y_u\right)^2 = r_i^2 \ ,i = 1..n \qquad (1)$$

In the first entry of the mobile reference node in to radio radius of the sensor node, the BPs with maximum received signal strength should be selected from among the BPs recorded in the sensor node memory in order to have minimum error in calculating position of a sensor node. Two values are needed for initial positioning in this list. The best selection includes values with PreRSSIMax and RSSIMax.

Now, three points (two BPs and one sensor node) and their distance from each other, which forms a triangle, are available. If there are sufficient BPs in radio radius of the sensor node, ideal state happens and the line connecting the sensor node and one of the BPs will be perpendicular on movement path of the mobile anchor node. Thus, the lowest error is present in calculating probable position of the sensor node.

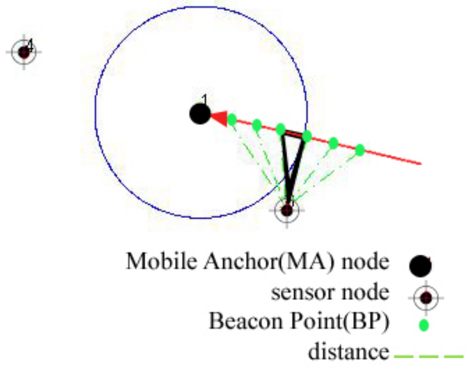

Fig. 3. BPs selected

3.2. Estimating Two Positions of the Sensor Node

Fig. 4 depicts the estimating to positions. According to the Trigonometric Laws, two equations are obtained:

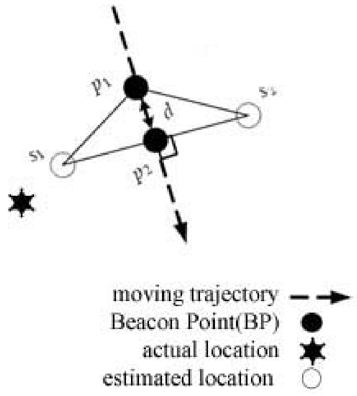

Fig. 4. Estimating two positions

$$h^2 = (x_2 - x_3)^2 + (y_2 - y_3)^2 \qquad (2)$$
$$d^2 + h^2 = (x_1 - x_3)^2 + (y_1 - y_3)^2$$

in which two BPs, P1 and P2 with known (x1, y1) and (x2, y2) coordinates, and the point (x3, y3) which is the sensor node coordinates, are unknown. Solving the equation yields two positions of S1 and S2, one of which is main position of the sensor node.

3.3. Selecting main location of fixed sensor node

Main location of the fixed sensor node and selecting from among S1 or S2 probable positions can be done using one of the following schemes:

3.3.1. Neighbor Scheme:

Localization is done via a newly localized sensor node within radio radius of the sensor node [12]. In other words, the localized sensor node appears as the fixed reference node and helps in localization of other sensor nodes. Accordingly, the sensor node is able to find its location via a newly localized neighbor node when experiencing passage of the reference node only once (see Fig. 5 and Fig. 6).

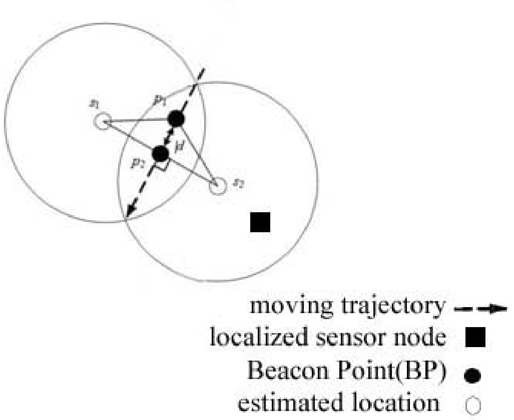

Fig. 5. Neighbor scheme

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\\ communication range of MA and sensors is R.
\\ localized neighbor sensor is T.
d1 = distance(S1, T)
d2 = distance(S2, T)
if ($d1 \ge R$ and $d2 \le R$)
location of the sensor node is S2.
Else if ($d1 \le R$ and $d2 \ge R$)
location of the sensor node is S1.
Else if ($d1 \le R$ and $d2 \le R$)
Wait for next status.
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Fig. 6. pseudo code for Neighbor scheme

3.3.2. Anchor Return Scheme:

Localization is done by second return of the reference node to communication area of the sensor node and recording two BPs in radio radius of the sensor node; i.e. there will be two more probable locations in addition to the two probable locations in the first passage. As a result, there will be four probable locations. Two out of these four probable locations are closer to each other and position of the sensor node is estimated by finding these two locations and calculating their average.

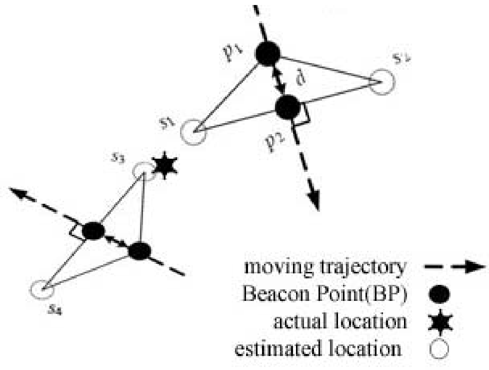

Fig. 9. Anchor Return Scheme

3.3.2. Three Nodes Scheme:

If one node does not meet or only once meets the mobile reference node, it may later face a state in which three or more localized fixed nodes are within radio radius of the localized node (see Fig. 10).

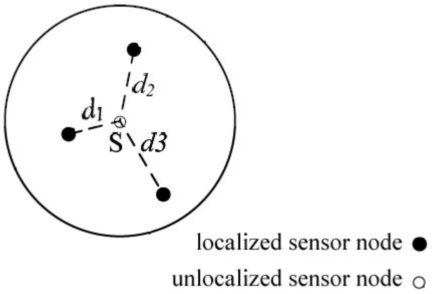

Fig. 10. Three Nodes Scheme

In this state, three neighbors with minimum distance from the fixed reference node are selected and localization is performed.

On the other hand, it is true that the three neighbor scheme enhances speed of the algorithm; however, there is increase of error rate in some cases in which three neighbor nodes have higher error in estimating their own positions.

Once a sensor node is localized, it has the opportunity of reposition itself every time the mobile reference node meets it in a smaller distance until the end of the algorithm; undoubtedly, the resulting error will be less than the previous error. Thus, new position will replace the previous one and is saved in the memory. Finally, a threshold limit is defined for a more precise localization so that localization is done whenever rate of received RSSI exceeds a certain limit.

4. Performance evaluation

4.1.Two important metrics

Two important metrics to evaluate the performance of our localization method are:

Average Location Errors(ALE): which is equal to average distance between the estimated location (xei, yei) and actual location (xi, yi) of all sensor nodes.

$$Average\,Location\,Error = \frac{\sum_{i=1}^{n}\sqrt{(X_{e_i} - X_i)^2 + (Y_{e_i} - Y_i)^2}}{n(number\ of\ sensor\ nodes)} \qquad (3)$$

Average Execution Time(AET): which is the average time required for localization of all sensor nodes.

$$Average\,Execution\,Time = \frac{\sum_{i=1}^{n} Exec\_time_i}{n(number\ of\ sensor\ nodes)} \qquad (4)$$

4.2.Change results of step by step application:

Here, results of applying the three schemes are separately investigated:

Table 1

simulation parameters

parameters	value
size of the sensing region	1000×1000 m^2
Transmission range	10-45 m
Number of sensor nodes	100
Speed of MA	10 m

4.2.1. Applying neighbor node scheme:

The more the number of nodes or the radio radius, the more the execution of this scheme would be.

Individual application of this scheme will accelerate reduced execution time due to fast localization.

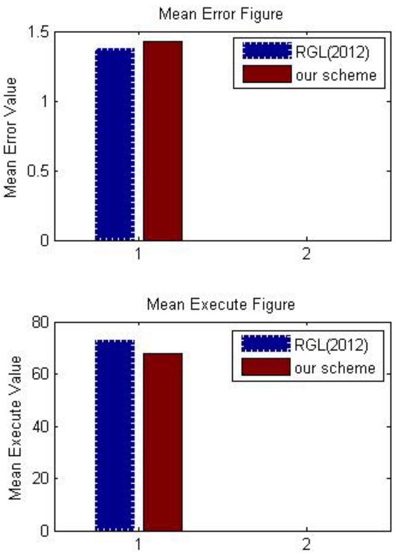

Fig. 11. Applying neighbor node scheme

4.2.2. Applying three neighbor scheme:

This scheme has a small degree of errors; but, it helps increase localization speed because, as soon as three neighbor nodes are localized, sensor nodes ask for their help. The results of applying three neighbour schemes are depicted in Fig. 12.

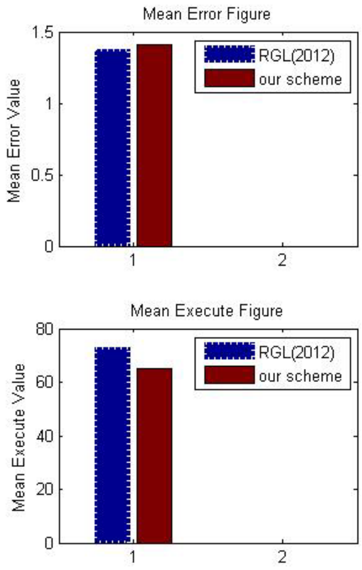

Fig. 12. Applying three neighbor scheme

4.2.3. Applying threshold limit scheme while reference node is entered:

When the reference group enters radio radius of a sensor node and its received signal strength exceeds a certain limit, it can be used in localization.

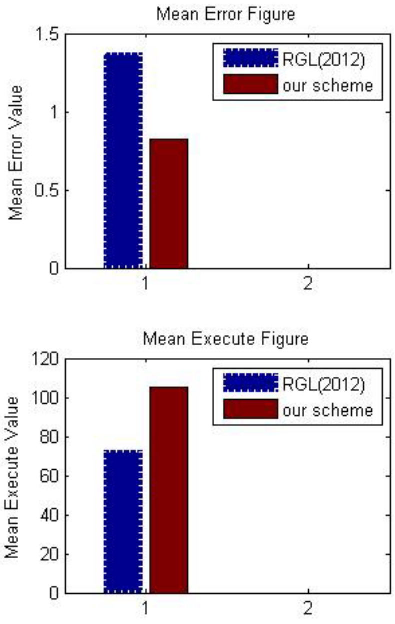

Fig. 13. Applying threshold

4.2.4. Simultaneous application of all the three schemes:

Simultaneous application of these three schemes leads to obtaining acceptable results. Although AET is a bit high, it can be reduced later by changing the radius. The results of Simultaneous application of all the three schemes are depicted in Fig. 14.

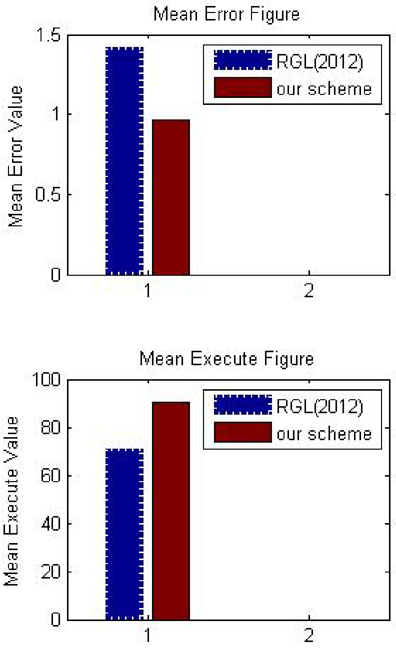

Fig. 14. Simultaneous application of all the three schemes

4.3.Effects of changes in radio radius on ALE and AET:

With increased radio radius, ALE also increases, which is because of weakened strength of the received signal and consequently increased distance between mobile reference node and fixed sensor node. The result of this weakened signal includes increased positioning estimation of nodes and enhanced ALE.

The obtained results are very reasonable for average execution time of the algorithm since, with increased radio radius, the number of nodes positioned at one moment is also high and, in every passage of the reference node, more nodes can estimate their positions. Also, with increased radio radius, the neighbor node and three node schemes have more chance of execution, which reduces the required time.

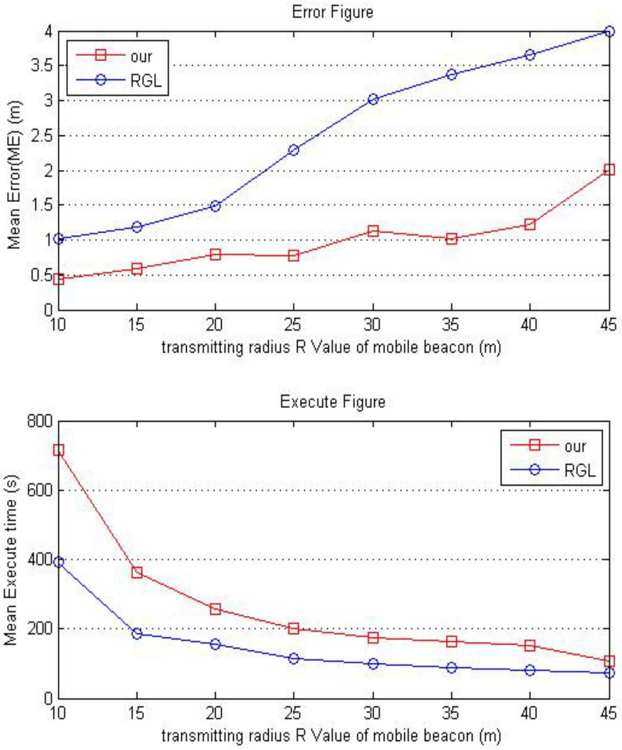

Fig. 15. Effects of changes in radio radius on ALE and AET

Moreover, using neighbor scheme and three node scheme led to decreased AET. The proposed algorithm performed much more efficient than the basis algorithm in ALE; but, as far as AET was concerned, although more time was spent on localization in the beginning, average line slope of the AET was much steeper than that of the basic algorithm. So, the proposed algorithm would be more efficient when radio radius is higher.

5. Conclusion

As shown by the results of simulation, the combination of three schemes could improve ALE and reduce AET with steeper slope. The proposed algorithm would be more efficient in positions requiring high radio radius.

There was a relationship between localization error and execution time of this algorithm; in order to reduce localization error rate, more precise investigation and more improvement of the algorithm were required, which increased its execution time. In contrast, when faster response of the algorithm was needed in estimating position of nodes, radio radius had to have a slight increase and, as a result, increased estimation error was obtained.

For future works, a few recommendations are presented: Given that reference nodes may fail later, measures should be taken that, when reference nodes stop working, fixed nodes automatically control the positioning algorithm and finish this process. Generalizing positioning in three-dimensional and real environments Finding large errors during the execution and correcting them and Security in the positioning area.

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