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Safety Management Method of Coordinate-tetrahedron Centroid Localization Based on RSSI

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Abstract. Three-dimensional localization is one of the important technologies in wireless sensor networks. A new algorithm of RSSI aided three-dimensional space coordinate-tetrahedral centroid localization algorithm is proposed. Because the reality environment is often very complex, there is a case that anchor nodes tetrahedron consists of four does not contain unknown nodes, by filtering the high quality RSSI value, the distance between the unknown node and the anchor node is converted to the distance between the nodes and the anchor nodes, in that case, calculation and comparison of tetrahedral volume to rule out; Using the way of centroid iterative to solve tetrahedral which contains unknown node as well. In addition, the RSSI mean weighted centroid localization algorithm is used to solve the problem that the condition is not satisfied. Simulation results show that the algorithm better than just using tetrahedron of reference centroid localization algorithm on the error that this algorithm should be small, and increasing the average RSSI weighted algorithm improves the localization coverage.

Introduction

WSN (sensor network wireless) is one of the most promising technologies in twenty-first Century [1]. It is a kind of self-organizing network, and it uses the way of inter node cooperation to sense, collect and process the information of objects in the monitored area [2]. In wireless sensor networks, the location information is very important to monitor the sensor network; it is the reference value when we know the location of the node, the detected events or collected data [3].

WSN are widely used, with the technology constantly mature and improve, all walks of life are related to the application of wireless sensor networks [4-5]. Node localization technology is an important support of technology for wireless sensor networks [6]. At present, many algorithms have been proposed for localization of wireless sensor networks, but most of them are based on 2D plane localization, which involves little on 3D localization. In the real environment, such as forest, ocean, mine, atmosphere and outer space, sensor nodes are randomly deployed in such complex three-dimensional space, it is difficult to know the location information of all nodes in advance. So the research on the localization of the sensor nodes in the three-dimensional space has a very important practical significance [7].

The algorithm of WSN localization can be divided into two categories: the localization of distance measurement and independent on the localization of distance measurement. RSSI [8] is the wide research way to rang and position, compared with the distance independent positioning method, RSSI added additional useful information, and easy to obtain, it can improve the accuracy of positioning as well. Now many of the independent distance positioning algorithms are combined with the RSSI technology.

The distance independent localization algorithm, as the coordinate-tetrahedral centroid localization algorithm has been proposed by [9]. This algorithm error is smaller than the traditional centroid algorithm, and has similar characteristics with the traditional centroid algorithm, such as it does not has the effect of hop count and hop distance, but the algorithm only considers the unknown nodes in all the tetrahedral, in the actual situation may be unknown nodes out a tetrahedron. The paper [10] In order to reduce the complexity of the algorithm and reduce the communication overhead, this paper proposes a method to replace the grid scanning method in 3D APIT algorithm by using the centroid algorithm, but the algorithm is still not enough that without considering all the anchor nodes that the unknown node can receive and cannot find the condition of the tetrahedral or the condition of the number less than 4. In order to improve the coverage rate, the paper [11] proposes an improved APIT algorithm, which is to improve the localization of unknown nodes to anchor nodes, and to determine the unknown nodes. Literature [12] combined with RSSI technology proposed a Landscape-3D positioning algorithm, the algorithm uses the mobile LA (Location-assistant) device according to the specified running track, periodically broadcast their location information, and through the RSSI measurement of LA equipment and the distance between nodes to determine the node location, its defect is the entire positioning process depends on the LA equipment, and a large amount of computation, the node storage capacity requirements are higher.

Combined with the above positioning algorithm, this paper first puts forward the problem of positioning method, and then introduces the excellent screening RSSI value and the distance between the unknown node and anchor node through the RSSI value calculation. This paper focuses on the realization of the iterative localization algorithm of coordinate tetrahedral centroid.

Algorithm Description

Put forward question

In the practical application environment, the sensor nodes are randomly deployed in the three-dimensional space, the space position of unknown nodes cannot be predicted, so the use of coordinate tetrahedral centroid algorithm to estimate the position of unknown nodes in the [9], while did not consider the situation that the unknown nodes outside tetrahedron, as shown in figure 1:

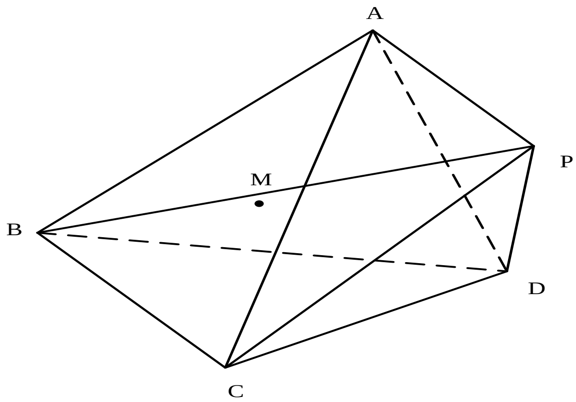

Figure 1. Node location map.

Known A, B, C, D is not in the same plane of the four anchor nodes, the composition of the tetrahedral ABCD. The unknown node P is located outside the ABCD, and the point M is the center of the tetrahedral. It can be seen from the figure that the location of the unknown node M estimate the point P position, it is obvious that it will cause a lot of errors. Therefore, in the application of centroid algorithm to estimate the unknown nodes, we should first determine whether the point P in the corresponding tetrahedral.

In addition, for the literature [10], if the unknown node receives all the anchor nodes in the presence of a tetrahedral but does not contain unknown nodes, or anchor nodes are less than 4, the algorithm is invalid for this case. And three dimensional APIT algorithms has erroneous judgement to judge the unknown node in the inner and outer of the unknown node, the document [11] to take the average method of all the neighbors of the unknown node to take the average method, reducing the possibility of false positives [11]. However, due to the random deployment of nodes in three-dimensional space, after taking the average value is still a certain false that that is likely to be in the interior of the internal sentence in the external, originally in the internal.

RSSI distance calculation

RSSI (Signal Strength Indicator Received) is a received signal strength indication ranging method that calculate the propagation loss by measuring the transmission power and receive power, and then use the signal attenuation model so that the transmission loss is converted to the transmission node and the receiving node distance [13]. This is a low power, low-cost ranging technology, with the characteristics of low cost, less equipment, far away, easy access.

In practical application environment, due to the interference of various obstacles, reflection, multipath propagation, temperature and propagation mode, the electromagnetic wave transmission loss is in accord with the log normal shadowing model, which can be described by the modified path loss model [14]:

$$PL(d) = PL(d_0) + 10n\lg\left(\frac{d}{d_0}\right) + X_\sigma \tag{1}$$

Among them, PL (d) is the loss that after the signal spreading distance d, unit dBm; PL (D0) is the loss that after the signal spreading distance d0, unit dBm; n is the transmission factor (often taking 2~5); the masking factor, is a mean of 0, the variance of the Gauss random noise variable, unit dBm.

PL (D0) can be calculated by the model of outdoor radio free space propagation. Free space propagation model [15]:

$$PL(d_0) = 32.44 + 10n\lg(d) + 10n\lg(f_c) \tag{2}$$

Among them, fc is the frequency of the transmitted signal, the unit is MHz; d is the distance between the sending node and the receiving node, the unit is km; usually take d0 = 1m.
The signal strength of the anchor node is received by the unknown node:

$$RSSI = P_s + P_a - PL(d) \tag{3}$$

Among them, Ps is the transmission power of node signal; Pa is the antenna gain; PL (d) is the loss after the signal spreading distance d. According to formula (1) ~ formula (3) can calculate the distance.

Screening RSSI better value

Due to the complexity of mine environment in wireless sensor networks, the wireless signal is affected by various factors, so it is not helpful to locate all the anchor nodes in the communication range of unknown nodes. Instead, it will increase the positioning error instead, it will increase the positioning error.

The distance between the unknown node and anchor node is closer, the smaller differ on the RSSI's maximum and minimum value, that is, the better the corresponding relationship between the distance and RSSI value. When the distance between the unknown node and anchor node is further, the random deviation of the measured data will be greater, and the collected data is almost not available at this time [16]. From the RSSI distance formula, it can be known that the closer the RSSI value is, the greater the distance between the anchor node and the anchor node. Therefore, selecting the RSSI value of the larger anchor nodes to participate in positioning.

Node Anchor periodic broadcast contains its own location information and transmit signal strength of the radio signal, the unknown node to receive the signal within its communication range, record RSSI value, according to the order from big to small set up RSSI value of the collection:

$$RSSI_A = \{R_{A1}, R_{A2}, R_{A3}, \cdots R_{An},\} \tag{4}$$

From the above, select the RSSI value of the larger anchor nodes, the anchor node is selected and then through repeated broadcasts with unknown nodes to communicate, record the RSSI value, and discard the RSSI value of undulate obviously. Finally, the RSSI value of the N number of the unknown node to the same anchor node is obtained, and the arithmetic average value is taken as the final RSSI value of the corresponding modified anchor node.

$$RSSI = \sum_{i=1}^{N} R_{An}(i) / N \tag{5}$$

Coordinate tetrahedral centroid iterative localization algorithm

This paper based on literature [9] and [10] proposes the problems and defects existing in the method of coordinate tetrahedral centroid localization, and in combination with the literature [12], we use RSSI method to optimize and improve the algorithm:

Before the coordinates of the coordinate system are used to estimate the position of unknown nodes, firstly to select the tetrahedral by measuring the RSSI value, and then compare the volume of the method to judge to discard a tetrahedral that does not contain an unknown node, and use coordinate tetrahedral centroid iterative algorithm to improve the positioning accuracy and reduce computational complexity. For all the anchor nodes which are not received by the unknown node and the condition of the condition is not found, or the number of anchor nodes is less than 4, and the position estimation is carried out by means of the RSSI mean weighted 3D centroid algorithm.

The specific implementation steps that improved coordinate tetrahedral centroid localization algorithm are as follows:

Step 1. Filter RSSI better value of anchor nodes

The unknown node receives the signal of all the anchor nodes in the communication range, record their RSSI value, and set up a set of RSSI values in the order from big to small, then take the RSSI value of the larger anchor nodes.

Selecting anchor nodes and then through a number of radio and unknown nodes to communicate, record the RSSI value, which discard the obvious RSSI value. Finally, the N number of RSSI value of the unknown node to the same anchor node is obtained, the arithmetic mean ($RSSI = \sum_{i=1}^{N} R_{An}(i) / N$) is taken as the final RSSI value of the anchor node.

Step 2. Calculate the distance between the unknown node and the anchor node

From step 1 to get the unknown node corresponding to each of the anchor nodes RSSI value, the value is substituted into the formula (1) ~ (3) can gain the distance of the unknown node and the anchor nodes.

Step 3. To determine whether the unknown node in the tetrahedral

If the number of anchor nodes received by the unknown node is received, the execution step 5. Otherwise, the random selection of a set of anchor nodes to form a tetrahedral. As shown in Figure 2, A1, A2, A3, A4 is the four known-mark of anchor node, it is easy to calculate the distance of A1A2, A1A3, A1A4, A2A3, A2A4, A3A4. From step 2, get the distance of MA1, MA2, MA3, MA4.

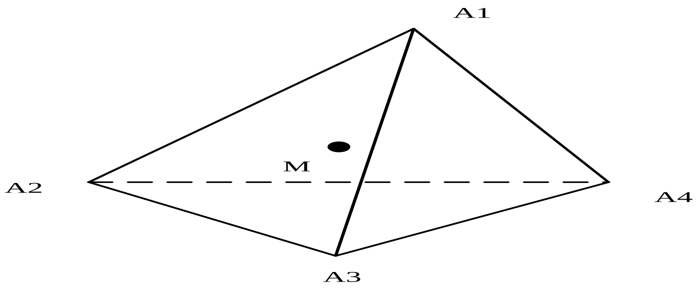

Figure 2. Tetrahedral A1A2A3A4.

Then use the formula (6) and (7) calculate the volume of A1A2A3A4, MA1A2A3, MA1A2A4, MA1A3A4, MA2A3A4, the volume value V is as V1, V2, V3, V4, respectively. If $((V_1+V_2+V_3+V_4)>V)$, you can determine the M in the outside of the tetrahedral A1A2A3A4, discard the modified tetrahedral.

The Cartesian coordinates of the four vertices are, (x1, Y1, z1), (X2, Y2, Z2), (X3, Y3,), (Z3, Y4, x4, Z4), r_{ij} is the distance between the vertices I and j. Then the formula for the calculation of its volume is as follows:

$$V=\frac{1}{6}\begin{vmatrix}1 & 1 & 1 & 1\\ x_1 & x_2 & x_3 & x_4\\ y_1 & y_2 & y_3 & y_4\\ z_1 & z_2 & z_3 & z_4\end{vmatrix}=\frac{1}{6}\begin{vmatrix}x_2-x_1 & y_2-y_1 & z_2-z_1\\ x_3-x_2 & y_3-y_2 & z_3-z_2\\ x_4-x_3 & y_4-y_3 & z_4-z_2\end{vmatrix} \tag{6}$$

Or,

$$V^2=\frac{1}{288}\begin{vmatrix}0 & 1 & 1 & 1 & 1\\ 1 & 0 & r_{12}^2 & r_{13}^2 & r_{14}^2\\ 1 & r_{12}^2 & 0 & r_{23}^2 & r_{24}^2\\ 1 & r_{13}^2 & r_{23}^2 & 0 & r_{34}^2\\ 1 & r_{14}^2 & r_{24}^2 & r_{34}^2 & 0\end{vmatrix} \tag{7}$$

Random selection of anchor nodes may be repeated, therefore, in the process of selecting the anchor node group, can be based on the unknown nodes around the anchor nodes to set the appropriate number of selection. For example, when there are 10 anchor nodes, 4 of them, there are $C_{10}^4=210$ methods, when there are more anchor nodes, in order to reduce the time cost of the algorithm, we must set a threshold for the number of times.

Step 4. Coordinate tetrahedral centroid iterative solution

① The centroid of the tetrahedral is calculated by using the coordinate tetrahedral centroid algorithm, then get a set of coordinates of the center of mass.

② Last step obtain a set of centroid coordinates then one group per 4, composed of new tetrahedral set, if the group is not divisible by 4, then the rest of the centroid coordinates into the next round of the tetrahedron of reference centroid iteration calculation.

③ Repeat the two step until the number of coordinates of the center of mass is less than 4, if the final 1 coordinates are the coordinates of the unknown node estimates; if the final 2 or 3 centroid coordinates are taken as the final coordinates of the final coordinates of the unknown node.

Step 5. Weighted centroid algorithm estimation location.

If the number of anchor nodes received by the unknown node is $N \le 3$ or empty, then the RSSI mean weighted centroid algorithm is used to estimate the unknown node position.
The number of anchor nodes to receive the anchor node is K, the corresponding RSSI value is $R_1, R_2, \ldots, R_k$, the weighted factor of the No i anchor node is $Q_i = \frac{K \times Ri}{\sum_{i=1}^{k} R_i}$, then the RSSI mean weighted centroid algorithm estimates the coordinates as:

$$(x, y, z) = \left(\frac{\sum_{i=1}^{k} Q_i x_i}{k}, \frac{\sum_{i=1}^{k} Q_i y_i}{k}, \frac{\sum_{i=1}^{k} Q_i}{k} \right) \tag{8}$$

Location Error

Location error formula:

$$error_i = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2 + (z_i - z_0)^2} \tag{9}$$

Among them, (xi, yi, zi) is the estimate the coordinates of the unknown nodes, (x0, y0, z0) is the actual coordinates of unknown nodes.
The average location error of n is:

$$\overline{error} = \frac{\sum_{i=1}^{n} error_i}{n} \tag{10}$$

Simulation Analysis

Using Matlab to verify the positioning algorithm, the simulation environment is the simulation of mine near the power plant 100 meters long, 100 meters wide, 100 meters high atmospheric pollution source emission monitoring area, unknown sensor nodes are randomly deployed to monitor the emission of atmospheric pollution sources, the simulation results are in the same conditions for 50 times the average value of the experiment, as shown in figure 3~ figure 6.

First, we take the number of unknown nodes as 100, communication distance 40m, according to the random selection of 4 anchor nodes consisting of the tetrahedral whether contains unknown nodes to filter the error caused by the positioning. Can be seen from the figure 3, in all the anchor nodes in the random selection of 4 components of the tetrahedral, the positioning error of the filter to be compared to the situation without the node, to bring a lot of positioning error. Therefore, it is very necessary to screen the tetrahedral. At the same time, it can be shown from Figure 3 that the number of unknown nodes is fixed, and the location error decreases with the increase of the number of anchor nodes.

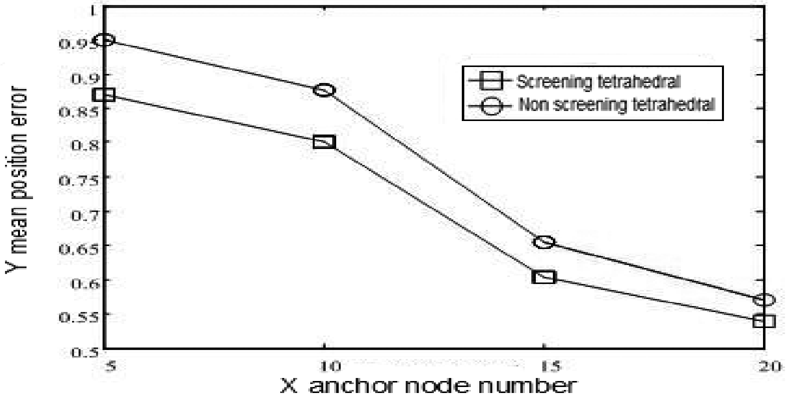

Figure 3. Positioning error of different number of anchor nodes.

Figure 4 shows the location error of the two schemes at the node communication distance from 30m to 70m. Experimental fixed anchor nodes and unknown nodes are 20 and 100 respectively. From the observation of Figure 4, further proof of the positioning error is smaller than the positioning. At the same time, it can be seen that the positioning error decreases with the increase of the communication distance between nodes. This is because of the increase of the node communication distance, which makes the distance estimation more close to the Euclidean distance between nodes.

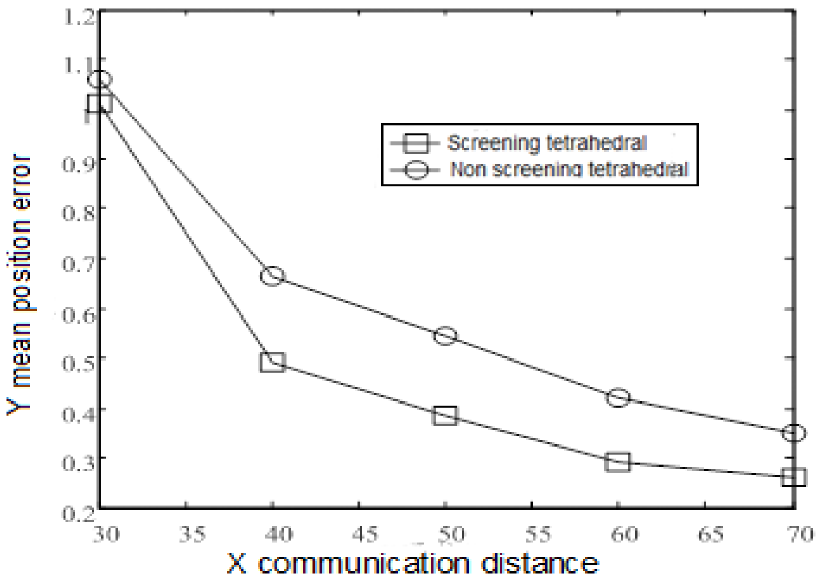

Figure 4. 20 positioning error of anchor nodes.

Figure 5 shows that the number of unknown nodes is 160, and the location error of each algorithm is compared with the communication distance 40m. It can be seen that the algorithm proposed in this paper is less than the localization error of the [9] and [10] using the tetrahedral centroid algorithm. Although these two algorithms are all of the unknown node in the case of the unknown node to estimate the location of the coordinates of the unknown node, but this paper and literature [11] algorithm using the tetrahedral centroid iterative method for solving the location of the center of mass, than the average value of all the coordinates of the coordinates of the method to reduce the positioning error. And [10] due to the judgment of the unknown node whether in tetrahedral, misjudgment of the situation, resulting in large localization error. Although the literature [11] has made the further improvement to the miscarriage of justice, but still has the certain miscarriage of justice.

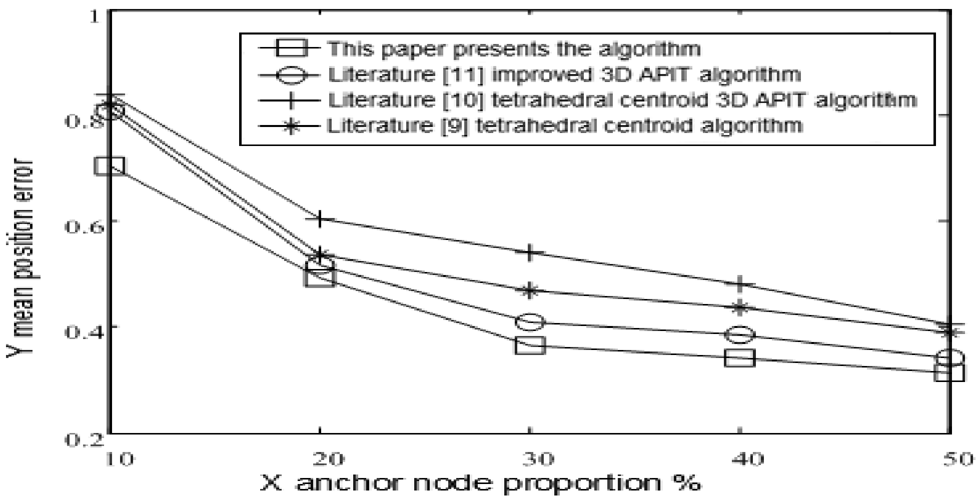

Figure 5. Comparison of the positioning error of the improved algorithm.

Figure 6 is in the case of the choice of 160 nodes, so that the proportion of the anchor nodes increased from 10% to 50% when the impact of various algorithms on the location coverage. It is not difficult to see from Figure 6, the algorithm coverage rate is better, which is based on the lack of [9] and [10] algorithm in this paper, the number of anchor nodes is less than 4 and the existence of the anchor node is not unknown nodes in the situation, the RSSI mean weighted centroid localization method is adopted. As can be seen from Figure 6, the algorithm of the RSSI mean weighted centroid localization method is used to increase the coverage rate of the anchor nodes in this paper. And the literature [11] in the anchor node ratio is small, which can locate the unknown node, then the promotion of the anchor node is less, so the low coverage rate. RSSI mean weighted centroid localization method is adopted in the whole, and its coverage rate is very high. At the same time, it can be seen that when the number of nodes is constant, only the ratio of anchor nodes is changed, the coverage ratio increases with the increase of the ratio of the anchor nodes.

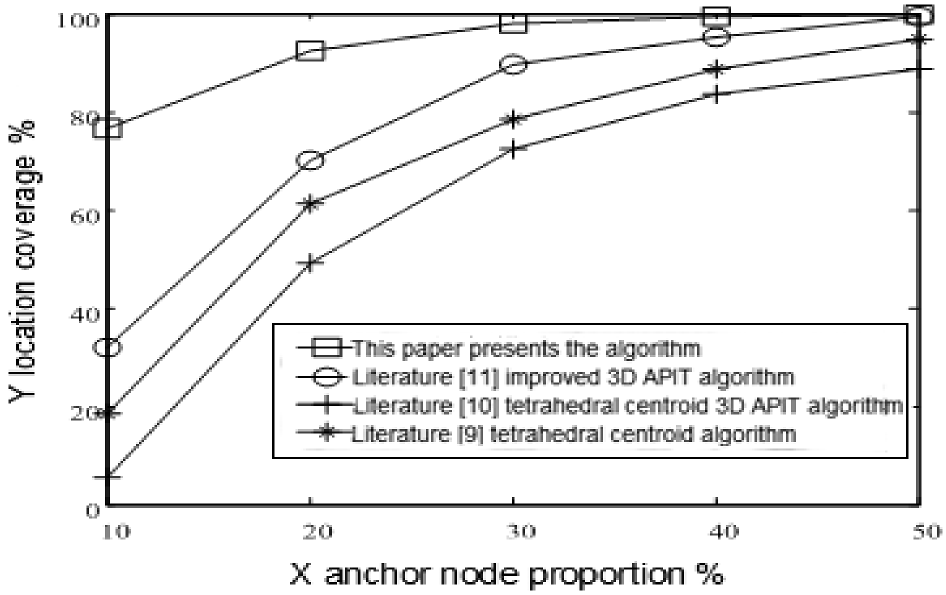

Figure 6. Effect of anchor node proportion on coverage.

Conclusion

In this paper, we have optimized and improved the localization method of [9] and [10] that using the method of locating the centroid of the tetrahedral, and based on the literature [12], this paper proposes a RSSI assisted three-dimensional space coordinate tetrahedral centroid localization algorithm using RSSI distance measurement method. This algorithm combines the RSSI ranging for random selection of tetrahedral screening, excluding the real environment of the tetrahedral does not contain unknown nodes, to meet the conditions of the tetrahedral centroid to further use the tetrahedral iterative method to solve the centroid coordinates, and to do not meet the conditions use the RSSI mean weighted centroid localization method. Simulation results show that the proposed algorithm can reduce the positioning error and increase the coverage rate. Compared with the literature [9] and [10], the algorithm is more suitable for the complex environment.

Acknowledgements

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