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AN IMPROVED APIT ALGORITHM FOR NODE LOCALIZATION IN WIRELESS SENSOR NETWORKS

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Abstract

The node localization problem of wireless sensor networks is one of the key issues of wireless sensor networks. Wireless sensor networks can detect, sense, and collect information about various environments and detection objects in real-time, process them, and transmit them to the required users, so they have very wide application prospects. APIT algorithm (Approximate Point-In-Triangulation Test) is one of the node localization algorithms, which has the unique advantage of low communication overhead and node density requirements and is more practical in resource-constrained wireless sensor networks. In this paper, we study the node localization algorithm in wireless sensor networks, improve the traditional APIT algorithm, and propose an improved localization algorithm with better performance. Simulation results show that the algorithm has performance of high localization accuracy, low communication overhead, low computation, and high coverage.

Keywords: APIT, Location calculation method, Node localization, Process innovation, WSN.

1. Introduction

Wireless sensor localization technology is an emerging research hotspot [1]. Many research institutions have proposed many localization algorithms [2] specifically for wireless sensor networks, which can be classified into two main categories based on the different mechanisms of node location estimation by the localization algorithms that have emerged so far: distance-based localization algorithms and distance-independent localization algorithms [1]. Distance-independent localization algorithms, on the other hand, have advantages over range-based methods in terms of cost and power consumption [3]. Among them, the basic idea of the APIT localization algorithm is simple and easy to implement. In addition, it is widely used and studied due to its low power consumption for localization, low cost, and high accuracy of node localization [4].

The work in this paper is concentrated on the APIT localization algorithm for wireless sensor networks with the following research questions.

- How does the APIT algorithm's positioning mechanism work?
- What is the difference between the current and improved APIT positioning?
- How to perform an improved APIT algorithm for simulation experiments?

The objectives of the study are as follows.

- Define the APIT algorithm's positioning mechanism.
- Outline the difference between the current and improved APIT positioning.
- Perform an improved APIT algorithm for simulation experiments.

APIT algorithm has the advantages of high localization accuracy and low communication overhead, and it can be well adapted to node localization in WSNs, but after a deeper study of the principle of the APIT algorithm and its process, it can be found that the APIT algorithm also has shortcomings [3, 5].

The unknown node becomes unlocatable when the number of neighbour anchor nodes of the unknown node is less than three or when the node is outside the triangle formed by any three neighbour anchor nodes; when the unknown node has only three neighbour anchor nodes, the number of triangles that can be formed by the neighbour anchor nodes is smaller, which has a greater impact on the positioning of the node[6]. The unknown node is not inside the triangle formed by neighbouring anchor nodes, resulting in the unknown node becoming unlocatable [7].

2.Methodology

For the analysis of the traditional APIT localization algorithm, this paper proposes an improved algorithm that reduces the error generation compared with the traditional algorithm. The improved algorithm uses the received signal strength comparison before the point test within the triangle and uses the calculation of the center of mass of the center of gravity of the triangle formed by the anchor node instead of the grid scan method to estimate the location of the unknown node, and finally upgrades a part of the localized nodes as anchor nodes to improve the coverage. The flow chart of the simulation process of the improved algorithm is shown in Fig. 1.

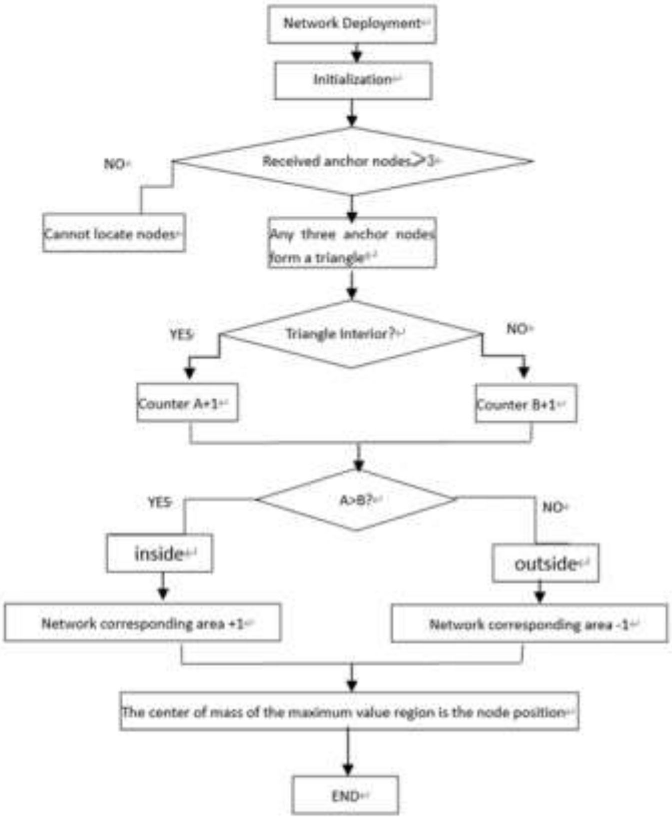

Fig. 1. Algorithm flowchart.

After selecting any three anchor nodes to form a triangle, the distance of the unknown nodes from the sides of the triangle is first checked to see if it is greater than the constraint factor d. Counter A is used to count the triangles containing the unknown nodes, while counter B records the number of triangles that do not contain unknown nodes. The improved algorithm adds a counter K to record the number of triangles used in locating the unknown node, to determine whether the upgrade condition K>4 is met when upgrading the anchor node.

3. Results and discussion

The first step in the improved algorithm is the selection of the constraint factor d. In Fig. 2, 200 nodes are randomly deployed in the simulation area, and the percentage of anchor nodes is 20%. By plotting the average positioning error generated by the algorithm when positioning with the variation of the constraint factor d, the impact of different constraint factors d on the average positioning error of the algorithm is compared to determine the size of d be selected in the algorithm.

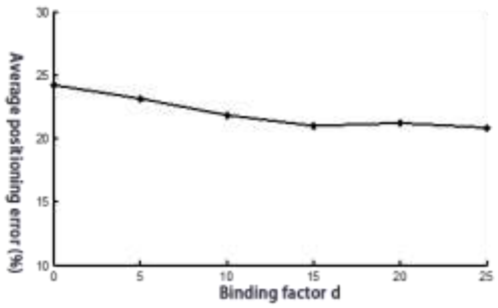

Fig. 2. Choice of constraint factor d.

It can be seen from Fig. 2 that the localization error is smaller around the constraint factor d of 15 so 15 is chosen as the value of d.

Figure 3 is a comparison of the average positioning error between the conventional APIT algorithm and the improved algorithm at different anchor node ratios for 200 nodes randomly deployed in the simulation area with anchor node ratios of 10%, 15%, ..., 40%, and constraint factor d of 15. Under the same conditions, the average positioning error decreases steadily with increasing anchor node proportion. From Fig. 3, it can be seen that the average positioning error of the improved algorithm is significantly smaller than that of the traditional algorithm.

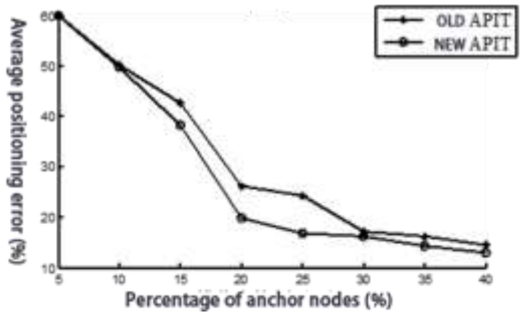

Fig. 3. Relationship between average positioning error and ration of anchor nodes.

Figure 4 compares the average localization error of the conventional and improved algorithms by keeping the percentage of anchor nodes at 20% in the experimental area, the total number of nodes varying from 150 to 400, and the constraint factor d at 15. It can be seen from Fig. 4 that the average positioning error of the improved algorithm is smaller than that of the traditional algorithm.

Figure 5 shows the comparison of the coverage of node localization with the percentage of anchor nodes for the APIT localization algorithm and the improved algorithm. Two hundred nodes were randomly deployed in the experimental area with anchor node proportions of 5%, 10%, 15%, ..., 30%, and a constraint factor d of 15. The improved algorithm showed a significant improvement in localization coverage over the APIT localization algorithm, and when the number of anchor nodes was small, the improved algorithm showed a larger improvement in localization coverage than the original algorithm.

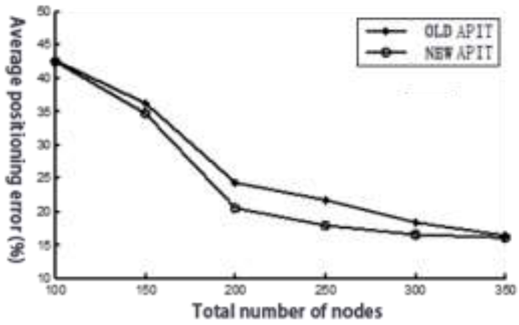

Fig. 4. Relationship between average positioning error and quantity of nodes.

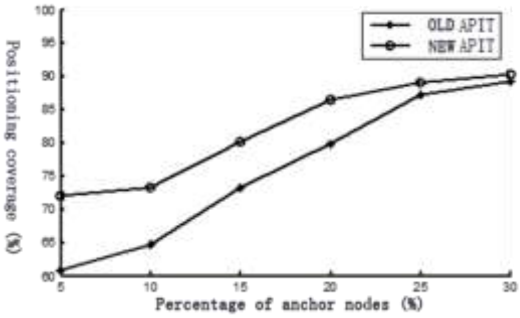

Fig. 5. Relationship between average positioning error and ration of anchor nodes.

A comparison of the simulation curves of the coverage of node localization with the number of nodes for the APIT localization algorithm is shown in Fig. 6. The percentage of anchor nodes is kept at 20% in the simulation area, the total number of nodes is varied from 30 to 200, and the constraint factor d is 15. The simulation results show that the improved algorithm significantly improves the localization coverage over the original APIT algorithm when the total number of nodes is less than 140.

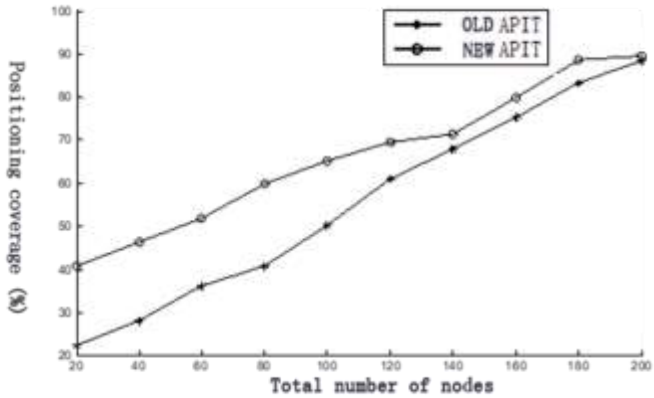

Fig. 6. Relationship between localization cover ratio and quantity of nodes.

During network transmission, it is inevitable to include some redundant data, which are necessary for transmission, due to the need to change data formats for the transmission of signals, and the proportion of these redundant data in the source data is called overhead [8]. The communication overhead of the algorithm is expressed in terms of the number of packets transmitted during the localization process [9]. The difference between the improved algorithm and the traditional algorithm only lies in the packets broadcasted by the last upgraded located unknown node when locating a previously unlocatable node. Therefore, the increase in communication overhead is not particularly obvious when comparing the improved algorithm with the original algorithm [10, 11].

In terms of computational overhead, the improved algorithm compares the sum of the distances of the two vertices on one side of the triangle formed by the unknown node and the anchor node with the side length of the triangle before approximating the point test inside the triangle, adding the estimation of the distance between the unknown node and the anchor node and the anchor node to the computational overhead. However, the improved algorithm does not use the traditional mesh scanning method when performing the unknown calculation but directly calculates the center of mass of the center of gravity of the triangle formed by the anchor node, eliminating the comparison of the triangle region with each mesh boundary during the mesh scanning in this process, which significantly reduces the computational overhead.

The improved algorithm increases the communication overhead compared with the original algorithm, and because the energy of the unknown nodes is smaller than that of the anchor nodes, some of the upgraded unknown nodes will fail due to premature energy depletion, but considering that the nodes are generally densely arranged in wireless sensor networks, such a drawback does not pose a threat to the network [12-14]. In terms of computational overhead, the improved algorithm saves a significant amount of computational overhead and can reduce the rate of energy loss of sensor nodes. Overall, the improved algorithm improves the accuracy and coverage of localization without adding hardware devices and is of interest in the study of node localization in wireless sensor networks.

According to the performance evaluation criteria of node localization algorithms in wireless sensor networks, the following criteria are used to measure the improved APIT localization algorithm.

- Positioning accuracy: From the results of simulation experiments, it seems that the improved positioning algorithm has some improvement in positioning accuracy than the original algorithm. In the case of random deployment of network nodes, the positioning error of the algorithm is 40% under the condition that the proportion of anchor nodes is 15%, while the positioning error is close to 20% when the proportion of anchor nodes rises to 20%, which can be used in networks with not very high positioning requirements.
- Environment: Different positioning systems' live algorithms are applied in different scales and environments. The algorithm of the improved APIT is suitable for large outdoor sensor networks with a large arrangement of sensor nodes. This is because the positioning accuracy of the algorithm is not very high and can only provide the approximate location of the nodes, which is less suitable for positioning on campus, in a building, in a one-story building,

or just in a room with high requirements for positioning accuracy. In addition, this algorithm has no hardware support and does not require high requirements for a network environment.

- Anchor node density: The anchor nodes deployed through manual deployment are affected by the network environment and do not facilitate the expansion of the network, so in most sensor networks, the location information of the anchor nodes is achieved by GPS and the value of the network increases due to the high cost of the anchor nodes. The localization accuracy of this algorithm is strongly dependent on the density of anchor nodes, and it needs to be in a network with a relatively large density of anchor nodes to play a proper role.
- Node density: The increase in node density also increases the deployment cost of the network, but the improved APIT algorithm needs to exchange the information of neighbouring nodes to complete when determining the possible triangle area of unknown nodes in localization, and the final part of localization also needs to upgrade some of the already localized nodes, which may fail early due to energy depletion due to the increase in communication overhead, to ensure the robustness of the algorithm, it is required that the impact of the failed nodes on the whole network is as low as possible, which means that the nodes in the network have a certain density. Therefore, the dependence of this algorithm on the node density is also relatively strong.
- Fault tolerance and self-adaptation: The algorithm is applied to a large-scale network environment outdoors, where individual nodes are positioned in a fully distributed manner, and the problems of multipath propagation, fading, and non-visual range existing in the outside world within the communication range of the sensor nodes have little impact on the algorithm. The algorithm is relatively fault-tolerant and can reduce the impact of various errors through its adjustments and has a certain degree of self-adaptability.

4. Conclusions

In summary, according to the simulation experimental results and analysis of the improved algorithm, the improved algorithm and the original algorithm are compared according to the performance evaluation criteria of node localization algorithms in wireless sensor networks, and the results show that the new algorithm has certain improvement in localization accuracy and coverage than the traditional algorithm; the improved algorithm does not have high requirements on the network environment; the algorithm is more fault-tolerant and has the certain adaptive capability.

In this paper, we mainly analyse the sensor network localization technology of the APIT algorithm and propose an improved algorithm based on the APIT algorithm. The APIT improvement algorithm proposed in this thesis has some improvement in localization accuracy and localization coverage than the original algorithm, but because of the improvement algorithm nodes need to pass more information between them, which increases the communication between nodes and increases the energy consumption of nodes, how to find a balance between localization accuracy and the energy consumption is the next problem we need to solve.

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