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Research on accuracy optimization of improved dv-hop localization algorithm in wireless sensor network

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Abstract. By analyzing the classic DV-Hop localization algorithm and DV-Hop algorithm improvement of the wireless sensor network, this paper attempts to propose an energy-saving high-accuracy DV-Hop localization algorithm with the combination of the low energy consumption requirement of wireless sensor network on the basis of taking advantages of various improvement algorithms. A simulation experiment is conducted as well, results of which indicate the positioning error can basically be stable at around 20% when the connectivity is higher than 15 in the experiment. When the anchor node proportion is 10% and the network connectivity is above 7, 100% positioning can basically be realized. When the network connectivity is 10, 100% positioning coverage can be achieved as long as there are more than three anchor nodes in the network. According to the results, higher positioning accuracy can be realized by the improved algorithm compared to the classic DV-Hop localization algorithm, thus reaching the purpose of improving the accuracy.

Key words. Wsn, dv-hop, positioning accuracy.

1. Introduction

Wireless network is formed via self-organization and multi-hop by the wireless sensor, and it can perceive, collect, process and transmit information of relevant objects within the region covered by the network. Finally, the information will be delivered to the owner of the network. It is widely applied to fields like military defense, target tracking, environment monitoring and intelligent transportation. In most applications of these fields, 80% of data needed by users is relevant to locations, which requires wireless sensor network to be equipped with reliable positioning technologies.

The simplest way of wireless sensor network positioning is to use the GPS tech-

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nology [1][2]. However, due to economic factors, node energy restriction and certain requirements of the deployment environment for GPS, feasibility of the scheme is negative. There are many WSN positioning algorithms [3]. Currently, there are 3 relatively general classification ways: ranging algorithm and non-ranging algorithm, single-hop algorithm and multi-hop algorithm, distributed algorithm and centralized algorithm. It is generally believed that ranging and non-ranging algorithm classification is clearer [4]. As for the ranging positioning algorithm, the distance between nodes or the angle information should be measured by the ranging technology first. There are many ways to realize the ranging measurement, and commonly used ones are RSSI ranging, TOA ranging and TDOA ranging [5]. As for the non-ranging positioning algorithm, network connectivity and information communication between nodes are used to calculate the position of unknown nodes. It can be divided into the centroid algorithm, APIT algorithm and DV-Hop algorithm [5]. The power consumption is low, so is the positioning accuracy [6]. Thus, improved wireless sensor network positioning algorithms have been put forward by scholars, which effectively improves the positioning accuracy, but it still fails to meet the actual need [7].

To improve the node positioning accuracy of wireless sensor network, an energy-saving high-accuracy DV-Hop localization algorithm is proposed. According to the simulation results, higher positioning accuracy can be realized by the improved algorithm compared to that of classic DV-Hop localization algorithm, thus reaching the purpose of high accuracy.

2. DV-Hop localization algorithm and its improvement

2.1. DV-Hop localization algorithm

The positioning process of DV-Hop localization algorithm [8][9] does not rely on the ranging method, instead, it relies on the network connectivity. Through gradual hop conveying, anchor node information of the whole network can be received by nodes, so as to improve the positioning accuracy and make the positioning coverage huge.

DV-Hop localization algorithm does not need additional hardware support. The positioning error of the algorithm is about 30% of the node communication distance. To Complete the positioning process, it is required the number of anchor nodes should be no fewer than 30% of the total nodes. The quantity and distribution of anchor nodes can affect the positioning accuracy significantly. In addition, the communication overhead and calculation overhead of DV-Hop localization algorithm are huge.

2.2. DV-Hop localization algorithm improvement

Currently, specific to the above shortcomings of DV-Hop algorithm, some improvement has been obtained by domestic and overseas researches, which mainly focus on the first stage and second stage of the algorithm. By making use of the redundant information of the whole network, grouping information, error correction of each hop distance, checkout, weighting, collinearity and upgrading anchor nodes are used to improve the average hop distance and correct problems about the hop section distance, sparse anchor nodes and high communication expense. Literatures improve the DV-Hop algorithm, but there are still more or less defects which makes it possible for further improvement of the algorithm.

(1) The positioning accuracy of the improved algorithm has not been improved much. Only 2-3 positioning accuracy can be improved on the basis of the classic DV-Hop algorithm by most improvement algorithms and a few good ones can improve about 5%.

(2) Energy consumption of nodes has increased. Most improvement ideas aim to reduce the error of the hop section distance between nodes at the cost of the node communication amount and calculation amount, so as to enhance the positioning accuracy. A few improvement ideas of upgrading the anchor node re-circulation algorithm can intensify the consumption of the node communication expense a lot.

(3) The dependence on network connectivity is still high for the algorithm without inhibition or improvement for the node density.

3. An improved high-accuracy DV-Hop localization algorithm

Specific to disadvantages of the above DV-Hop algorithm, this paper tries to analyze the existing DV-Hop algorithm improvement idea and discuss about how to increase the positioning accuracy of the algorithm without increasing any cost to the classic DV-Hop algorithm. The improved algorithm mainly aims to resolve the following few problems:

(1) A new controllable flooding agreement will be found, which will not reduce the reliability of the flooding broadcast way or decrease information implosion or overlapping, thus reaching the purpose of reducing the quantity of data packages to be sent. On the basis of meeting positioning accuracy and positioning coverage, the communication expense of nodes can be reduced to the maximum degree.

(2) The balance between the decreased communication amount and the positioning coverage of grouping broadcast will be found, that is, a formula about limiting the minimum hop value and the monitored anchor node number on unknown nodes will exactly be proposed to seek for the balance.

(3) Some new approaches will be found to correct the error of the node hop section distance and to replace the existing way of circulated refinement, so as to prevent the influence of the measured error on the positioning result.

(4) The mode of the upgrading anchor node will be improved, so that the node communication amount can be reduced during the self-positioning of adverse nodes.

The improved DV-Hop algorithm can be divided into four stages: information broadcast stage, distance calculation stage, positioning calculation stage and adverse node positioning stage.

The first stage: At the time of network initialization, the neighborhood node set is obtained by all nodes. After the initialization, the hop between one node and all anchor nodes as well as the GPS coordinate of anchor nodes is obtained via controllable flooding broadcast of all nodes. The last hop node ID which has the shortest distance to all anchor nodes is calculated.

The second stage: First, the shortest path table stage is corrected selectively and the minimum hop that may be large is corrected. Second, the best unbiased estimation way is used to calculated the anchor node and obtain the average hop distance of the whole network along with broadcast. While calculating the average hop distance, the hop section distance of the anchor node whose minimum hop is one in the shortest path table is calculated via neighborhood node overlapping of unknown nodes. Third, after the average hop distance of the whole network broadcast by anchor nodes is received by an unknown node, the average whole network and local hop distance of the node calculated through two-stage best unbiased estimation. Finally, the hop section distance between this node and the anchor node with more than one hop is calculated.

The third stage: More than three nodes containing anchor node information are obtained. The optimum strategy is selected by making use of anchor nodes to select an appropriate anchor node group before positioning calculation with the maximum likelihood method.

The fourth stage: After networking positioning, unknown nodes that haven't conducted self-positioning should send positioning requests to their neighbor nodes, so as to obtain the coordinate information of positioned unknown neighbor nodes and calculate the hop section distance by making use of the neighbor node overlapping. When the obtained anchor node information amount is more than three, self-positioning will be conducted.

4. Simulation experiment analysis and results

4.1. Simulation environment

MATLAB7.0.1

4.2. Experimental scene layout

The following scene layout is adopted for the experiment in this chapter without additional indication:

(1) Monitoring zone: 1000m $\times$ 1000m

(2) Node communication radius R: 200m

(3) Total number of nodes: 200

(4) Anchor node proportion: 10%

The above parameters are selected mainly to make the network connectivity and the total node number show linear relationship. At this time, the network average connectivity is basically stable at around 20. Each time when the total node number changes 10, the network average connectivity will change 1.

4.3. Algorithm positioning accuracy analysis

4.3.1. Improvement degree of the positioning accuracy In standard scenes, positioning results of the classic DV-Hop algorithm and the DV-Hop improved algorithm of this paper are shown below:

(1) Node distribution is shown in Figure 1, where "." means the anchor node and "," is the unknown node.

(2) The positioning error is shown in Figure 2.

(3) Positioning results are shown in Figure 3, where "." means the anchor node without positioning error and "," is the estimated coordinate of the unknown node. "——" line segment is the error between the estimated coordinate of the unknown node and the real coordinate position.

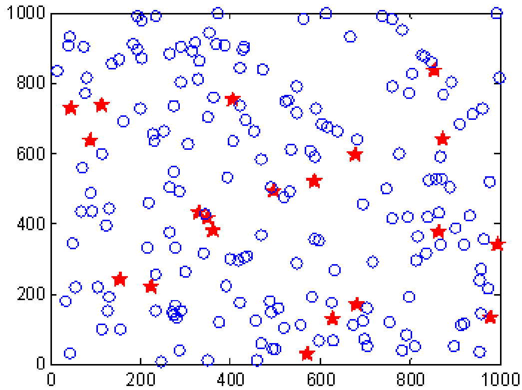

Fig. 1. Node distribution

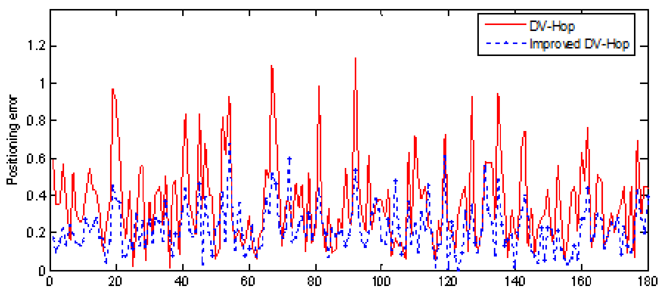

Fig. 2. Positioning error

By operating the standard scene for 1000 times, the obtained average positioning error is 21%. Compared to classic DV-Hop algorithm, the positioning error of the improved DV-Hop algorithm can be reduced by 14.9% at most and 5.9% at least.

Seen from the figure of positioning results, the positioning error of nodes in classic algorithm distributed on the boundary of the monitoring zone is large and those distributed in the center has positive positioning effect. The situation can

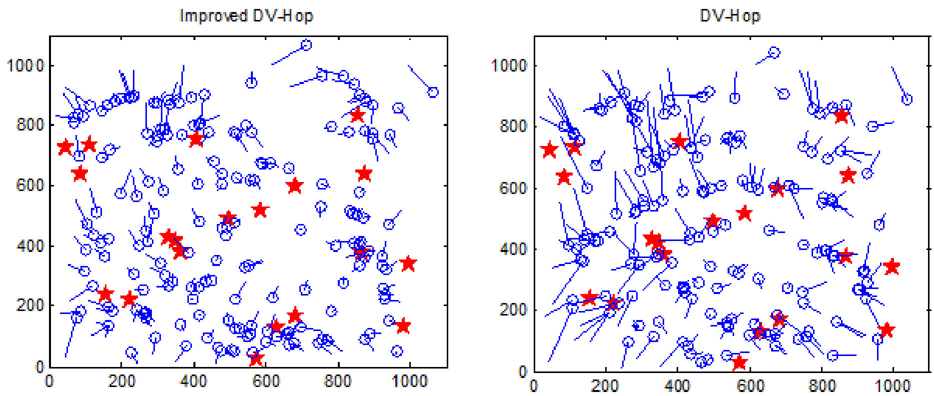

Fig. 3. Location results map

significantly been improved by the DV-Hop algorithm of this paper. Meanwhile, the use of grouping broadcast can also help to reduce boundary nodes to some extent.

4.3.2. The positioning accuracy is affected by connectivity Figure 4 shows the positioning error under different connectivity when the anchor node proportion is 10%.

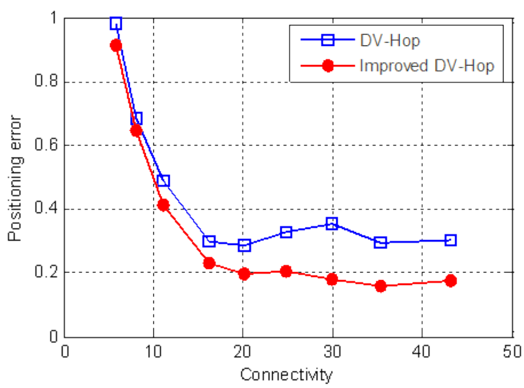

Fig. 4. Influence of connectivity

According to the above figure, the positioning error gradually decreases with the increase of network connectivity. When the network connectivity is lower than 15, the positioning accuracy can dramatically be affected by connectivity whose slight increase can lead to obvious improvement of the positioning accuracy. When the network connectivity is higher than 15, the positioning error will basically be stable at around 20% and the influence of connectivity will be small. Meanwhile, with the increase of the network connectivity, the positioning accuracy of the improved DV-Hop algorithm will be higher.

4.3.3. Influence of the anchor node proportion on positioning accuracy Figure 5 shows the positioning error under different anchor nodes proportions when the connectivity is 20. As can be seen from the figure above, positioning accuracy of the

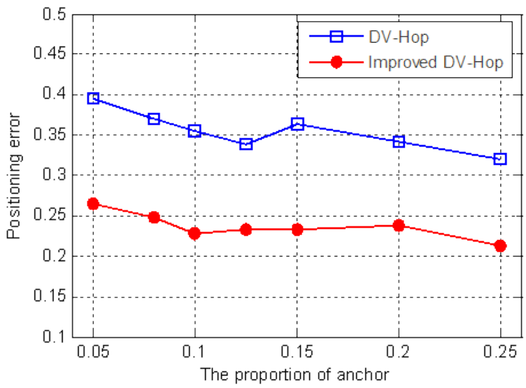

Fig. 5. Influence of the ratio of anchor

improved algorithm shows positive stability in standard scenes specific to different anchor node proportions.

4.3.4. Positioning coverage Figure 6 shows the location coverage under different network connectivity degrees when the anchor node proportion is 10%. When the

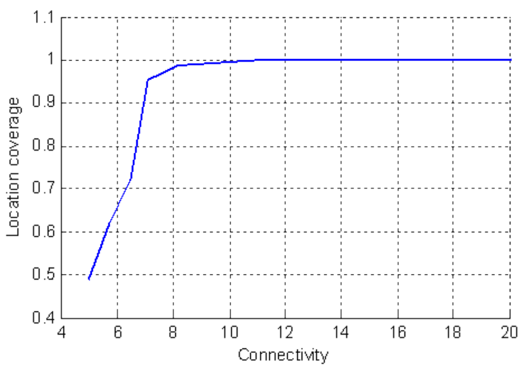

Fig. 6. Influence of the ratio of anchor

anchor node proportion is 10% and the network connectivity is higher than 7, 100% positioning can basically be realized. When the network connectivity is 10, 100% positioning coverage can be realized as long as there are more than three anchor nodes in the network.

5. Conclusions

Via the in-depth elaboration of DV-Hop algorithm and its improvement ideas, the combination of advantages of various ideas and the inspiration by these ideas, an improved high-accuracy DV-Hop localization algorithm is proposed by this paper. Through a new controllable flooding agreement, the phenomenon of information implosion can be reduced. The joint probability density calculation way is introduced, and the limited hop number of grouping broadcast and the conversion relation between anchor nodes that are required at least to be monitored by unknown nodes in the application are corrected. The neighbor node overlapping degree is utilized to replace the overlapping area, calculate the note distance and correct the hop section distance of one hop node; By making use of the conversion relation between the hop distribution proportion of the neighbor node and the distance, the hop section distance of nodes with two or more hops is corrected. It is put forward that the concept of upgrading the temporary anchor node will be used to replace the traditional upgrading anchor node mode, thus resolving possible problems like the large positioning error caused by the monitoring of a small number of anchor nodes by unknown nodes and the improvement of adverse node positioning. Experimental results suggest higher positioning accuracy can be achieved via the improved algorithm compared to the classic DV-Hop algorithm and that the purpose of improving accuracy can be reached.

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