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Research Article

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The research on WSN node positioning based on Cuckoo searching algorithm

Xiaohui Wang and Shengpu Li

Pingdingshan University, College of Computer Science and Technology, Pingdingshan Henan, China

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ABSTRACT

This paper first corrects the distance of the average hop in DV-Hop algorithm, then introduces cuckoo searching algorithm to optimize the sensor node positioning errors, and finally applies simulation experiment to test the performance. The simulation experiment illustrates the proposed algorithm needs extra hardware support in order to increase the Sensor positioning precisions compared to DV-Hop algorithm. Even with fewer anchor nodes, the proposed algorithm can obtain ideal positioning results with high practical value.

Key words: Sensor Node Positioning, DV-Hop Algorithm, Cuckoo Searching Algorithm, Accumulative Errors

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INTRODUCTION

Wireless sensor network (WSN) is composed of a large number of miniature sensors with perceptive, computing and communication abilities. But the energy the sensors are limited. In the application of WSN, there are no meanings for the surveillance data with out the position information of the nodes. Therefore, node positioning is focus and hotspot in current WSN researches [1~5].

The nodes positioning algorithms with distance finding mainly are received signal strength (RSSI),time of arrival(TOA),angle of arrival(AOA) and time difference of arrival(TDOA) [6~8]which measure the distance of contiguous nodes [9~13]. Non-distance finding algorithms can find the positions of the sensors through the network connectivity without the hardware support. They have the advantages in cost and power consumption [14~16] which are suitable for large scale sensor network application. The main algorithms are centric algorithm, amorphous algorithm and DV-Hop algorithm.

Cuckoo Search(CS)is a group intelligent optimization algorithm which not only combines the special Levy flight mode of the birds and flies and increases the information communications among groups, but also has the advantages of fast convergence speed, fewer parameters and easy to implement[17].

Aiming at the shortcomings of the DV-Hop algorithm, this paper puts forward a WSN positioning algorithm combining cuckoo searching algorithm and DV-Hop algorithm [18-19]. First, this paper analyzes the DV-Hop mechanisms, and then it computes the positions of the sensor nodes need to be located. Finally, CS algorithm is used to correct the positioning errors which can increase the precisions of the positioning algorithm. The experiment verifies the validity of the algorithm.

DV-Hop mechanisms
The operation steps of the DV-Hop algorithm is as follows.
(1) The sensor nodes need to be located can obtain the minimum hops of each anchor node, then each sensor node need to be located have a table {ID, xi, yi, hopi}in which ID represents the identifier of each anchor node,{xi ,yi} represents the location of each anchor node, and hopi is the minimum hops between the anchor node I and the sensor node need to be located.

(2) The average hop distance can be estimated according to the equation (1).

$$C_i = \frac{\sum_{i \neq j} \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}}{\sum_{i \neq j} hops_{ij}} \tag{1}$$

In the equation,{xi ,yi}is the coordinate of the anchor node, hops in the minimum amounts of hop between two hops.

(3) The distance between the anchor node and the sensor node need to be located can be computed as follows.

$$d_i = C_i \times hops \tag{2}$$

Equation (1) can compute the average hop distance of A, then the distance between node A and P can be computed.

In the operation of DV-Hop algorithm, when computing the distance between the anchor node and the sensor node need to be located, normally the hop distance is used to replace the distance in the straight line.

In order to solve the shortcomings of the DV-Hop algorithm, some researchers propose to apply average hop distance (cc) to replace the average hop distance Ci of the anchor node I. The deviation between the computed average hop distance and the actual average hop distance can be obtained. The computation equation is as follows.

$$cc = \frac{\sum C_i}{n} \tag{3}$$

$$\delta = \frac{\sum_{i \neq j} \left| d_{true_{ij}} - d_{estimated_{ij}} \right|}{\sum_{i \neq j} hops_{ij}} \tag{4}$$

In the equation, $\left| d_{true_{ij}} - d_{estimated_{ij}} \right|$ is the absolute of the difference between the actual distance and the computational distance of arbitrary two anchor nodes.

The actual and computational distances between the anchor node i and j can be obtained through the equation (5) and (6) respectively.

$$d_{true_{ij}} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2} \tag{5}$$

$$d_{estimated_{ij}} = cc \times hops_{ij} \tag{6}$$

Thus, the DV-Hop algorithm positioning algorithm can be as follows.
(1) The minimum amounts of hops from all the nodes to each anchor nodes are recorded.
(2) Each anchor node's own average hop distance is computed and the correction is flooded in the whole network.
(3) cc and δ can be computed according to equation (3) and (4). The sensor nodes need to be located will accept the correction value and add it to the database.
(4) The average hop distance can be computed as:

$$HopSize_{new} = cc \times k\delta \tag{7}$$

In the equation, k is variable which is determined by the network environment.
(5) The product between the minimum amount(hops) of hops from the nodes need to be located to the anchor nodes and the average hop distance is computed to obtain the distance between the sensors need to be located and the anchor nodes.

$$d_i = HopSize_{new} \times hops \tag{8}$$

After obtaining the distance between the unknown nodes and anchor nodes there-edge measurement can be used to fulfill sensor node' self positioning.

Assume the coordinates of the sensor nodes need to be located is (x, y),the coordinates of the itch anchor nodes is (x,yi),the distance between the itch anchor nodes and the nodes need to be located is di.

According to the previous known data, the system equations (9) can be established.

$$\begin{cases} d_1^{\ 2} = \left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2 \\ d_2^{\ 2} = \left(x_2 - x_2\right)^2 + \left(y_2 - y_2\right)^2 \\ \vdots \\ d_n^{\ 2} = \left(x_n - x_n\right)^2 + \left(y_n - y_n\right)^2 \end{cases} \tag{9}$$

The following equation can be obtained by solving(x,y).

$$f\ (x, y) = \sum_{i=1}^{n} \sqrt{\left(x_i - x\right)^2 + \left(y_i - y\right)^2 - d^{\ 2}{}_i} \tag{10}$$

Generally speaking, the sensor nodes positioning problem can transfer to multiple constrains problem. If equation (10) is nonlinear optimal problem and the traditional mathematical can't solve accurately, thus cuckoo searching algorithm should be applied to solve equation (10).

Sensor nodes' positioning errors correction by cuckoo searching algorithm

Cuckoo Search (CS) is a kind of group intelligent optimization algorithm proposed by Yang and Deb in 2009 which is based on the Pa parasitic reproductive strategy of the cuckoo species and combines the special Levy flight mode of the birds and flies. In order to simulate the nest searching behavior of the cuckoo, CS set three rules and the details are as follows.

(1) The cuckoo lays one egg once which represents the solution for one problem. The egg is randomly placed in one nest to incubate.
(2) Some parts of nests have high quality eggs which means there are perfect solutions and there nests will be kept for the next generation.
(3) The amount of available nests is fixed. The probability of the eggs being discovered by the host birds is $P_a \in (0,1)$ .Once some nest is discovered, the host bird will discard the eggs or the nest to search new nest in order not to affect the searching of the optimal solutions.

Based on these three rules, assume $x_i^{(t)}$ represents the location of i_{th} nest in t_{th} generation. $L(\lambda)$ represents the random searching path, then the path and position update with cuckoo algorithm as shown in the following equation.

$$x_i^{(t+1)} = x_i^{(t)} + \partial \oplus L(\lambda), i = 1, 2, \cdots, n \tag{11}$$

After positions updated between [0,1]is randomly generated. If r>Pa, $x_i^{(t+1)}$ will randomly changes. Otherwise, it remains the same. Finally, the nest positions $y_i^{(t+1)}$ with better test results are kept and they are still marked as $x_i^{(t+1)}$.

The sensor nodes' results correction procedure by cuckoo searching algorithm.

(1) N nests are randomly generated and the nest positions correspond to the coordinates of the sensors.
(2) The positioning errors corresponding to each team of nest positions are computed to find the fewest errors of the current optimal nests.
(3) The optimal nest positions which are corresponded to the fewest errors of previous generation are kept.
(4) The other nests are updated to obtain a team of new nest positions and the positioning errors are computed.
(5) According to the positioning errors, the new nest positions are compared with the nest positions of the previous generation. The nest with better positions will replace the bad ones to obtain the positions with optimal positions (kt).
(6) The random number r and Pa are compared. The nests with fewer discovery probabilities in kt are kept and the nests with larger probabilities are randomly changed. The positioning errors of the new nests are computed and compared with A, The nest positions with fewer positioning errors are used to replace the worse nest positions in order to obtain the nests with more optimal positions.
(7) The most optimal nest positions can be found input and evaluate whether the fewest precision can meet the requirements of the nodes positioning precisions in WSN. If the requirements are met, the searching can stop and out put the global fewest errors and the corresponding most optimal nests.

Otherwise, return step (4) to keep searching the optimal solution.

(8) The final coordinates of the sensor nodes can be determined by the optimal nest positions.

Simulation experiment

In order to testify the performance of the nodes positioning algorithm combining cuckoo searching algorithm and DV-Hop algorithm. Matlab 2012b toolboxes are used to simulate the experiment with Windows 7 operation system. Several wireless sensors are randomly distributed in the rectangle area with the size of 200 mx200 m. DV-Hop algorithm is applied as comparison algorithm. The average positioning results from 5 times of experiments are used as the final results.

When the amounts of the anchor nodes are different, the precisions changes of the combination algorithm and the single DV-Hop algorithm are shown as figure 1.In figure 1,at beginning the anchor nodes are quite few, the average positioning errors of the combination algorithm and single DV-Hop algorithm are quite high and the positioning precisions are low. With the increase of anchor nodes, the average positioning errors of the combination algorithm and the single DV-Hop algorithm become reducing. The error reduction of the combination algorithm is larger than that of DV-Hop algorithm.

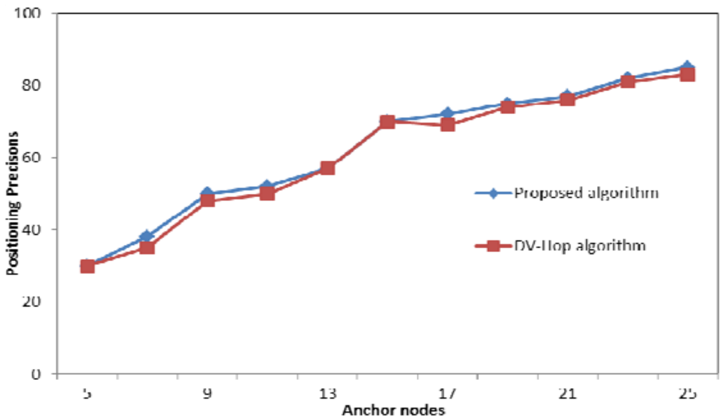

Fig1. The relationship between the positioning precision and amount of anchor nodes

The experiment illustrates the positioning performance of the combination algorithm is better than that of DV-Hop algorithm. When the positioning precisions are the same, the combination algorithm needs fewer amounts of anchor nodes which can reduce the cost of the Wireless Sensor Network but increase the sensors' positioning precisions. The results prove the errors correction of the cuckoo, researching algorithm for DV-Hop algorithm is effective and feasible.

Under the conditions of different amounts of sensor nodes, the average precisions changes of the combination algorithm and single DV-Hop algorithm are shown in figure 2. From the figure 2,compared to DV-Hop algorithm, the average positioning precisions of the combination algorithm are relatively high. The algorithm can effectively reduce the node positioning errors because the cuckoo searching algorithm can correct the positioning errors of the

DV-Hop algorithm and reduce the harmful effects of the accumulative errors during the sensor positioning procedure which is able to further increase the DV-Hop positioning precisions.

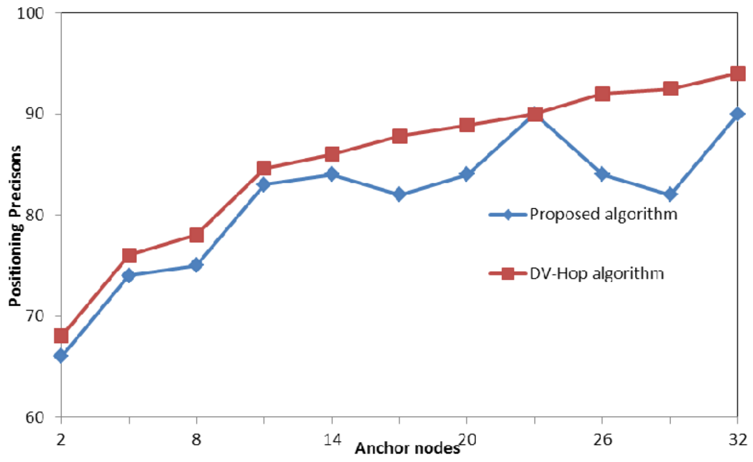

Fig2. The relationship between the positioning precision and the amount of the nodes

CONCLUSION

The sensor node positioning is the supportive technology in Wireless Sensor Network. First, this paper analyzes the shortcomings of the DV-Hop algorithm and corrects the distance of average hop in DV-Hop algorithm, then it introduces cuckoo searching algorithm to further reduce the sensor positioning errors. The simulation experiment illustrates the proposed algorithm needs extra hardware support in order to increase the sensor positioning precisions compared to DV-Hop algorithm. Even with fewer anchor nodes, the proposed algorithm can obtain ideal positioning results with high practical value.

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