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The Research of DV-HOP Positioning Algorithm Based on RSSI Calibration

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Abstract

Because of the DV-HOP algorithm in wireless sensor network (WSN), the first jump range error, which affect the positioning error of the whole node network problems. This paper puts forward an improved algorithm is proposed. The algorithm is mainly using the RSSI ranging technology, in the process of DV-HOP first jump range through correction of RSSI ranging technology, to reduce the distance measuring error, in order to improve positioning accuracy. The simulation results show that compared with traditional DV-HOP algorithm. The improved algorithm can without additional hardware and computation under the premise of improving positioning accuracy.

Keywords*: location algorithm, DV-HOP, RSSI, hybrid positioning*

1. Introduction

Wireless sensor network (WSN) is a kind of brand-new information acquisition and processing method. It is composed of many Light quality, small size, and the price of cheap sensor nodes [1]. Equipped with a low-power transceivers and limited data processing capability. Nodes are randomly deployed in a area of interest. Random deployment node cannot know in advance their position. Many wireless sensor network applications are based on self-positioning sensor, such as target tracking, environmental monitoring, etc. It all depends on the location of the sensor node itself information. Positioning technology played a key role in wireless sensor network applications. Nowadays, there are many since localization algorithm, generally can be divided into two categories, range-based and range-free [2-3]. Range-based algorithm which using the absolute distance between point and point or point of information between the sensor node positioning. Many algorithms based on distance, all need actual distance measurement. Such as: TOA [4] technology, TDOA [5] technology, AOA [6] technology, as well as the RSSI [7] technology. At present many nodes have RF transmission function. For the hardware overhead and energy consumption problems, Used to estimate the distance based on the RSSI. But because the RF signal is easily affected by environmental factors, using RSSI ranging technology to obtain the distance error is bigger, the algorithm accuracy is not satisfactory, other ranging algorithm based on distance, although compared to the RSSI algorithm improved on the positioning accuracy, but it is limited by power consumption and the cost of hardware. Range-free technology does not need to predict the distance between the sensor nodes Angle information. The typical range-free algorithm includes DV-Hop [8] algorithm, centroid algorithm [9], MDS-MAP [10] algorithm and APIT [11] algorithm, etc. MDS-MAP algorithm needs global network structure information, does not apply to this energy limited wireless sensor networks. Centroid algorithm positioning using the connectivity of beacon nodes and blind node easy to operate, without coordination, a small amount of calculation, high scalability, but the positioning error is bigger. DV-Hop [12-13] algorithm is easy to implement, on general terms of the hardware environment is a good choice. Compared with the range-based, in the aspect of cost, hardware, power consumption range-free algorithm requires less, and less affected by environmental factors. This positioning of coarse accuracy to meet the accuracy requirements of the position is not strictly Applications.

DV-Hop algorithm using the product of the average hop distance and number of hops between nodes is the distance, then use trilateral positioning algorithm to obtain location information of unknown nodes. But because the algorithm using jump distance express line

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distance, therefore, no matter how far the actual distance between two adjacent nodes, its hops are 1, estimate of the distance of adjacent nodes are to jump from the average. It will lead to larger positioning error, while the existing algorithm in view of the error of the problems of the first jump, less research. This paper proposes a DV-Hop improved algorithm based on RSSI calibration, can improve the positioning accuracy.

2. DV-HOP Algorithm

2.1. DV-HOP Algorithm

Niculescu and Nath proposed a kind of distributed computing localization algorithm. The core idea of the algorithm is use the average distance per hop and the hops between unknown nodes and anchor nodes instead of the distance between unknown nodes and anchor nodes. When an unknown node receives three or more anchor nodes information, the unknown node through the trilateral measurement method to calculate their own location information. The algorithm mechanism follows.

1) Node broadcast to their neighbor node with their location information, including the hop field, Initialized to zero, record the receiving node with the minimum number to each anchor node, ignoring the larger the number of hops a packet from the same anchor nodes then record the hop is one and forwarded to a neighbor node, in this way, all the nodes in the network can record down to the minimum hop count each anchor node.

2) Through the received information, anchor nodes calculating average length of each jump, And broadcast average hops distance to the entire network. The unknown node calculated the distance between the anchor node by node hops from the anchor and the average per-hop distance information.

3) When the unknown node calculates a distance of three or more anchor node distance information, through the trilateral measurement method or the maximum likelihood estimation method calculate. Using the formula (1) to estimate the actual distance of every hop.

$$C_i = \frac{\sum_{j \neq i} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{j \neq i} h_j} \qquad (1)$$

In the formula (1), (x_i, y_i), (x_j, y_j) is the coordinates of anchor nodes I and j, h_j is the number of hops between anchor nodes I and j($i \neq j$).

2.2. DV-Hop Algorithm Inadequate

In Figure 1, anchor nodes are L1,L2,L3. A is the unknown node needs to locate. Three anchor nodes know the distance between each other, as shown in Figure are 30,30 and 40. The distance between A and L1 is 15, hop count is 1.The number of hops A to L2 and L3 are three. Assuming the length of each side is 10.

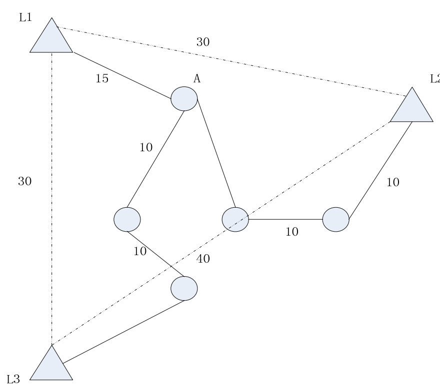

Figure 1. The Schematic of DV-Hop Algorithm

DV-hop algorithm shows L1, L2, L3 calculated as follows:

L1：（30+30）/（4+4）=7.5

L2：（30+40）/（4+6）=7

L3：（30+40）/（4+6）=7

L1，L2，L3 will be broadcast their calculations. So A to L1 distance is 7.5, because only jump is per jump distance. the distance A to L2 and L3 are 7.5*3=22.5. However, the actual distance of A and L1 is 15, with DV - Hop algorithm to estimate the distance of 7.5, this positioning error is reached 200%.

2.3. An Improved Algorithm Based on RSSI Auxiliary

When the hops between nodes A and anchor node L1 is 1 can be easily obtained. but the DV-Hop algorithm will increase the error. Therefore, the introduction of RSSI technology assisted positioning. The RSSI ranging method can reflect the difference which caused by the uneven distribution of nodes from the actual jump. But the transmission power loss is used to calculate the distance is often affected very great by environmental factors such as topography, geomorphology. To avoid this problem, this paper does not directly use RSSI algorithm, but with the ratio between each hop between two nodes RSSI path length and the average RSSI path length as RSSI path length correction factor. Then with correction coefficient and DV-Hop counts per jumping from multiplication to fix each jump distance.

Then use the correction factor with average distance of every jumping from multiplication to fix each jump distance. The jump distance can be used as a jump from the distance between nodes is 1. And it is not affected by environmental factors.

Algorithm specific process is described as follows:

First step, like with the DV-Hop algorithm, Anchor nodes flooding broadcast their information which include its location information, their own ID, the initial value of 0 jump hops with Fixed power, receives the data node Hop+1 and recorded in the packet. Unlike the DV-Hop algorithm. the packet is added by the theoretical model of the measured RSSI path length value called RSSID(n), node then forwards the packet to its neighbors at a fixed power, after the neighbor node receives the forwarded message, The hops number plus one, RSSI received by the own path length measured value and the value of the path length in the packet is added to the previous hop, and adding a packet. When it arrive at a node by n jumps, the data in the packet is coordinates, hops RSSID(1)+RSSID(2)+…+RSSID(N)=RSSIDN ID, Hops. The same as the DV-Hop algorithm, when received the packets of the same ID in the hop count is less than the existing hop, to be replaced, otherwise discard. when the data of an anchor node is received to another anchor node through N jumps. Through the method DV-hop algorithm to calculate the average hop distance. At the same time, calculate the average jump RSSI average path length, just like Formula (2).

$$RSSID_{av} = \frac{RSSID(1) + RSSID(2) + \cdots + RSSID(n)}{n} \tag{2}$$

Then broadcasts the average hop distance (HOPsize) and the average RSSI path length (RSSIDav) in the way of DV-Hop algorithm.

Second step, establish correction factor of jump distance, with the any first jump RSSI path length RSSID(1) divided by the average path length RSSIDav, like Formula (3), as a correction coefficient of Jump distance.

$$\lambda = \frac{RSSID(1)}{RSSID_{av}} \tag{3}$$

Therefore, when the hop count between nodes is 1, and the distance between calculate two points, such as Formula (4).

$$d = \lambda \times Hop_{size} \tag{4}$$

When the number of hops between two nodes is greater than 1, calculate the distance between two points according to the traditional DV-HOP algorithm. Hop count is 1 of the unknown node can use the information table which include the value of the RSSID and the average path length, with this can easy to calculate the distance to the anchor node.

The third step, use the trilateration in formula(5), calculate the unknown coordinates of unknown nodes, after unknown nodes use the measured values of jump distance which is unknown node to each anchor node. Then the trilateral measurement method is used to estimate the unknown coordinates of its own. Known n nodes coordinates were （x1,y1），（x2,y2），（x3,y3）… (xn,yn) in order, distance from node D, respectively d1, d2, d3, ..., dn, and it is known that the coordinates of the node D is (x, y).
There are the following formula:

$$\begin{cases} (x_1 - x)^2 + (y_1 - y)^2 = d_1^{\ 2} \\ \vdots \\ (x_n - x)^2 + (y_n - y)^2 = d_n^{\ 2} \end{cases} \tag{5}$$

Subtracting the last equation from the first start equations were:

$$\begin{cases} x_1^2 - x_n^2 - 2(x_1 - x_n)x + y_1^2 - y_n^2 - 2(y_1 - y_n)y = d_1^2 - d_n^2 \\ x_2^2 - x_n^2 - 2(x_2 - x_n)x + y_2^2 - y_n^2 - 2(y_2 - y_n)y = d_2^2 - d_n^2 \\ \vdots \\ x_{n-1}^2 - x_n^2 - 2(x_{n-1} - x_n)x + y_{n-1}^2 - y_n^2 - 2(y_{n-1} - y_n)y = d_{n-1}^2 - d_n^2 \end{cases} \tag{6}$$

Represented as a linear equation AX = b, Among them:

$$A=\begin{bmatrix} 2(x_1 - x_n) & 2(y_1 - y_n) \\ \vdots & \vdots \\ 2(x_{n-1} - x_n) & 2(y_{n-1} - y_n) \end{bmatrix} \tag{7}$$

$$b=\begin{bmatrix} x_1^{\ 2} - x_n^{\ 2} + y_1^{\ 2} - y_n^{\ 2} + d_n^{\ 2} - d_1^{\ 2} \\ \vdots \\ x_{n-1}^{\ \ 2} - x_n^{\ 2} + y_{n-1}^{\ \ 2} - y_n^{\ 2} + d_n^{\ 2} - d_{n-1}^{\ \ 2} \end{bmatrix} \tag{8}$$

$$X=\begin{bmatrix} x \\ y \end{bmatrix} \tag{9}$$

Finally, use the minimum mean square error method to obtain the coordinates of the nodes.

$$X=\left(A^T A\right)^{-1} A^T b \tag{10}$$

3. The Simulation Results

In the matlab environment for the proposed modified DV-Hop algorithm simulation, and comparative analysis on the original DV-Hop algorithm. Assuming the actual coordinates of the unknown node (xi,yi), estimates for the node coordinates for (xr,yr), communication radius is the R.

Absolute positioning error shown in Formula (11).

$$err = \sqrt{(x_r - x_i)^2 + (y_r - y_i)^2} \tag{11}$$

Relative positioning error shown in Formula (12).

$$error = \frac{\sum_{i}^{n} err}{R} \tag{12}$$

3.1. Different Communication Radius, Performance Comparison

In order to more comprehensive analysis and evaluation of the improved algorithm, change the node communication radius in turn. The experiment compare performance under different communication radius. As shown in Figure 2, under the environment of 100 x 100 rectangular simulation experiment, the number of nodes 200,the anchor node 20 in the environment. Communication radius from 10 starts superposition in turn, after each data run independently, and then the data are averaged. Ranging error can be calculated between nodes.

It can be seen from the Figure 2, improved algorithm when the communication radius is small relative to the original algorithm can greatly improve the positioning accuracy, after radius is more than 20, the improved algorithm has not improved algorithm performance. Because when R is small, located nodes within the scope of 1-hop, located nodes can use little or no anchor nodes. Introducing auxiliary RSSI ranging at this time to ensure the estimation error between unknown node and anchor node between is smaller. However, with the increase of R, Average hop distance in network becomes larger. Located nodes can use more anchor nodes within the scope of 1-hop, Sensitive to the change of the radius is not so.

Therefore when the radius is lesser, the improved algorithm can be larger performance improvement.

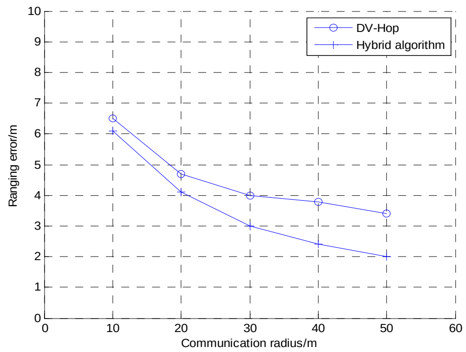

Figure 2. Ranging Error under Different Communication Radius

3.2. Different Number of Anchor Nodes, the Algorithm Performance Comparison

Simulations are in the 100×100 network environment, the total number of nodes 200, the communication radius of 20, changing the number of anchor nodes in the network. Simulation experiments performance under different number of anchor nodes. And the proposed algorithm is measuring the position information of the node and the actual node location under different communication radius. at last obtain the relative positioning error.

The simulation results are shown in Figure 3, as the number of anchor nodes to improve, original algorithm and improved algorithm can be greatly improved. When the anchor node reaches a certain percentage, then improve the number of anchor nodes, the algorithm performance increased slowly, however, the improved algorithm is still better than the DV-HOP algorithm.

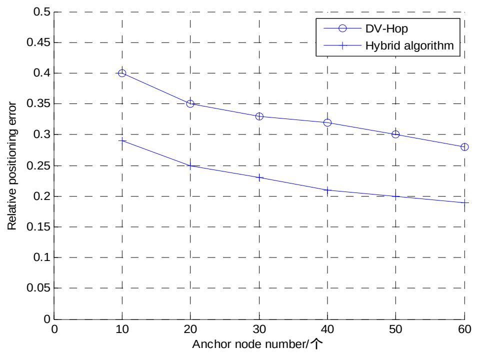

Figure 3. Different Anchor Nodes Positioning Error

3.3. Network Location Coverage under the Different Number of Anchor Nodes

In the experiment of positioning coverage, Sensor nodes are randomly distributed in the environment of 100×100, node number changes between 100-200.The number of anchor nodes is 20.Node communication radius is 10. The node distribution is shown in Figure 4, improved algorithm compared with DV-Hop algorithm positioning coverage as shown in Figure 5.

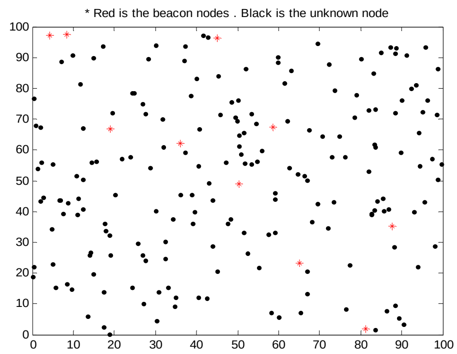

Figure 4. The Random Node Distribution

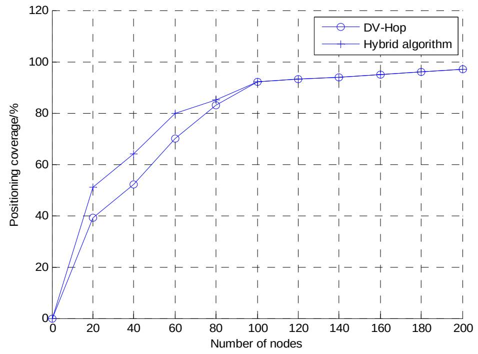

Figure 5. Positioning Coverage under a Different Number of Nodes

As can be seen in Figure 5, with the increase of number of nodes, positioning coverage also will be increasing. Because coverage caused by node density. The greater the density, the greater the positioning coverage, because this improved algorithm according to the hop count is 1 node adopt auxiliary RSSI ranging. Hop count is 1 of the unknown nodes which need only one anchor node information can be positioned. While traditional DV-Hop algorithm to get at least three anchor node information to solve the unknown node location. It is evident to see in the number of nodes is less than 90, the density of node in network node are rare From figure (5).Then auxiliary positioning to the unknown node which hop count is 1 by the RSSI technology. It can reduce reliance on anchor nodes. Positioning coverage was significantly better than DV-Hop algorithm.

4. Conclusion

In recent years, scholars proposed many improved algorithm To the lack of DV-HOP algorithm. The research of 1 hop distance error in the DV-HOP algorithm is not a lot. In this paper, the improved algorithm is proposed in order to reduce this effect. By introducing the auxiliary RSSI ranging, reduce the estimation distance error between nodes. At last achieve the goal of eventually reduce the positioning error. The simulation results show, the algorithm did not increase the amount of calculation and hardware equipment. The improved algorithm Can better improve the positioning performance. Stay algorithms are discussed on the basis of the simulation experiments in this paper. In the future How to implement in practical system, and test the algorithm performance in the real environment is also an urgent need to solve the problem.

Acknowledgements

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