Exploration of a New Location Algorithm for Wireless Sensor Network

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Chao Huang(✉), Yuang Mao
Guangxi Medical University, Guangxi, China
chaohuangxg12@126.com

Abstract—To further study the basic principle and localization process of DV-Hop location algorithm, the location error reason of traditional location algorithm caused by the minimum hop number was analyzed and demonstrated in detail. The RSSI ranging technology was introduced to modify the minimum hops stage, and the minimum hop number was improved by the DV-Hop algorithm. For the location error caused by the average hop distance, the hop distance of the original algorithm was optimized. The improved location algorithm of DV-Hop average hop distance was used to modify the average range calculation by introducing the proportion of beacon nodes and the optimal threshold value. The optimization algorithm of the two different stages was combined into an improved location algorithm based on hop distance optimization, and the advantages of the two algorithms were taken into account. Finally, the traditional DV-Hop location algorithm and the three improved location algorithms were simulated and analyzed by beacon node ratio and node communication radius with multi angle. The experimental results showed that the improved algorithm was better than the original algorithm in the positioning stability and positioning accuracy.

Keywords—wireless sensor network, DV-Hop location, minimum hops, average hop distance

1 Introduction

There are many methods for the division of node location technology. The most commonly used is the division standard based on ranging and positioning technology and non-ranging location technology. The ranging location algorithm mainly obtains the location of the unknown node by measuring the angle or distance between the nodes. In order to accurately measure the information, the requirements for the sensor are high and the power consumption is high. However, at the same time, the accuracy of the algorithm is relatively high. The non-ranging location algorithm has low hardware requirements and low power consumption. Its implementation is relatively simple, and its application is more extensive. However, the location precision of the non-ranging finding algorithm is also lower than the ranging algorithm. For example, the centroid method is a kind of non-ranging location algorithm, which is simple and easy to calculate. It is popular in practical applications. At the same time, its positioning accuracy is low, which has become a limiting factor for the development of the algorithm.

The above two kinds of location algorithms have certain location defects in all aspects. With the development of wireless communication networks, the requirements for positioning services are increasing, and there is no algorithm that can adapt to changing needs. Therefore, it is necessary to study the high performance positioning algorithm with the improvement of the WSN performance requirement in the application field.

2 Literature review

DV-Hop algorithm is a multi-hop algorithm between nodes. It is one of the distributed node localization algorithm "APS", which is proposed by Zaidi and other scholars [1]. Orojloo and Haghighat [2] believed that the first stage of traditional DV-Hop positioning step is: the minimum number of hops between the beacon node and the unknown node is calculated. First, the beacon nodes in the region propagate the data tuples with their own certain information through a WSN vector distance exchange protocol in the network. It includes the coordinate position (x_i,y_i) of the beacon node, the ID identity of the node, and the number of hops of the beacon node from propagating to receiving node. Aliaa et al. [3] held that when the broadcast of the data is completed, the sensor nodes in the region get the coordinates of the beacon nodes that can be connected and the number of hops to reach them. Alsultan, M. et al. [4] thought that for a node, if many packets of the same beacon nodes are accepted, but the number of hops arriving at the same time is different, the smaller number of hops is retained. In this way, the shortest path of the beacon node to itself is obtained.

Tomic and Mezei [5] explored the improvement strategies for dv-hop localization algorithm for wireless sensor networks, discussed the relationship between dv-hop localization algorithm and wireless sensor network positioning algorithm and tested the accuracy of the positioning algorithm. Habib Mostafaei and Mohammad Shojafar [6] proposed a new meta-heuristic algorithm, which has the advantages that the wireless sensor network positioning algorithm does not have, so as to maximize the lifetime of wireless sensor networks. Mesmoudi, A. et al. [7] talked about a novel localization algorithm for wireless sensor networks, which was efficient area-based. And they verified the positioning precision. Li and other scholars [8] analyzed five commonly used localization algorithms for wireless sensor networks mainly from the perspectives of advantages, disadvantages, applications and so on. Yan et al. [9] put forward a new localization algorithm based on multi-hop, which was improved on the basis of traditional wireless sensor network localization algorithm. Wei and others [10] proposed an indoor localization algorithm based on dynamic measurement compressive sensing for wireless sensor networks by using compressive sensing theory.

To sum up, dv-hop algorithm is mainly discussed, and improvement strategies for dv-hop algorithm are explored, but the performance of dv-hop algorithm is not deeply explored. To further study the basic principle and localization process of DV-Hop location algorithm, the location error reason of traditional location algorithm caused by the minimum hop number is analyzed and demonstrated in detail. For the location error caused by the average hop distance, the hop distance of the original algorithm is optimized. The improved location algorithm of DV-Hop average hop distance is used to modify the average range calculation by introducing the proportion of beacon nodes and the optimal threshold value. In a word, the improved algorithm is better than the original algorithm in the positioning stability and positioning accuracy.

3 Research on optimization of DV-Hop algorithm

3.1 Analysis of location error caused by the minimum hops

In the DV-Hop positioning process, when the node gets the minimum hops of the beacon node, it ignores the actual distance between the nodes and only calculates the arriving hops of the node. That is to say, when the node receives the broadcast packets from the adjacent nodes, the number of hops is added directly. Then, it continues to forward and ignores that the real distance between adjacent nodes is not an equal space. In the actual application environment, the deployment of wireless sensor network is accomplished by airplanes. Therefore, the distribution of nodes is generally uneven. In addition, the path between nodes is not a linear transmission, but a zigzag. As a result, the minimum hops transferred between nodes cannot reflect the real situation well. If it is used directly to calculate the distance between nodes, the positioning will have a larger accuracy deviation. The following will give an example of this problem.

As shown in figure 1, O represents the unknown nodes. A, B and C are beacon nodes. In addition, the actual distance between AB and AC is 20. The actual physical distance of AD is 4 and the distance of DO is 10. The average hop distance of the beacon node is equal to 4 according to the positioning step of the traditional DV-Hop. The minimum hops from A to O are 2. The average hop distance of the node A is multiplied by the hops, and the estimation distance of AO is 8. There is a lot of error between this and the real distance.

The random distribution of nodes may be uneven, and the minimum hops cannot truly reflect the physical distance of the actual adjacent nodes in the environment. In this way, the distance error between the unknown node and the beacon node is larger than the beacon node. To solve this problem, we can give different correction coefficients based on the real physical distance between nodes, which can solve the defect of DV-Hop location algorithm better.

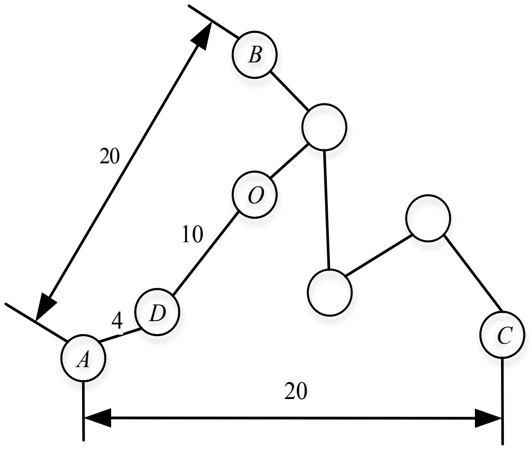

Fig. 1. Hop number error analysis

3.2 Algorithm improvement based on hop optimization

In the previous section, the minimum number of hops that is unreasonable can lead to the positioning error. According to this, different weights are given to the nodes by the real physical distance between the nodes. The hops of information transfer between nodes are corrected. A more reasonable minimum hop between nodes is obtained to eliminate the error. The RSSI technology is introduced to optimize the original algorithm, and the traditional DV-Hop algorithm is improved based on the minimum hops. The positioning flow chart of the improved algorithm is shown in figure 2.

The basic idea of DV-Hop improvement algorithm based on the minimum hops is as follows: The RSSI value between the beacon node and the adjacent node is used as a reference value, and the weight value is initialized to 1. Then, after the other nodes receive the information, the hop number is corrected according to the weight value of the hop number and the reference value. Then, we continue to forward and obtain the minimum hops after the weight correction. The specific location process of the DV-Hop improved algorithm based on the minimum hops is as follows:

The beacon node first broadcasts a packet containing its own information, and the information contains the node's own ID number. The coordinates of the beacon node are (x,y). The minimum hops with an initial value of 0 are h. The initial value of the RSSI reference value RB (RSSIBASIC) of the adjacent node information received by the beacon node is 0.

After receiving the initial information of the beacon node, the adjacent nodes add 1 to the minimum hops. The RSSI value of the received information is recorded and the reference value RB is vested.

After updating the hop, jump distance, RSSI value and other information, the node forwarded the packet to the next adjacent node. The next neighbor node takes the RSSI value as R when receiving data packets, and calculates the hop weight value h=R/RB of the step. The weights are modified to h=h+h ', and the adjacent nodes broadcast the revised packets again.

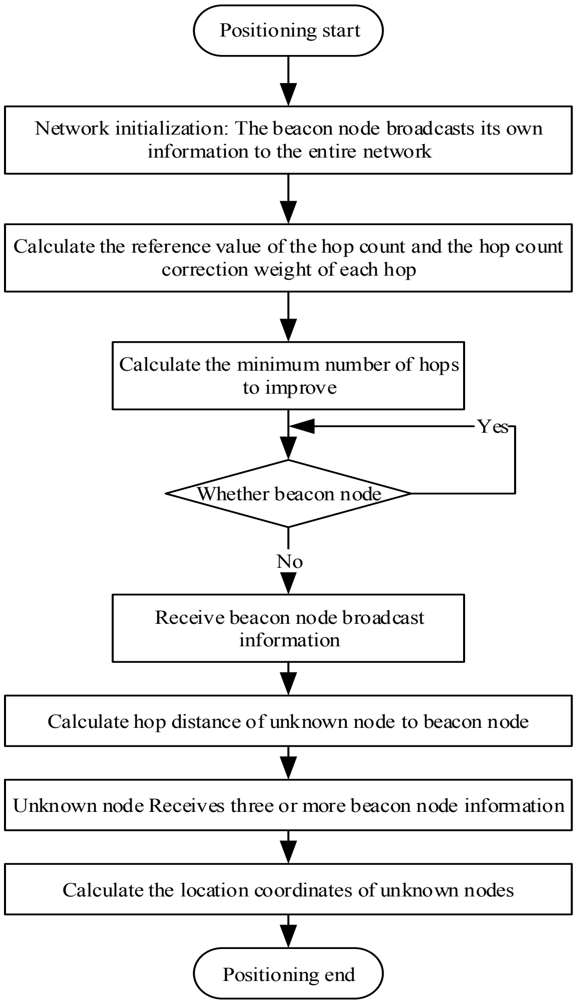

Fig. 2. Improved DV-Hop Location flow chart based on minimum hops

When the nodes in the network receive more than one message from the same beacon node, they are compared with the h values of the hop weight values that are stored in their own storage. If it is smaller than the existing hop weight, it returns the third steps, otherwise it will be abandoned.

After finally obtaining the minimum hops of the RSSI weighted correction, the average hop distance is calculated according to the steps of the original DV-Hop location algorithm. Then, the estimation distance between the unknown node and the beacon node is calculated, and the estimation position is obtained.

3.3 Analysis of location error caused by average hop distance

The minimum hops and average hop distance are two main factors that affect the positioning accuracy of the traditional DV-Hop positioning algorithm. In the third chapter, aiming at the minimum hops of traditional algorithm, RSSI technology is added to improve it. The simulation results show that the improved algorithm has a significant development in positioning accuracy. In this section, the error caused by the average hop distance of the algorithm is analyzed in detail. In addition, the traditional DV-Hop location algorithm is improved on the basis of the average hop distance optimization.

In the localization process of the traditional DV-Hop location algorithm, some of the algorithms have many defects. The algorithm relies too much on the two data factors such as the minimum hops and the average hop distance. Therefore, two positioning data can lead to congenital positioning error. In addition to the minimum hops, the average hop distance also has a great influence on the positioning accuracy.

When the distance between several hops is used to replace the actual distance between the nodes, the average hop distance is inaccurate when the hops are not reasonable. Moreover, in the structure of wireless sensor networks, the actual distance between a beacon node and an unknown node is the hops between the two and the product of average hop distance.

The beacon node closest to the unknown node is used to locate the node. This may cause a relatively large error and cannot reflect the situation of the entire network. Moreover, the average hops of a number of beacon nodes in the network have effective use information, and the information is wasted. Therefore, it is necessary to analyze the influence of the average hop distance on the positioning accuracy of the traditional algorithm. The following example illustrates the cause of the average hop error.

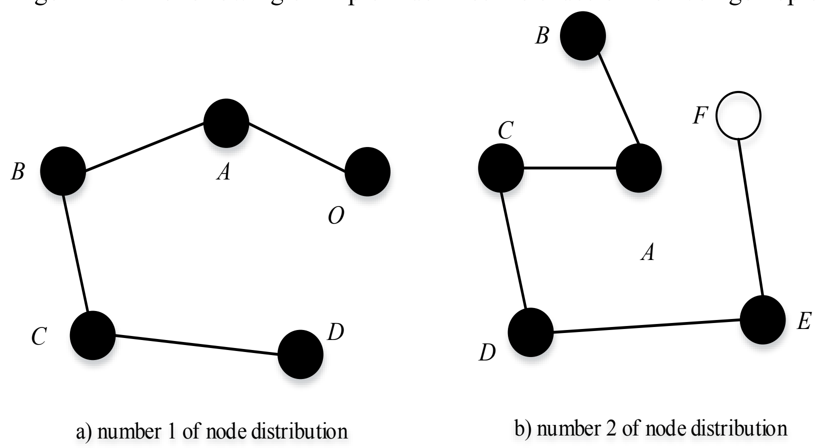

Fig. 3. Network structure diagram

As shown in figure 3 (a), five sensor nodes are distributed in the network, of which A, D are beacon nodes, and the rest are unknown nodes. According to the definition of the traditional algorithm, the hops between A and D are 3. However, the real physical distance between A and D is far less than 3. Because the distribution of beacon nodes in the network is likely to be deployed randomly, it results in the uneven location of nodes in the network and leads to the zigzag of the connected path. The information between nodes is not strictly propagated in a straight line.

According to the calculation, the average hop distance of node A is $HopSize_A = |AD|/3$. In the figure, the hop of AO is 1. The distance value is |AD|/3. In fact, the real physical distance of AO is roughly equal to the real distance of AD. In this way, the distance between the nodes calculated according to the average distance of the error is only 1/3 of the actual distance, and the value is less than the actual value, resulting in a drop in the final positioning accuracy.

As shown in figure 3 (b), in network connected graphs, five beacon nodes from A to E are distributed in the network. The real distance between the A and the other four beacon nodes is approximately the same, and the hops from A to other beacon nodes are 1, 1, 2, and 3, respectively. The average hop distance of the node A can be obtained by the formula (2).

$$HopSize_A = \frac{d1 + d2 + d3 + d4}{1 + 1 + 2 + 3} \approx \frac{4d1}{7} \tag{2}$$

If an additional beacon node F is added to the network, the actual distance between the A and F is close to the actual distance between the A and the other nodes. However, due to the zigzag of the connected path, the increase speed of the minimum hops is faster than the increase of the hop distance. Therefore, the average hop distance of the A is smal, and the error will be added with the connectivity complexity of the node. The average hop distance of the node A after joining the node F is as follows:

$$HopSize_A = \frac{d1 + d2 + d3 + d4 + d5}{1 + 1 + 2 + 3 + 4} \approx \frac{5d1}{11} < \frac{4d1}{7} \tag{3}$$

3.4 Improvement of average hop distance of DV-Hop

According to the above analysis, the traditional DV-Hop algorithm does not take into account the path zigzag of the actual node communication in the calculation of the average hop distance. Therefore, the average hop distance cannot reflect the real distance relationship between the nodes, which is smaller than the actual physical value. Moreover, with the increase of beacon nodes, this error will have a cumulative decrease trend. Finally, the estimation distance between the unknown node and the beacon node is deviate from the actual distance, and the positioning accuracy is greatly influenced.

Therefore, based on the location deviation of the WSN nodes caused by the average hop distance, an improvement on the average hop distance optimization is carried out for the traditional DV-hop. The basic ideas of the improved algorithm for the optimization of the average hop distance are analyzed as follows.

Parameter introduction: First, the number of node in network is set to n. The number of beacon node is m. Then, the parameter is defined as p=m/n. p represents the proportion of nodes that the beacon nodes occupy in the entire network. The previous error analysis shows that the greater the p is, the more the average hop distance HopSize of the node needs to be optimized. In a typical wireless sensor network application scenario, beacon nodes generally occupy less than 25% of all sensor nodes because of their cost and power consumption. Therefore, p=0.25 is set. Then, the mean value aveHS which measures the overall average hop distance of a beacon node in a network is defined. In the subsequent processing of the optimization of the node average hop distance, it is used as a lower limit value of the optimization. At the same time, the upper limit value maxHS of the optimized processing is defined, which is the maximum of the hop distance. The value is generally 0.8 times of the communication radius R of the beacon node.

Optimization treatment: After introducing three parameters, to some extent, the percentage of nodes in all sensor nodes can be adjusted by the average hop distance between beacon nodes. When the ratio of the beacon nodes changes, the average hop distance of the beacon nodes is optimized by the aveHS and maxHS mentioned before.

When the number of beacon nodes is less than a certain proportion p, with the increase of the number of beacon nodes, the average hop distance of the beacon nodes increases proportionately. When the number of beacon nodes reaches or exceeds p, the maximum maxHS of the hop distance is used as the processing hop distance after the beacon node's hop distance is optimized. An optimal correction sketch map of the average hop distance of the beacon nodes is shown in figure 4.

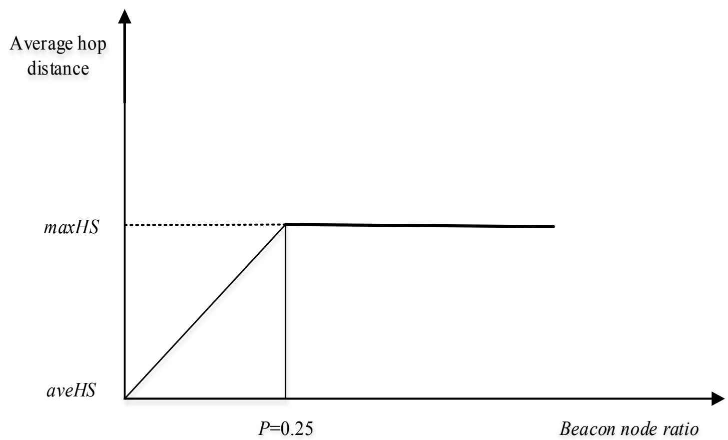

Fig. 4. Relationship between Beacon Node Ratio and Average Hop Distance

When the average hop distance of the node is optimized, the calculation formula is as follows:

$$\begin{cases} HopSize_A = 2(\max HS - aveHS) * p + aveHS, & p < 0.25 \\ HopSize = \max HS, & p \geq 0.25 \end{cases} \tag{4}$$

According to the algorithm improvement in above steps, the beacon nodes can be optimized in different ways according to the proportion of the actual nodes in the calculation of the average hop distance. The added maximum value maxHS ensures that the average hop distance caused by the increase of the beacon nodes in the network does not appear the over-optimized phenomenon.

4 Results

4.1 Positioning simulation of DV-Hop minimum hops improved algorithm

Simulation environment of the influence of beacon ratio on positioning accuracy: 200 sensor nodes are randomly distributed within the range of 100m × 100m in the network area. Among them, the communication range of the node is 30 meters. The proportion of the beacon node in the network is increasing, from 5% to 35%.

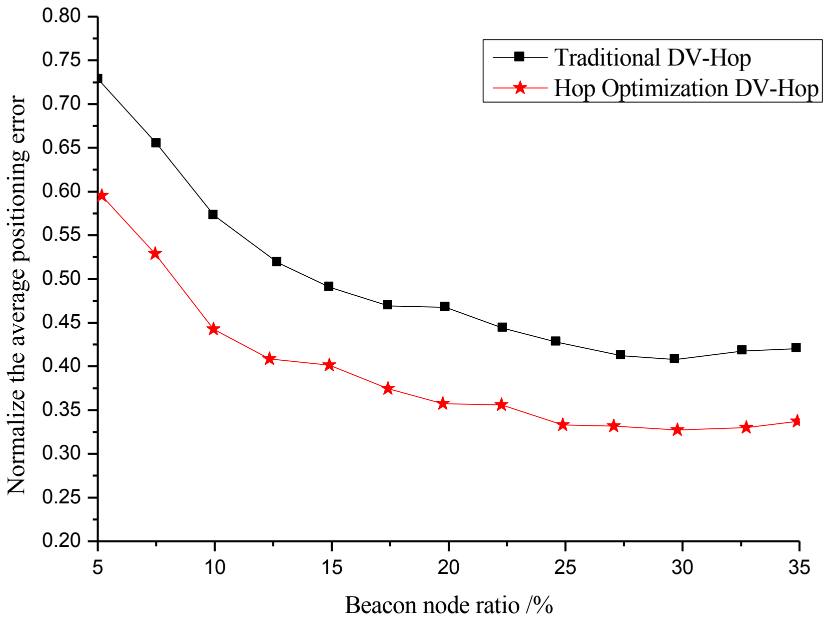

Fig. 5. Square Deviation Relative Positioning Error of the Ratio of Different Beacon

As shown in figure 5, the positioning accuracy of the improved DV-Hop algorithm based on the minimum hops is always better than the original algorithm. In addition, the average relative positioning error tends to be stable with the increase of the ratio of beacon nodes.

4.2 Positioning simulation of improved DV-Hop average hop distance algorithm

The location accuracy of improved algorithm based on hop distance optimization needs to be verified. This section uses MATLAB software to compare the positioning performance before and after the improvement from multiple angles.

Simulation environment of the influence of beacon ratio on positioning accuracy: 200 sensor nodes are randomly distributed within the range of 100m × 100m in the network area. Among them, the communication range of the node is 30 meters. The proportion of the beacon node in the network is increasing, from 5% to 35%.

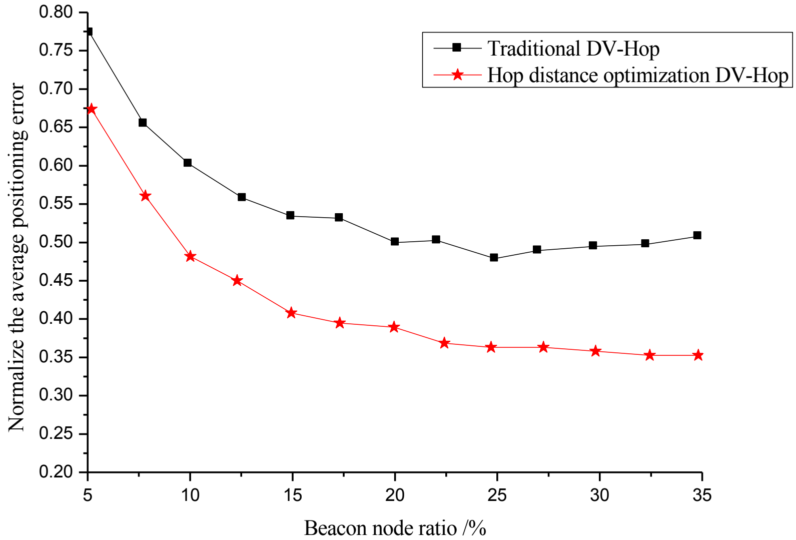

Fig. 6. SquareDeviationRelativePositioningErroroftheRatioofDifferentBeacon

As shown in figure 6, the simulation results show that when the proportion of beacon nodes increases, the small error of the average hop distance of the traditional algorithm increases. As a result, the accuracy of the algorithm reduces. Because the smaller error of the average hop distance is optimized, and the upper bound processing is increased after the proportion of the beacon nodes increases. Therefore, there is no error increase in the DV-Hop average hop distance improved algorithm. The relative positioning error is about 0.34, the positioning accuracy is relatively high, and the stability is better than the DV-Hop algorithm.

4.3 Performance simulation of improved algorithm based on minimum hops and average hop distance

Simulation environment layout: The network is deployed within a range of 200m × 200m, with a number of 200 nodes. The number of beacon nodes increases from 5% to 35%. The communication radius of the node is 50m.

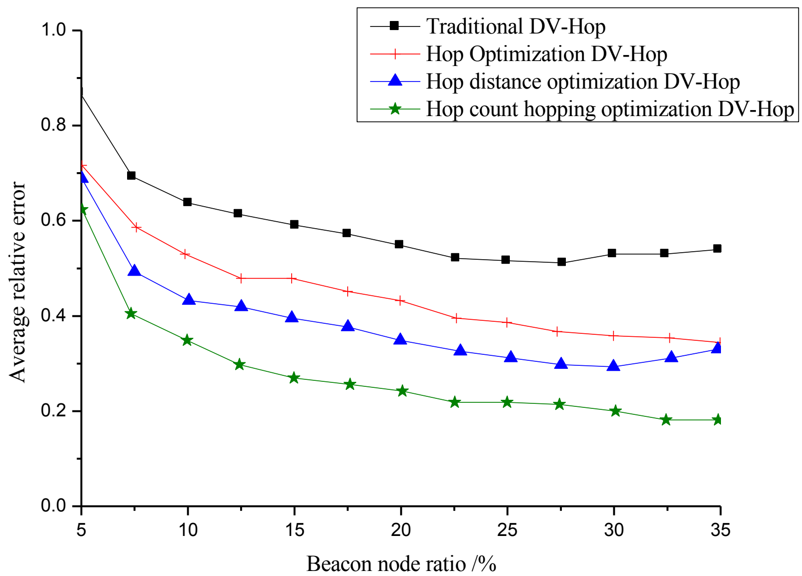

Fig. 7. Comparison of relative positioning errors of three improved algorithms

As shown in figure 7, when the proportion of beacon nodes is very small, the relative positioning error of the DV-Hop minimum hop improved algorithm is higher than the other two improved algorithms. After the RSSI weight correction, the minimum hops can also be better close to the actual node hops when the beacon nodes are smaller. The location accuracy of location algorithm continues to improve after increasing the proportion of beacon nodes. However, the location accuracy of traditional DV-Hop algorithm and DV-Hop minimum hops algorithm is reduced slightly, because the average hop distance is small and the error accumulation increases. After combining the advantages of two improved algorithms, the two error defects are eliminated by the improved algorithm after optimizing the minimum hops and the average hops. The positioning accuracy is the best in the four algorithms.

5 Conclusions

The two main reasons for the location error generated by the DV-Hop location algorithm are the minimum hops between the beacon and the node to be located and the average hop distance between the beacon nodes. RSSI ranging distance technology is introduced. The minimum hops calculation stage of DV-Hop algorithm is optimized, and the algorithm is improved for the minimum hops. By introducing three parameters, such as the proportion of the beacon nodes and the optimal threshold value, the average jump distance calculation is modified, and the improved algorithm for the optimization of the average hops is made. Finally, the two optimization links of the minimum hops and the average hops distance are combined to the new DV-Hop improved location algorithm. The traditional DV-Hop location algorithm and the three improved location algorithms are simulated and analyzed by beacon node ratio and node communication radius with multi angle. The following conclusions are drawn:

Firstly, the improved algorithm is better than the original algorithm in the positioning stability and positioning accuracy.

Secondly, the performance of the improved location algorithm with DV-Hop hops and distance is the best.

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7 Authors

Chao Huang and **Yuang Mao** are with Guangxi Medical University, Guangxi, China.

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