An Improved Node Localization Algorithm Based on Positioning Accurately in WSN

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Abstract

Node localization technology, as an important technology of wireless sensor networks communication, whether it can accurately locate is the most important prerequisite to support site of the monitoring information. Due to the development of localization technology is affected by environment factor, localization precision and energy consumption, so how to reduce error and improve positioning accuracy of node is the focus of the current research. DV-hop (Distance Vector-hop) is put forward to solve the problem effectively, which can effectively use beacon nodes position to estimate unknown nodes position and improve nodes abilities of positing. For this, the paper proposes the IMDV-hop algorithm. Considering average distance of the whole network is replaced by average distance of beacon nodes, which results in decline in the localization accuracy, so it gives new average hop distance Formula in order to effectively reduce error between whole network average hop distance and real distance values. Then, average distance of the whole network is modified by introducing proportional parameter to make it approach the true distance for achieving the improvement of the positioning accuracy. The results show that the IWDV-hop (Improved Weighted Distance Vector-hop) algorithm to improve positioning accuracy of nodes and reduce positioning error is effective.

Keywords: Localization technology, Wireless sensor networks, Beacon nodes, Hop

1 Introduction

With the rapid development of the social networks [1-5], the network is closely related to people's daily life, and the information is widely used in various fields, which makes the network become the communication hub of the world [6]. With the gradual maturity of wireless communication technology, sensor technology and embedded technology, wireless sensor networks (WSN) [7-9] play a leading role in life, focusing the world's information on the human eye. The wireless sensor network as one of the many networks, which combines information processing technology, sensing technology and communication technology in one. Many sensor nodes with low cost, perceptual, computational and wireless network communication [10-12] capabilities are deployed in a random or more regular manner in the environment for monitoring, whose nodes will collaborate to acquire, collect and process the information of the target in the network and send it to the user [13-14], so as to realize the purpose of monitoring network area and provide strong support for the decision object.

The basic function of wireless sensor network is to determine the position of the event information, whose position information is critical to the monitoring of the network [15-18]. Without position information, even if the monitoring data is collected, it doesn't make any sense [19], and only in the case that the sensor node position information is known, the specific position of events can be determined, the observer can be based on the collected data and position information to make decisions, it can be seen that positioning is a particularly important function in the WSN sensor node.

Positioning technology [20-21] is both an important and difficult task for wireless sensor networks. First of all, many technologies of wireless sensor networks need to use the position information of nodes. For example, the geographical routing protocol to transmit data needs to use the position information of the nodes, which avoid the information diffusion in the network, so as to achieve effective information query data [22]. Furthermore, the routing efficiency of some routing protocols [23-24] is also improved by using the position information of the nodes. Secondly, the node position information is used to construct the topology structure by the network topology control, so as to evaluate the distribution trend of the nodes. The difficulty is caused by a large number of nodes, and random distribution, which is difficult to pre-deployment of nodes to the harsh environment. At the

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same time, in order to reduce the overhead of sensor nodes, its storage capacity, communication distance and energy are limited. But if all nodes are equipped with GPS positioning system [25], undoubtedly it increased cost and energy consumption of the nodes faster. Therefore, positioning technology is required to reduce overhead and energy consumption as much as possible, thus prolonging the life cycle of the entire network. So, wireless sensor networks need localization algorithms with high localization accuracy and low algorithm complexity, which is the core problem to study the position of unknown nodes in WSN networks.

2 Related Works

Positioning error and positioning accuracy are the main criteria for the localization algorithm, so these two indicators are the key to our consideration in the algorithm. However, in recent years, many positioning algorithms have always been unable to make the two indicators tend to the best situation. In [26], the average hop distance of beacon node is improved according to the shortage of distance calculation between unknown node and beacon node, the unknown nodes of beacon nodes less than 3 are estimated and located, and the non-positioning nodes caused by topology are eliminated. In the literature [27], the average hop distance is corrected by compensating the average hop distance, and the method of renaming the unknown node coordinates in the fixed area is used to estimate the average jump distance accurately for reducing the positioning error of the node. In [28], the positioning accuracy of the DV-hop algorithm is affected by the hop count information and the average hop distance between the nodes, so RSSI technology is introduced to classify each hop and modify the number of hops between the nodes. At the same time, the average hop distance is modified based on the minimum mean square error criterion, which can improve the positioning accuracy and algorithm performance. In [29], for the beacon node to estimate the average distance per hop can not reflect the overall situation of the network and the traditional positioning model itself is flawed. Under this circumstance, an adaptive mean distance estimation method and a position estimation model based on improved differential evolution algorithm are proposed to achieve the goal of approaching the actual situation and precisely positioning in the network. In [30], considering that the original positioning algorithm only receives the average jump distance estimated by the nearest beacon node, the weighted average jump is used to replace the average jump in the traditional algorithm and uses the average hop distance estimated by multiple beacon nodes to reduce the positioning error caused by the jump distance calculation, thereby improving the positioning accuracy. In [31], the influence of the three-point approximate collinearity problem on the DV-hop position is analysed, and a three-point approximate collinearity criterion is proposed to allow the maximum hop error rate and the maximum hop count to check the beacon node combination validity. The IMDV-hop algorithm is used to improve the performance of node position when the number of effective beacon nodes of unknown nodes is set to a fixed threshold and the new beacon nodes are expanded. In [32], the paper calculates the average beacon nodes distance and joins the weighting factor, where it puts forward the primary node definition and learning strategies. The purpose of it is to fully consider the network structure and avoid falling into local optimum. In [33], the new node localization algorithm is put forward, which evaluates beacon nodes information based on linear parameter to estimate network node position, so that it can calculate the linear parameter values and find the optimal beacon triangle, then using the weighted mechanism to calculate the average of beacon nodes distance for getting accurate information. In [34], in order to solve DV-Hop low localization accuracy, a novel localization method based on modified weighted average hop-size and improved particle swarm optimization algorithm (PSO) is proposed. In [35], the paper introduces the cuckoo search algorithm to dynamically adjust probability and the parameters of β in order to improve the convergence speed and the ability of local search. In [36], because of the deviation between hop count and hop distance estimation, an improved scheme is proposed. And the improved algorithm introduces the multi-communication radius method to refine the number of hops between nodes. When calculating the average hop distance of unknown nodes, the isolated nodes are eliminated and the average hop distance obtained by the anchor nodes is weighted normalized so that the positioning accuracy of unknown nodes is improved. In [37], in view of the traditional DV-Hop localization algorithm, the positioning error is large, and the beacon nodes participating in the positioning are unreasonable. An improved method is proposed in which the covariance method is applied to the selection of the beacon node group so that the co-linearity satisfies the predetermined range, and all the beacon node groups satisfying the collinearity range are selected. In each combination, the positional relationship between the beacon node and the unknown node is determined. This scheme reduces the positioning error and improves the accuracy of positioning, and is not affected by the individual positioning error on the final result.

The contributions of this paper are as follows:

(1) Considering the average distance of the whole network is replaced by average distance of beacon nodes, which results in declining in the localization accuracy, it gives its new average hop distance

Formula in order to effectively reduce the error between whole network average hop distance and real distance values.

(2) The average distance of whole network is modified by introducing the proportional parameter to make it approach the true distance for achieving the improvement of the positioning accuracy.

The remainder of this paper is organized as follows. The research of DV-hop algorithm is described in detail in Section 3. And, algorithm defects and the thought of the IMDV-hop algorithm are introduced in Section 3. Next, in Section 4, experiments of our method and the compared methods on some parameters demonstrate the capability of position and improved performance of the improved method. Finally, we conclude this paper and discuss the future work in Section 5.

3 Materials and Methods

3.1 DV-hop Position Algorithm

DV-hop position algorithm is proposed by D.Niculescu and B.Nath of Rutgers University, which is based on the distance vector algorithm to calculate the number of hops [26]. The basic principle of the algorithm is to calculate the minimum hop between the beacon node and the unknown node, and estimate the average distance between each hop by the Formula. Then, the distance between the unknown node and the beacon node is obtained according to the hop count and the estimated average hop distance. Finally, the unknown node is positioned by the existing positioning algorithm.

3.2 Algorithm Positioning Process

DV-hop algorithm positioning process can be divided into the following three stages [38]:

(1) The minimum hop between unknown nodes and beacon nodes is determined.

In the WSN, the beacon node broadcasts its own hop count and position information to other nodes in the network via the flooding algorithm [39], which includes a hop field initialized to 0. After other nodes receive messages, the minimum hops and position information are recorded to other beacon nodes, and the hop value plus 1 is forwarded to other nodes. If the same data of beacon node in the broadcast message is received, the number of hops in the beacon node is discarded, and the minimum hop count of all nodes to the beacon node is recorded in this way.

(2) The average distance between the unknown node and the beacon node is determined.

The beacon node use the Formula (1) to obtain the average hop distance by the number of hops and position information recorded in the first step.

$$Hopsize_i = \sum_{i \neq j} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \,/ \sum_{i \neq j} h_{ij} \tag{1}$$

The Formula (1) represents the average hop distance of the beacon node i based on the minimum hop count and position information between the beacon node *i* and the other beacon nodes. Where (x_i, y_i) represents the coordinates of the beacon node *i*, (x_j, y_j) represents the coordinates of the beacon node *j*, h_{ij} represents the minimum hop between the beacon node *i* and the beacon node *j*. $Hopsize_i$ represents the average hop distance of the beacon node, whose values are received by broadcast to unknown nodes. When it receives different distance values, the unknown node will save the distance from the nearest beacon node and then forward the other information to the neighbor node. The unknown node uses $Hopsize_i$ value and the recorded beacon node hop count to determine the estimated distance to a beacon node.

(3) The three sided measurement method or the maximum likelihood estimation method is used to estimate their position.

According to the hop distance of the beacon nodes recorded in the previous stage, when the unknown nodes obtain the distance between three or more beacon nodes, the self coordinates are determined by the three sided measurement method or the maximum likelihood estimation method to complete the positioning of the unknown node. DV-hop algorithm illustrates the process.

Algorithm 1: The weighted Corrections of DV-hop algorithm

Network Initialization
$Region \leftarrow rand(2, NodeAmount)$
$B_i = BroadcastJPM(\,)$
$Bides = Receive\,(B_i)$
do{
    if (HaveReceiveMS ( ))
{ compare and save MinHopCount }
    else
{ RecordHopMS ( ) }
  $HopCount \leftarrow HopCount + 1$
  NerghbourNodes = Receive (MS)
 } while (!BroadcastFinished ( ))
$D_i = BroadcastAHD(\,)$
$F_i = FindCloser\,(D_i)$
$UnknowNodes = Recerive\,(F_i)$
$UnknowNodes = Calculate\,(F_i)$
UnknowNodes finish to be positioned
The positioning error and accuracy of UnknowNodes des is represented

Where *BroadcastPJM* ( ) represents beacon node broadcasts its own hops and position information, *HaveReceiveMS* ( ) is the message of beacon nodes, *RecordHopMS* ( ) represents hops information, *BroadcastFinished* ( ) represents the end of the broadcast packet, *BroadcastAHD* ( ) is the average jump distance, *FindCloser* (D_i) is the closer distance from beacon nodes.

3.3 Maximum Likelihood Estimation

In the maximum likelihood estimation method [40], the node representation is shown in Figure 1. The coordinates of the unknown node A is (x, y), it supposes that the coordinate of the beacon node B_1 is (x_1, y_1), the coordinate of the beacon node B_2 is (x_2, y_2), and coordinate of the beacon node B_n is (x_n, y_n). When the distance between the unknown node and the beacon node is known, it will be calculated by the following Formula [41-43].

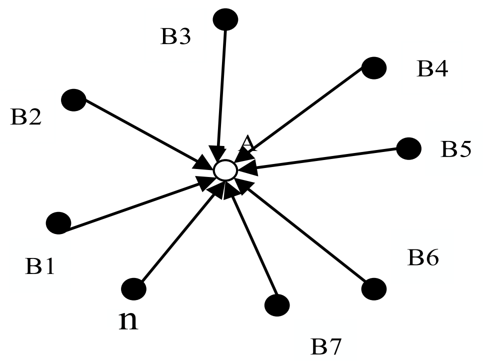

Figure 1. Flow chart of maximum likelihood estimation

The Formula (2) is expanded, and the last equation is reduced from the first equation to the last one, it can be expressed by linear equations, which is AX=B. The results are as follows:

$$\begin{cases} (x_i - x)^2 + (y_i - y)^2 = d_1{}^2 \\ \vdots \\ (x_n - x)^2 + (y_n - y)^2 = d_n{}^2 \end{cases} \quad \textbf{(2)}$$

Combining Formula (3), Formula (4), and Formula (5), and based on minimum mean square error estimation, the coordinate of unknown node A is:

$$A = \begin{bmatrix} 2(x_1 - x_n) & 2(y_1 - y_n) \\ \vdots & \vdots \\ 2(x_{n-1} - x_n) & 2(y_{n-1} - y_n) \end{bmatrix} \quad \textbf{(3)}$$

$$B = \begin{bmatrix} x_1^2 - x_n^2 + y_1^2 - y_n^2 + d_n^2 - d_1^2 \\ \vdots \\ x_{n-1}{}^2 - x_n{}^2 + y_{n-1}{}^2 - y_n{}^2 + d_n{}^2 - d_{n-1}{}^2 \end{bmatrix} \quad \textbf{(4)}$$

$$X = \begin{bmatrix} x \\ y \end{bmatrix} \quad \textbf{(5)}$$

$$\hat{X} = (A^T A)^{-1} A^T B \quad \textbf{(6)}$$

3.4 Defects in DV-hop Algorithm

It is well known that the position algorithm can be divided into ranging and non-ranging based on localization algorithm [44] according to whether the actual node spacing needs to be measured or not during the localization process. The DV-hop algorithm belongs to the latter, which is characterized by which is characterized by no need to measure the information, and the nodes achieve positioning according to the estimated distance between nodes, whose operation is simple and the communication cost is low. Since the position accuracy of DV-hop algorithm is similar to that of homosexual networks, the localization accuracy will be lower for the network with irregular topology. The traditional DV-hop algorithm determines the hop distance obtained by the unknown node from the nearest beacon node, and the average hop distance of the whole network can not be reflected by the estimated distance of single beacon node, which undoubtedly makes the positioning accuracy of the unknown nodes decreased. In addition, due to the random distribution of nodes in wireless sensor networks, the hop distance between nodes may be different, so it is easy to generate the positioning error when calculating the distance between unknown nodes and beacon nodes. To solve the above problems, this paper proposes a IMDV-hop algorithm to improve the positioning accuracy of the nodes by distance weighted estimation method.

3.5 Improved DV-hop Algorithm

In the process of calculating the hop distance by the traditional DV-hop algorithm, the average hop distance is used to replace the actual hop distance of beacon nodes, which will undoubtedly lead to errors. And it takes into account the sensor node distribution of non-uniform and irregular, resulting in unknown nodes to different reference nodes between the situation is different, if the DV-hop positioning algorithm uses the same average skew calculation, the error will be generated. The improved scheme of this paper will make the estimated distance between the unknown node and each reference node closer to the real distance, so as to correct the unknown node of the region. For the basic idea of literature [45], this paper proposes the improved method by introducing the weighted parameters to definite the average distance Formula in the whole network, then calculate the hop distance error of each beacon nodes and modify the network average jump distance which is received by original algorithm, so as to achieve the purpose of close to the actual average hop distance. The average hop distance of networks is:

$$H_p = \frac{\Sigma\, Beaconhop}{BeaconhoAmount} \quad \textbf{(7)}$$

The average hop distance error of beacon node *i* is:

$$dis_i = \sum_{i \neq j} | d_{true} - d_{est} | / hop_{ij} \quad \textbf{(8)}$$

Where Beaconhop is the jump distance of beacon nodes, BeaconAmount is the number of beacon nodes. The node i represents the remaining beacon nodes except the beacon node, hop_{ij} represents the number of hops between *i* and *j*, d_{true} represents the actual distance between the beacon nodes, and d_{est} represents estimated distance between beacon nodes. The average hop distance of the whole network is:

$$Hopsize_{adv} = \sum_{i \neq j} Hopsize / N_{total} + p * \sum_{i \neq j} Hopsize / N_{total} \quad \textbf{(9)}$$

The average hop distance error of the beacon node is:

$$c_{dis_i} = \frac{\Sigma\, dis_i}{N_{beacon}} \quad \textbf{(10)}$$

The modified average jump distance is:

$$Hopsize_{new} = \frac{N_{beacon}}{N_{total} - N_{beacon}} * Hopsize_{adv} + \frac{N_{total} - 2N_{beacon}}{N_{total} - N_{beacon}} * c_{dis_i} \quad \textbf{(11)}$$

Wherep represents the percentage of unknown nodes in the total number of nodes. The *p* is designed to complement the average hop distance of unknown nodes. N_{total}, N_{beacon} respectively represents the total nodes and beacon nodes in the network. The value of $(N_{total} - N_{beacon})$ represents the number of unknown nodes, and ensures the value of $\frac{N_{beacon}}{N_{total} - N_{beacon}}$ in the range of 0~1.

Therefore, when the average hop distance is modified, the estimated distance between each node of the unknown node and beacon node is:

$$d_i = Hopsize_{new} * hop_i \quad \textbf{(12)}$$

The IMDV-hop algorithm illustrates this process.

Algorithm 2. The IMDV-hop algorithm

1. Network Initialization
2. Region ←rand (2, NodeAmount)
3. B_i =BroadcastJPM ( )
4. Nodes=Receive (B_i)
5. do{
6. if (HaveReceiveMS ( ))
7. { compare and save MinHopCount }
8. else
9. { RecordHopMS ( ) }
10. HopCount ← HopCount + 1
11. NerghbourNodes = Receive (MS)
12. } while (!BroadcastFinished ( ))
13. D_i =BroadcastAHD ( )
14. D_i is received by Nodes
15. BeaconNodes calculate distances from other BeaconNodes
16. Weighted average distances and error are calculated by BeaconNodes
17. BeaconNodes calculate corrected average distances
18. Estimated distances are calculated by BeaconNodes
19. UnknowNodes = get (coordinates)
20. UnknowNodes = correct (coordinates)
21. UnknowNodes=Ensure (position)
22. UnknowNodes finish to be positioned
23. The positioning error and accuracy of UnknowNodes is represented

Where *get (coordinates)* represents the coordinates of the unknown node based on the estimated distance, *correct (coordinates)* represents the unknown node coordinate correction, *Ensure (position)* represents unknown nodes coordinates position which is determined.

4 Simulation Results

4.1 Simulation Environment

The simulation software platform of this article is based on windows10 system. In view of the DV-hop algorithm, the proposed IMDV-hop algorithm is compared with the other two algorithms, and the performance of the IMDV-hop algorithm is detected.

Our simulation scenario takes place within a 100*100 m^2 area [46]. The number of nodes in the whole network is 100, and the unknown nodes and beacon nodes are randomly distributed in the region. The distribution of nodes is shown in Figure 2. In this Figureure, 40 of the 100 nodes are beacon nodes represented as star, while others are normal nodes. This illustrates a 40% ratio of beacon nodes, which is defined as the ratio of the number of beacon nodes to the total nodes.

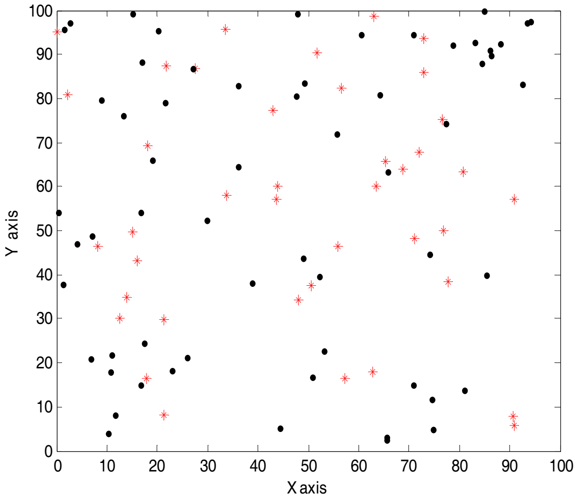

Figure 2. The scheme of node distribution

In the following, we will set static scenario based on our DV-hop localization algorithm, and we aim to obtain specific performance of DV-hop algorithm without influence of node movement, where the communication radius of the node is 50m, the beacon nodes ratio is 40%.

4.2 Comparison of Simulation Results

In paper, the average hop error of beacon node, the average positioning error and positioning accuracy of unknown node are selected to compare IMDV-hop algorithm with DV-hop algorithm and weighted modified DV-hop algorithm under the environment of simulation software platform. Removing the interference of external factors, the red "*" is used to indicate the beacon node and the black "." is used to indicate the unknown node.

Assume that the actual coordinates of an unknown node is (x_t, y_t), the estimated coordinate is (x_e, y_e) and the communication radius is R. So the average positioning error is defined as:

$$err = \frac{\sqrt{(x_e - x_t)^2 + (y_e - x_e)^2}}{N_t - N_b} \quad \textbf{(12)}$$

Average positioning accuracy of nodes is:

$$Accuracy = \frac{err}{R} \quad \textbf{(13)}$$

Figure 2 shows the algorithm node distribution map, 100 nodes were randomly distributed in the 100 * 100 area, where the number of beacon nodes is 40, which are expressed in red, the unknown nodes are 60, which are represented by black. It can be seen from the Figureure, the nodes distribute randomly and it confirms the actual situation. At the same time it provides a certain basis for the research of node localization.

Figure 3 shows the simulation results of the average per hop distance error of beacon node on the IMDV-hop algorithm, DV-hop algorithm and weighted modified DV-hop algorithm. From this Figure, we can see that the beacon node error of the IMDV-hop algorithm is about 725m, the error of the weighted modified DV-hop algorithm is 885m, the error of the DV-hop is 900m. So the average per hop error reduced relatively about 160m and 175m in the term of the weighted modified DV-hop algorithm and DV-hop algorithm. The error reduction rate is about 18.1% and 19.4%, the reason is that the new hop distance error Formula can reduce the error between the estimated distance of the beacon node and the real distance, which shows that the IMDV-hop algorithm is better to reduce the beacon node error than weighted modified DV-hop algorithm and the DV-hop algorithm, and which is helpful to improve the positioning performance of the node.

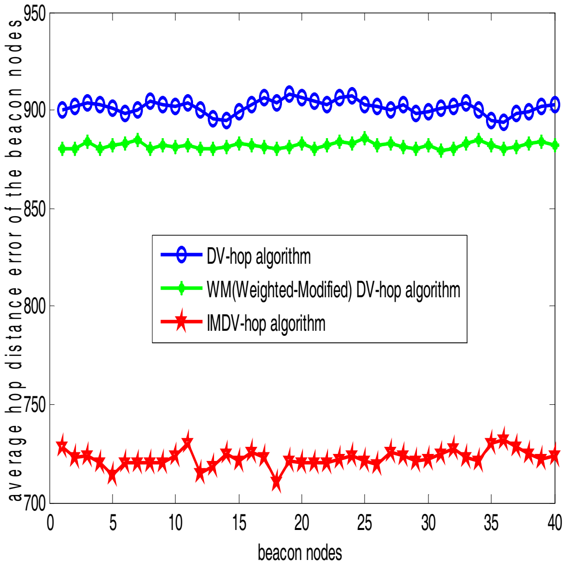

Figure 3. Average distance of beacon nodes

Figure 4 is a comparison of node average positioning error for the three algorithms. It can be seen from the comparison of three algorithms, the unknown average node positioning error of the IMDV-hop algorithm is relatively less than the error of weigthted modified DV-hop algorithm and DV-hop algorithm, and error reduction ratio is 8.8% and 12.9%, the reason is that we fix the average distance of the whole network so that it is close to the real jump distance, so as to achieve the improvement of positioning accuracy, which shows the average positioning error of improved algorithm is relatively smaller than the weigthted modified DV-hop algorithm and DV-hop algorithm, and it is more used to improve the positioning accuracy of the node.

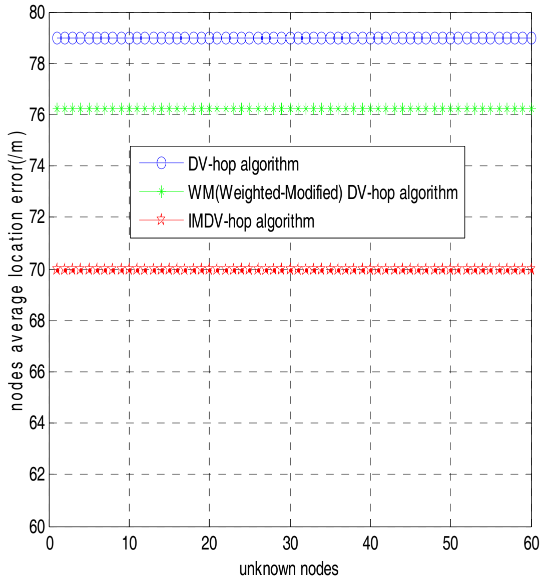

Figure 4. Localization error of unknown nodes

Figure 5 shows the positing error results of selecting 10 beacon nodes on three algorithm. We can see from this Figureure that in the case of keeping the number of nodes unchanged, the localization error decreases with the increase of the beacon node, and from the amplitude of the curve, the IMDV-hop algorithm is more stable than the other two algorithms, indicating that the accuracy of the positioning error is relatively more stable and more conducive to accurate positioning, which also proves that the IMDV-hop algorithm is effective to positioning accuracy.

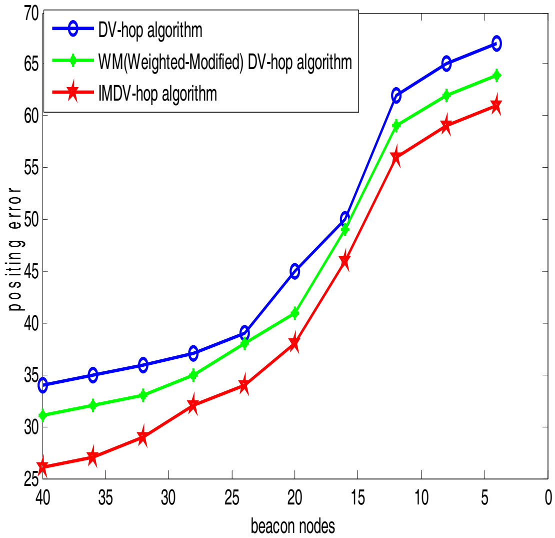

Figure 5. The positing error of beacon nodes

Figure 6 shows the gap between the average positioning accuracy of the three algorithms in the same environment. It can be seen from the Figureure that the average positioning accuracy of the IMDV-hop algorithm is improved 10.2% and 4.9% compared with the original algorithm and the weighted modified DV-hop algorithm. This shows that our proposed scheme takes advantage of the precise position of nodes, and demonstrates the effectiveness and feasibility of our proposed algorithm. Although the localization accuracy is not much improved, this is very significant for the localization of unknown nodes, which will help us further explore the localization of unknown nodes.

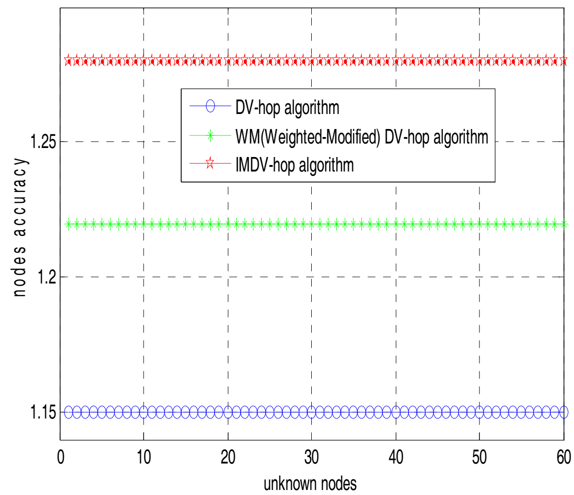

Figure 6. The average positioning accuracy of nodes

Figure 7 represents the positioning error comparison chart of each unknown node for three algorithms. It is pretty obvious that the positioning error of IMDV-hop algorithm is much smaller than the original algorithm and weighted modified DV-hop algorithm. From the curve itself, the curve of the improved algorithm is always below the two algorithms, and the positioning error rate of the unknown node is less than that of the two algorithms, and the variance of IMDV-hop algorithm is smaller than the two algorithms. It effectively tests the enforceability of our proposed scheme, and improve the positioning performance of nodes.

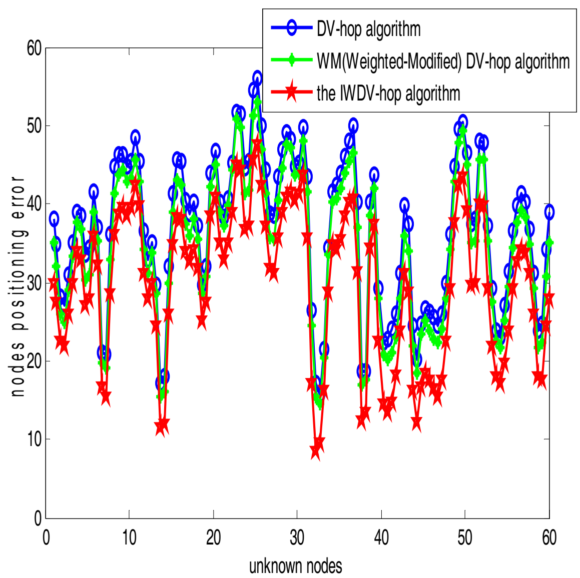

Figure 7. Positioning error of each unknown nodes

Figure 8 shows the comparison of the positioning error in the three algorithms with the increase of the beacon ratio. As can be seen from the Figureure, the error of the original DV-hop algorithm is about 85 when the beacon node is 5%, and the error of the IMDV-hop algorithm is 75, and it almost reduced by 10, with the increasing of the beacon nodes, the error of the three algorithms is gradually reduced. From the curve descending speed, the IMDV-hop algorithm is faster and its positioning error is small. It is obvious that the IMDV-hop algorithm has obvious advantages of positioning error. The positioning error is small to prove that our proposed algorithm performance is better.

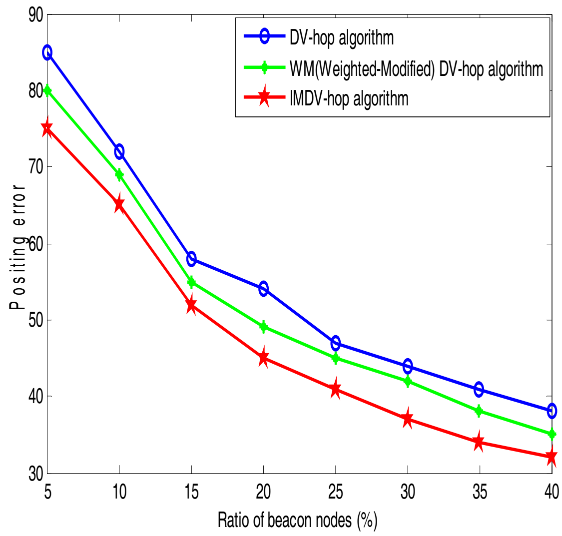

Figure 8. Percentage of beacon nodes

In this paper, we develop an improved method to reduce the error and improve the positioning accuracy. Experimental results in Figureure show that our method outperforms compared method on positioning error and accuracy. From these Figureures, they has explained our algorithm better than other algorithms. Positioning accuracy and error is an indicator of the positioning algorithm, which can effectively indicate the validity of the algorithm you are proposing. The better performance of improved algorithm over these methods verifies that the new average hop distance Formula and the proportional parameter do make a positive contribution to the improvement of DV-hop.

5 Conclusions

We use the method of node distance weighted estimation and correction hops to improve the positioning error and positioning accuracy of nodes in this article. The localization error and accuracy of the existing algorithms do not fully consider the estimated distance and hop count of the beacon nodes, so it can not effectively improve the positioning accuracy of the unknown nodes in the network. Considering the defects of algorithm to calculate the distance from the unknown node to the beacon node, a new Formula is presented to reduce the error between the estimated distance of the beacon node and the real distance. Then, the average distance of the whole network is corrected by introducing the proportion parameter, so that it is close to the real hop distance, so as to improve the positioning accuracy. Thus, simulation results show that the IMDV-hop algorithm can effectively reduce the localization error and improve the localization accuracy of nodes. Although the distance estimation and the distance between nodes are improved, there are still some shortcomings. In future work, the research includes the following aspects:

(1) The WSN research is limited to simulation software. Its effect in reality is not known. So it is imperative to simulate the real environment to verify the superiority and the possibility of the IMDV-hop algorithm.

(2) Node movement leads to the change of network structure, which is not considered in the design of routing algorithm;

(3) The selection of the ratio coefficient has a certain randomness, which may affect the effect of the algorithm.

(4) Localization algorithm for wireless sensor networks is mostly distributed in a plane. However, in the practical application, the nodes are distributed in three dimensional space, so the research of the algorithm in 3D space will be the future research work.

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