DOI: 10.2298/CSIS110222051Q

An Improved Node Localization Algorithm Based on DV-Hop for Wireless Sensor Networks

Qingji Qian[1], Xuanjing Shen[2,3], and Haipeng Chen[2,3]

[1] College of Physics, Jilin University,
130022 Changchun, China
qianqj@jlu.edu.cn
[2] College of Computer Science and Technology, Jilin University,
130012 Changchun, China
[3] Key Laboratory of Symbolic Computation and Knowledge Engineering,
Ministry of Education, Jilin University, 130012 Changchun, China
{xjshen,chenhp}@jlu.edu.cn

Abstract. Sensor node localization is the basis for the entire wireless sensor networks. Because of restricted energy of the sensor nodes, the location error, costs of communication and computation should be considered in localization algorithms. DV-Hop localization algorithm is a typical positioning algorithm that has nothing to do with distance. In the isotropic dense network, DV-Hop can achieve position more precisely, but in the random distribution network, the node location error is great. This paper summed up the main causes of error based on the analysis on the process of the DV-Hop algorithm, aimed at the impact to the location error which is brought by the anchor nodes of different position and different quantity, a novel localization algorithm called NDV-Hop_Bon (New DV-Hop based on optimal nodes) was put forward based on optimal nodes, and it was simulated on Matlab. The results show that the new proposed location algorithm has a higher accuracy on localization with a smaller communication radius in the circumstances, and it has a wider range of applications.

Keywords: Wireless sensor networks, Node localization, DV-Hop Algorithm, Optimal nodes

1. Introduction

In the application of wireless sensor networks, the sensor node location information is critical to the monitoring activities of sensor networks. The location of the incident or the node position of the obtained information is the important information that must be included in the sensor nodes monitor messages. It is meaningless for the monitor messages of no place messages. GPS (Global Positioning System, GPS) is the most accurate and most perfect positioning technology, which has high accuracy, strong anti-interference, and can locate in time, etc. But if we use GPS to position, the cost of the node is two times higher in terms of magnitude than the ordinary nodes. That is to say, when the nodes of 10% are equipped with GPS, the cost of the entire network will increase 10 times around. At the same time, for sensor nodes using battery-powered, GPS equipment with high energy consumption is not more suitable for extensive application in sensor nodes with limited energy. So, generally, it dose not use GPS to position all the nodes, but through some nodes of the known location to locate other nodes.

In recent years, research on localization algorithm of wireless sensor networks has achieved fruitful results [1-4]. According to whether to measure the actual distance between nodes in the process of position, the localization algorithm of wireless sensor networks can be divided into two parts: range-based localization algorithm and range-free localization algorithm. The range-based localization algorithm need to measure distance of nodes or angle information, and some algorithms may also need precise clock synchronization. Therefore, there is a high requirement for hardware of the wireless sensor networks nodes, and the algorithm in some applications is also greatly influenced by the surrounding environment, which has limited the application of such methods to some extent. Compared with the range-based localization algorithm, the range-free location algorithm has the advantages of low cost, small power consumption, simple hardware and robust to noise and so on, and can provide acceptable accuracy in positioning. So people are very concerned about it in recent years.

The range-free localization algorithm can achieve localization of nodes according to the connectivity of the network. In 2000, Bulusu, the professor of the Southern California University proposed a location algorithm not based on distance—centroid method, which points out, when the quantity of signals of the anchor nodes received by the unknown nodes, is more than a preset threshold in a time, this node will identify the position of itself for the polygon centroid which is constituted of anchor nodes and connected with this node. The method is completely based on network connectivity, relatively simple to achieve, and owns smaller computation, but more number of anchor nodes is needed. In 2001, Niculescu, the professor of the Rutgers University of the United States proposed a new solution—DV-Distance algorithm [5-6]. The method requires measuring the distance between adjacent nodes, then, substitutes the sum of sub-distance with straight-line distance between unknown nodes and anchor nodes. A disadvantage of DV-Distance is that at the time of multi-hop transmission, the measure error of nodes can produce accumulation effect. When the network is large, number of anchor nodes is relatively small and hardware error of node measure distance is relatively large, the cumulative errors become more apparent. A more robust approach is to use the network topology information by calculating the number of hops, rather than the cumulative distance to finish, Niculescu and Nath named it as DV-Hop [5-6].

In this paper, we propose an improved DV-Hop scheme localization, the main idea of our approach is to select a certain number of anchor nodes to achieve the positioning of the unknown nodes without increasing hardware cost of sensor node. Simulation results show the proposed algorithm has better performance than the classic DV-Hop. The main contribution of this paper to the localization problem in WSN is: proposing a practical, effective and easy localization scheme with relatively higher accuracy and lower cost. The performance evaluation is conducted on a medium scale WSN.

The paper is organized as follows. Section 2 introduced the related work on DV-Hop algorithm. Section 3 described the classic DV-Hop algorithm, and then summed up the main source of error based on the detailed analysis of DV-Hop algorithm, and the simulation experiment's results also proved the existence of error. In section 4, we introduced the improved DV-Hop scheme, and the section 5 introduced the simulation experiments, the experiment results have been given and the localization errors were discussed. Finally, we concluded the paper looked into the future in section 6.

2. Related Work

The research on wireless sensor networks node localization is still one of the focus at home and abroad at present [7-13]; especially, some internal research has been made on the DV-Hop algorithm research.

Zhang Zhaoyang et al [14] proposed two improved DV-Hop algorithms and integrated them reasonably into a self-adaptive positioning algorithm called SAP which includes two modes. Rough-precision mode uses DV-Hop I algorithm and high-precision mode uses DV-Hop II algorithm. In SAP, the first mode saves the energy consumption, the second mode which use RSSI to measure distances between nodes is enabled when target incidents happen, so the algorithm strikes a good balance between positioning accuracy and energy consumption. The simulation results demonstrate that SAP is more efficient in precision and robust than DV-Hop.

Huang Hao et al [15] proposed an enhanced DV-Hop Algorithm. First, it analyzes the location error of a similar "block effect", and then adjusts the location result of unknown node for unknown nodes of around anchor node. Finally, through simulation, "block effect" has effectively been resolved; the algorithm improved positioning accuracy and robustness.

Based on the characteristics of the DV-Hop, an improved scheme was proposed by Chen Kai et al [16] for this typical range-free localization algorithm in wireless sensor network. Its main principle is estimating distance of the hops according to the number of neighbours in the same block. In order to reduce the localization error, it uses weighted node distances to calculate the node's final coordinate.

Yi Xiao et al [17] put forward an improved positioning algorithm based on the DV-Hop algorithm, it shows a differential error correction scheme, in which average per hop distance of the position network and modified value of distance error are introduced, which is proposed to reduce cumulative distance error and node location error accumulated over the multiple hops. Simulation results show that the proposed algorithm can increase location accuracy obviously.

To improve the poor locating performance of DV-Hop algorithm in calculating the distance of unknown nodes to beacon nodes, Bao Xirong et al [18] presented an improved DV-Hop localization algorithm on the basis of analyzing the error of beacon nodes' estimated distances and actual distances. It mainly focuses on two respects: Firstly, the average one-hop distance error of beacon nodes was modified. Secondly, considering several beacon nodes' average one-hop, the average one-hop distance used by each unknown node was modified by weighting the received average one-hop distances from beacon nodes.

To enhance positioning accuracy of wireless sensor network node, a differential error correction scheme was put forward based on the DV-Hop algorithm by Yi Xiao et al [19], in which average per hop distance of the position network and modified value of distance error are introduced, it can reduce cumulative distance error and node location error accumulated over the multiple hops. Simulation results show that the proposed algorithm can increase location accuracy obviously and is applicable to asymmetrical network scene.

Wu Yanhai et al [20] had done the theoretical analysis of the DV-Hop algorithm and gave an improved algorithm. To use correction value as estimated distance between anchor nodes and unknown nodes. Meanwhile, TLS is applied to node localization algorithm to make further localization accuracy. It is proved that the improved algorithm gives better localization accuracy results than original algorithm and other existing improved algorithms.

To improve the accuracy of localization, Li Jian et al [21] proposed an improved DV-Hop algorithm. It is derived from DV-Hop algorithm, and uses weight of anchors to improve localization accuracy without needing no additional hardware device. Simulation results show that the improved DV-Hop algorithm can provide more accurate location estimation than the DV-Hop algorithm.

Zhang Jia et al [22] had used adjusted value of multi-hops and corresponding correction value to reduce the distance error based on the analysis of error sources. Meanwhile, the unknown node coordinates are solved by introducing total least squares method, which effectively suppress the error accumulated to improve the positioning accuracy. However, the computation is significantly increased due to the introduction of multi-hop distance and the corresponding correction value.

3. DV-Hop Algorithm Analysis

3.1. Implementation Process

The core idea of DV-Hop algorithm is: the distance between the unknown nodes and the anchor nodes is indicated by the product of multiplication of the first received with the average distance per hop and the number of their hops. Then the location information of unknown nodes is achieved by using the estimated distance to all anchor nodes. DV-Hop algorithm consists of three phases:

1) Information broadcasting

Each anchor node will convey the location information to all neighbouring nodes. Broadcasting information format is {id_i , x_i , y_i , $Hops_i$}, which contains the identity id_i of the anchor node, location coordinates (x_i , y_i) and the number of hops of $Hops_i$ information, and $Hops_i$ is initialized to 0. Each node receives this data and records $Hops_i$ +1 to a table, and then continues to broadcast the new neighbours' node.

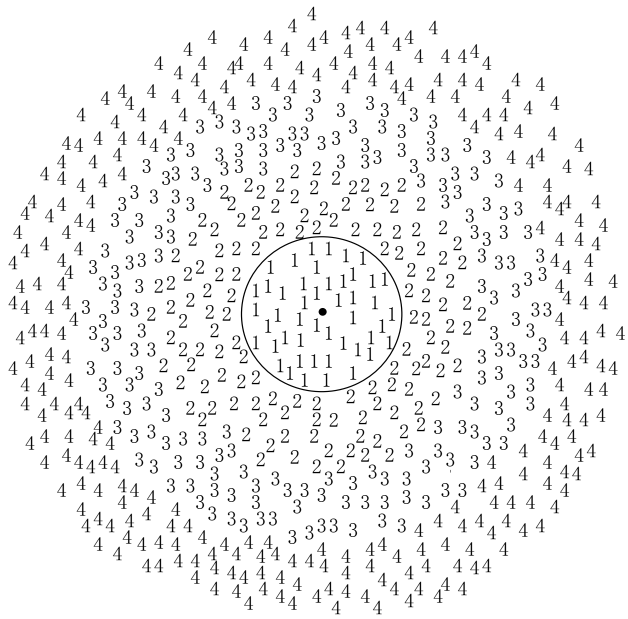


Fig. 1. Broadcasting process of DV-Hop algorithm information

If a node receives a packet with the same id, then it compares Hopsi with Hopsi of packet with the same id on the table. If the new hop count is less than the hop already existing in the table, the new hop will update the information of hop in the table; other wise the packet will be discarded and no longer be forwarded.

The information of each anchor node is broadcasted in the form of flooding on the entire network, thus the hops from each node to each anchor node is obtained. Meanwhile, the anchor node also accesses to the coordinates and hops of all other anchor nodes. So the distance of average per hop for anchor node is calculated by type (1)：

$$c_i = \sum \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \Big/ \sum h_{ij} \ . \tag{1}$$

Where, j is the other anchor node; h_{ij} is the number of hop between the anchor node i and the anchor node j.

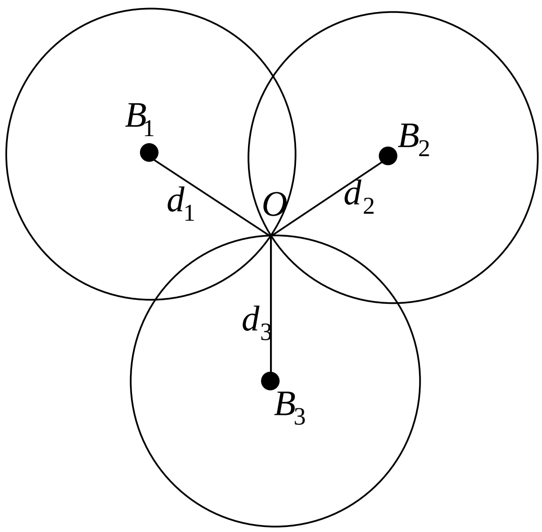


Fig. 2. Geometric representation of unknown node what is located by three anchor node

2) Distance calculation

As for every average distance of per hop calculated by each anchor node broadcast, its data packet format is {id_i, c_i}. The unknown node receives the data packets of each anchor node, and saves the average distance of per hop of each anchor node with a table, and then continues to broadcast to its neighbours. The data packet will be discarded in the event of meeting duplicate data packets. After the broadcast of information, the mean value of each anchor node's the average distance of per hop is calculated, then get the average distance per hop of entire network, here, we use '*cc*' to indicate it. Then each unknown node can calculate the distance of the node itself to each anchor node and save it into the table.

3) Localization calculation

According to the distance information of many anchor nodes that has been obtained, the unknown node calculates its coordinates using the maximum likelihood estimate of trilateration or multilateral measurement.

When the distance *d* between all anchor nodes and the location node *O* is known, according to (2) calculate:

$$\begin{cases} (x_1 - x) + (y_1 - y)^2 = d_1^{\ 2} \\ \ldots \\ (x_n - x) + (y_n - y)^2 = d_n^{\ 2} \end{cases} . \quad (\mathbf{2})$$

While (2) can be expressed as:

$$\begin{cases} x_1^{\ 2} - x_n^{\ 2} + 2(x_1 - x_n)x + y_1^{\ 2} - y_n^{\ 2} \\ -2(y_1 - y_n)y = d_1^{\ 2} - d_n^{\ 2} \\ \ldots \\ x_{n-1}^{\ \ 2} - x_n^{\ 2} + 2(x_{n-1} - x_n)x + y_{n-1}^{\ \ 2} - y_n^{\ 2} \\ -2(y_{n-1} - y_n)y = d_{n-1}^{\ \ 2} - d_n^{\ 2} \end{cases} . \quad (\mathbf{3})$$

The linear equation of (3) representation for:

$$AX = B \ . \quad (\mathbf{4})$$

Where,

$$A = \begin{bmatrix} 2(x_1 - x_n) & 2(y_1 - y_n) \\ \ldots & \\ 2(x_{n-1} - x_n) & 2(y_{n-1} - y_n) \end{bmatrix} . \quad (\mathbf{5})$$

$$B = \begin{bmatrix} x_1^{\ 2} - x_n^{\ 2} + y_1^{\ 2} - y_n^{\ 2} + d^2{}_n - d_1^{\ 2} \\ \ldots \\ x_{n-1}^{\ \ 2} - x_n^{\ 2} + y_{n-1}^{\ \ 2} - y_n^{\ 2} + d^2{}_n - d_{n-1}^{\ \ 2} \end{bmatrix} . \quad (\mathbf{6})$$

According to (4), the coordinates of location node *O* can be obtained using estimation methods of the standard minimum mean square.

$$X = (A^T A)^{-1} A^T B \ . \quad (\mathbf{7})$$

3.2. Error Source Analysis and Existing Optimization Strategies

From the execution process of DV-Hop algorithm, it is known that the error mainly comes from two aspects:

1) Algorithm makes the product of the number of hop and the average distance with per hop as the estimated distance between unknown nodes and the anchor nodes. This algorithm has a better result only in the situation when the true distance between nodes in the network is approximately close. The actual situation is different. When the location of unknown node is equated by applying the estimated distance of these anchor nodes, the position precise is low because of the accumulated error. Figure 3 show the generating process of error.

In the Fig.3, L_1、L_2、L_3 are all anchor nodes. A is the unknown node which need localization. The three anchor nodes know the distance to any other one, shown as Fig. 3.: 30, 30 and 40. The distance between A and L_1 is 15, the number of hop is 1. The hops between A and L_2 or L_3 is 3. Suppose the length of the other each edge is 10.

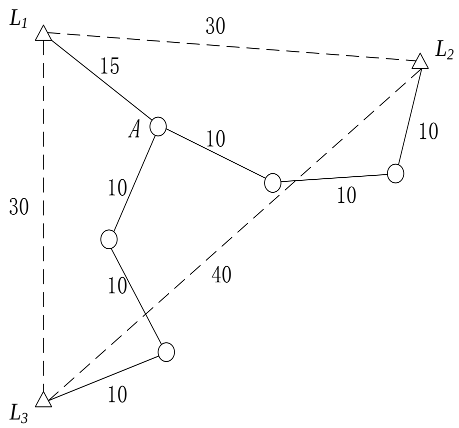


Fig. 3. Analysis diagram of DV-Hop localization error

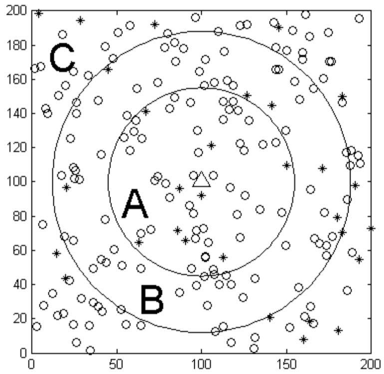
Known by the DV-Hop algorithm, L_1, L_2 and L_3 is calculated as follows:

L_1: (30+30) / (4+4)=7.5;

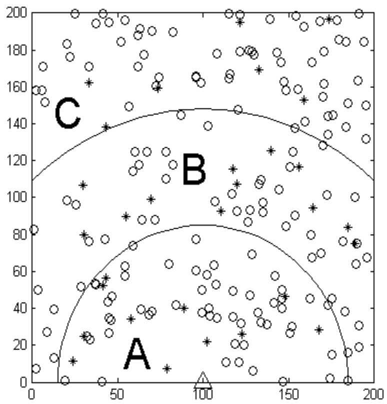
L_2: (30+40) / (4+6)=7;

L_3: (30+40) / (4+6)=7;

After the average distance of per hop computed by the anchor node, the anchor nodes will broadcast this value in the network. The unknown node takes the first value of receiving as the average distance per hop. In the example, L_1、L_2 and L_3 will respectively broadcast the calculated value which is 7.5、7 and 7. Because there is only one hop between node A and L_1, 7.5 is the average distance of per hop of node A, then node A will calculate the distance between itself and three anchor nodes. The distance between A and L_1 is 7.5, and the distance between A and L_2 or L_3 is 22.5. In fact, the distance between A and L_1 is 15, but the calculated distance is 7.5, the error reaches 50%. It is clearly unacceptable. The error is generated from this point.



(a) The node locate centre



(b) The node locate edge

Fig. 4. Distribution of reference anchor node

2) The number of hop between the unknown node and this anchor node is larger when the anchor node is farther away from the unknown node. Error exists in the average distance of per hop itself, so if the hop count is larger, the error of estimate distance is much larger. If the coordinates of the

unknown node are solved by using the estimate distance of these anchor nodes, then the localization precise of node will reduce.

In Fig. 4, the area of 200*m*×200*m* randomly distribute 200 nodes (* stands for anchor node, o stands for the unknown node). Where, the proportion of the anchor node is 15%, the node communication radius is 50m.

To illustrate the simulation process, (a) and (b) are given the choice situation respectively for the reference anchor node of the unknown node in (100,100), (100, 0). Simulation process is divided into three parts:

1. Select the anchor node near to the unknown node as the reference anchor node, relative to the selected two nodes, shown as following, the area named A in Fig.4. At this time, most are one hop between the unknown nodes and anchor nodes, and only a few nodes own two hops.
2. Select the anchor node far from the unknown node as the reference anchor node, relative to the selected two nodes, shown as following the area C in Fig.4. At this time, the hop count between the unknown nodes and anchor nodes are two hops at least.
3. Select all anchor nodes in the network as the reference anchor. The process is same to DV-Hop algorithm.

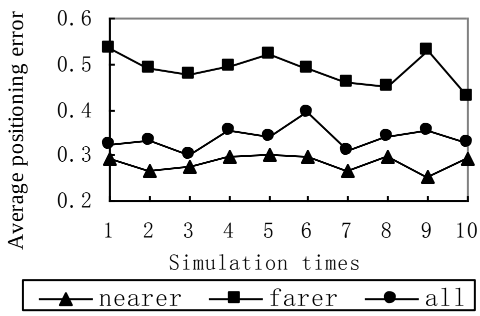


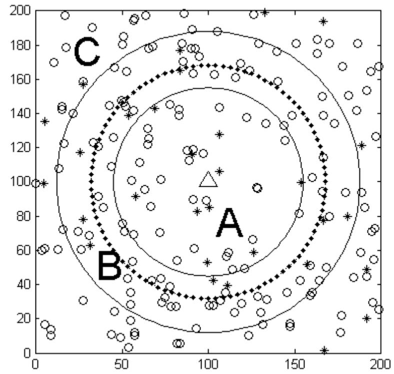
Fig. 5. Average location error of the different position anchor nodes in environment

Analysis of experimental data showed that, when select the anchor node far from the unknown node as the reference anchor node, the average location error obtained is about 48.70%. In the same condition, when select the anchor node near to the unknown node as the reference anchor node, the average location error obtained is about 28.94%, finally, when selecting all anchor nodes in the network as the reference anchor, the average location error obtained is about 33.88%. It is said that when select all anchor nodes in the network as the reference anchor, the average positioning error is far greater than the other two cases. The main source of error caused is the far away anchor nodes. Finally, we conclude that:

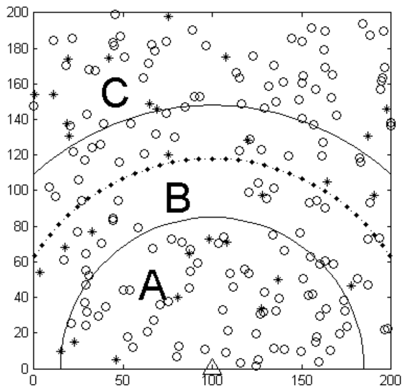
1. The average error of selecting all the anchor nodes in the network anchor node as a reference node is not the lowest.

2. The affect of localization error is larger when the anchor node is far away the unknown.

At the same time, in the simulation process we also found that, with the difference of the size of region A, the average location error is relatively larger when select from the unknown node closer to the different number of anchor nodes. Aimed at the two nodes selected, we change the size of A area when only considering the node itself position error, finally we got the anchor node selection condition up to the lowest location error through several simulation experiments. The area is indicated by dot line in Fig.6.



(a) The node locate centre



(b) The node locate edge

Fig. 6. Minimum location error distribution of reference anchor node

4. A New Location Algorithm NDV-Hop_Bon

4.1. The Location Idea

Under the premise of DV-Hop idea, the number of hops among nodes is generally fixed. In order to obtain the minimum error between the estimated distance and actual distance, it can be obtained by adjusting to the average distance of per hop. It was found that the average location error is not the smallest when selecting all the anchor nodes as reference anchor node of unknown nodes, but it has a better result when select the node near the unknown node. At the same time, the achieved product of average distance of per hop and the hops count is the true of closet. Experimental results show the number of optimal anchor nodes that can be up to the lowest average location error is involved with the network environment parameters, and different parameters of the network environment. Besides, the number of optimal anchor nodes is different.

Thus, a new localization idea is proposed. First of all, each unknown node initially sets a threshold named *N*. After exchanging information, we can get the estimate distance of the anchor node. Then select the information of N nodes which is received firstly, equate the coordinates of unknown nodes using least square method. Due to only selecting the anchor nodes with the short distance, the new localization algorithm not only reduces the computational in the process and improve efficiency, but also achieves a minimum average positioning by selecting the number of optimal reference anchor nodes.

4.2. Setting the Threshold N

Lots of simulation experiments showed that the number of optimal anchor nodes is involved with the following parameters of the network environment:

1. The area of the sensing region, we take A as the side of the sensing region, and assuming that a sensor area is always square.
2. Communication radius of sensor nodes, it is said that the nodes within the region of R can communicate with each other.
3. The proportion P of anchor node in the network, which means the number of anchor nodes in the network takes the proportion of the total number of nodes, the number of all nodes is denoted by *TN*.
4. The average θ of connectivity between the unknown nodes and the anchor nodes in the network. Define:

$$\theta = \frac{\sum_i Con\_Anc_i}{Un} \quad . \tag{8}$$

Where, Un is the number of the unknown nodes; Con_Anch_i is the connectivity between the node i and anchor nodes in the network, that is to say, the number of anchor nodes that unknown nodes can communicate with.

The threshold N need to change in accordance with the changes of the network environment parameters, the specific change process is as follows:

1. The coverage of each node in the network is relatively smaller when the sensing area is greater and the communication radius of sensor nodes is smaller, that is to say, $A^2/\pi R^2$ is greater. Then the number of anchor nodes for locating the unknown nodes is larger; it is said that the value of N is directly proportional with $A^2/\pi R^2$.
2. When the connectivity between unknown nodes and anchor nodes is larger, that is θ has a larger value, the number of anchor nodes within one hop far away from unknown nodes is larger. At this time, the anchor nodes calculate the average distance of per hop. Because the number of per hop is smaller, it makes the average distance of per hop that is equated too large. So the number of optimal nodes should be increased and make it balance the length of the average distance of all per hop.
3. When P is very small (less than 5%), because the number of anchor nodes is very few in the network, at this time, better results can be gotten through selecting all anchor nodes. It's said that the value of N is fixed *1/P.* When P is larger than 5%, the number of all anchor nodes is increased with the accretion of the proportion P of anchor nodes in the network. As the relationship is not linear proportional relationship, we can set an option βP to adjust, which is a proportional factor. The value of βP is changed by adjusting the value of β .Thus it makes the value of βP tend to optimal.

The above analysis, the formula of the threshold N is defined as:

$$N = \begin{cases} \frac{A}{R}\frac{1}{\sqrt{\pi}} \times \theta \times (1 + 0.1P) & P > 25\% \\ \frac{A}{R}\frac{1}{\sqrt{\pi}} \times \theta \times (1 + \beta P) & 5\% \le P \le 25\% \\ \frac{1}{P} & P < 5\% \end{cases} \quad . \tag{9}$$

4.3. Determination of β Factor

The above formula β is the factor of adjusting the proportion P of the anchor nodes to the threshold. When the sensing area size and node communication radius is constant, with changes of the proportion for the anchor node in the network, the value will change accordingly to achieve the control of unknown node selecting the optimal number of anchor nodes. A large number of experiment data are obtained, and the final statistical analysis shows:

1. With the increase of the ratio P of anchor nodes, on the one hand, the number of optimal anchor nodes is growing with the increase of proportion of the anchor nodes. On the other hand, the proportion that the best anchor node relative to the total number of anchor nodes is constantly reducing. When the ratio of anchor nodes in the network increases, the number of the total anchor nodes increases and the anchor nodes of around unknown nodes are increased correspondingly. Then the increase of the number *N* of optimal anchor nodes ensures that there is enough anchor nodes to locate, which helps to improve the positioning accuracy. But due to the more overall anchor node, it can reach optimum positioning accuracy by selecting a relatively small proportion of the total number of anchor nodes anchor node. Reflected in the formula, the value of β is reduced as the constant decrease of the radio P .

2. When the ratio of anchor nodes in a certain range of 1) (for example from 5% to 10%, from 10% to 15%). With the increase of the ratio of anchor nodes, the number of anchor nodes of around unknown nodes in the network can increase. At the same time, it can receive more high positioning accuracy when number of the optimal anchor nodes increases relatively. It is said that the value of β is relatively fixed which makes N grow with the increase of P in the process of the increase of P in this region.

3. With further increase of the ratio of anchor nodes (Greater than 25%). The number *N* of optimal anchor node will remain in a stable range. At this time, unknown nodes around the anchor node are enough, while the number of optimal anchor nodes selected can achieve a lower average position error. In theory, the value of β should continue to become smaller to meet the fixed value of *N*. But because the value of β is already smaller, the change of itself has little effect on the number of the optimal anchor nodes, that is, the value of β has stabilized. It means when *P* is greater than 25%, the fixed value of β is 0.1.

Finally, the relationship between β factor and the ratio of anchor nodes is given, as shown in Table 1.

Table 1. The relationship between β factor and the ratio of anchor nodes

P	5%~10%	10%~15%	15%~20%	20%~25%	>25%
β	20	5	2.5	0.5	0.1

5. Simulation and Analysis

To verify the performance of the new algorithm, we use Matlab to simulate, here, assuming the sensor area is square region. The definition of the average location error is shown as follows:

$$Error = \frac{\sum_i D_i / R}{Un} \quad . \tag{10}$$

Where, D_i is the difference of the estimated distance and the real distance; R is communication radius, UN is the number of the Unknown node.

Here, the prerequisite are the following supposition: (1) The node deployed region of wireless sensor network is the two-dimensional surface region, and the node has the function of adjusting the correspondence radius scope; (2) The node uses the model of free space radio wave propagation, that is to say, the node's communication range is take the node as a central concentric circle; (3) The node has the ability of symmetrical correspondence, and suppose the messages of all send can be received correctly; (4) The neighbour node can carry on the correspondence directly, namely the two nodes in the scope of correspondence radius can carry on the correspondence directly; (5) The part of nodes have realized own localization through installing the GPS instalment or deploying artificially beforehand, this kind of node is called as the anchor node; (6) There is only two kind of nodes in the network: the anchor node and the unknown node; (7) Besides the own position data known, the other attributes of the anchor node are the same as the unknown node.

Fig.7 and Fig.8 show the influence of the different proportion of anchor nodes to the average positioning error. Simulation environment are separately (a): 200 nodes are distributed randomly in the region of 200$m\times$200m; the communication radius is 50m; (b) 100 nodes are randomly distributed in the region of 100$m\times$100m; the communication radius is 50m.

The data in chart shows that the average positioning error of NDV-Hop_Bon algorithm is lower than that of DV-Hop algorithm, and will reduce with the increase of the proportion of anchor nodes. The positioning accuracy of DV-Hop algorithm tends to stabilize when the proportion of anchor nodes is larger than 15% in the environment of (b). The new positioning accuracy of the positioning algorithm can still be improved; the positioning accuracy is 22.3% when the anchor percentage is more than 25%.

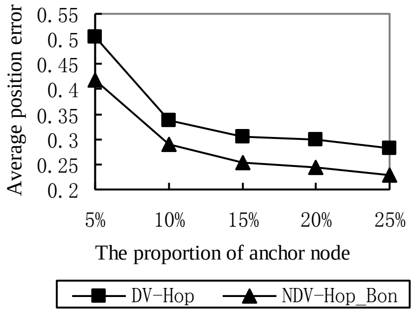


Fig. 7. The average location error of the proportion of the different anchor nodes in environment (a)

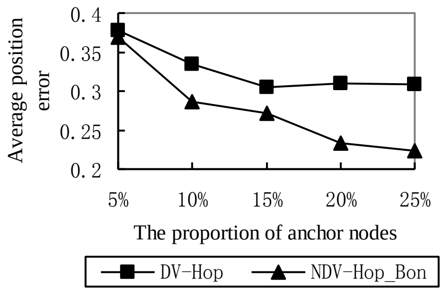


Fig. 8. The average location error of the proportion of the different anchor nodes in environment (b)

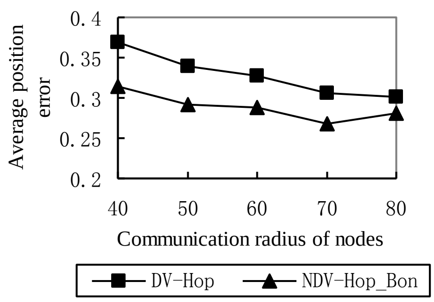


Fig. 9. The average location error of different communication radius in the environment (a)

Fig.9 and Fig.10 show the influence of the different communication radius to the average positioning error. Simulation environment are separately (a): 200 nodes are distributed randomly in the region of 200*m*×200*m*; the ratio of anchor nodes is 10%; (b) 100 nodes are randomly distributed in the region of 100*m*×100*m*; the ratio of anchor nodes is 10%.

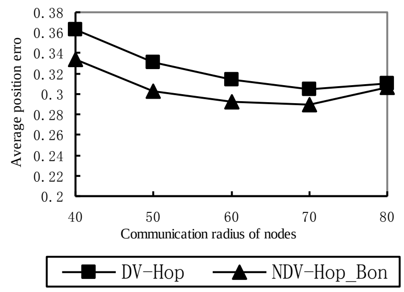


Fig. 10. The average location error of different communication radius in the environment (b)

We can see from the Fig.9 and Fig.10, NDV-Hop_Bon algorithm is superior DV-Hop Algorithm in both environments. The average position error of the new position algorithm is growing with the increase of communication radius when the communication radius is up to 80m. The reason is that the communication radius has reached 40% of sensing region side, and it is said that most of nodes can directly communicate with any other one. Generally, there is one hop between the anchor nodes and the unknown nodes, so the estimate distance of computation will be smaller, thus affecting the positioning accuracy. When the communication radius of the anchor node is 70m in the environment (b), at this time the proportion between the communication radius and the sensor region side is 70%. Almost all of the nodes in the network are one hop, and the error of estimated distance also is high, so there is a decline in positioning accuracy. This can explain that the new location algorithm has a lower requirement for the communication radius of nodes. It is said that the algorithm can achieve a high positioning accuracy when the nodes communication radius are set very small. From the energy point of view, the energy consumption is the lowest in the situation of the same position accuracy.

Fig.11 shows the influence of the average position error for the sensor region of difference size. Simulation experiment's environment is: the proportion of the anchor nodes is 10%, and the communication radius of nodes is 50m. The number of nodes becomes larger with the increase of sensing region and the number is increased from 100 to 500. It can be seen from the figure that the positioning error of NDV-Hop_Bon algorithm is lower than the effect of the DV-Hop Algorithm. However, the position error can increase with the growing of the area of sensor region. Through analysis, we can infer that it is the affect of communication radius of node. The number of hops between most unknown nodes and position anchor nodes using is relatively large if the communication radius is too small. Due to the increasing number of hops resulted in cumulative error, thereby affecting the positioning accuracy.

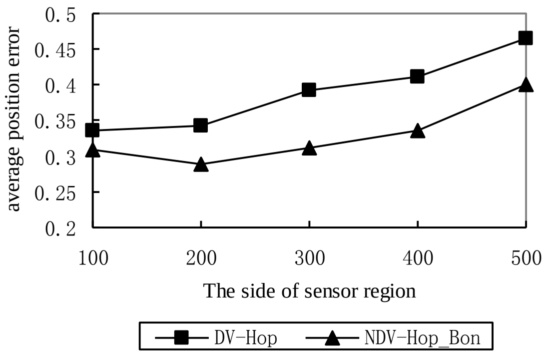


Fig. 11. The influence of the average position error for the sensor region of difference size

6. Conclusions

In order to improve the position performance of the node localization algorithm in the sensor network of distributing randomly, the paper summed up and analyzed the error of the position process of DV-Hop algorithm, then proposed a new position algorithm NDV-Hop_Bon in view of the disadvantage of all anchor node position. The new localization algorithm selects the reference nodes of a certain number to position the unknown nodes based on different environments. Finally, the results show that the positioning accuracy of the new positioning algorithm is better than DV-Hop. And the algorithm has a more prominent performance with the growing of the proportion of anchor nodes, the increase of sensor region area and the increase of the number of sensor nodes. Meanwhile, due to a lower requirement on the node communication radius, on one hand, it saves the energy; on the other hand, it can also be more suitable for the positioning of the large sensor networks.

As the newly proposed algorithm still has the limitation on the application, when the anchor node's energy is too low, the positioning accuracy can not meet the requirements. At the same time, communication expense is increased due to introduce of the computation for the number of optimal anchor nodes. Therefore, the key issues for further research and direction is to improve the scalability of the algorithm, optimization of anchor nodes when the proportion is too low, and ensuring the case of the lower positioning error with the reduction algorithm communication.

References

1. Chatterjee, A.: A Fletcher-reeves Conjugate Gradient Neural-Network-Based Localization Algorithm for Wireless Sensor Networks. IEEE Transactions on Vehicular Technology, Vol. 59, No.2, 823-830.(2010)
2. Li, M., Liu, Y.: Rendered Path: Range-Free Localization in Anisotropic Sensor Networks With Holes. IEEE/ACM Transactions on Networking, Vol. 18, No.1, 320-332. (2010)
3. Kwon, O., Song, H., Park, S.: The Effects of Stitching Orders in Patch-and-Stitch WSN Localization Algorithms. IEEE Transactions on Parallel and Distributed Systems, Vol. 20, No.9, 1380-1391. (2009)
4. Katenka, N., Levina, E., Michailidis, G.: Robust Target Localization from Binary Decisions in Wireless Sensor Networks. Technometrics, 448-461. (2008)
5. Niculescu, D., Nath, B.: Ad-Hoc Positioning Systems (APS). In Proceedings of the 2001 IEEE Global Telecommunications Conference [S1]: IEEE Communication Society, 2926-2931. (2001)
6. Niculescu, D., Nath, B.: DV Based Positioning in Ad Hoc Networks. Journal of Telecommunication Systems, Vol. 22, No.4, 267-280. (2003)
7. Umer, M., Kulik, L., Tanin, E.: Spatial Interpolation in Wireless Sensor Networks: Localized algorithms for Variogram Modeling and Kriging. GeoInformatica, 101-134. (2010)
8. Xiong, K., Thuente, D.: Dynamic Localization Schemes in Malicious Sensor Networks. Journal of Networks, Vol. 4, No.8, 677-686. (2009)
9. Baouche, C., Freitas, A., Misson, M.: Radio Proximity Detection in a WSN to Localize Mobile Entities within a Confined Area. Journal of Communications, Vol. 4, No.4, 232-240.(2009)
10. Caballero, F., Merino, L., Gil, P., Maza, I., Ollero, A.: A Probabilistic Framework for Entire WSN Localization Using a Mobile Robot. Robotics and Autonomous Systems, Vol. 56, No.10, 798-806.(2008)
11. Pei, Z. M., Deng, Z. D., Xu, S., Xu, X.: A New Localization Method for Wireless Sensor Network Nodes Based on N-Best Rand Sequence. Acta Automatica Sinica, Vol. 36, No.2, 199-207. (2010)
12. Wang, J. C., Huang, L. S., Xu, H. L., Xu, B., Li, S. L.: A Novel Range Free Localization Scheme Based on Voronoi Diagrams in Wireless Sensor Networks. Computer Research and Development, Vol. 45, No.1, 119-125. (2008)
13. Wang, S. S., Yin, J. P., Cai, J. P., Zhang, G. M.: Localization Algorithm for Wireless Sensor Networks Based on RSSI. Computer Research and Development, Vol. 45, No.suppl, 385-388. (2008)
14. Zhang, Z. Y., Gou, X., Li, Y. P., Huang, S. S.: DV-Hop Based Self-Adaptive Positioning in Wireless Sensor Networks. The 5th International Conference on Wireless Communications Networking and Mobile Computing. 1-4.(2009)
15. Huang, H., Lu, W. K., Xu, C. H., Ye, M. Q.: An Enhhanced DV-Hop Algorithm in WSN. Periodical of Ocean University of China, Vol. 38, 217-220. (2008)
16. Chen, K., Wang, Z. H., Lin, M., Yu, M.: An Improved DV-Hop Localization Algorithm for Wireless Sensor Networks. IET International Conference on Wireless Sensor Network, 255-259.(2010)
17. Yi, X., Liu, Y., Deng, L., He, Y.: An Improved DV-Hop Positioning Algorithm with Modified Distance Error for Wireless Sensor Network. The 2th International Symposium on Knowledge Acquisition and Modeling, Vol. 2, 216-218.(2009)
18. Bao, X. R., Bao, F. P., Shi, Z., Liu, L.: An Improved DV-Hop Localization Algorithm for Wireless Sensor Networks. The 6th International Conference on Wireless Communications Networking and Mobile Computing, 1-4.(2010)

19. Yi, X., Liu, Y., Deng, L., He, Y.: An Improved DV-Hop Positioning Algorithm with Modified Distance Error for Wireless Sensor Network. The 2th International Symposium on Knowledge Acquisition and Modeling. Vol. 2, 216-218.(2009)
20. Wang, Y. H., Zhang, J., Nan, W., Fang, G.: An Improved DV-Hop Localization Algorithm for Wireless Sensor Networks. International Conference on Intelligent Computation Technology and Automation. Vol. 2, 576-579.(2011)
21. Li, J., Zhang, J. M., Liu, X. D.: A Weighted DV-Hop Localization Scheme for Wireless Sensor Networks. The 8th International Conference on Embedded Computing. 269-272.(2009)
22. Zhang, J., Wu, Y. H., Shi, F., Geng, F.: Localization Algorithm Based on DV-Hop for Wireless Sensor Networks. Journal of Computer Applications, Vol. 30, No.2, 23-326. (2010)

Qingji Qian, female, born in 1962, associate professor in the College of Physics, Jilin University. Her main research interests include wireless sensor networks, embedded technology, and applied optics.

Xuanjing Shen, male, born in 1958. professor and PhD supervisor currently in the college of computer science and technology, Jilin University. His research interests are wireless sensor networks, multimedia technology, computer image processing, intelligent measurement system, optical-electronic hybrid system, and etc.

Chen Haipeng, born in 1978. Ph.D., a lecturer in the college of computer science and technology, Jilin University. Member of China Computer Federation (E200015167M). His main research interests include wireless sensor networks, digital image processing and pattern recognition, and computer network security.

Received: Februar 22, 2011; Accepted: April 22, 2011.