The Improvement of Wireless Sensor Networks Node Location Algorithm in Extreme Environment

Yanbin Shi¹, Guangyu Wang²*, and Junjie Zhou³

¹Flight research institute, Air Force Aviation University, Changchun 130022, China
²Basic Aviation College, Air Force Aviation University, Changchun 130022, China
³Unit 85826 of PLA, Changchun 130022, China
*Corresponding author e-mail: wangguangyu@ccdh1.onexmail.com

Abstract. WSN is a wireless network composed of quantities of sensor nodes in a self-organizing multi-hop mode. Its used for perceive, collect and handling the information data to the monitoring center or the terminal user, to realize the communication between "people and things" and "things and things". Among them, position fixing technology is the basic technology of many applications of WSN. The using of sensor nodes for positioning is very valuable in many practical applications. This paper introduces a modified DV-Hop location algorithm without range measurement, which has the characteristics of high positioning accuracy, low cost, low energy consumption, etc., and has important practical significance. The simulation results show that the positioning accuracy will be higher, because the process is easy to improve the calculation, does not need to add additional hardware, so it has a strong applicability.

Keywords: Location Algorithm, DV-Hop Location, Extreme Environment

1. General
The history of MEMS, wireless communication and embedded technique advances the development of wireless sensor network [1]. In the military field, WSN plays a principal role in battlefield surveillance, homeland security, battlefield reconnaissance, target positioning, target tracking and other aspects. Among them, location technology is the basic technology of many applications of wireless sensor network. Node localization is based on several known node localization algorithm to determine the unknown location of the node information, the establishment of node localization mechanism in wireless sensor network. Although GPS can obtain high-precision, it is not fitting to space, underground, underwater, mining and other extreme environments, it is unsuitable for large-scale sensor nodes. Firstly, the GPS receiver needs at least 3 satellites to determine the target position, which is impossible in many cases, such as laboratory and underground. Secondly, in a computing environment, smaller sensor nodes are not suitable for large and valuable GPS receivers. Finally, sensor nodes are often deployed in harsh environments or areas inaccessible to humans, where batteries cannot be replaced. Therefore, GPS is insufficient of wireless sensor network, if the sensor is equipped with GPS, the price is expensive, will lead to the waste of resources. Positioning with sensor
nodes is very important in many practical applications. At present, the most widely used classification process are range-based and range-free location algorithms. Considering energy consumption and cost, small range localization algorithm has been paid more and more attention. Because the positioning algorithm does not need to mainly rely on network connectivity for positioning, the cost is low, easy to implement, and can meet the precision requirements of most applications. DV-Hop algorithm [2] is widely used in small range location algorithms. The main idea of DV-Hop algorithm is to use the least number of hops to make the average hop from the black node to the white node from the nearest white node to the black node, then calculate the range between the black node and the white node, and then calculate the position of the black node [3], which can be separated into the following three phases:

1.1 To Obtain the Least Number of Hops Between Nodes and White Nodes
The white node broadcasts data packets to the network in the form of flooding. The information includes the ID, location information of the white node and a hop value with an initial value of 0. The format is as follows. The packet data of the white node will be received and recorded by the receiving node, and then the hop number plus one will be transferred to the next node. In the whole process of information transfer, the node may receive the packets of the same white node many times. The node compares the hop number information of the data information of the same white node, and the packets with the least hop number are filtered and recorded the packet with larger hop value is discarded.

1.2 Calculate the Range between the White Node and the Black Node
This regulation process means that the apparatus-deaw-point keeps constant, but the number of air delivered to the workshop is altered. Compared with the former, workshop supply-air-state is also apparatus-deaw-point [4] and it remains unalterable. This approach not only results in no cold-and-heat offset, but at meanwhile, also reduce the fan power consumption.

When every white node knows the least hop number information with other white nodes in the network, the mean hop range can be computed by Formula (1):

$$\text{HopSize}_i = \frac{\sum_{j=1}^{N} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{j=1}^{N} h_j}$$  \hspace{1cm} (1)

Where, HopSize$_i$ represents the mean hop range of white node $i^{th}$, ($x_i, y_i$) and ($x_j, y_j$) are coordinates of white node $i$ and white node $j$ respectively, $h_j$ is the least hops between nodes.

2. Shortages of DV-Hop
Because of the defects and shortages of the DV-Hop positioning algorithm, it is proposed that a modified algorithm which combines the multilateral positioning process and Taylor series expansion process to estimate the coordinates of black nodes by three processes [5-7].

Firstly, the multilateral positioning method is proposed to approximately estimate the position of nodes, and then the estimated position is used as the original value for reference, the priority values of nodes are set up, and the nodes directly located by 3 or more white nodes have the highest priority value, it is the first grade node. In the positioning of the second grade nodes, the first grade nodes are regarded as white nodes for positioning, and so on, the coordinates of nodes with lower location nodes can be obtained step by step;

Secondly, the coordinates of black nodes are corrected by the average positioning error. In reference [8], for the traditional location algorithm, if the range between two nodes is less than the network communication radius, it is a hop. When the range between two nodes is very small and the error is relatively large, a modified algorithm of multiple communication radius is proposed.
3. Modified Algorithm

3.1 Weighted DV-Hop Location Algorithm

The conventional location algorithm uses the mean hop range of the white node with the least hop range from the black node as the mean hop range of the black node, while the weighted DV-Hop location algorithm considers the mean hop range of all white nodes comprehensively, and uses the hop number between the white node and the black node as the weight value of the different mean hop range. The weight value can reflect the white node [9-10] The influence of nodes on the mean hop range of black nodes can effectively reduce the estimated position error caused by using the mean hop range of a single white node. The sum of all weights of a black node is equal to 1. Supposed that the black node receives the average per hop range of white nodes in total, and the range to the white node is $N_i$, the weight of the white node can be expressed by Formula (2):

$$\omega_i = \frac{1}{N_i} \sum_{j=1}^{N} \frac{1}{N_j} \quad (2)$$

From the formula (2), it can be seen the least hop between the black node and the white node can reflect the weight value, which is an inverse relationship. The larger least hop between the black node and the white node, the smaller the corresponding weight, and the smaller least hop between the black node and the white node, the larger the corresponding weight. If the mean hop range[11] of white node is $d_i$, and its corresponding weight is $\omega_i$, then the mean hop range $d$ of black node can be expressed by Formula (3):

$$d = \sum_{i=1}^{N} \omega_i d_i \quad (3)$$

Compared with the traditional algorithm, the modified algorithm can reduce the location error and improve the location precision.

3.2 The Min-Max Correction Algorithm

The modified DV-Hop algorithm still has problem of inaccurate positioning of individual nodes. Therefore, the third step needs to be modified. After the coordinates of black nodes are calculated by trilateral positioning method or maximum likelihood estimation, the position algorithm of black nodes is modified by min max correction algorithm. The basic principle of the correction algorithm as follow:

Take the three closest white nodes to the black node, and make a square with the range from the white node to the black node twice as the side length. The three squares will have overlapping areas. If the black node is in the overlapping area [12], the coordinates will not be modified. If the black node is not in the overlapping area, the coordinates need to be modified.

The steps of the modified algorithm are as follows:

1. The white node broadcasts packets to the network in the way of flooding, and the node obtains the least number of hops with the white node.

2. When the black node get the range of three or more white nodes’, the coordinates of the black nodes can be calculated by the trilateral measurement process or maximum likelihood estimation process.

3. The black node coordinates are modified by Min-Max algorithm. If the estimated coordinates of nodes are in the area of square overlap, the node coordinates need not be modified. If the estimated coordinates of nodes are not in the area of square overlap, the black node coordinates need to be modified.
4. Algorithm Simulation
In order to fully understand the positioning accuracy of the modified algorithm, simulate software is used to realize the algorithm [13]. In the sensing area of 100m*100m, sensor nodes are randomly distributed, with a communication radius of 20m, among which there are black nodes and some are white nodes with known GPS positions. The following discusses the influence of the proportion of white nodes and the total number of nodes on the positioning accuracy of traditional positioning algorithm and modified algorithm respectively. When the algorithm be carried 100 times, then the 100 results can be got and as the final result, the average value of node positioning error can be expressed by Formula (4), where $E$ is the node positioning error, $(x, y)$ is the actual coordinate of the node, $(x', y')$ is the estimated coordinate of the node, and $R$ is the communication radius of the node. The sum of the positioning errors of the black nodes that have been located is divided by the number is equal to the average positioning error of the nodes.

$$E = \frac{\sqrt{(x - x')^2 + (y - y')^2}}{R} \times 100\%$$ (4)

Figure 1 shows the error comparison between Min-Max algorithm and traditional algorithm when the number of white nodes is fixed and the total number of nodes is 100, 120, 140, 160, 180, 200, 220. It can be seen from the figure that when the total number of nodes is small, the positioning effect of Min-Max algorithm is significantly better than that of traditional positioning algorithm. With the increase of the total number of nodes, when the total number of nodes is greater than 13. The location error of Min-Max algorithm is more and more similar to that of traditional algorithm, so Min-Max algorithm is not suitable for the situation of large number of nodes, but increasing the total number of nodes in practical application will inevitably increase the cost, so Min-Max algorithm is still practical.

![Figure 1. The relationship between nodes and positioning error](image)

5. Conclusion
This paper introduces a DV-Hop location algorithm without range measurement. The mean hop range of each black node is determined by the nearest white node and the mean hop range of all white nodes in whole of the network [14]. According to the range between the white node and the black node, the weight corresponding to the mean hop range of the white node is calculated, and then the weighted mean hop range of all black nodes is decided. Finally, the coordinate of the black node is corrected by using the least-maximum algorithm. The simulate results show that the traditional positioning process using only modified algorithm of weighted least or maximum modified algorithm improved the positioning accuracy to a certain extent, but the first to use the weighted algorithm to improve the average jump range, and then use the smallest biggest algorithm to modify the black node coordinate, positioning accuracy is higher, because of modified process to calculate easily, does not need to add additional hardware, thus has a strong suitability.
Acknowledgments
This research was supported by Education Department of Jilin Province “13th Five-Year” scientific research planning project (project number: JJKH20201208KJ).

References
[1] Lv X, Sun X, Zhou X, et al. DV-Hop-MSO based Localization Algorithm in Wireless Sensor Networks. Computer Engineering & Applications, 2007, 43(20):312-316.
[2] On Modified DV-Hop Localization Algorithm for Accurate Node Localization in Wireless Sensor Networks. SHEN Shikai, YANG Bin, QIAN Kaiguo, SHE Yumei, WANG Wu. Chinese Journal of Electronics. 2019(03).
[3] DV Based Positioning in Ad Hoc Networks. Telecommunication Systems. 2003(1).
[4] C Feng, Valaee, et al. Received signal strength based indoor positioning using compressive sensing. IEEE Transactions on mobile computing, 2012, 11(12):1983-1993.
[5] Fang, Wangsheng, H. Xu, and G. Yang. "Improved DV-Hop Algorithm Based on Minimum Hops Correction and Reevaluate Hop Distance." 2019 5th International Conference on Information Management (ICIM) 2019.
[6] Fang W, Xu H, Yang G. Improved DV-Hop Algorithm Based on Minimum Hops Correction and Reevaluate Hop Distance// 2019 5th International Conference on Information Management (ICIM). 2019.
[7] Kansong Chen, Chenqi Wang, Liangqing Chen, Xinxin Niu, Yan Zhang, Jixiang Wan. "Smart safety early warning system of coal mine production based on WSNs", Safety Science, 2020
[8] Falsi D, Mucehi L, et al. Time of Arrival Estimation for UWB Localizers in Realistic Environments. EURASIP Journal on Applied Signal Processing, 2006, 56:1-13.
[9] Warm H Y. Hybrid TOA/AOA estimation error test and non-line of sight identification in wireless location. Wireless Communications and Mobile Computing, 2009, 9(6):859-873.
[10] N. Patwari, A. Hero, M Perkins, N. Correal, et al. Relative location estimation in wireless sensor networks. IEEE Transactions on Signal Processing, 2003, 51(8):2137-2148.
[11] Liu Y, Yang Z. Location, Localization and Localizability Location-awareness Technology for Wireless Networks. Springer, 2011:73-80.
[12] Kirkpatrick S, Gelatt Jr C D, Vecchi M P. Optimization by Simulated Annealing. Science, 1983, 200(4958):671-680.
[13] GAJJAR S H, PRADHAN S N, DASGUPTA K S. Wireless sensor network: application led research perspective. Recent Advances in Intelligent Computational Systems(RAICS), 2011:025-030.
[14] Fan B, Supeng L, Kun Y. GPS: A method for data sharing in Mobile Social Networks[C]. Networking Conference, IFIP, 2014:1-9.