An Improved DV-Hop Localization Algorithm via Inverse Distance Weighting Method in Wireless Sensor Networks

Wenming Wang[1,2(✉)], Xiaowei Cao[1,2], Meng Qian[1,2], and Liefu Ai[1,2]

[1] College of Computer and Information, Anqing Normal University, Anqing 246011, China
Wangwenming500@163.com

[2] The University Key Laboratory of Intelligent Perception and Computing of Anhui Province, Anqing Normal University, Anqing 246011, China

Abstract. The node localization is an important problem in wireless sensor network (WSN). An improved algorithm is proposed by analyzing the deficiencies of random distribution in DV-Hop. Different from the previous results, minimum mean-squared error (MSE) and inverse distance weighting method are adopted to deal with the average one-hop distance in improved algorithm. Improved algorithm and DV-Hop are simulated by MATLAB R2015b, and the results of these two algorithms are analyzed and compared. The results show that the positioning accuracy is improved on the condition of no increasing complexity and cost.

Keywords: Wireless sensor networks · DV-Hop · Mean-squared error (MSE) · Inverse distance

1 Introduction

Wireless sensor network (WSN) [1] consist of many static and moving energy-autonomous microsensors distributed in a certain detection area. Its purpose is to perception, collection and processing of observed objects in the detection area [2–5]. At present, the WSN is mainly used in military, environmental testing and industrial fields.

Sensor node location information is very important to WSN, which can realize the monitoring of real-time monitoring and information acquisition [6]. How to achieve accurately node localization is a main concern for wireless sensor network, which plays a very important role in WSN. According to the distance between measurement nodes in the localization process, WSN node localization consists of range-based and range-free localization algorithms [7]. In this scheme, the nodes that are aware of their positions are called beacon nodes, while others are called unknown nodes. Range-Based positioning algorithm needs measure the distance, angle and other information between nodes, so the positioning accuracy is high relatively. Currently, typical Range-based localization

F. Chen and Y. Luo (Eds.): Industrial IoT 2017, LNICST 202, pp. 163–168, 2017.
DOI: 10.1007/978-3-319-60753-5_17

algorithms included RSSI, TOA, TDOA, AOA [8,9], and so on. However, it is at the expense of increasing the cost and power consumption. Range-Free algorithm relies on network connectivity for localization, do not need range hardware support and are immune to range measurement errors. Several techniques based on Range-free included centroid location algorithm, DV-Hop, MSD MAP and APIT [10–12], and so on.

We discuss the DV-Hop algorithm, and propose two improvements about it in this paper. Improved algorithm can improve the positioning accuracy on the condition of without increasing complexity and cost. Compared with traditional DV-Hop algorithm, it is a simple and practical algorithm, and more available for WSNs.

This paper is organized as follows. The related work is presented in the next section. Section 3 analyzes the shortcoming of traditional DV-Hop algorithm and proposes our improved algorithm. Simulation results are shown in Sect. 4. Finally, we present our conclusions in Sect. 5.

2 Related Work

DV-Hop algorithm is one of the important Range-free localization algorithms, which is proposed by Niculescu and Badri [13] originally. The algorithm mainly consists of three steps [14–16].

In the first step, each beacon node broadcasts a packet, which includes its location information and initial hop value 0, to the neighboring nodes throughout the network. The receiving node retains the minimum hop count value of all received value from the beacon node, then adds 1 to the hop count and forwards it to the neighbor node. Then, each node will know the hop distances from itself to all anchors by the method.

In the second step, an beacon node can compute an average distance per hop (ADPH) according step 1, which is then flooded to the entire network. The average distance per hop can be calculated by the following formula (1).

$$C_i = \frac{\sum_{j \neq i} d_{i,j}}{\sum_{j \neq i} h_{i,j}} \tag{1}$$

where $d_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - x_y)^2}$, (x_i, y_i) and (x_j, y_j) are the location of anchor nodes i and j, $h_{i,j}$ is the hop value between anchor nodes i and j.

After calculating the ADPH of each beacon node, it is broadcasted to the whole wireless sensor network. Unknown nodes will only receive and save the information of ADPH from the nearest anchor node, then forward it to their neighbor nodes. After distance per hop and hops to the beacon nodes obtained, the distance between all unknown nodes and anchor nodes can be calculated.

In the third step, the trilateral medium [17] will be used to determine the position information of nodes.

3 Improved Algorithm

In this section, we analyze the shortcoming of traditional DV-Hop algorithm and improve it focus on step 2.

Firstly, the ADPH of the beacon node is calculated based on the unbiased estimation criterion at the step 2 of DV-Hop algorithm, and its measurement error mean is zero.

In fact, the errors are subject to Gaussian distribution normally. Therefore, the traditional DV-Hop algorithm has a strong dependence of the ADPH. If the ADPH value has error, the positioning accuracy will be inaccurate. So in order to improve the accuracy of location of unknown nodes, the mean square error method is more reasonable than that of using the variance or deviation. Consequently, the ADPH computed by the minimum MSE as the formula (3) in this paper.

$$f = \frac{\sum_{j \neq i}(d_{i,j} - C_i h_{i,j})^2}{N-1}. \tag{2}$$

Let $\frac{\partial f}{\partial C_i} = 0$, then

$$C_i = \frac{\sum_{j \neq i}(h_{i,j} \cdot d_{i,j})}{\sum_{j \neq i} h_{i,j}^2}. \tag{3}$$

Secondly, using the ADPH information obtained by the unknown node from its nearest beacon node as the average on hop distance from the unknown node to beacon nodes in traditional DV-Hop algorithm. However, this method has the limitations where it can not fully take into account the random distribution of nodes in WSN. If just only a single beacon node is used to calculate the ADPH, it will generate a large deviation, and the localization accuracy of the unknown node will decreases.

In fact, different beacon nodes have different effects on unknown nodes. Therefore, in order to improve the positioning accuracy, we should take advantage of the information of beacon nodes in the network, and give a different weight to beacon nodes depending on the distance. So using inverse distance weighting to deal with the ADPH is another improvement in this paper. Assuming that the unknown node has saved the ADPH from the n beacon nodes, the weights Wi are given for each ADPH value of all beacon nodes respectively. In this paper, it is computed as follows:

$$W_i = \frac{h_{i,j}^{-1}}{\sum_{j=1}^{n} h_{i,j}^{-1}}. \tag{4}$$

$$C = \sum_{i=1}^{n}(W_i C_j) = \sum_{i=1}^{n}\left(\frac{h_{i,j}^{-1}}{\sum_{j=1}^{n} h_{i,j}^{-1}} \cdot C_j\right). \tag{5}$$

4 Simulation and Evaluation

To validate our improved method, DV-Hop and improved algorithm are simulated by MATLAB R2015b in this section. Both of the results are analyzed and compared (Fig. 1).

The simulation region is a square area with an area of 100 m 100 m, which is randomly produced by rand function. As shown in Fig. 2, there are 200 nodes in this area and the radius range of sensor nodes change from 15 m to 25 m. The number of anchor nodes increase from 5 to 25. Each experiment state is simulated 50 times, and takes the average value eventually.

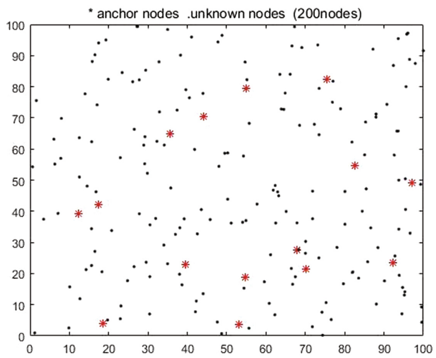

Fig. 1. Nodes distribution.

The average positioning error is defined as the ratio of the sum of the errors of all the successfully located unknown nodes to the communication radius. The formula is showed as follows:

$$\delta = \frac{\sum \sqrt{(x_i - x_i')^2 + (y_i - y_i')^2}}{R \cdot N}. \tag{6}$$

where, (x_i, y_i) and (x_i', y_i') are the real coordinates and positioning coordinates of unknown node i, respectively.

The curves showed in Figs. 2, 3 and 4 display the variation of the positioning error under different radius. Compared with the DV-Hop, the performance of improved algorithm is better in positioning accuracy with different radius range of sensor nodes. The experiment curve shows that the estimation accuracy is improved as increase of anchor node amounts, when the radiu reach a certain value. The localization error tends to be stable when the number of beacon nodes reach a certain value. When the beacon nodes share the same proportion, the localization error is obviously decrease as the increase of the radiu.

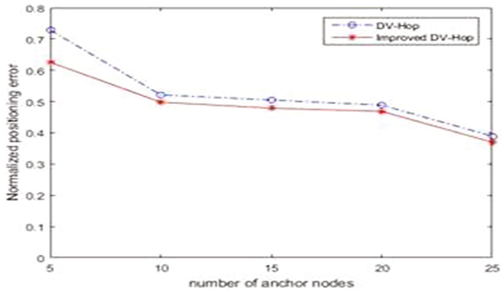

Fig. 2. The position error when the radiu is 15 m.

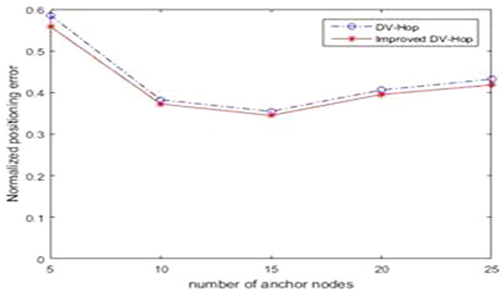

Fig. 3. The position error when the radiu is 20 m.

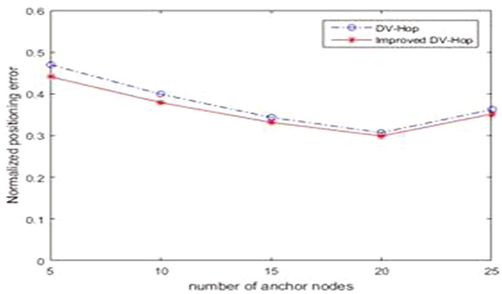

Fig. 4. The position error when the radiu is 25 m.

5 Conclusions

Unknown node localization in WSN has always been a research focus in WSN. To solve the deficiencies of random distribution in DV-Hop, an improved algorithm has been proposed in this paper. The simulation results show that the positioning accuracy is improved on the condition of no increasing complexity and cost. The improved algorithm is a simple and practical algorithm.

Acknowledgements. This work is supported by Youth Foundation of Anqing Normal University (KJ201406, KJ201303), Natural Science Foundation of Anhui Province (1608085MF144).

References

1. Tan, Z., Liu, Y.: An improved DV-Hop localization algorithm for wireless sensor networks. Int. J. Adv. Comput. Technol. **17**(4), 1–7 (2012)
2. Stefan, T., Ivan, M.: Improvements of DV-Hop localization algorithm for wireless sensor networks. Telecommun. Syst. **61**(1), 93–106 (2016)
3. Zhang, J., Cao, D., Fu, M.: Improvement on location error and coverage rate in DV-Hop algorithm. J. Comput. Appl. **31**(7), 1944–1947 (2011)
4. Liu, F., Zhang, H., Yang, J.: An average one-hop distance estimation algorithm based on weighted disposal in wireless sensor network. J. Electron. Inf. Technol. **30**(5), 1221–1225 (2008)
5. Doherty, L., Pister, K., Ghaoui, L.E.: Convex position estimation in wireless sensor networks. In: IEEE INFOCOM (2001)
6. Chen, J., Yao, K., Hudson, R.: Source localization and beamforming. IEEE Signal Process. Mag. **19**(1), 30–39 (2002)
7. Xu, C.H.X., Chen, J.Y.: Research on the improved DV-HOP localization algorithm in WSN. Int. J. Smart Home **9**(4), 157–162 (2016)
8. Yang, M., Qing, Q.Q.: Research on centroid localization algorithm for wireless sensor networks based RSSI. Comput. Simul. **28**(5), 163–166 (2011)
9. Ji, W.W., Liu, Z.: An improvement of DV-Hop localization algorithm in wireless sensor networks. Int. Conf. Wirel. Commun. **25**(10), 1–4 (2006)
10. Tao, X., Zou, G.H.: An improved DV-HOP localization algorithm based on beacon nodes at borderland of wireless sensor networks. Futur. Wirel. Netw. Inf. Syst. **143**(1), 147–154 (2012). Springer
11. Li, Y.F., Jiang, M., Lou, K., et al.: Improved DV-Hop localization algorithm in wireless sensor network. Comput. Eng. Appl. **50**(3), 79–81 (2014)
12. Gui, L., Val, T., Wei, A., Dalce, R.: Improvement of range-free localization technology by a novel DV-Hop protocol in wireless sensor networks. Ad Hoc Netw. **24**, 55–73 (2015)
13. Ji, W.W., Liu, Z.: Study on the application of DV-Hop localization algorithms to random sensor networks. J. Electron. Inf. Technol. **30**(4), 970–973 (2008)
14. Chen, H.Y., Sezaki, K., Deng, P.: An improved DV-Hop localization algorithm for wireless sensor networks. Int. Conf. Wirel. Commun. Netw. Mob. Comput. **9**(6), 2232–2236 (2010)
15. Tian, S., Zhang, X.M.: A RSSI-based DV-Hop algorithm for wireless sensor networks. In: International Conference on Wireless Communications Networking and Mobile Computing (2009)
16. Zhang, J.M., Guo, L.P., Zhang, X.D.: Effects of interpolation parameters in inverse distance weighted method on DEM accuracy. J. Geomat. Sci. Technol. **29**(1), 51–56 (2012)
17. Niculescu, D.: Positioning in ad hoc sensor networks. IEEE Netw. **18**(4), 24–29 (2004)