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Research on Optimization of 3D Location Algorithm Based on Non-ranging Wireless Sensor Network

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Abstract: *In order to solve the problem of node location in 3D space WSN (Wireless sensor network), this article summarizes the structure and characteristics of WSN, then uses weighted centroid algorithm to estimate the location, designs a new non-ranging 3D node location algorithm for wireless sensor network, and gives the theoretical basis and implementation steps of this algorithm design. The algorithm does not need to measure the actual distance between nodes, but only needs the anchor nodes to broadcast their own beacon information, and the unknown nodes within the one-hop communication range of the anchor nodes receive and store the monitored beacon information, and estimate their own positions according to these information. The final simulation results show that, compared with the existing 3D localization algorithm based on non-ranging, there is no need for unknown nodes to communicate with each other, which has less communication overhead and does not depend on the proportion of anchor nodes. And it is robust to the network topology. As a non-ranging positioning algorithm, its positioning error is only about 15% in the set 3D space.*

Keywords: *Non-ranging WSN, 3D, Node location algorithm*

1. Introduction

WSN is a self-organizing network system deployed in a certain area to monitor various environmental parameters in the area. After the sensor captures the information, it transmits the corresponding data to the terminal, which provides a reference for users to make strategies [1]. Self-localization of nodes in WSN is one of the important research contents in the field of wireless sensor networks, which has important research value and application significance [2-3]. In the near future, WSN will be widely used in many fields, such as military reconnaissance, geological exploration, disaster prediction, environmental protection and so on, changing people's life, work and interaction with the physical world [4]. In these applications, the location information of nodes is very important to the monitoring activities of sensor networks. The location of the event is the important information contained in the monitoring messages of sensor nodes, and the monitoring messages without location information are often meaningless. However, the existing self-localization algorithms of WSN nodes all have shortcomings in different degrees, and the research and improvement of self-localization algorithms of WSN nodes is a research hotspot of scholars.

Node localization in WSN has become a hot research topic, and the location information is very important to the monitoring activities of sensor networks [5]. The information returned by a wireless sensor node must contain the location information of the node itself. In most application scenarios, the information sent back by a node must be combined with its own location to make sense. Sometimes, it is only necessary for the node to send its own location [6]. Therefore, the location of nodes is one of the essential information in the whole sensor network [7]. Node location technology is the premise of many applications such as target identification, monitoring and tracking in WSN, and it is one of the supporting technologies in WSN. However, restricted by the hardware conditions of sensor nodes and various factors, wireless sensor network location technology is still a technical difficulty [8]. At present, a variety of localization algorithms have been proposed, but most of the existing localization algorithms are designed for 2D plane, and few localization algorithms are suitable for 3D space [9]. It can realize the accurate self-positioning of sensor nodes, which not only provides support for applications such as regional monitoring that need accurate location information, but also has important significance for related research of wireless sensor networks such as routing based on geographic location information. This article summarizes the structure and characteristics of WSN, and then focuses on the optimization of 3D localization algorithm based on non-ranging WSN.

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2. Optimization of 3D location algorithm based on non-ranging WSN

The data returned by the sensor can reflect the change of the physical state of the monitored point, and determining the accurate position of the sensor nodes placed in the monitoring area plays a key role in monitoring personnel's correct analysis of the returned information m[10]. All deployed nodes in the monitoring area must locate their exact positions, and the accuracy of node location directly affects whether the returned information is effectively used. In practical applications, sensor nodes are small in size, and their energy and memory are limited. Therefore, it is one of the key problems of WSN that how to obtain the unknown node position more accurately while minimizing the communication times and computing energy consumption.

Most of the existing localization algorithms are proposed for nodes in two-dimensional plane layout [11]. Compared with wireless sensor networks in two-dimensional space, wireless sensor networks deployed in three-dimensional space have richer location information, and the network scale and distribution density have also increased, which is more in line with the actual node distribution. Anchor node is also called beacon node, which accounts for a small proportion of network nodes. It can obtain its own accurate position by carrying GPS positioning equipment or pre-configuring, etc. It is the reference of unknown node positioning, and is usually uniformly or randomly distributed in WSN. In an ideal environment, the relationship between the transmitted power of the signal and the radius of the area covered by the signal can be described by the following equation:

$$\frac{P_t}{P_r} = \frac{(4\pi fd)^2}{c^2} \tag{1}$$

In the traditional algorithm, the actual distance is replaced by the sum of the jumping distances, so that with the increase of the distance between the anchor node and the unknown node, the positioning error of the unknown node with large jumping distance from the anchor node will gradually increase. In order to reduce the accumulation of this error, this article sets the receiving threshold on the node, so that the unknown node can only receive the information of the anchor node in the local area with a short distance, thus improving the positioning accuracy. Each unknown node keeps a grid-represented area table, and the grid ticket value reflects the degree of the anchor node's recognition of the grid. The larger the ticket value, the greater the possibility that the unknown node is in the grid. If an anchor node determines that a small grid is within its effective coverage, it will vote for the grid. After voting, the centroid of the grid area with the highest votes is selected as the estimated position of unknown nodes. The unknown node has stored the coordinate information of the three nearest nodes. According to the theory of higher mathematics, these three wrong nodes can determine a plane. On this plane, according to the positional relationship of the three wrong nodes, infer another node, or the four paving nodes, so that they form a square with a side length of 20m. D is the midpoint between A_2 and A_4 in Figure 1; Q is the center of gravity of triangle $A_2A_3A_4$, and M is the center of mass of tetrahedron $A_1A_2A_3A_4$.

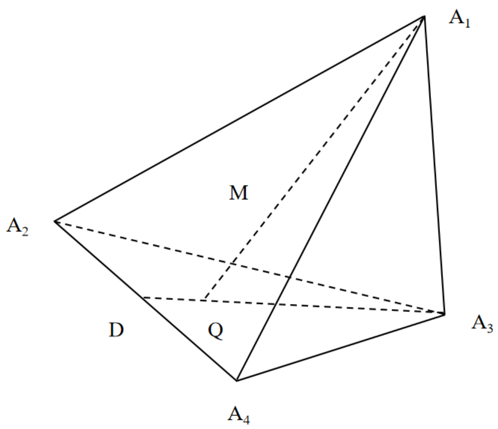

Figure 1: Derivation diagram of centroid algorithm

From Figure 1, it can be deduced through calculation that:

$$h_{c1} = \frac{1}{V}\begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix} - \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix} = \begin{bmatrix} 1/4 \\ 1/4 \\ 1/4 \\ 1/4 \end{bmatrix} - \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix} \tag{2}$$

The calculation formula of unknown target node position can be obtained by calculation as follows:

$$Z_{c1} = \left(G_c^T G_c\right)^{-1} G_c^T h_{c1} \tag{3}$$

When an anchor node group is selected, the above formula can be used for position estimation to obtain a position. Each selected anchor node group will get a coordinate value, and then broadcast this coordinate value to the nearest anchor node, which uses the estimated coordinate value of the unknown node and the other three anchor node pairs to locate itself.

In the ranging-based location algorithm, the grid representation of the area is well used. At present, the gridding representation of the area to be located has been widely used in non-ranging algorithms. This algorithm also adopts the region representation method based on solid grid. The whole network area is divided into several small cubes with the same size. The edge length is a, and the smaller the value, the thinner the whole network area is divided. Choose three adjacent anchor nodes in an unknown node, test whether they are in the triangle, and use different anchor node combinations to repeat the test until all combinations are exhausted or the required positioning accuracy is achieved. The location of the virtual center node is determined by the unknown node itself, and this process does not need too much energy, thus ensuring the energy efficiency of the algorithm and further prolonging the life of the whole network.

3. Result analysis and discussion

In the test, some anchor nodes are randomly placed in the 3D space with the simulation area of 500m×500m×50m. Including the anchor node, whose communication radius is tentatively set at 35m. Two thresholds need to be set, namely, the hop count threshold and the threshold for judging whether it is inside the tetrahedron. The unknown nodes have the same communication radius R, so take R=50. In order to eliminate the error caused by random distribution, the simulation results are the average of 100 simulations under the same parameters. The positioning errors of 600 nodes are shown in Figure 2.

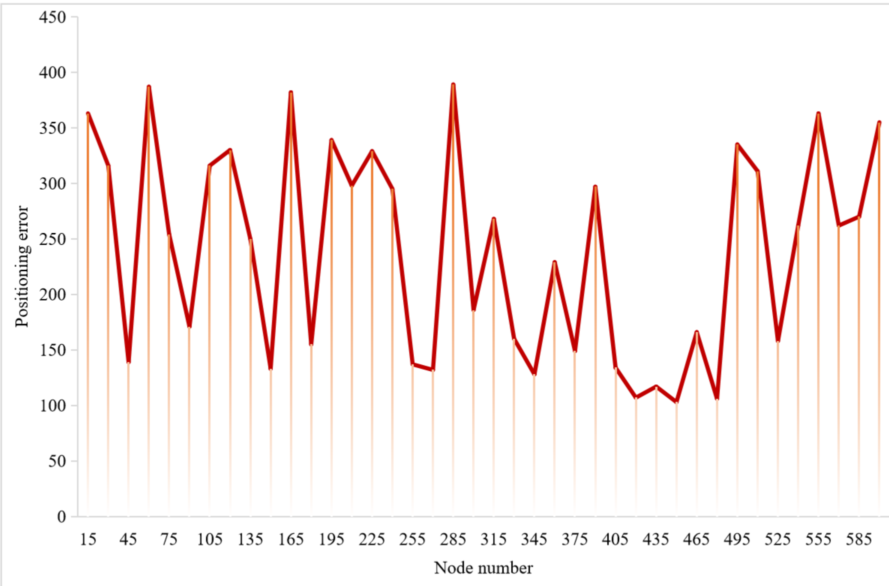

Figure 2: Positioning error of the algorithm

It can be seen from the above simulation diagram that the positioning error of the algorithm proposed in this article is at a low level. Under the condition of a certain grid resolution, with the increase of communication radius of anchor nodes, the positioning ratio and positioning error will be improved, but this improvement will not be unlimited. When the communication radius of the anchor node can cover the whole positioning area, the positioning performance will not be improved much if the communication radius of the anchor node is increased. Due to the setting of various thresholds, the number of localization nodes in the new algorithm has been seriously affected, but as long as the parameters are properly selected, good localization accuracy and coverage can be obtained. If the hop count threshold is 6 and the body threshold is 2, 460 nodes can be positioned, and the positioning accuracy can reach 0.302. The positioning performance of the proposed algorithm is independent of the network connectivity. In positioning, only the anchor nodes need to broadcast their own information many times, and only the distribution and setting of anchor nodes will affect the positioning performance, which is a great improvement over the previous non-ranging 3D algorithm.

Each node is considered to have the same attribute, that is, each node has the same maximum communication radius. Usually, we think that the larger the communication radius is, the smaller the error will be, but the actual simulation results are different from this. The influence of communication radius is shown in Table 1.

Table 1: Influence of Communication Radius

Communication radius		20	30	40	50
Number of positioning nodes	Algorithm in this article	510	510	510	510
	DV-hop	40	126	220	319
Average positioning error /m	Algorithm in this article	8.9216	13.2154	15.1579	17.2478
	DV-hop	19.4581	25.1478	26.6782	27.9843
Positioning accuracy	Algorithm in this article	0.4451	0.4415	0.4342	0.4301
	DV-hop	0.9702	0.9215	0.8027	0.6952

Table 1 shows the influence of communication radius on positioning accuracy and the number of positioning nodes. With the increase of communication radius, the number of positioning nodes of the 3D positioning algorithm in this article has obviously increased, and the positioning accuracy has slightly improved. The positioning accuracy of 3D extension of DV-hop is also improved with the increase of communication radius. Compared with the existing 3D localization algorithms based on non-ranging, this method does not need unknown nodes to communicate with each other, has less communication overhead, and does not depend on the proportion of anchor nodes. And it is robust to the network topology; Its positioning error is only about 15%.

In the actual environment, the transmission of wireless signals usually has different attenuation in different directions, so the signal transmission path is not an ideal sphere. The algorithm in this article can effectively resist the influence of this irregularity. The use of non-ranging 3D node location algorithm in wireless sensor networks is not affected by the density of network nodes, and the algorithm is distributed, which is convenient for unknown nodes to execute. In addition, when the network topology changes, such as adding, moving or withdrawing some unknown nodes, it is only necessary to change the nodes and reposition them, while the positioning of other unknown nodes will not be affected. Therefore, to some extent, this algorithm is robust to the network topology.

4. Conclusions

WSN, as a booming research field, has put forward a lot of challenging research topics for scientific and technological workers in both basic theory and engineering technology. In WSN, location information is an indispensable part of data collected by sensor nodes, and monitoring messages without location information are often meaningless. Therefore, the node location technology is a supporting technology of WSN, which plays a key role in the effectiveness of WSN application. Based on this, this article summarizes the structure and characteristics of WSN, then uses weighted centroid algorithm to estimate the location, designs a new non-ranging 3D node location algorithm for wireless sensor networks, and gives the theoretical basis and implementation steps of this algorithm design. The positioning accuracy of this algorithm is better than that of the traditional classical algorithm, especially in terms of positioning time, because a lot of calculation processes are saved and the positioning time is maximized. The final simulation results show that, compared with the existing 3D

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localization algorithm based on non-ranging, this method does not need unknown nodes to communicate with each other, has less communication overhead, and does not depend on the proportion of anchor nodes; And is robust to the network topology; Its positioning error is only about 15%. This proves that the algorithm in this article can effectively reduce the positioning error. It is believed that the work done in this article can provide a useful reference for the subsequent research of node self-localization algorithm.

References

[1] Shang Chao, Wang Feng, Nie Baisheng, et al. Research on 3D localization algorithm of wireless sensor network in coal mine [J]. Coalfield Geology and Exploration, 2016(1):7.
[2] Zhang Xinhui, Xu Jingjing, Xu Bixiao, et al. Research on 3D localization algorithm of wireless sensor networks [J]. Computer Technology and Development, 2016, 26(12):5.
[3] Hu Zhongdong, Xiaohua Wei. Node localization algorithm for wireless sensor networks adapted to mountain terrain [J]. Computer Engineering and Application, 2016, 52(10):4.
[4] Jiang Rui, Gong Qingyong. An iterative estimation method for 3D localization in wireless sensor networks [J]. Computer Science, 2019, 46(11):7.
[5] Li Jun. Research on 3D ship positioning method based on wireless sensor network nodes [J]. Ship Science and Technology, 2018(8X):22-24.
[6] Chen Yong, Zhang Xinhui, Zhao Xuejian, et al. An improved 3D localization method for wireless sensor networks [J]. Computer Technology and Development, 2019, 29(7):5.
[7] Zhang Xinhui, Xiong Xiaoxiao, Zhao Xuejian, et al. An improved localization algorithm for wireless sensor networks [J]. Computer Technology and Development, 2019(007):029.
[8] Wang Zhaoyu. Research on an optimized 3D localization algorithm for mobile wireless sensor networks [J]. Mobile Communications, 2017, 41(4):5.
[9] Liang Juan, Wu Yuan. Node localization of three-dimensional wireless sensor network using WSVM [J]. Journal of Huaqiao University: Natural Science Edition, 2016, 37(1):5.
[10] Dang Xiaochao, Shao Chenguang, Hao Zhanjun. Three-dimensional coverage algorithm for wireless sensor networks with adjustable radius [J]. Computer Application, 2018, 38(9):7.
[11] Liu Wei, Li Zhuo, Yang Xiaofei, et al. Three-dimensional localization method of wireless sensor network nodes based on SCE-PSO [J]. Journal of Sensing Technology, 2019, 32(5):6.