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A Method of Improving WSN Localization Algorithms Based on Hopsize Deviation

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Abstract: This paper analyzes the DV-HOP algorithm which is a range-free localization algorithm. We improve this algorithm by revising the hop-size. In our method, uniform distribution model and secondary reference nodes are introduced to localize the unknown nodes. In addition, the hop-size of the nearest hop is used during the estimation of the distances between the beacon nodes to the unknown nodes. Simulation results show that this improved algorithm could achieve higher localization accuracy compared with original method. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Range-free localization algorithm, DV-HOP, Hop-size, Localization accuracy.

1. Introduction

In the Wireless Sensor Network (WSN), the estimation of the average hop-size of beacon nodes that are used to calculate the distance to the unknown nodes in the DV-Hop algorithm plays an essential role in the accuracy of the localization results [1-4]. In the original algorithm, the beacon node estimates the self average hop-size by the distance and the hop count to other beacon nodes [5]. However, during this estimation process, the routine between the beacon node and the others could contain angles. The closer to 180° the angle is, the more accurate the estimation is. If the angle is no more than 90°, the deviation in the estimation of average hop-size will increase. Therefore, we propose a method to improve this estimation based on hop-size deviation.

2. Uniform Distribution of Reference Nodes

The beacon nodes are firstly distributed uniformly. Then the average value of the average hop-sizes of all the beacon nodes in the network is computed, which is used as the adjustment of the average hop-size. The uniform distribution model of beacon nodes is introduced when deploying the nodes in the network [8]. The distance between the unknown nodes and the reference nodes (beacon nodes) is calculated. The self hop-size of the beacon node is estimated according to the following formula:

$$\text{HopSizex}_{i=} \frac{\sum_{j\neq i} \sqrt[2]{\left(x_i - \mathrm{x}_{\mathrm{j}}\right)^2 + \left(y_i - y_{\mathrm{j}}\right)^2}}{\sum_{j\neq i} h_j} \qquad (1)$$

After the estimation, the hop-size of every beacon node is broadcasted to the network. As long as the connectivity and the coverage are well enough, each unknown node will receive at least one grouping information containing hop-size and record the first one in order to calculate the distance.

After obtaining the average hop-size, the beacon nodes broadcast this information as the adjustment to the whole network. The format of the information package is {Id, Hop-Size$_i$}, where Id is the identification of the beacon node and Hop-Size_i is the average hop-size of that beacon node. When receiving the information package, the node will add the information to its list and broadcast to its neighbour nodes. The repetitive information package from the same ID will be ignored. By this way, all the nodes will receive Hop-Size_i. The average hop-size of the entire network is calculated using the following formula:

$$HopSize_{ave} = \frac{\sum_{i=1}^{n} HopSize_i}{n} \quad (2)$$

In the above formula, n is the number of the beacon nodes and Hop-Size_i is the value obtained by formula 1. Finally, the unknown nodes calculate the distance to the beacon nodes based on hop count and average hop-size of the entire network by the following formula:

$$d_i = \text{hops} \times HopSize_{ave} \quad (3)$$

In the above formula, d_i is the distance between the unknown nodes to the beacon nodes, hops is the hop count from the nodes to the beacon nodes, and $HopSize_{ave}$ is the value obtained by formula (2).

In DV-HOP algorithms, the localization result is obtained based on the calculated distance that is used in the trilateration method with the beacon nodes. To improve accuracy of the localization result of DV-HOP algorithm, the two dimensions Hyperbolic location algorithm is adopted instead of trilateration method. Least square method is suggested to use during the estimation of the coordinates of the starting nodes, which are achieved by the following formula:

$$\begin{cases} x = Z_c(1) \\ y = Z_c(2) \end{cases} \quad (4)$$

3. Adoption of Secondary Reference Nodes to Assist Localization

Secondary reference nodes are adopted to assist the beacon nodes for localization, i.e., the unknown nodes that have been localized are taken as the reference nodes for further localization. The number of the beacon nodes has an effect on the results of WSN localization algorithm. If there are only few of beacon nodes, the deviation of localization will increase [9-11]. The secondary reference nodes whose distance to the beacon nodes is one hop are localized by three or more beacon nodes. The principle of the algorithm is to localize the secondary reference nodes first, and then to take those nodes as beacon nodes to assist the existing beacon nodes to localize other unknown nodes. This improved algorithm can avoid the effect from the independent nodes.

In Fig. 1, the black nodes are beacon nodes while the white nodes are the unknown nodes. Nodes A, B, C, D are secondary reference nodes. The hop-size of B can be calculated by the following formula:

$$HopSize_b = \frac{\sum_{b\neq a}^{k} \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2}}{\sum_{b\neq a}^{n} h_b} \quad (5)$$

where (x_a, y_a), (x_b, y_b) are the coordinates of secondary reference nodes A and B respectively, while h_b is the hop count between A and B (B≠A).

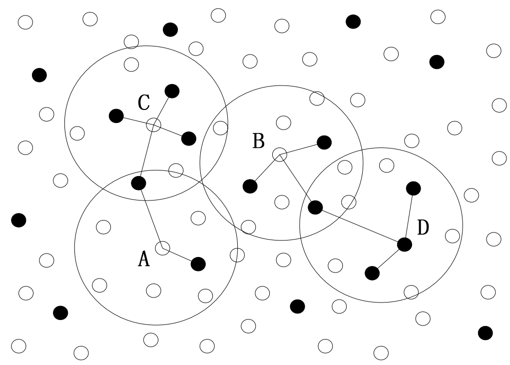

Fig. 1. The graph of secondary reference nodes.

4. The Usage of the Hop-size of the Nearest Hop

The hop-size of the last hop of the beacon nodes can be used as the average hop-size during the calculation of the distance. Though DV-HOP algorithm could derive the locations of the unknown nodes, the deviation of the average hop-size will be quite large if only taking use of the hop count. To a certain unknown node, the hop-size of the nearest hop to the beacon nodes is actually smaller than that of the estimation. If there are more beacon nodes and much better connectivity in the WSN, the hop counts from the beacon nodes to the unknown nodes will be much smaller, and as a result the deviation will be obviously increase.

In Fig. 2, A is the beacon node while B, C, D are unknown nodes. The dash lines show the radio range of current node. Beacon node A sends message to all the nodes locating within its radio range, through which the message is delivered to other nodes that are out of the range. Node D receives the hop count of the beacon node through node B and C. This routine is the trajectory of the minimum hop-count. The distance between node D and node C is smaller than the average hop-size. Therefore, it will increase the deviation to multiply the average hop-size and hop count as the distance from node D to beacon node A.

Currently, the distance from the unknown nodes to the beacon nodes is value that the hop-size of the nearest hop adds the result by multiplying the nearest hop-size with the value that is the hop count minus one.

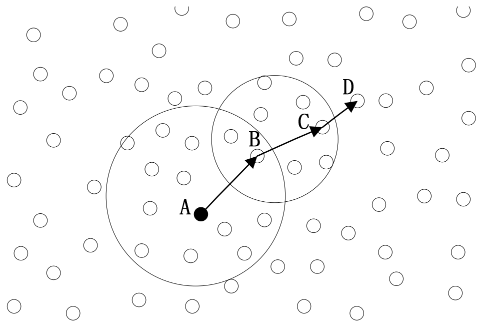

Fig. 2. The diagram of the hop-size of the nearest hop (1).

In Fig. 3, D1, D2 and D3 are beacon nodes. The distance from D2 to D1 and that from D2 to D3 are 50 m and 160 m respectively. D is the unknown node that has the minimums hop-size to D2. Its hop counts to D1, D2 and D3 are 3, 2 and 3 respectively. By measuring the last hop-size through ranging technique and lowering the transmission power, the hop-size of the nearest hop of D to D1, D2 and D3 are obtained: 35 m, 30 m and 25 m. The formula to calculate the average hop-size is shown as the following:

$$d_{D_2} = \frac{L_{D_2D_1} + L_{D_2D_3}}{h_{D_2 \to D_1} + h_{D_2 \to D_3}} = \frac{50m + 160\text{m}}{2+5} = 30\text{m} \quad (6)$$

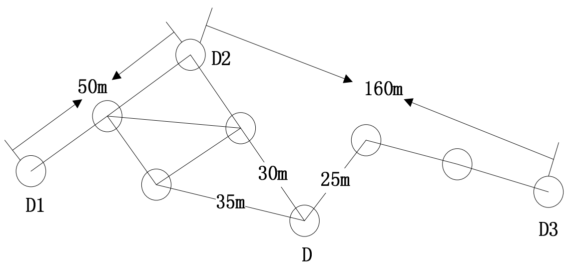

Fig. 3. The diagram of the hop-size of the nearest hop (2).

The following formula is to calculate the distance to D1, D2 and D3.

$$\begin{cases} d_{DD_1} = (3-1)\times 30 + 35 = 95m \\ d_{DD_2} = (2-1)\times 30 + 30 = 60m \\ d_{DD_3} = (3-1)\times 30 + 25 = 85m \end{cases} \quad (7)$$

5. Simulation Results and Analysis

The improved DV-HOP algorithm was simulated and analyzed. The parameters for the simulation experiment are: a square area of 100 m*100 m, radio range of 30 m, 200 nodes in which there are less than 30 % beacon nodes. The distribution of the nodes is illustrated as Fig. 4:

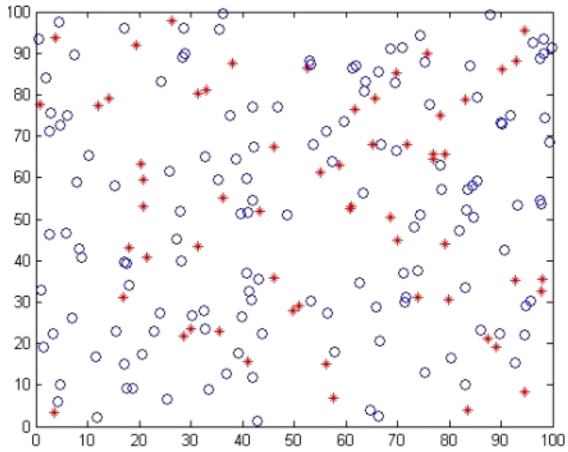

Fig. 4. Distribution of nodes.

Fig. 4 shows the distribution of the nodes in DV-HOP algorithms, in which the circles denote the unknown nodes and the stars denote the beacon nodes.

During the simulation experiment, the deviation distribution of the nodes was firstly verified and the results illustrated in Fig. 5 were obtained.

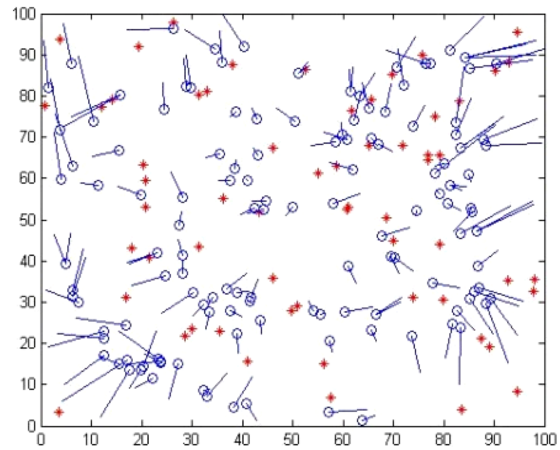

Fig. 5. The results of the improved algorithm based on the deviation distribution.

Comparing Fig. 4 and Fig. 5, we can find that the localization accuracy was improved when the deviation decreased. The experiment was executed by 100 times. The improved algorithm increase the localization accuracy by 3 % in average compared with the original algorithm. This result also depends on the density of the nodes distribution. When the beacon nodes distribute uniformly in the entire network, the localization accuracy has great improvement by using this algorithm.

6. Conclusions

This paper studied one of the range-free localization algorithms, i.e., DV-HOP algorithm and suggested a method to improve this algorithm based on the hop-size deviation. The uniform distribution model was introduced and the average hop-size of the entire network was estimated when analyzing the deviation hop-size. Moreover, the secondary reference nodes were suggested to assist localization. In addition, the hop-size of the nearest hop was used to calculate the distance from the beacon nodes to the unknown nodes. The simulation results showed that the improved DV-HOP algorithm improved the accuracy by 3 % than original DV-HOP algorithm.

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