A New Distance Independent Localization Algorithm in Wireless Sensor Network

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ABSTRACT: *A new distance independent localization algorithm in wireless sensor network is proposed. In the algorithm, improvement strategies is proposed for traditional DV-Hop algorithm to calculate the distance between unknown node to beacon nodes. Weighting for estimated average hop distance of each beacon node and using estimated average hop distance of multiple beacon nodes to reduce positioning error in the calculation of average hop distance.*

Keywords: Wireless Sensor Network, Node Localization, DV-Hop

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1. Introduction

Dragos Niculescu proposed a series of distributed localization algorithm using distance vector routing and GPS positioning principle, named Ad Hoc Positioning System[1]. It includes six kinds of algorithms: DV-Hop, DV-distance, Euclidean, DV-coordinate, DV-Bearing and DV-Radial. DV-Hop is one of the most widely used algorithms in nodes self-localization algorithms. The algorithm can be applied to outdoor scenes and the environment that nodes can not be manually installed. So many outdoor occasions use DV-Hop algorithm to achieve the position of nodes. The positioning mechanism of DV-Hop is very similar to the routing mechanism of traditional network distance vector. In the distance vector positioning mechanism, the unknown node firstly calculates the minimum number of hops to the beacon node, then estimates the average distance per hop by using the minimum number of hops multiplied by the average per-hop distance to get the estimated distance between the unknown node and the beacon node, finally using trilateration or maximum likelihood estimation method to calculate the coordinates of the unknown node. Distance vector algorithm uses average hop distance to calculate the actual distance with low hardware requirements for the node and easy to realize. The disadvantage is that there are some errors using jump distance instead of the straight-line distance.

In order to improve the positioning accuracy of DV-Hop algorithm, there are already a lot of researchers who have proposed improved DV-Hop algorithms. Improved DV-Hop algorithm based on degree of trust improves the positioning accuracy through the trust value judgments filter out the appropriate distance value per jump[2]. sensor network node localization algorithm based on vector and particle swarm optimization uses the difference between the estimated distance and measurement distance to construct the position correction vector, using beacon node as cluster head to cluster node, establishing a comprehensive range error objective function to reduce the position error[3]. Wireless sensor networks localization algorithm based hops uses the ratio of the number of hops to replace the distance ratio and introduces RSSI technology in the calculation of the single-hop distance to improve node positioning accuracy so that the node energy consumption during positioning is reduced[4]. RHDV-Hop algorithm introduced a received signal strength indicator technology to replace calculation methods of jump distance in the original algorithm in calculating hop distance from the unknown node to beacon node, and used 2-D Hyperbolic algorithm instead of DV-Hop trilateration algorithm to improve the positioning accuracy[5]. These algorithms made improvements from average per hop distance and hops.

2. Theory of NDILA algorithm

When traditional DV-Hop algorithm calculates distance jump, unknown node is used to obtain the average distance value of each jump from the nearest beacon nodes. Average per-hop distance value estimated by single beacon nodes can not accurately reflect the actual average per hop distance of full network, which resulted in a low location accuracy of unknown node. When the algorithm calculates the distance from unknown node to each beacon node, the same average hop distance is used. As wireless sensor network nodes are randomly distributed, which makes the jump distance between nodes varies. The communication path is not always a straight line, so there are a great deal of positioning error in calculating the average hop distance. Taking into account the above-described problems, NDILA algorithm proposes an algorithm based on a weighted average hop distance estimation to improve the positioning accuracy.

In NDILA algorithm the concept of weights is introduced in calculating the average per-hop distance from unknown node to beacon node. The distance between the beacon nodes is denoted by d_i, the number of hops between beacon nodes is denoted by hi, average jump distance calculated by beacon node i is denoted by c_i, Angle of beacon nodes at both ends to its intermediate nodes is denoted by θ_i ($0 < \theta_i \leq \pi$), weights of average hop distance of each beacon node is denoted by u_i(i=1,2,3).

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By observing and analyzing the distribution of nodes in the network it can be found that the smaller the distance between nodes, the more the number of segments hop, and the larger the angle between the two ends of the beacon node and intermediate nodes, then this path is closer to a straight line with correspondingly higher positioning accuracy. Based on consideration of the above three factors, assuming an unknown node has received information from n beacon nodes, weights of average hop distance of each beacon node can be desirable as the formula:

$$u_i = \frac{\frac{h_i \theta_i}{d_i \pi}}{\sum_{j=1}^{n} \frac{h_j \theta_j}{d_j \pi}} \quad (1)$$

In formula(1), it is normalized so that the calculation of the position of the unknown node has a uniform standard, and ensures that the sum of weights of average hop distance of each beacon node is one. The values of hi and d_i is known value of θ_i can be get in the following ways. A_1, A_2 are two beacon nodes, in Fig. 1 N is intermediate node, θ is the angle between the intermediate node and A_1, A_2 . In Fig.2 N_1, N_2 are intermediate nodes, θ_1, θ_2 are respectively the angles.

In Fig.1, when the number of hops between the beacon nodes A_1 and A_2 is an even number, the value of θ can be get by formula(2).

In Fig.2, when the number of hops between the beacon nodes A_1 and A_2 is an odd number, after using the law of cosines to get the value of θ_1 and θ_2, the average value of θ_1 and θ_2 is the value of θ .

$$\cos\theta = \frac{|A_1N|^2 + |A_2N|^2 - |A_1A_2|^2}{2|A_1N||A_2N|} \qquad (2)$$

Figure 1. The hop count between anchor nodes is even number

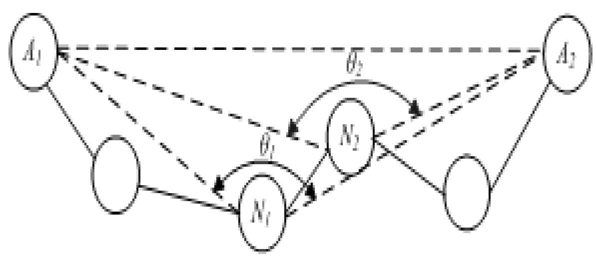

Figure 2. The hop count between anchor nodes is uneven number

The positioning process of NDILA algorithm is divided into the following stages.

The first stage Each beacon node broadcast its own position information packet to the neighbour node which include hop words, self-identification (ID) number and the position coordinates (x, y), hops words initialized to 0. The message is recorded after the receiving node receives the broadcast message, hop count is incremented each time a message is received and transfer to the neighbor node.

The second stage. After receiving the location information of the other beacon nodes, each beacon node calculate the average distance per hop.

The third stage. The average hop distance values of beacon node to an unknown node can be get by the value and the average hop distance values of each beacon node. Average per hop distance can be get as the formula(3).

$$C = \sum_{i=1}^{n} u_i c_i \qquad (3)$$

The fourth stage. After the unknown node to calculate the average per hop distance value, then based on hops between the unknown node and another the beacon node i , the distance between them is gotten.

The fifth stage. When an unknown node receives three or more broadcast messages from beacon nodes, the position of the unknown node itself can be calculated by using trilateration or maximum likelihood estimation method.

3. Simulation of NDILA algorithm

The experiment analysis the simulation of hop distance between nodes. The ranging error of NDILA algorithm and DV-Hop algorithm when beacon node in the proportion of 10% are showed in Fig.3 and Fig.4.

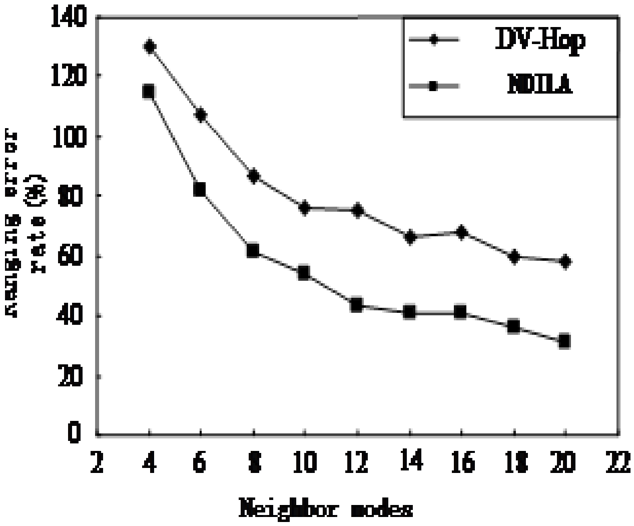

Figure 3. Range error when the total number of nodes is 100

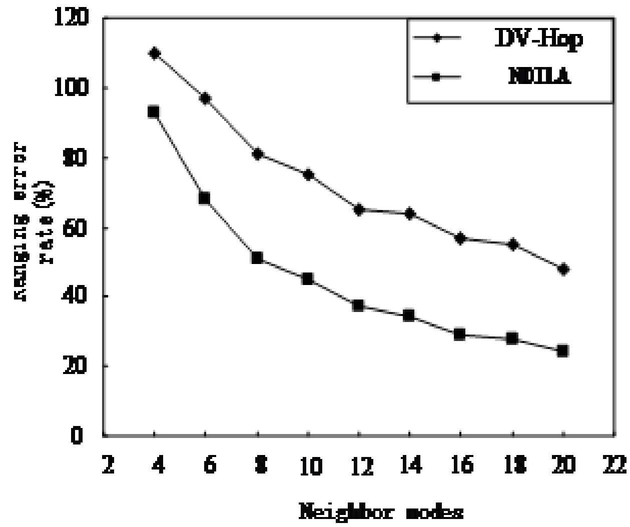

Figure 4. Range error when the total number of nodes is 100

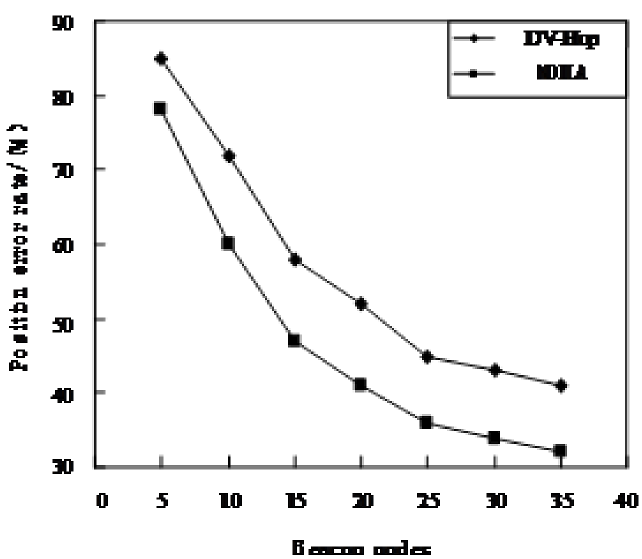

Figure 5. Position errors when the total number of nodes is 100

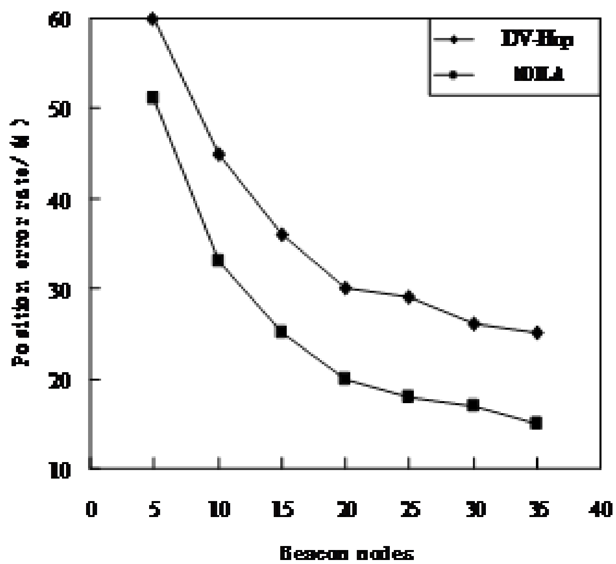

Figure 6. Position errors when the total number of nodes is 300

Fig.3 and Fig.4 describe a randomly generated scene and the ranging error of NDILA algorithm and DV-Hop algorithm when the total number of nodes is 100 and 300. Simulation results show that with the increase in the total number of nodes, the ranging error of NDILA algorithm and DV-Hop algorithm decrease both.

In the process of neighbour nodes changing from 4-20, the ranging error of NDILA algorithm is smaller and the ranging error curve tends to be more smooth than DV-Hop algorithm, The experimental results is closer to the real node spacing. This is because NDILA algorithm considers the average value of per hop distance of multiple beacon nodes, weighted according to the number of hops, hop distance and angle makes estimated average per hop distance values more accurately. Therefore, it reflects the actual pitch of the network nodes better.

In Fig.3 when the total number of nodes is 100, the average ranging error of NDILA algorithm reduces 24.8% than DV-Hop algorithm. In Fig.4 when the total number of nodes is 300, the average ranging error of NDILA algorithm reduces 27.0% than DV-Hop algorithm.

In the simulation process, randomly selecting 5,10,15,20,25,30,35 nodes as beacon nodes. Compute the location of unknown nodes based on these beacon nodes, then get the positioning error of unknown nodes.Fig.5 describes the changes of positioning error rate when the total number of nodes is 100, Fig.6 describes the changes of positioning error rate when the total number of nodes is 300.

It can be seen from the experimental results that when the number of beacon nodes is small, compared with DV-Hop algorithm, NDILA algorithm increases the positioning accuracy just a little. As the number of the beacon nodes increases, connectivity of the network increases, the unknown nodes can get the closer beacon node information which makes weights more accurately in NDILA algorithm. The average distance between hop gets a good correction, the node localization errors are effectively reduced.

In Fig.5 when the total number of nodes is 100, the average position error rate of NDILA algorithm reduces 9.7% than DV-Hop algorithm. In Fig.6 when the total number of nodes is 300, the average position error rate of NDILA algorithm reduces 10.3% than DV-Hop algorithm. NDILA algorithm has been significantly improved positioning accuracy than the DV-Hop algorithm and volatility curve positioning error is smaller. The reason is that the NDILA algorithm uses a normalized weighted estimated average hop distance of several beacon nodes that makes the changes of positioning error tend to be more stable.

4. Conclusions

NDILA algorithm uses average hop distance values estimated by a plurality of beacon nodes to replace average hop distance value estimated by the nearest beacon node in DV-Hop algorithm. Estimated average hop distance value of each beacon nodes were weighted according to the three factors of the number of hops, hop distance and angle which makes the average hop distance of whole network closer to the actual average per hop distance and reflect the actual state of the location of the network Better. Further more, NDILA algorithm does not change the positioning process of traditional DV-Hop algorithm. NDILA algorithm need no additional hardware so the cost is low.

Acknowledgments

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