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# An Improved Location Algorithm for DV-HOP Based on Trusty Degree Average Hop Distance in Wireless Sensor Networks

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**Abstract:** Location awareness is an attractive research issue in the wireless sensor networks (WSN) because sensor nodes are randomly scattered over a region and can get connected into a network on their own. However, precise location information may be unavailable due to the constraint in energy, computation, or terrain. In this paper, an improved DV-HOP location algorithm based on trusty degree average hop distance for wireless sensor networks was proposed. Using the trusty degree to select the average hop distance for each anchor node and calculate the average hop distance of the whole network, then use dynamic correction error scheme to correct the error. Simulation experiments are conducted to compare the traditional DV-HOP algorithm, improved DV-HOP algorithm and our scheme, the simulation results show that the proposed methods has better performance on average location error based on the different communication radius for irregular network.



**Keywords:** Wireless sensor networks (WSN), DV-HOP, Trusty degree, Average hop distance, Location.

## 1. Introduction

Recent, wireless sensor networks (WSN) have been used in many applications with advances of the micro-electro-mechanical system (MEMS) technology. Interesting applications of WSN include target tracking, disaster management, environmental monitoring, smart home applications, intelligent transportation and reconnaissance, etc. [1]. In all of these WSN applications, a wireless sensor network is composed of a large number of sensor nodes that are densely deployed in a field, the sensor nodes should have the ability to sense, process and communicate. There are several issues in wireless sensor networks. Location is one of the most important subjects, this is because that sensed data are meaningful to most applications only when they are labeled with geographical position information; position information is essential to many location-aware sensor network communication protocols, such as packet routing and sensing coverage. It has been a challenging task to design a practical algorithm for node localization given the constraints that are imposed on sensors, including limited power and low cost [2]. The simplest possible localization solution would be to attach a global positioning system (GPS) to all the sensor nodes. However, in many applications, hundreds or thousands of sensor nodes might be involved and it is not practical to use a GPS for all the sensor nodes because of cost concerns and some technical problems related to line-of-sight [3].

## 2. Related Work

Many localization algorithms for wireless sensor networks have been proposed. These localization protocols are classified into range-based and range-free algorithms. The range-based algorithm uses absolute point-to-point distance or angle estimates for calculating the location, which are relatively precise but require additional hardware and their cost is relatively high, On the contrary, the range-free algorithms do not need the distance or angle information to the sensor nodes from the anchor nodes for their localization, they provide more economic and simpler estimates than the range-based ones, but their results are not as precise as those of the range-based [4].

In range-based schemes, nodes determine their locations based on distance or angle estimations to some reference points with known coordinates. GPS (Global Positioning System), a representative positioning device, is widely used in localization due to its simplicity. Based on radio waves and time spacing, GPS can exactly locate the nodes with the limited error. Two time-based methods, time of arrival (ToA) and time difference of arrival (TDoA) are used in [5], ToA is based on the range estimations by the signal arrival time, while TDoA relies on the difference in time between two arrived signals. Angle of arrival (AoA) to estimate node position is proposed in [10], the principle of AoA is to detect the originators of signals according to the angle of arrival, and then to calculate the positions of nodes by means of triangulation. Maximum likelihood estimation (MLE) is an alternative used in AHLoS system (Ad-Hoc Localization System) [6], whose aim is to minimize the differences between the measured distances and estimated distances to determine the position of nodes. However, equipping all sensor nodes with a GPS receiver is not a realistic solution because it increases the cost, size and energy consumption of the sensor nodes [7].

The range-free scheme enables sensors to learn their location information without the aid of range estimates, it is suitable for sensor positioning due to its cost-effectiveness. An amorphous positioning algorithm, DV-HOP, addressed in [8], employs offline hop-distance estimations to improve location estimates via neighboring information exchanges. In [9], DV-HOP localization algorithm based on improved average hop distance and estimate of distance considered the feature of coincidence or part of the overlap which existed in the path from unknown nodes to beacon nodes and the path between the anchor nodes, it improved average hop distance and used the error to correct. In [10], an improved localization algorithm for DV-HOP based on trusty degree used estimating the value of trusty degree to filter appropriate average distance per hop. In [11], an improved DV-HOP localization algorithm for wireless sensor networks used the angle to compute the distance of unknown nodes and anchor nodes, the angle ∠ABC formed by three neighbor nodes A, B and C in the path of unknown nodes and beacon nodes, and given distance data among the nodes. This angle ∠ABC was estimated with an overlapping degree of B's neighbor node sets collecting with A and C, respectively. In [12], an improved DV-HOP positioning algorithm based on angle threshold was proposed, which can set the angle threshold to filter out the anchor nodes and improve DV-HOP's positioning capability. New node localization scheme virtual beacons-energy ratios localization (VB-ERL) and its refinements for the WSN are presented in [13]. In the scheme, the mobile node moves in the surveillance field based on the Gauss-Markov mobility model and periodically broadcasts the information packets. Each static unknown node receives the virtual beacons and energy in its sensing grange, and estimates its location by finding the intersection of a set of hyper-spheres. A two-objective evolutionary approach based on topological constraints for node localization in wireless sensor networks was proposed in [14], it takes concurrently into account during the evolutionary process both the localization accuracy and certain topological constraints induced by connectivity considerations. A direction-based localization scheme (DLS) was proposed in [15], whose main goal is for each sensor to determine its direction rather than its absolute position, DLS considers multiple messages received for a sensor to determine its direction and anchor deployment strategy to improve the estimated correctness in direction of the sensor within the communication range of the sink.

## 3. System Model

Localization in WSN can be regarded as the location discovery problem. Unlike much research, whose main objective is precise coordinate estimation, the localization problem we are concerned with is that given some anchors and each sensor is able to determine the hop distance.

There are a set of anchor nodes and a set of sensor nodes in a WSN.A fixed number of anchor nodes are placed with the regions of coverage overlapped and serve as reference points, broadcasting periodic beacon signals. The sensor nodes are distributed randomly in the sensing field and receive messages from anchor nodes. The main responsibility of the anchor nodes is to send out beacon signals to help the sensor nodes to locate themselves. Each sensor node listens for a fixed time period and collects the RSS information of all beacon signals from adjacent anchor nodes. In this environment, it is assumed that [4].

1) The anchor nodes know their positions through GPS or by other means such as pre-configuration.

2) The radio propagation is perfectly spherical and the transmission ranges for all radios are identical.

Let us consider a sensor network SN= $\{ n_1, n_2, \dots n_{M+N} \}$, among these nodes, nodes from 1 to M, with M<N, are anchor nodes whose coordinates are known, while from M+1 to N, are general nodes whose coordinates are unknown. All unknown sensors are uniformly scattered in the

network. The communication range of a sensor, denoted as r, is a circle centered at the sensor. Each sensor has the communication capability, so as to exchange messages. Currently, we consider an obstacle-free environment, in which each sensor is able to communicate with all of its neighbors. We also consider a connected network, within which each sensor has at least one neighbor [19].

Here, it is assumed that the anchor nodes are always aware of its physical position and helps in locating other nodes. Its position is obtained by manual placement or by external means such as a GPS receiver. This node forms the basis for most positioning systems in WSN, we denote the position of each anchor node as:

$$p_i = (x_i, y_i)^T \; i = 1, ..., M. \quad (1)$$

The positions of the other N sensor nodes $\{n_{M+1}, n_{M+2}, ..., n_{M+N}\}$ are initially unknown nodes, but managed to estimate its position by using a positioning system, we denote the position of each unknown node as:

$$p'_i = (x'_i, y'_i)^T \; i = M+1, ..., M+N. \quad (2)$$

In this localization, the only available measurement is the proximity information denoting the number of hops between all the nodes. Let us define the real geographic distance between two nodes $n_i$ and $n_j$ as

$$d_{real}(i,j) = d_{real}(j,i) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \; i,j \in [1,M] \quad (3)$$

We adopt a simple disk model for network connectivity: nodes i and j can communicate with each other if and only if $d_{ij} < r$, where r is the connectivity range.

## 4. Improved Location Algorithm for DV-HOP Based on Trusty Degree

Wireless sensor nodes were randomly distributed in the perception region, one unknown node utilized the average distance per hop of anchor nodes or the entire network to estimate the average hop distance is easily causes a large error, and ignored the nodes distribution in the network. In this paper, we proposed an improved location algorithm for DV-HOP based on trusty degree average hop distance (TDAHD), which have three improvements for unknown nodes location based on the analysis of the existing algorithms, first, we add a broadcast data packet for entire network and another broadcast data packet within a radius of anchor node in the process of location. Second, we use trusty degree to select the minimum error anchor nodes as the reference nodes. Third, we utilized a dynamic error correction scheme to revise the estimated location for unknown nodes.

There are four stages to achieve trusty degree average hop distance improvement:

Step 1: each anchor node broadcasts a data packet includes $id_i$, $(x_i, y_i)$ and $h_{ij}$, (i,j=1,2..M) which $id_i$ is the unique identifier of the anchor node i, $(x_i, y_i)$ is the coordination of anchor node i, and $h_{ij}$ is the hops between anchor node i and j and $h_{ij} = h_{ji}$. For anchor node i, the initialization of $h_{ij}$ is 0, each neighbor node j (it is perhaps an anchor node or an unknown node) achieves the anchor node i, then $h_{ij} = h_{ij}+1$, and stores this data in its hop-table and forwards to the new neighbors. When a node received a data packet which has the same $id_j$, it will compared the $h_{ij}$ with the same $id_j$, if the new $h_{ij}$ is less than the old, the new $h_{ij}$ will replace the old $h_{ij}$ and transmits the new $h_{ij}$ to its neighbor nodes, otherwise, it discards the packet and does not forward transmit.

So all the anchor nodes in entire network will get the shortest hops and coordinates from all other anchor nodes and all unknown nodes also get the shortest hops and coordinates from each anchor node. Then each anchor node i computes the average distance from other anchor nodes through formula (4):

$$Avg_{ij} = \sum_{i \neq j} d_{real}(i,j) / \sum_{i \neq j} h_{ij} \;\; i,j \in [1,M], \quad (4)$$

where j is the anchor node which stored in the table of anchor node i, $h_{ij}$ is the hops between the anchor node i and anchor node j.

Step 2: filter stage, filter the average hop distance through trusty degree. An example of anchor node 1, there are M-1 $Avg_{j1}$ (j=2, 3, …M) between anchor node i and other M-1 anchor nodes, we take one of the values as the reference object, such as $Avg_{21}$ between anchor node 2 and anchor node 1, we compute the error between $Avg_{21}$ and other $Avg_{j1}$ (j=3,…M) and represented by $W_{j1}$:

$$W_{j1} = \sum_{j=3}^{M} (Avg_{i1} - Avg_{21})^2 \quad (5)$$

Each error corresponding trusty degree $TD_{j1}$ by formula (6):

$$TD_{j1} = \frac{1}{W_{j1}} = \frac{1}{\sum_{j=3}^{M} (Avg_{i1} - Avg_{21})^2} \quad (6)$$

Obviously, if is $TD_{j1}$ smaller, then its trusty degree is higher, so we select the Avgj1 as the average hop distance $C_1$ which has the maximum $TD_{j1}$ as the finial average hop distance between anchor node 1 and unknown nodes.

Repeating the above method, we can select $C_i$ as the other M-1 average hop distance between anchor node i and unknown nodes (i = 2,…M).

Step 3: each anchor node i broadcasts a data packet which includes $id_i$ and $C_i$ to entire network, each anchor node will store this data in its average-distance table and forward to all neighbor nodes.

So all anchor nodes in entire network will get the $C_i$ and computes the average distance of the entire network through the formula (7):

$$cc = \sum_{i=1}^{M} C_i / M \quad , \tag{7}$$

where $C_i$ is the average distance of the anchor node I which has maximum trusty degree, M is the total number of anchor nodes in entire network.

So the estimate distance between anchor node i and anchor node j is

$$d_{estimate}(i, j) = cc \times h_{ij}, i, j \in [1..M], i \neq j \tag{8}$$

At the same time, those unknown nodes in the r range only stores the data packet in the neighbor-anchor table and do not transmit to other nodes. so the unknown node p will know its neighbor anchor nodes information in the r range and the $N_p$ is the number of anchor nodes for unknown node p ($p \in [M+1, M+N]$) in the r range.

For unknown node p, if Np is greater than or equal 3, then unknown node p will computes the new $C_{p3}$ to replace the cc through formula (9):

$$C_{p3} = \sum_{r \neq q} (d_{real}(r, q) / h_{rq}) / N_p \quad , \tag{9}$$

where r, q are the id of neighbor anchor node in the neighbor-anchor table for unknown node p.

If Np is equal to 2, the unknown node p will compute the new $C_{p2}$ to replace the cc through formula (10):

$$C_{p2} = ((d_{real}(r, q) / h_{rq}) + cc) / 2 \tag{10}$$

If $N_p$ is equal to 1, the unknown node p will compute the new $C_{p1}$ to replace the cc through formula (11):

$$C_{p1} = (C_i + cc) / 2 \quad , \tag{11}$$

where i is the only anchor node of unknown node p.

Else if Np is equal to 0, the Cp of the unknown node p is equal cc, namely, Cp=cc.

## 5. Simulation Results

In order to compare the performance of the TDAHD algorithm to the traditional DV-HOP algorithm and the improved DV-HOP algorithm [13], we assumed that the network is a square area with the size of 100m×100m. All sensors are randomly scattered with a uniform distribution with in the square area. User input the number of anchor nodes N and unknown nodes M, the program randomly generates N+M nodes within the region according to the user input. Assume that all nodes in the same network environment, the final result is the average of experiment results. The location error is the main performance.

Fig. 1-2 are the localization error comparing results of TDAHD algorithm, DV-HOP algorithm and improved algorithm on the different ratio. We can see from pictures, the localization error of TDAHD algorithm and improved DV-HOP algorithm are lower than DV-HOP algorithm when all anchor nodes have the same communication radius. When the proportion of anchor nodes in 10 %, the average localization errors of the TDAHD algorithm and improved DV-HOP algorithm are reduced 10 % - 15 %. When the proportion of anchor nodes is more than 10 %, the average localization error of improving algorithms are reduced by about 18 % to 25 %. With the increase of the anchor nodes proportion, the localization errors are gradually reduced, when the proportion of anchor nodes are reach 50 %, the localization errors are small changes and gradually stabilized. The positioning accuracy of TDAHD algorithm is slightly higher than the improved algorithm and has a minimal position error. When the proportion of the anchor nodes is small, the localization error of two improved algorithm have a little difference, about in the range of 2 % to 4 %; when the proportion of the anchor nodes from 20 % to 40 %, the localization error of TDAHD algorithm reduced from 4 % to 6 % than the improved algorithm. The overall average positioning error of TDAHD algorithm is reduced by about 5 %. Furthermore, we can also see from the figures, there are higher localization errors for DV-HOP algorithm or improved algorithms when they have larger communication radius (30 m,), with the reducing of communication radius, the localization error is reduced. This is because the communication radius increases will cause the average hop distance estimation error becomes large, and DV-HOP algorithm and the improved algorithm through the average hop distance to calculate unknown node position, resulting in increasing of the node localization errors.

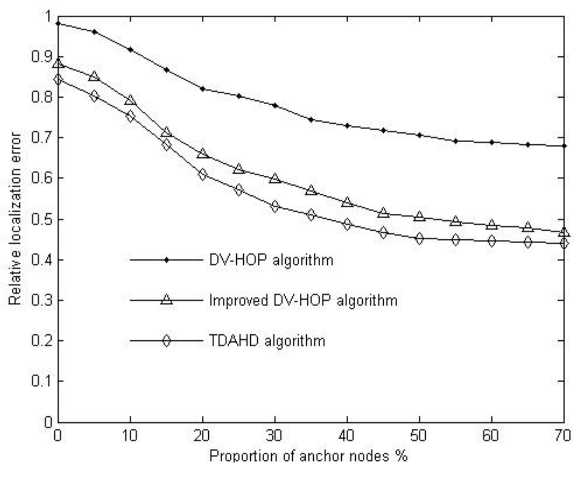


**Fig. 1.** Localization error curve with the anchor nodes (R=30 m).

However, in the same communication radius, TDAHD algorithm's average positioning error is less than the DV-HOP algorithm and improved algorithm. The variable parameter k value in the improved algorithm is a priority, it directly impact on the positioning accuracy of the unknown nodes; at the same time, the improved algorithm adds an anchor nodes broadcast data packet stage and increases the node traffic. In contrast, the amount of traffic of TDAHD algorithm is less than the improved algorithm and has same computational complexity, but the positioning accuracy is better than the improved algorithm.

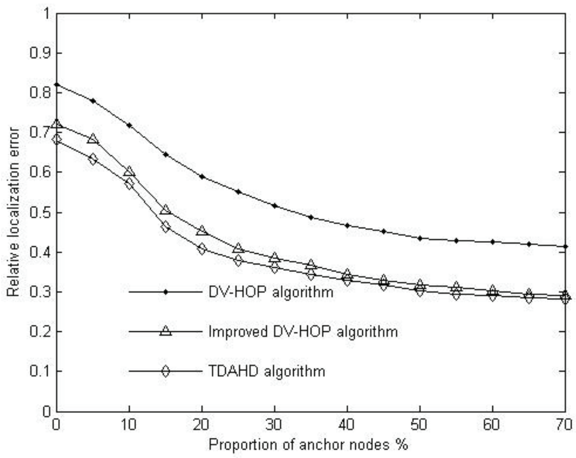


**Fig. 2.** Localization error curve with the anchor nodes (R=20 m).

## 6. Conclusions

In this paper, in order to against the localization accuracy is not high, and does not apply to irregular network of DV-HOP algorithm, we proposed an improved location algorithm for DV-HOP based on the trusty degree average hop distance. The algorithm does not change the basic orientation of the DV-HOP algorithm process, and does not require additional hardware support. From the results of the simulation, we can see that the localization accuracy of the proposed algorithm in irregular network is better than the DV-HOP algorithm and the improved algorithm. But also there are some inadequacies, such as the amount of traffic and calculation and the energy consumption of the proposed algorithm in node are greater than the DV-HOP algorithm, which are far problems for improved DV-HOP algorithm. Therefore, the focus of future research work is possibly reduces the computational complexity and energy consumption.

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