International Journal of Smart Home
Vol. 9, No. 10, (2015), pp. 197-204
http://dx.doi.org/10.14257/ijsh.2015.9.10.22

An Improved DV-Hop Localization Algorithm Based on the Node Deployment in Wireless Sensor Networks

Jianmin Zhang[1], Ning Guo[2] and Jian Li[1]

[1]*College of Computer, Henan Institute of Engineering*
Zhengzhou 451191, China
[2] *Henan Education Information Center*
Zhengzhou 450018, China
zjm1996@163.com, gn@haedu.gov.cn, lj2006@163.com

Abstract

Localization algorithm is an important and challenging topic in Wireless Sensor Networks (WSNs), especially for the applications requiring the accurate position of the sensed information. In this paper, an improved DV-Hop algorithm based on the node deployment was proposed. The proposed algorithm improves the localization accuracy by taking the advantage of the node deployment when computing the distance between the unknown node and the anchor. Simulation results prove that the improved DV-Hop algorithm offers the better performance compared to the original DV-Hop algorithm in localization accuracy without requiring additional hardware.

Keywords: *wireless sensor networks, localization, DV-Hop*

1. Introduction

In wireless sensor networks (WSNs), localization has received world wild research and industrial interest, such as border security, asset management, habitat monitoring, building automation as well as environment observation [1]. WSNs have been considered as a promising tool for many location-dependent applications, such as battlefield surveillance, environments monitoring, indoor user tracking. In addition, location information is considered to be a fundamental requirement for broadcasting and routing [2] in WSNs. Although sensor node localization plays an important role in these applications, as the constraint in size, power, and cost of sensor nodes, the investigation of efficient location algorithm which satisfy the basic accuracy requirement for WSN meet new challenges.

Sensor nodes could be equipped with a global positioning system(GPS) to provide them with their absolute position[3], and this is currently a costly solution or impossible solution to some indoor cases[4]. Therefore, it is often the case with a general assumption that the positions of some nodes (called anchors),are known, so that it is possible to find the absolute positions of the remaining nodes (called unknown nodes) in the WSNs. There is a large body of literature on the localization problem in WSNs and the sensor nodes localization algorithms fall into the ranged-based schemes range-free schemes. Range-based localization schemes rely on absolute distance from transmitting to receiving sensor nodes. These algorithms can be implemented by using the Received signal Strength Indicator (RSSI)[5], Time of Arriving[6], Time Difference of Arrival (TDOA)[7], and Angle of Arriving signal[8]. The range-based schemes in general provide more accurate location estimates that the range-free scheme: however the ranging operation leads to an increase in the installation cost and reduction in the network lifetime due to the need of additional hardware of procedure. For these problems that are critical to WSNs with limited resources, the range-based schemes are considered improper solutions

ISSN: 1975-4094 IJSH

to the localization problem in WNS. In contrast, range-free algorithms do not need absolute range information or angle between sensor nodes, only need network connectivity and other information, so the range-free algorithms are more economical, cost-effective, and feasible for the large-scale wireless sensor networks. The accuracy is less than the range-based but satisfies many applications' requirements. Therefore the range-free algorithms have been drawn much attention. The typical rang-free algorithms include Cenroid [9], CPE (Convex Position Estimation) [10], and DV-hop (Distance Vector-hop) [11-12].

Among many of range-free localization algorithms, DV-Hop algorithm is a neat scheme which worth further investigation. The advantages of the DV-Hop scheme are its simplicity and easy to implement. However, its average localization error is in the order of 30% of the communication radius. One reason leads to the low accuracy of DV-Hop is the hop-distance ambiguity problem: Those nodes with the same hop count to an anchor will the have the same estimated distance, although they do have different distances to the anchor. To improve the localization accuracy, many algorithms based on DV-hop have been proposed recently [13-17]. In [13],the author summed up the main causes of error based on the analysis on the process of the DV-Hop algorithm and aimed at the impact to the location error which is brought by the anchor nodes of different position and different quantity. Based on these, the author proposed a novel localization algorithm called NDV-Hop_Bon (New DV-Hop based on optimal nodes).In [14], the author proposed an improved algorithm o improve the poor locating performance of the DV-Hop algorithm, in which the average one-hop distance between anchor nodes is modified, and the average one-hop distance used by each unknown node for estimating its location is modified through weighting the received average one-hop distances from anchor nodes. In [15], the authors proposed an improved DV-hop algorithm which introduces threshold M, it uses the weighted average hop distances of anchor nodes within M hops to calculate the average hop distance of unknown nodes. In [16] , the author primarily investigated a kind of target localization technology based on the improved DV-Hop algorithm in wireless sensor networks. They firstly compute the distances measured by RSSI and the mean value of one-hop distance. Then they can use the differences between the mean and the actual distance to get the error correction between the total distance and average one-hop distance. In [17], the authors presented two improved algorithms: Checkout DV-hop and Selective 3-Anchor DV-hop. Checkout DV-hop algorithm estimates the mobile node position by using the nearest anchor, while Selective 3-Anchor DV-hop algorithm chooses the best 3 anchors to improve localization accuracy.

In this paper, we propose an improved DV-Hop algorithm to increase the location accuracy. The rest of the paper is organized as follows. In the next section, we give the overview of the DV-Hop algorithm. The proposed works are described in Section 3. In Section 4, simulation results are shown and localization performance is discussed. Finally, the conclusions are given in section 5.

2. Overview of the DV-Hop Algorithm

In this section we describe the DV-Hop algorithm [9, 10] in brief. DV-Hop algorithm is a classical localization method for WSNs. The basic idea of the this algorithms is that the node itself only exchange information with its adjacent nodes, the distance between the unknown nodes and the anchor is computed by the product of the network average Hop distance and the shortest path between two nodes, and then uses trilateral measurement to obtain the node location information. The algorithm implementation consists of three steps.

In the first step, each anchor node broadcasts anchor node packets with its location information and hop-count value initialized to 0. Each sensor node in the network, which receives anchor node packets, maintains a table (x_i, y_i, $HopCount_i$) for every anchor node, where (x_i, y_i) is the coordinate of anchor node i and $HopCount_i$ is the minimum number of hops from anchor node i. If a received packet contains less hop-count value to a particular anchor node, the corresponding hop-count $HopCount_i$ will be replaced with the hop count value of the received packet. And this packet is forwarded in the networks with increasing hop-count value by one. Otherwise this packet is discarded. Through this mechanism, all nodes in the network have the minimal hop-count from every anchor node.

In the second steps, the anchor node i calculate the average size for one hop from other anchor nodes as follow:

$$HopSize_i = \frac{\sum_{j \neq i} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{j \neq i} HopCount_{ij}} \tag{1}$$

Where (x_i,y_i), (x_j,y_j) are coordinates of anchor node i and anchor , h_{ij} is the minimum number of hops between anchor node i and anchor node j. After calculating the average hop-size, each anchor node broadcasts its hop-size to network by using controlled flooding.

When the unknown node receives the average hop-size, it only records the first received average, and forwards the received hop-size to its neighbor nodes. After obtaining hop-size, using the following the equation unknown node i computes the distance to the anchor node j.

$$d_{ij} = HopCout_{ij} \times HopSize \tag{2}$$

where $HopCount_{ij}$ is the minimal hops between anchor node i and unknown node j. Based on this method, each anchor node can convert the distance to physical distance. $HopSize$ is the first received average hop-size.

In the third step, each unknown node estimates its location coordinate by polygon method. Let (x, y) be the unknown node P location and (x_i, y_i) the known location of the i'th anchor node receiver. Let d_i be the i'th anchor node distance to unknown nodes P, then we have

$$d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2} \tag{3}$$

If the node P gets its distance to three or more anchor nodes, the position of node P can be computed by using the following equation.

$$AX=B \tag{4}$$

where,

$$A = 2 \times \begin{bmatrix} x_1 - x_n & y_1 - y_n \\ x_2 - x_n & y_2 - y_n \\ \vdots & \vdots \\ x_{n-1} - x_n & y_{n-1} - y_n \end{bmatrix} \qquad B = \begin{bmatrix} d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ d_2^2 - d_n^2 - x_2^2 + x_n^2 - y_2^2 + y_n^2 \\ \vdots \\ d_{n-1}^2 - d_n^2 - x_{n-1}^2 + x_n^2 - y_{n-1}^2 + y_n^2 \end{bmatrix}$$

$$b = \begin{bmatrix} d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ d_2^2 - d_n^2 - x_2^2 + x_n^2 - y_2^2 + y_n^2 \\ \vdots \\ d_{n-1}^2 - d_n^2 - x_{n-1}^2 + x_n^2 - y_{n-1}^2 + y_n^2 \end{bmatrix} \qquad X = \begin{bmatrix} x \\ y \end{bmatrix}$$

Now the least square solution is estimate for P that minimizes $\| AX - b \|^2$, then the position of P can be computed by the following formula:

$$X = (A^T A)^{-1} A^T b \qquad (5)$$

3. The Improved CPE Algorithm

In the DV-Hop algorithm, the distance between unknown nodes and the anchor nodes is estimated by the product of the number of hop and the average distance with per hop. This algorithm has a better result only in the situation when the true distance between nodes in WSN is approximately close. When the nodes are distributed unevenly, it leads to the low accuracy of DV-Hop. One reason of this problem is that a node has the same distance estimation to all of its one-hop neighbors. Those nodes with the same hop counts to an anchor will have the same estimated distance, although they do have different distances the anchor. As shown in Fig 1, the hop counts between the unknown node and the anchor node A_1 and the hop counts between the unknown node U and the anchor A_2 are both 4. In the DV-Hop algorithm the distance, the distance between the unknown node U and the anchor node A_1 is equate to the distance between the unknown node U and the anchor A_2, but they are obviously different. To improve the accuracy the distance calculating between the anchor nodes and the unknown nodes, we need to consider the nodes distribution while computing the distance between the unknown nodes and the anchors.

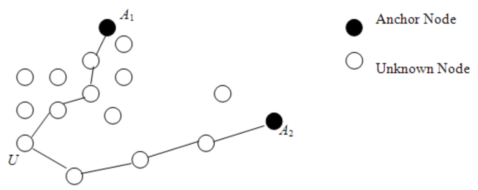


Figure 1. Example of Nodes Deployment

After a thorough study of the principle of original DV-Hop localization algorithms, we proposed an enhanced algorithm to improve the localization accuracy by considering the nodes distribution in WSN. Generally, the hop distance between nodes in area with low node densities is shorter than that in area with high node densities. As it is difficulty to get the density of sensor nodes in WSNs, here we use the neighbors of nodes to replace the node density. The basic idea of the proposed scheme is that more average neighbors of nodes on a given path, the shorter distance between nodes on this path. The changes in improved algorithm are mainly in the first two steps. And the details of changes are described below.

In the first step each intermediate node not only get minimal hop-count from every anchor node but also get have the total numbers of neighbors of nodes on the shortest hop path to anchor nodes. To do this, the broadcast packet is changed into (x_i, y_i, $HopCount_i$, n_i), where n_i is the total numbers of neighbors of nodes on the shortest hop path between the node to anchor node i.

In the second step, we use the weighted hop-size to replace the simple first received hop-size when computing the distance of between the unknown node and the anchor node. Suppose (x_i,y_i), (x_j,y_j) are coordinates of anchor node *i* and anchor , $HopCunt_{ij}$ is the minimum number of hops between anchor node *i* and anchor node *j*, n_{ij} is the total numbers of neighbors of nodes of which are on the way with minimal *HopCount* between anchor. The weight of the hop-size is computed as following:

$$w_{ij} = \frac{HopSize_{ij} / n_{ij}}{\sum_{k \in anchomodes} HopSize_{ik} / n_{ik}} \quad (6)$$

And the distance between the unknown node *j* and anchor node *i* is computed as following

$$d_{ij} = w_{ij} \times HopSize_i \times HopCount_{ij} \quad (7)$$

4. Simulation and Analysis

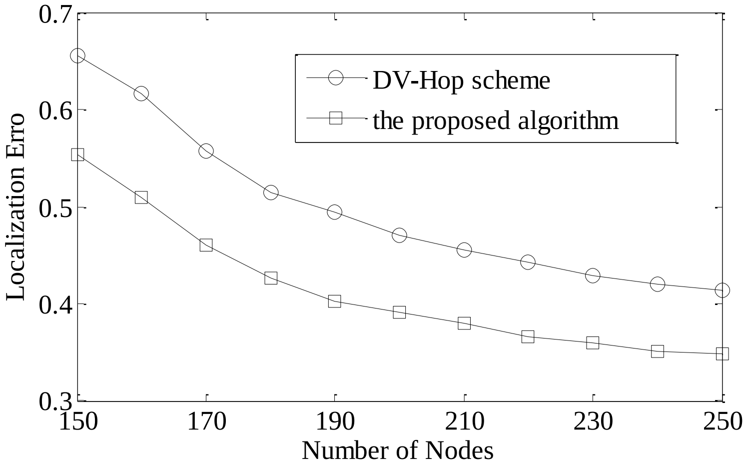
To verify the performance of the improved algorithm, in this section we use Matlab to simulate and analyze the traditional DV-Hop algorithm and the improved algorithm in different scenarios. The simulations of all the algorithms run on 100 times randomly generated sensor node deployment scenarios, and the average values are use for comparison.

For our simulation experiments, we offer simulation results under the following simulation circumstance: The anchor nodes and unknown are all random deployed in two dimensional area of $100m \times 100m$ and the two algorithms are validated by changing the number of anchor nodes, the number of sensor nodes and the communication range respectively. In the simulation, the localization error is defined as the average error function as follows [8, 9]:

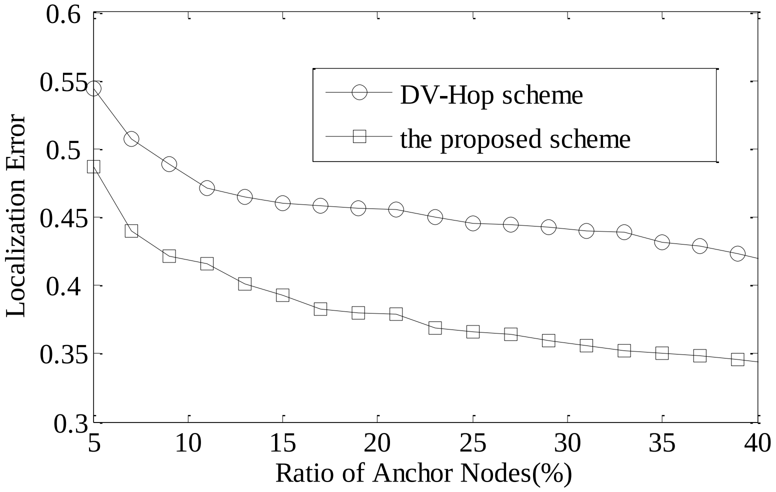
$$e_i = \sum_{i=N'}^{N} \frac{\sqrt{(x_i^e - x_i^r)^2 + (y_i^e - y_i^r)^2}}{R} \quad (8)$$

Where (x_i^r, y_i^r) is the real coordinate of the unknown node *i* is, (x_i^e, y_i^e) is the evaluated coordinate, *R* is the communication range of sensor nodes, and *N* is the total number of unknown sensor nodes, *N'* is the number of anchor nodes. The localization error reflects the accuracy of localization algorithm. Lower localization error the algorithm shows better performance.

The performance comparison is shown in Figure 2. Figure 2(a) gives the impact of total number nodes on positioning error and Figure 2 (b) gives the influence of ratio of anchor node on the positioning error. In Fig, 2 (a), we suppose that the number of all nodes is 200. Gradually, we increased the ratio of anchor node, and get different results in different situations. In Figure 2(b), we suppose that the ration anchor nodes are 15%. From the figure, we can clearly see that that the proposed scheme is much superior to DV-Hop scheme. As shown in Figure 2(b), with the ratio of anchor nodes increase, the average positioning error two algorithms show a decreasing trend. But under the same conditions, the average location error the improved algorithm is smaller than traditional DV-Hop algorithm. For example, when the beacon nodes ratio is 25%the average localization error is about 44.52% in DV-Hop scheme and 36.50% in the proposed scheme.



(a)



(b)

Figure 2. Comparison with Localization Error for Two Algorithms

5. Conclusions

In this paper, we present an improved DV-Hop algorithm that reduced the localization error without requiring additional hardware cost. The proposed algorithm considers the nodes deployment when computing the distance between unknown nodes and anchor nodes. The simulation studies are carried out to compare the performance the improved DV-Hop algorithm with the traditional DV-Hop algorithm. The effects of anchor node ratio and network density on the performance on the improved are investigated. The simulation results indicate that the improved DV-Hop algorithm outperform the DV-Hop algorithm in all simulation cases.

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