무선 센서 네트워크를 위한 개선된 Range-free 위치인식 알고리즘

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A Modified Range-free localization algorithm for Wireless Sensor Networks

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Abstract

Wireless Sensor Networks have been proposed for several location-dependent applications. For such systems, the cost and limitations of the hardware on sensing nodes prevent the use of range-based localization schemes that depend on absolute point to point distance estimates. Because coarse accuracy is sufficient for most sensor network applications, solutions in range-free localization are being pursued as a cost-effective alternative to more expensive range-based approaches. In this paper, we proposed a modified DV-Hop (range-free localization) algorithm which reduces node's location error and cumulated distance error by minimizing localization error. Simulation results have verified the high estimation accuracy with our approach which outperforms the classical DV-Hop.

1. INTRODUCTION

A Wireless Sensor Network (WSN) is a distributed collection of nodes which are resource constrained and capable of operating with minimal or no user intervention. Many applications of WSN are based on sensor self-positioning, such as battlefield surveillance, environments monitoring, indoor user tracking and others, which depend on knowing the location of sensor nodes. Because of the constraint in size, power, and cost of sensor nodes, the investigation of efficient location algorithms which satisfy the basic accuracy requirement for WSN meets new challenges. As such, many localization schemes have been proposed recently, with most assuming the existence of a few anchors(know their locations) for example through GPS or manual configuration. Localization can be divided into two categories: *range-based* and *range-free*. The former use absolute point-to-point distance (range) or angle estimates in location derivations, while the later depend on messages from neighboring sensors and/or anchors. Range-based solutions can provide more accurate locations, but have higher hardware requirements for performing precise range or angle measurements. On the other hand with less hardware requirements, range-free approaches only guarantee coarse-grained location accuracy. In this paper, we propose a modified range-free localization algorithm based on the DV- Hop algorithm.

The rest of this paper is summarized as follows. In section 2 we describe localization techniques and methods of estimating locations and positions including some related works. In section 3 we briefly talk about the original DV-Hop. We continue in Section 4 to analyze our proposed algorithm. In Section 5 we show the simulation results and the paper is finally concluded in Section 6.

2. RELATED WORKS

Several localization algorithms using hop-counts have been proposed. In the DV-Hop [1,4] algorithm, each node exchanges information containing the location of, and the hop-counts to, the anchor nodes. After the information exchanges between anchor nodes are complete, an average distance per hop is calculated. This distance is finally used to estimate the positions of nodes through the “lateration” method. [5] estimates the average one-hop distance by the Hop-TERRAIN method. In Hop-TERRAIN, an intermediate node sends a new broadcast message to a particular anchor node only if the hop-count information in the message is less than the previous one. In the refinement phase, each node iterates lateration using the estimated positions and ranges of neighbor nodes. In N-Hop Multilateration [6], the distance from an anchor node to an unknown node is determined by adding the physically measured distance. The unknown node maintains the shortest distance to the anchor nodes, and constructs a bounding box for each anchor node. The position of the unknown node is estimated to the center of the intersection of bounding boxes. DHL [7] has been proposed to reduce the error of the accumulated range. DHL adjusts the hop distance according to the density of neighbor nodes, and employs the lateration method. The comparison of the three hop-count based localization techniques, DV-Hop, Hop-TERRAIN, and N-Hop Multilateration, is summarized in [8].

3. THE DV-HOP ALGORITHM

In [2] Niculescu and Nath proposed the DV-Hop algorithm consisting of three non overlapping stages. In the first step, each anchor node broadcasts a message to be flooded throughout the network containing the location information and a hop-count parameter initialized to 1. Each receiving node maintains a table (x_i, y_i, h_i), where x_i and y_i are coordinates of anchor nodes it received, and h_i is the minimum hop-count to the particular anchor node. If a received message contains lower hop-count value to a particular anchor node, the corresponding item in the table will be replaced with the information in this message. And this message is flooded to the entire network with hop count values incremented by 1. Contrary, if a received message contains higher hop-count value to a particular anchor node, this message will be ignored. Through this mechanism all nodes in the network get the shortest distance, in hops, to every anchor node.

$$HopeSize_i = \frac{\sum_{i \neq j} \sqrt{(x_i - x_j)^2 + (y_i - x_j)^2}}{\sum_{i \neq j}^{n} h_{ij}} \qquad (1)$$

In the second step, the hop count is converted into physical distance. Once an anchor node obtains location and hop count information to other anchor nodes inside the network, it estimates an average size for one hop as in (1).

Where (x_i, y_i) and (x_j, y_j) are the coordinates of anchor i and j, h_{ij} is the distance, in hops, between anchor i to j. Once the average hop-size is calculated, anchor propagates this information to the entire network by controlled flooding. This implies that once a blind node gets and forwards an average hop-size, it will ignore all the subsequent ones. This policy ensures that most blind nodes will only receive the average hop-size from the closest (in hops) anchor. In the third step, blind nodes calculate the distance estimation to anchors by multiplying the average hop size by the minimal hop count value. Once a blind node can calculate the distance estimation to at least 3 anchors, it uses triangulation to estimate its location.

4. THE MODIFIED DV-HOP ALGORITHM

In this section we deal with the improvement of the original DV-Hop by (1) Anchors amending self average hop distance. (2) minimizing the error between the DV calculated distance and the Euclidean distance of between a pair of anchors.

- THE ALGORITHM

We know that the real distance (r_{ij}) between anchors $i(x_i, y_i)$, and $j(x_j, y_j)$ is given by $r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - x_j)^2}$.

On assumption that anchors $i(x_i, y_i)$ and $j(x_j, y_j)$, have h hops between them, the distance calculated by DV-Hop from anchor i to j is given by $\hat{r}_{ij} = h_{ij} * HopSize_i$

We can define the modified value of distance error in the route from anchor i to $j(e_{ij})$ as the difference between the DV calculated distance and the Euclidean distance calculated by the anchors themselves as in(2) then,

$$e_{ij} = r_{ij} - \hat{r}_{ij} \qquad (2)$$

The average hop error between i and j (e_{ij}^{ave}) is defined as difference between estimated distance ($\hat{r}_{ij}$) and real distance (r_{ij}) divided by the number of hops between them (h_{ij}).

$$e_i^{ave} = \sum \frac{e_{ij}}{h_{ij}} \qquad (3)$$

For the anchor i, there exists n-1path errors for a network of n anchors.. In this paper, node i takes the error value e_{ij}^{ave} of anchor j as the correction of average hop distance, where j denotes the index of the node whose message with position information reaches first. And then node i broadcasts the both corrected average hop distance and node ID to the network with a limited lifetime. The unknown node also takes the hop error obtained firstly as the amending value, and calculates the amended average hop distance

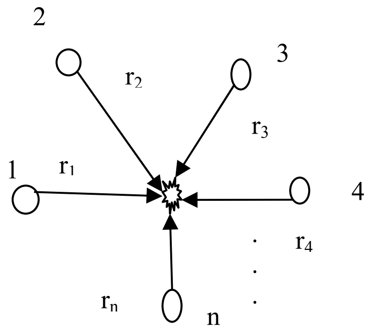
Mod$Hopsize_i$ according to formula

$$\text{ModHopsize}_i = \text{Hopsize}_i - e_i^{ave} \quad (4)$$

The distance of the blind node is calculated as a function of Mod$Hopsize_i$ which we have to minimize.

- THE MAXIMUM LIKELIHOOD ESTIMATION [9].

Consider the network model with n anchor nodes and one unknown node for simplicity as shown in Figure1. Here, the unknown node coordinate is (x_o, y_o) and anchor nodes are (x_i, y_i), i=1,2,3,....,n. Measured distance between anchor and unknown node is denoted by r_i, i =1,2,3,...., n and between anchor nodes is denoted by r_{ij}, i =1,2, 3,...., n ; j =1,2,3,....,n.



(Figure 1) Network model

This algorithm estimates the position of unknown nodes by minimizing difference between measured and estimated distance. This estimation can be performed using minimum mean square error (MMSE) criterion. Our study for localization is limited to two dimensions only. In this case, MMSE needs more than 3 anchor nodes to resolve unknown node location accurately. If we define error e_i as between measured and actual distance by,

$$e_i = r_i - \sqrt{(x_i - x_o)^2 + (y_i - y_o)^2} \quad (5)$$

Considering ideal case as this error becomes zero and rearranging terms again we will have

$$-x_i^2 - y_i^2 + r_i^2 = (x_o^2 + y_o^2) - 2x_ix_o - 2y_iy_o \quad (5.1)$$

where $1 < i < n$.

Eliminate the squared terms of unknown nodes by using similar n^{th} anchor node equation,

$$-x_i^2 - y_i^2 + r_i^2 + x_n^2 + y_n^2 - r_n^2 = 2x_o(x_n - x_i) - 2y_o(y_n - y_i) \quad (5.2)$$

Using above equation for all anchor nodes we will have matrix which has well known solution of $y = Xb$

$$b = (X^T X)^{-1} X^T y \quad (6)$$

$$b = \begin{pmatrix} x_o \\ y_o \end{pmatrix}, \quad X = -2\begin{pmatrix} (x_n - x_1) & (y_n - y_1) \\ (x_n - x_2) & (y_n - y_2) \\ \dots & \dots \\ (x_n - x_{n-1}) & (y_n - y_{n-1}) \end{pmatrix} \quad (7)$$

$$y = \begin{pmatrix} -x_1^2 - y_1^2 + r_1^2 + x_n^2 + y_n^2 - r_n^2 \\ -x_2^2 - y_2^2 + r_2^2 + x_n^2 + y_n^2 - r_n^2 \\ \dots\dots\dots\dots \\ -x_{n-1}^2 - y_{n-1}^2 + r_{n-1}^2 + x_n^2 + y_n^2 - r_n^2 \end{pmatrix} \quad (8)$$

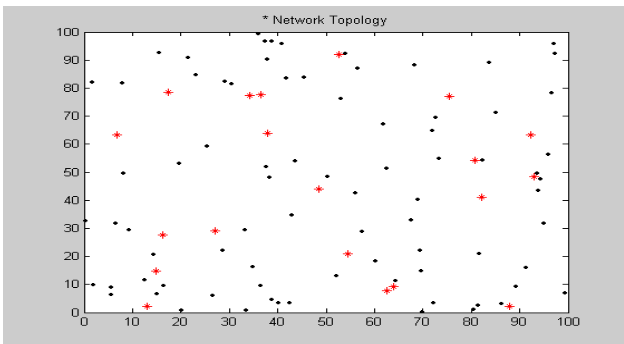
where, b gives the blind node's position estimate (x_o, y_o) with MMSE estimation.

5. PERFORMANCE ANALYSIS

In order to verify the validity of our algorithm, we use MATLAB for our simulation. The results are presented and analyzed mainly from the relative error (ERR_{rel}) which we define as the absolute value of the ratio of the DV-Hop and Modified DV-Hop distance between estimated coordinates and real coordinates to the communication radius of the nodes. Mathematically it is expressed as follows

$$ERR_{rel} = \frac{|r_i - r_e|}{R} \quad (9)$$

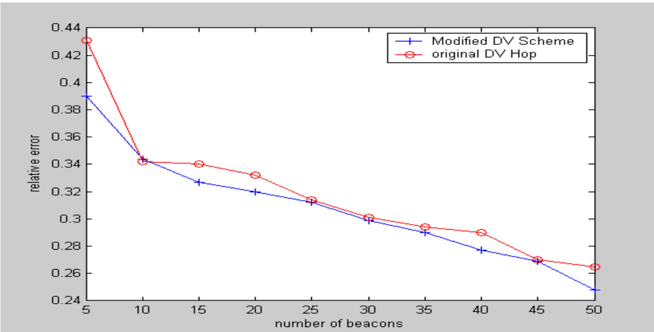
where r_i denotes real coordinates, r_e estimated coordinates, R is the transmission radius. In all simulation, we assume the maximum transmission ranges of all sensor nodes are the same. We simulated the DV-Hop and our proposed algorithm to evaluate location performance.



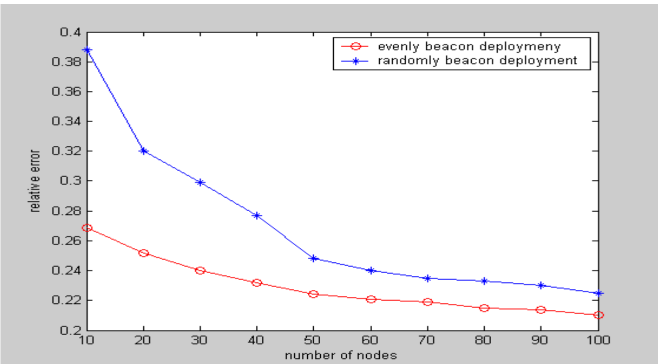
(Figure 2) Nodes Distribution *Beacons and blind nodes

The experiment region is a square area with the fixed size of 100 x 100 m^2 and the entire node has the same communication radius. The communication range of each node is sufficient to reach at least a node in the network.

As shown in Fig.2, We deploy 100 sensor nodes randomly in a two-dimensional space. It can be seen in Figure3 that the modified scheme outperforms the original DV-Hop with respect to relative error and it can be concluded that the more the number of beacon nodes in both cases the lower the relative error. When beacon nodes are randomly position the relative error is higher than when evenly distributed in the network as shown in Figure4. In figure5 as the transmission range is increased in the entire network the relative error decrease for both the modified scheme and the original DV hop, this is because the number of hops to each beacon decrease and eventually better estimation. But the relative error for the modified DV scheme is better than that of the original DV-Hop scheme. These values were made for a sample of ten runs and the average value taken.



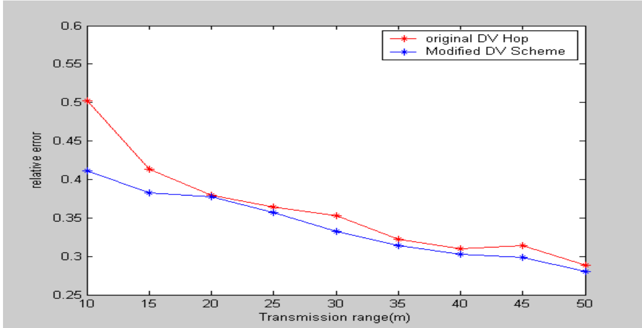
(Figure 3) Relative error of blind nodes with respect to the number of beacons



(Figure 4) Relative error of blind nodes with respect to the evenly and randomly distribution of Beacon nodes in the network

6. CONCLUSION

Range-free localization presents a promising solution for the localization problem in WSNs. In this paper, we proposed a modified DV-Hop algorithm for positioning the blind sensor nodes which aims at the anchor recalculating its distance to other anchors to minimize the cumulative



(Figure 5) Relative error of blind nodes with respect to the various transmission ranges in the network

distance error from original DV-Hop and hence the blind node's position error. As shown in the simulation results, it can be stated that this approach is more efficient than the original DV Hop and can be good for further works. We also explored the influence of anchor nodes on the DV-Hop algorithm. In the application scenario, we can place anchor nodes by manual work and it will be realized that the location performance will be enhanced.

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