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무선 센서 네트워크를 위한 DV-Hop 기반 계수 할당을 통한 위치 인식 알고리즘

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Coefficient Allocated DV-Hop algorithm for Wireless Sensor Networks localization

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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 Coefficient Allocated DV-Hop (CA DV-Hop) algorithm which reduces node's location error by awarding a credit value with respect to number of hops of each anchor to an unknown node. 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. Wireless sensor nodes operate in a cooperative and distributed manner. Localization can be defined as estimating the position or spatial coordinates of wireless sensor nodes. Localization is an inevitable challenge when dealing with wireless sensor nodes, and a problem which has been studied for many years. Nodes can be equipped with a Global Positioning System (GPS), which is an expensive solution in terms of power consumption and other parameters like volume and money [1,3,4].

With the development of sensor techniques, low-power electronic and radio techniques, low-power and inexpensive wireless sensors networks have appeared and been put into application. 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(beacons or landmarks) that are special nodes knowing their own 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 [6,7].

The rest of this paper is summarized as follows. In section 2 we briefly talk about the original DV-Hop. We continue in Section 3 to analyze the maximum likelihood estimation. Our proposed algorithm is described in Section 4. Section 5 evaluates the location estimation method. We show the performance analysis in section6 and the paper is finally concluded in Section 7.

2. THE DV-HOP ALGORITHM.

In [2] Niculescu and Nath proposed the DV-Hop, which is a localized, distributed, hop by hop positioning algorithm. The implementations of DV-Hop consist 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 (xi ,yi, hi), where xi and yi are coordinates of anchor nodes it received, and hi 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 (including anchor nodes which know the location) get the shortest distance, in hops, to every anchor node.

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 follows.

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

Where (xi, yi) and (xj, yj) are the coordinates of anchor i and j, hij 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

3. THE MAXIMUM LIKELIHOOD ESTIMATION [9]

Localization in WSNs is an optimization problem intrinsically, whose aim is to minimize the total estimation error of the computed positions for all the sensor nodes considered with respect to their true positions.

Consider the network model with n anchor nodes and one unknown node for simplicity as shown in Figure1. Here, the unknown node coordinate is (xo,yo) and anchor nodes are (xi,yi), i=1,2,3,...,n. Measured distance between anchor and unknown node is denoted by ri, i =1,2,3,..., n and between anchor nodes is denoted by rij , i =1,2, 3,..., n ; j =1,2,3,...,n .

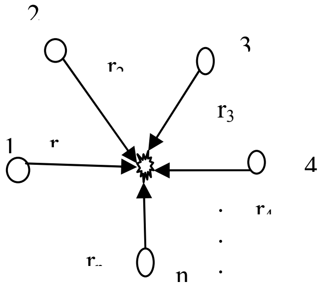

Figure1. network model

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 minimum three anchor nodes to resolve unknown node location accurately. If we define error ei as between measured and actual distance by,

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

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

$$-x_i^2 - y_i^2 + r_i^2 = (x_o^2 + y_o^2) - 2x_i x_o - 2y_i y_o \qquad (2.1)$$

Where $1 < i < n$

Eliminate the squared terms of unknown nodes by using similar nth anchor node equation,

$$-x_i^2 - y_i^2 + r_i^2 + x_n^2 + y_n^2 - r_n^2 = 2x_o(x_n - x_i) - 2y_o(y_n - y_i) \qquad (2.2)$$

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

$$y = Xb$$

$$\Rightarrow$$

$$b = (X^T X)^{-1} X^T y \qquad (3)$$

$$b = \begin{pmatrix} x_o \\ y_o \end{pmatrix}, \quad X = -2\begin{pmatrix} (x_n - x_1) & (y_n - y_1) \\ (x_n - x_2) & (y_n - y_2) \\ \dots & \dots \\ (x_n - x_{n-1}) & (y_n - y_{n-1}) \end{pmatrix} \qquad (4)$$

$$y=\begin{pmatrix} -x_1^2-y_1^2+r_1^2+x_n^2+y_n^2-r_n^2 \\ -x_2^2-y_2^2+r_2^2+x_n^2+y_n^2-r_n^2 \\ \cdots\cdots\cdots\cdots \\ -x^2_{n-1}-y^2_{n-1}+r^2_{n-1}+x_n^2+y_n^2-r_n^2 \end{pmatrix} \quad (3)$$

Where, b gives the blind node's position estimate (xo, yo) with MMSE estimation.

4. COEFFICIENT ALLOCATED DV-HOP (CADV-Hop).

Localization in WSNs is an optimization problem intrinsically,[8] whose aim is to minimize the total estimation error of the computed positions for all the sensor nodes considered with respect to their true positions. Since true locations of anchors are known, the major and only source of localization error comes but from the calculation of the average hop size(AHS), which if improved, the distance estimation will actually improve leading to smaller localization errors. This algorithm seeks to alleviate the calculation of the AHS values. With this a regular node calculates a credited AHS based on all the AHS values it receives from all the anchors in its transmission range instead of just taking the first received AHS from the nearest anchor.

We assume there are M anchors which are located at (xi,yi) i=1 to M, Here, we tend to adapt a more globalized formulation of the localization problem in any wireless sensor network defined as follows

$$f_i(x_e,y_e)=\min\sum_{i=1}^{i=M}\theta(r_i-\sqrt{(x_i-x_e)^2+(y_i-y_e)^2}))\quad (6)$$

Where (xe, ye) is the estimated location of the unknown node. (xi,yi) (i 1,2,...,M) is the true position of the i anchor node, ri is the measured distance between the i anchor and the unknown node , which is calculated by the ranging phase of DV-Hop, and the estimated distance separating them is given as $\sqrt{(x_i-x_e)^2+(y_i-y_e)^2}$. We know that the error estimation between the measured distance and the estimated distance of the unknown node to the i anchor is given as $r_i-\sqrt{(x_i-x_e)^2+(y_i-y_e)^2)}$.

In this paper, the credit parameter (θ) and the function (C) are related by

$$C(x_e,y_e)=\sum_{i=1}^{M}\theta_i^2 f_i^2(x_e,y_e)\quad (7)$$

θ is a parameter(credit allocated) relating the number of hops (h) between and unknown node and an anchor. In this paper this parameter is inversely proportional to the number of hop count between an unknown node and any anchor $\theta \propto 1/h$ (which is derived by the ranging phase of the classical DV-Hop) The estimated location of the unknown node is obtained by minimizing the above function (C) by MMSE.

5. LOCATION ESTIMATION.

An unknown node can calculate its location when it has get estimate distance to at least three anchors and credits of the three anchors. In DV-Hop algorithm, the position of unknown nodes is calculated by using least square method.

$$f_i(x,y)=\min\sum_{i=1}^{i=M}\theta_i^2(r_i-\sqrt{(x_i-x_e)^2+(y_i-y_e)^2)})^2\quad (8)$$

Where θ_i is the credit allocated to anchor i.

$$\overset{*}{y}=\overset{*}{X}\overset{*}{b}$$

$$\overset{*}{b}=\begin{pmatrix} x_o \\ y_o \end{pmatrix}$$

$$\overset{*}{X}=-2\begin{pmatrix} \theta_1^2\theta_n^2(x_n-x_1) & \theta_1^2\theta_n^2(y_n-y_1) \\ \theta_2^2\theta_n^2(x_n-x_2) & \theta_2^2\theta_n^2(y_n-y_2) \\ \cdots & \cdots \\ \theta_{(n-1)}^2\theta_n^2(x_n-x_{n-1}) & \theta_{(n-1)}^2\theta_n^2(y_n-y_{n-1}) \end{pmatrix}\quad (9)$$

$$\overset{*}{y}=\begin{pmatrix} \theta_1^2\theta_n^2(-x_1^2-y_1^2+r_1^2+x_n^2+y_n^2-r_n^2) \\ \theta_2^2\theta_n^2(-x_2^2-y_2^2+r_2^2+x_n^2+y_n^2-r_n^2) \\ \cdots\cdots\cdots\cdots \\ \theta_{(n-1)}^2\theta_n^2(-x^2_{n-1}-y^2_{n-1}+r^2_{n-1}+x_n^2+y_n^2-r_n^2) \end{pmatrix}\quad (10)$$

$$\overset{*}{b}=(\overset{*}{X}{}^{T}\overset{*}{X})^{-1}\overset{*}{X}{}^{T}\overset{*}{y}$$

6. PERFORMANCE AND SIMULATION RESULTS.

In order to verify the validity of our algorithm, we use MATLAB for our simulation. In our simulation experiments, we deployed sensor nodes over a 100 ×100 regular square area. The anchor placement has a significant impact on localization. According to [10], placing the anchor on the topology boundary equally improves the performance of the localization algorithm when compared to random anchor placement. The anchors were strategically placed at corners and positions that were uniformly distributed. The results are presented and analyzed mainly from the localization error (LE), which we define as the ratio of the difference between the estimated and real coordinates to the communication range of sensor nodes.

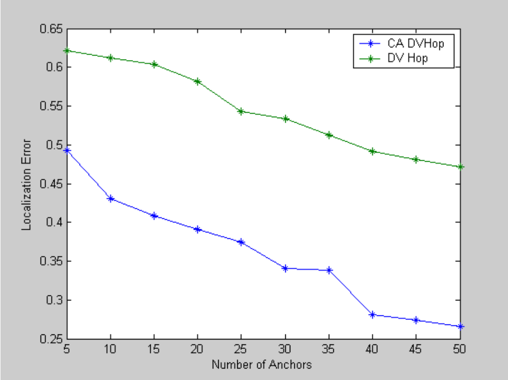

Fig 2. CA DV-Hop and DV Hop with respect to L.E

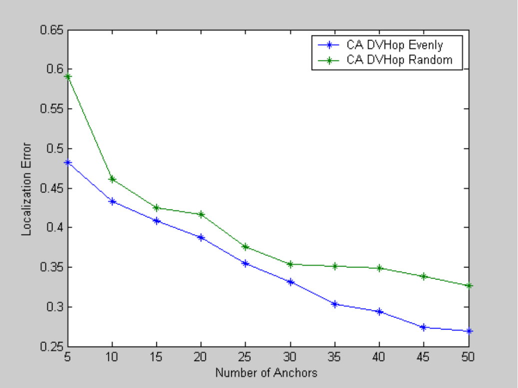

Fig 3.Even and Random Anchor placement CA-DVHop

This localization error reflects the accuracy of localization. The less the localization error is, the more accurate the localization performance. We simulated the DV-Hop and our proposed algorithm to evaluate location performance. The communication range of each node is sufficient to reach at least a node in the network.

It can be seen in Figure1 that CA-DVHop outperforms the original DV-Hop with respect to localization error and we see that the more the number of anchors in both cases the lower the localization error. When anchors are randomly position the localization error is higher than when evenly distributed in the network as shown in Figure2.

These values were made for a sample of ten runs and the average value taken.

7. CONCLUSION.

Range-free localization presents a promising solution for the localization problem in WSNs. In this paper, we present a Hop Credited Allocated DV-Hop (CA DV-Hop) algorithm that improves the original DV-Hop algorithm significantly. The proposed CA DV-Hop algorithm gives every anchor a coefficient which reflects the effects of anchor with respect to its number of hops to an unknown node. In this algorithm an unknown node computes the hop-size based on all the hop-size values it receives from the anchors, instead of just taking the first received hop-size value as in original DV-Hop algorithm. Using this strategy, the position of unknown nodes is calculated by using coefficient allocated least square method. The simulation results show that the proposed algorithm can improve location accuracy than the original DV-Hop algorithm. In the application scenario, we place anchor nodes uniformly and we realize that the location performance is enhanced.

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