The Selection of the Nearest Anchor Using Received Signal Strength Indication (RSSI)

Hichem Sassi, Tawfik Najeh, Noureddine Liouane

Abstract—The localization information is crucial for the operation of WSN. There are principally two types of localization algorithms. The Range-based localization algorithm has strict requirements on hardware, thus is expensive to be implemented in practice. The Range-free localization algorithm reduces the hardware cost. However, it can only achieve high accuracy in ideal scenarios. In this paper, we locate unknown nodes by incorporating the advantages of these two types of methods. The proposed algorithm makes the unknown nodes select the nearest anchor using the Received Signal Strength Indicator (RSSI) and choose two other anchors which are the most accurate to achieve the estimated location. Our algorithm improves the localization accuracy compared with previous algorithms, which has been demonstrated by the simulating results.

Keywords—WSN, localization, DV-hop, RSSI.

I. INTRODUCTION

A Wireless Sensor Network, which can real-time acquire and process information in the distribution area of network, is composed of plenty of sensor nodes. These nodes have the ability of sensing, computation, and wireless communication. Various applications of wireless sensor networks (WSNs) have practical significance while their position information of the sensor nodes is known. Such as national defense and military affair, environment inspection, traffic management, long distance control of dangerous region, and so on, WSN has shown its significance and capability in application. The observers can make emergency measure only if they know well accurate location information of the source. Therefore, reliable localization is an essential function of WSNs.

In WSNs, according to whether measuring the distances between nodes, localization algorithms can be divided into two kinds: range-based algorithms and range-free algorithms. Range-based algorithm need to measure the absolute distance between two nodes: time of arrival (TOA) [1], time difference on arrival (TDOA) [2], angle of arrival [3], receive signal strength indicator (RSSI) [4]-[6].

Range-free algorithm realizes nodes localization on the basis of the information of hop count or connectivity between anchor node and unknown node such as Centroid algorithm,

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DV-Hop algorithm [7], APIT algorithm [8], and Sequence-Based algorithm [9].

DV-Hop algorithm is a kind of APS localization algorithm, which relies mainly on distance vector routing protocol to achieve localization. Aiming to enhance positioning accuracy of DV-Hop algorithm, many improved localization schemes have been put forward. Recent researches [10] propose an algorithm in which an unknown node can calculate its position by selecting three anchors with reference to the nearest one. In [11] the proposed RDV-hop algorithm makes the unknown node which is one hop distance from anchors calculate the distance from it to the neighbor anchors using RSSI method instead of DV-hop method.

In this paper we propose a new algorithm which exploits the two last ideas to incorporate RSSI and DV-hop to implement unknown nodes localization together. The main idea of this algorithm is to make an unknown node can calculate its position by selecting three anchors with reference to the nearest one. The nearest anchor is fixed using the receive signal strength indicator (RSSI). Simulation results show the proposed algorithm has better performance than the classic DV-Hop and the improved algorithm [10].

This paper is organized as follows: DV-Hop algorithm is presented in Section II. In Section III, we will introduce our improved algorithm. Simulation results are provided in Section VI. The last section is to conclude this paper.

II. DV-HOP ALGORITHM

The DV-Hop algorithm was proposed based on the theory of distance vector routing by [12]. The algorithm implementation is composed of three steps:

In the first step, each anchor broadcasts through the network a message containing its own position and a hop count initialized as 0. This hop count value will increase with augment of hop during the broadcast of the message. Receiving nodes record the minimum hops to each anchor node and ignore the message with larger hops from the same anchor node. Then, the message is flooded outward to their neighbor nodes with one hop increased. During this mechanism, all nodes in the network get the minimal hop counts to every anchor node.

In the next step, once an anchor obtains hop-count value to other anchors, it estimates an average size for one hop. Then the estimated average size is transmitted to the whole network. The average hop-size is calculated using:

$$Hopsize_i = \frac{\sum\limits_{j \neq i} \sqrt{(x_i - x_j)^2 - (y_i - y_j)^2}}{\sum\limits_{j \neq i} h_{ij}} \qquad (1)$$

where (x_i, y_i), (x_j, y_j) are the coordinates of anchor i and anchor j respectively and h_{ij} are the hops between anchor i and anchor j.

The unknown nodes compute the distance to the anchor nodes based on two factors: hop-size and minimum hop count (hid), using:

$$d_i = h_{id} * HopSize_i \qquad (2)$$

In the third step, unknown node calculates its location by trilateration when it can estimate three or more distances to anchor nodes. Let (x,y) be the coordinates of the unknown node, and (x_i, y_i) the coordinates of anchor i. Let's say d_i is distance between anchor i to unknown nodes, and then we have:

$$\begin{cases} (x - x_1)^2 + (y - y_1)^2 = d_1^2 \\ (x - x_2)^2 + (y - y_2)^2 = d_2^2 \\ . \\ . \\ . \\ (x - x_n)^2 + (y - y_n)^2 = d_n^2 \end{cases} \qquad (3)$$

Formula (3) can be schemed with linear equation (4):

$$AN_{DV-Hop} = B \qquad (4)$$

where

$$N_{DV-hop} = \begin{pmatrix} x \\ y \end{pmatrix} \qquad (5)$$

$$A = -2 * \begin{bmatrix} x_1 - x_n & y_1 - y_n \\ x_2 - x_n & y_2 - y_n \\ .... & .... \\ x_{n-1} - x_n & y_{n-1} - y \end{bmatrix} \qquad (6)$$

$$B = \begin{bmatrix} d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ . \\ . \\ . \\ d_{n-1}^2 - d_n^2 - x_{n-1}^2 + x_n^2 - y_{n-1}^2 + y_n^2 \end{bmatrix} \qquad (7)$$

The unknown node can obtain its estimated position as:

$$N_{DV-hop} = (A^T A)^{-1} A^T B \qquad (8)$$

III. THE PROPOSED ALGORITHM

The whole idea of distance estimation by means of RSSI is based in ideal case on the assumption that the received Signal strength (RSS) is a function of the transmitted power and distance on the path between two radio devices.

The widely used radio propagation model is the log-distance path loss model [13]:

$$RSSI(d) = RSSI(ref) - 10 \cdot n \cdot \log \frac{d}{d_{ref}} \qquad (9)$$

where n is signal propagation constant, also named propagation exponent, d is the distance between emitter and receiver. RSSI (ref) the signal strength value at reference distance dref.

Based on (9), a generally used model for calculating the distance d is given in (10). RSSI (ref) is measured at (dref = 1 m).

$$d = 10^{\frac{RSSI(ref) - RSSI}{10n}} \qquad (10)$$

For an unknown node that is just one hop away from the anchors, it still needs to calculate its location according to average distance per hop. However, the distances between every couple of nodes are different in general case. For example, in Fig. 1 as:
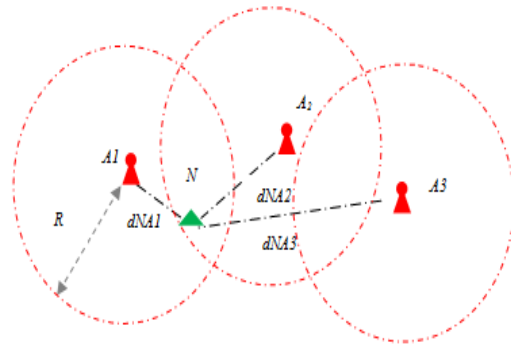

Fig. 1 The neighbor anchors of the unknown node

R is the communication range. In Fig. 1, we assume A1, A2 and A3 are all anchor nodes.

Node N is an unknown node who needs to be located. Node N is the one-hop neighbor of anchor nodes A1 and A2, but it's not in the coverage area of A3.

Suppose that A1 is the closest anchor for N, and the hop-size (average distance per hop) of A1 is superior then this of A2. The distances from unknown N to A1 and A2 are calculated using (2):

dNA1 = 1*hopsizeA1
dNA2= 1*hopsizeA2
hopsizeA1 > hopsizeA2   so   dNA1 > dNA2

As a result, N will consider A2 as the nearest anchor although the actual distances dNA1 < dNA2 and the nearest anchor is A1. Then, we propose a RSSI-based DV-hop localization algorithm, which incorporates RSSI and DV-hop to implement localization together.

The new algorithm is summarized as follows: All of the anchor nodes generate RSSI packets to broadcast in the

network, and any node which receives the packet can compute the RSSI-distance from itself to the anchor. If an unknown node is one-hop neighbor of anchor nodes, it can receive the RSSI packets from these anchors directly. After receiving the RSSI packets, N will compute the distances from different one hop anchors and select the nearest one. The one hop distances will be used in the localization process, even if the corresponding anchor not selected as the closest. The distance from other anchors will calculate using by average distance per hop.

After fixing the nearest anchor, the unknown node chooses any two anchors and is localized by trilateration. The position error of each combination is carried out. Finally, the location corresponds to the least error is selected as the most accurate estimated position.

IV. SIMULATION RESULTS

In this section, we used MatLab to carry out simulations and evaluate the DV-hop algorithm [10] and the rssdist-DV-hop algorithm proposed in this paper. The estimation accuracy of two localization algorithms is compared through our simulations. The localization accuracy is evaluated using the average localization error shown by:

$$AveError = \frac{1}{NR} \sum_{n=1}^{N} Error_n * 100 \%$$ (11)

with

$$Error_n = \sqrt{(x'_n - x_n)^2 - (y'_n - y_n)^2}$$ (12)

where N is the number of unknown nodes, and (x_n', y_n') are the estimated coordinates of the node N, (x_n, y_n) its actual coordinates.

1. The Error Diagram

The experiment region is a square with the fixed size of 50*50m2 and the radio range of sensor nodes (R) is set to 20 meter. The following figure represents 50 nodes randomly distributed among them 10 are anchors nodes.
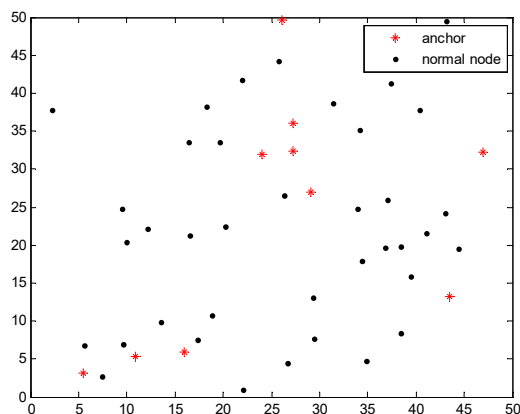

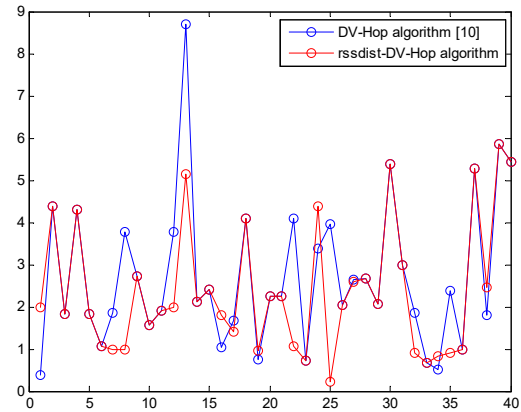Fig. 2 50 nodes randomly distributed, among them 10 are anchor nodes

Fig. 3 The error diagram of the unknown nodes

Fig. 3 represents the error diagrams of DV-hop algorithm [10] and the rssdist-DV-hop algorithm. These diagrams correspond to the location errors of the nodes of Fig. 2. It is clear that the locations errors calculated by the improved algorithm are smaller than those calculated by the DV-hop algorithm [10].

2. Simulation Results via Communication Range

We install 50 sensor nodes randomly in the 50*50m2, between them, 10 are anchor nodes. Table I presents the simulations results corresponding to different communication range (R):

TABLE I
THE COMPARISON BETWEEN DV-HOP ALGORITHMS THROUGH COMMUNICATION RANGE

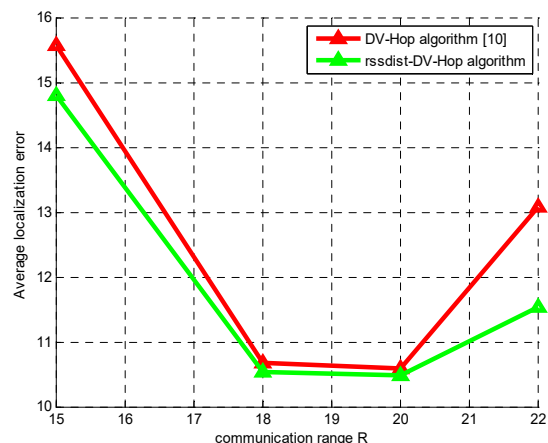| R(m)	DV-Hope [3]	rssdist-DV-Hop
15	15.5779	14.8028
15	10.6731	10.5271
20	10.5853	10.4784
22	13.0804	11.5406

Fig. 4 The comparison between DV-Hop algorithms through communication range

Figs. 2 show that the rssdist-DV-hop algorithm is better than the DV-hop [10] in estimation accuracy. In fact, we can see from Fig. 2, the position error is smaller when the

communication radius is large. For example, in the communication range of 22m, improved DV-hop algorithm is 11.5406 which is lower by 1.548% than the average error of the DV-hop [10]. This shows the superiority of the improved algorithm over the DV-Hop algorithm.

3. Simulation Results via Anchor Percent

The purpose of the simulation is to show the performance comparison experience when the ratio of anchor nodes is 20%, up to 50%. The communication range (R) is 40m and the experiment region is a square area with the fixed size of 100*100m2, where we randomly deploy 50 sensor nodes. The simulation results are shown in Table II.

TABLE II
THE COMPARISON BETWEEN DV-HOP ALGORITHMS THROUGH DIFFERENT ANCHOR PERCENT

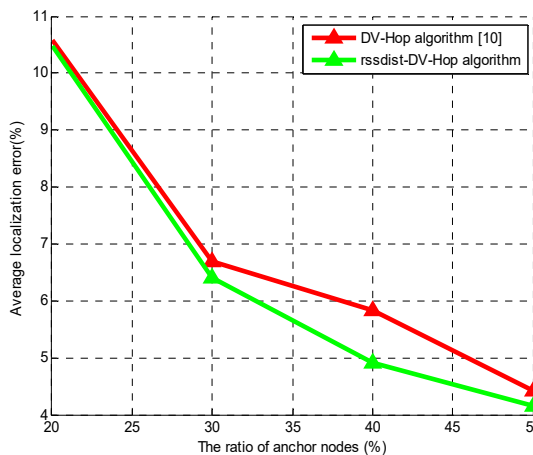| Anhor percent	DV-Hope [3]	rssdist-DV-Hop
20	10.5853	10.4784
30	6.6893	6.4035
40	5.8400	4.9042
50	4.4245	4.1569

Fig. 5 The comparison between DV-hop algorithms through Different Anchor Percent

In Fig. 3 it is clear that the estimation accuracy is improved as the number of the anchor node increase. So, the improved rssdist-DV-hop algorithm is better than DV-hop [10] with the increase of anchor nodes and with the large communication radius. This because the number of anchors neighbor nodes is increasing too, so RSSI distance can be used in more unknown nodes, the accuracy is achieving improvement.

V. CONCLUSION

Because of the deficiency of the original algorithm, a modified algorithm is put forward in [10]. Although the accuracy is enhanced but the selection of the nearest anchor needs to be more improved. In fact, in this paper, we propose an algorithm incorporates RSSI and DV-hop. The new rssdist-DV-hop algorithm makes the unknown node which is one hop away from anchors fixes its nearest anchor using RSSI technique instead of DV-hop algorithm. Using this method,

the estimate error in network is decreased. The experimental results have confirmed the validity of the new technique. The drawback of the algorithm is that only neighbors of anchor can update. Hence, our future purpose is to ask for the question how to accurately localize more unknowns' nodes and enhance the localization precision of the entire network?

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