Localization in Wireless Sensor Networks Using Improved DV-Hop Algorithm

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Abstract - *The Wireless Sensor Network (WSN) is a network which is composed of large number of low-cost sensor nodes which is limits in power, computational capacity and memory. Node localization is one of the critical issues in Wireless Sensor Networks. DV-Hop localization algorithm has attracted more attention of researchers due to its simplicity, stability, feasibility and less hardware requirement. However, DV-Hop algorithm exhibits poor localization error and accuracy. In this paper, improved DV-Hop algorithm based on correction in distance error has been proposed for the node localization. The results of proposed algorithm are simulated and analyzed in MATLAB. Simulation results establish the superiority of proposed algorithm in terms of localization error, error variance, and accuracy compared to existing DV-Hop localization algorithm.*

***Key Words*: Localization, DV-Hop, Range-free algorithms, WSN, MATLAB.**

1.INTRODUCTION

Wireless Sensor Network (WSN) is a network of inexpensive, tiny, multi-functional, and Smart Sensor Nodes (SNs) that can communicate with each other through a wireless medium [1]. These tiny Sensor Nodes (SNs) comprise a processor, dedicated memory, transceiver, actuator, sensor(s), and power module [2]. Sensor Nodes (SNs) can sense the desired physical phenomena, i.e., temperature, pressure, light, humidity, etc. Suppose an event occurs in the area of interest. In that case, SNs present within the vicinity of the event sense it and disseminate the sensed data through the multi-hop transmission to a centralized unit known as sink node or base station. The base station acts as a gateway between Wireless Sensor Network (WSN) and wired infrastructure, which provides a connection to the user end where the sensed data can be collected, processed, and analyzed. Wireless Sensor Network (WSN) has many prospective applications in various areas such as surveillance, habitat and environmental monitoring, military applications, healthcare, structural monitoring, disaster management, etc. [2]. Many such applications require accurate location of the sensor nodes to make sensed data meaningful. Some of these applications are forest fire detection, battlefield surveillance, search and rescue operations, target tracking, etc. [1, 2]. Localization is to determine the location and coordinates of the sensor nodes deployed randomly in the sensor network [3]. It is the important issue in location dependent applications of Wireless Sensor Network (WSN). Localization algorithms can be broadly categorized as range-based and range-free localization. Due to some limitations in range-based schemes, range-free schemes have attracted worldwide researchers' interest because these are cost-effective alternate methods for location calculation without any extra range determination hardware. Distance Vector Hop (DV-Hop) [4] is one of the widely used range-free localization algorithms. In this paper, an improved DV-Hop algorithm has been proposed for node localization.

2. LITERATURE REVIEW

Several papers corresponding to node localization in WSN have been studied. Some useful information from these papers is presented in this section. In [4], authors proposed DV based positioning in ad hoc networks. It is the basic hop-based range-free localization approach. In [5], authors suggested APIT (Approximate Point in Triangle) localization algorithm. In [6], authors proposed an improved localization algorithm. Authors suggested in this paper that the localization accuracy and coverage of anchor nodes in sparse environment can be enhanced by combining the advantages of both APIT (Approximate Point in Triangle) and DV-Hop (Distance Vector Hop) localization algorithm. In [7], authors proposed another refined algorithm based on hyperbolic and improved centroid approach that is applied over DV Hop for the accuracy enhancement. In [8], authors proposed a new algorithm for anisotropic environment named DVmax hop.

3. PROPOSED ALGORITHM

The working of the improved DV Hop Algorithm is divided into three stages as follows: -

3.1 Calculate the Minimum Hop Count

The proposed algorithm calculates the minimum hop count among the nodes like the first step of Basic DV-Hop algorithm. Here, each anchor starts floods the network with information {(Xi, Yi,), hi, id} wherein, hi contains the details of hop count and (Xi, Yi) contains the details of coordinates for the ith anchor. Initially, hop count (hi) is set to zero. The table consisting of the information {(Xi, Yi,), hi, id} that have obtained in the form of packets from the anchor node with the minimum hop count is maintained by every non-anchor node. The node will update its table and update the hop count value with the amount of one in its packet format if it received the packet with minimum hop count from a particular anchor. Further, it transmits the packet to the next node.

3.2 Calculate the distance between the anchor and non-anchor nodes

At first in this stage, using Eq. (1), anchors calculate the average hop size (AHS) as follows: -

$$AHS_i = \frac{\sum_{i \neq j} \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}}{\sum_{i \neq j} h_{i,j}} \quad (1)$$

where, (X_i, Y_i) - the coordinates of ith anchor node; (X_j, Y_j) - the coordinates of jth anchor node; $h_{i,j}$ - the hop count between the anchor nodes; n - the total anchor nodes.

Average Network Hop Distance ($ANHD_i$) of anchor node is calculated by using an average of the hop size for each anchor node as below:-

$$ANHD_i = \frac{\sum_{i \neq n} AHS_i}{n} \quad (2)$$

Distance error (DE_i) of each anchor for other anchors present in the network is calculated by using Eq. (3).

$$(DE_i) = \left(ANHD_i \times h_{i,j}\right) - \text{True Distance} \quad (3)$$

Average distance error (ADE_i) of every anchor with other anchors present in the network is calculated by using Eq. (4).

$$ADE_i = \frac{\sum_{i \neq n} DE_i}{n} \quad (4)$$

The overall average distance error for the non-anchor node for anchor nodes present in the network is obtained by using Eq. (5).

$$total\_error = \frac{\sum_{i \neq n} ADE_i}{n} \quad (5)$$

Finally, the distance between anchor and non-anchor nodes can be calculated by using Eq. (6).

$$D_{u,i} = (ANHD_i \times h_{i,j}) - \left(h_{i,j} \times total\_error\right) \quad (6)$$

3.3 Determine the position of non-anchor nodes

By using triangulation technique, the position of non-anchor nodes (U) can be estimated. Here, dn is defined as the distance calculated in step two above, n is total anchor nodes amount, (Xn, Yn) are the coordinates of anchor nodes, and (Xu, Yu) are the coordinate of non-anchor nodes (U). Using Eq. (7), we can obtain the coordinates as follows.

$$\begin{bmatrix} (X_u - X_1)^2 + (Y_u - Y_1)^2 = d_1^2 \\ (X_u - X_2)^2 + (Y_u - Y_2)^2 = d_2^2 \\ \vdots \\ (X_u - X_n)^2 + (Y_u - Y_n)^2 = d_n^2 \end{bmatrix} \quad (7)$$

Further, we can modify Eq. (7) such as AXu= b, where

$$A = 2 \times \begin{bmatrix} (X_1 - X_n)(Y_1 - Y_n) \\ (X_2 - X_n)(Y_2 - Y_n) \\ \vdots \\ (X_{n-1} - X_n)(Y_{n-1} - Y_n) \end{bmatrix} \quad (8)$$

$$b = \begin{bmatrix} X_1^2 - X_n^2 + Y_1^2 - Y_n^2 - d_1^2 - d_n^2 \\ X_2^2 - X_n^2 + Y_2^2 - Y_n^2 - d_2^2 - d_n^2 \\ \vdots \\ X_{n-1}^2 - X_n^2 + Y_{n-1}^2 - Y_n^2 - d_{n-1}^2 - d_n^2 \end{bmatrix} \quad (9)$$

$$X_u = \begin{bmatrix} X_u \\ Y_u \end{bmatrix} \quad (10)$$

Finally, we can obtain the position of the non-anchor node using Eq. (11) as below:-

$$X_u = \left(A^T A\right)^{-1} A^T b \qquad (11)$$

3. RESULTS AND DISCUSSION

In the study and analysis, the region for deployment of nodes is maintained as 100 m×100 m in two dimensional (2D) space, and different comparative variables, such as localization error, localization error variance and accuracy are determined by adjusting the number of total nodes. The following equations are used for the performance evaluation of algorithms as below:

Average Localization Error (ALE) =

$$\frac{\sum_{i=1}^{u}\sqrt{\left(X_i^u - X_i^a\right)^2 - \left(Y_i^u - Y_i^a\right)^2}}{N\times R}$$

Localization Error Variance (LEV) =

$$\sqrt{\frac{\sum\left(\sqrt{\left(X_i^u - X_i^a\right)^2 + \left(Y_i^u - Y_i^a\right)^2} - ALE\right)^2}{N\times R}}$$

$$\text{Localization Accuracy}(\%) = (1 - ALE)\times 100$$

where, (X_i^u, Y_i^u) - the coordinates of ith unknown nodes; (X_i^a, Y_i^a) - the coordinates of ith anchor node; R – Range of node transmission; N – Number of total nodes.

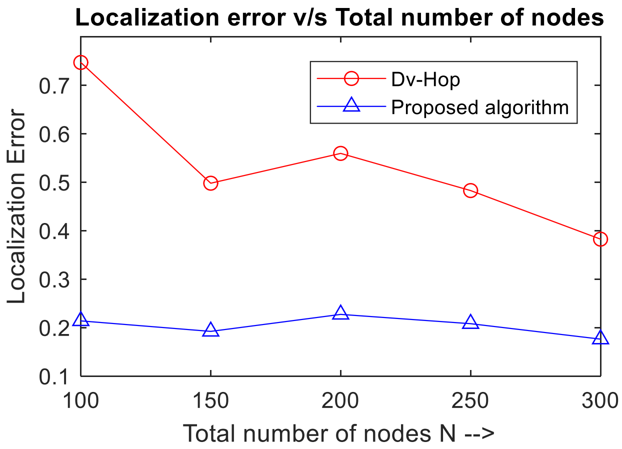

Fig. -1: Localization error versus Total number of nodes

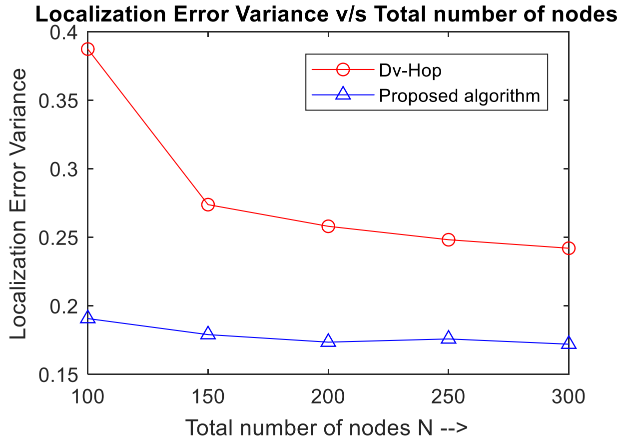

Fig. -2: Localization error variance versus Total number of nodes

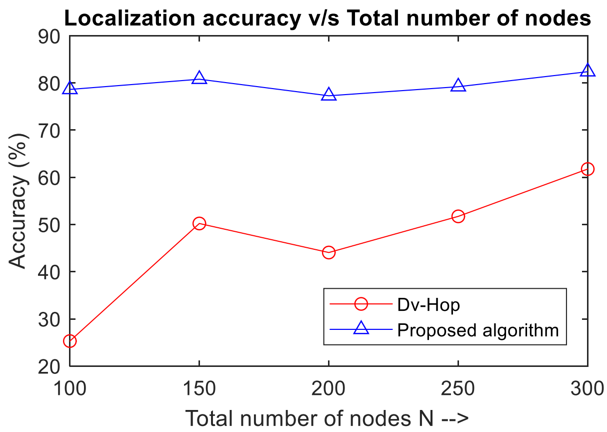

Fig. -3: Localization accuracy versus Total number of nodes

Fig. 1-3 shows that proposed algorithm has got better results as compared to DV-Hop in terms of localization error, localization error variance, and accuracy.

4. CONCLUSION

In this paper, an improved DV Hop algorithm is implemented based on correction in distance error. During the development phase various aspects like the hop count, hop size, node distance, distance error correction are formulated to get the error precision. MATLAB simulation results show that proposed algorithm performs better as compared to existing DV-Hop localization algorithm.

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