An optimum DV Hop Localization Algorithm for variety of topologies in Wireless Sensor Networks

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Abstract— **Today wireless sensor networks has become a key technology for different kinds of smart environments. Sensor node localization which is determining where a given sensor node is physically or relatively located is extremely crucial for most of the applications in wireless sensor networks. The procedure through which the sensor nodes obtain their positions is called localization. Sensors network can have topology of irregular shapes. We have simulated three different irregular shapes and also worked out for localization accuracy for the same.**

Keywords- ***sensor network, localization algorithms***

I. INTRODUCTION

Wireless sensor network (WSN) consist of a number of sensor nodes where each node is a small computing device. This has the capability of sensing and computing in addition to the ability to communicate with other nodes. Networked sensors have a broad spectrum of applications in the defense area, generating new capabilities for investigation and surveillance as well as other strategic applications. Localization is an important aspect in the field of wireless sensor networks that has attracted significant research interest recently.

The problem of localization in wireless sensor networks where nodes do not use ranging hardware remains a challenging problem, when considering the required location accuracy, energy expenditure and the duration of the localization phase. Wireless sensor network localization techniques are used to estimate the locations of the sensors with unknown positions in a network using the available a priori knowledge of positions of, typically, a few specific sensors in the network and inter-sensor measurements such as distance, time difference of arrival, angle of arrival and connectivity [1]. Sensors with the a priori known location information are called anchors and their locations can be obtained by using a global positioning system (GPS), or by installing anchors at points with known coordinates. The sensors with unknown location information are called non-anchor nodes or beacons and their coordinates need to be estimated using a sensor network localization algorithm.

II. MEASUREMENTS USED IN WIRELESS SENSOR NETWORKS LOCALIZATION

Measurement techniques in WSN localization can be broadly classified into three categories: Angle of Arrival (AOA) measurements, distance related measurements and RSS profiling techniques. All the nodes with unknown position find their location basically according to the anchor nodes. In general, the positioning technology can be divided into two types, the range based and range free. Range-based approach depending on the measurements of the distance or angles from point to point uses the Angle of Arrival (AOA), Time of Arrival (TOA) and RSSI (Received Signal strength Indicator) to compute the location of the node. The range-free approach includes DV-hop localization algorithm. The DV-hop localization algorithm is proposed by Niculescu and Nath [1].

I. **DV-HOP**

DV-hop is a classical localization method for wireless sensor networks. It uses a small amount of anchor nodes that know their location whereby other unknown nodes estimate their location from the information they receive. Based on the concept of distance vector routing (DV-routing), the DV Based Positioning System is proposed. The known-location nodes, called anchors, broadcast their position packets throughout the network. Like DV-routing, each other nodes after receiving the location packet will maintain a shortest hop count table.

Based on this method, each anchor can convert the distance, in hops, to physical distance and broadcasts the calculating result to neighbouring nodes. When an unknown node estimates its distances to three or more anchor nodes in the plane, execute maximum likelihood estimation to estimate the location of the unknown node. The algorithm implementation is comprised of three steps. In the first step, each anchor node broadcasts a beacon to be flooded throughout the network containing the anchors location with a hop-count value initialized to one. Each receiving node maintains the minimum hop-count value per anchor of all beacons it receives. Beacons with higher hop-count values to a particular anchor are defined as stale information and will be ignored. Then those not stale beacons are flooded outward with hop-count values incremented at every intermediate hop. Through this mechanism, all nodes in the network get the minimal hop-count to every anchor node.
In the second step, once an anchor gets hop-count value to other anchors, it estimates an average size for one hop, which is then flooded to the entire network. After receiving hop-size, blindfolded nodes multiply the hop-size by the hop-count value to derive the physical distance to the anchor. The average hop-size is estimated by anchor using (1)

$$Hop_i = \frac{\sum\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum h_i} \qquad \forall j, \quad i \neq j \tag{1}$$

Where $(x_i, y_i), (x_j, y_j)$ are coordinates of anchor *i* and anchor *j*, h_i is the hops between them. Given a set of reference nodes $R_i = (x_i, y_i)^T$, $i = 1,2,........M$ where M is reference nodes. The hop value between unknown node $X = (x, y)^T$ and i^{th} reference node is L_i .The distance between the unknown node and i^{th} reference node is given by $d_i = L_i Hop_i$ **.**
The unknown node location X can be obtained by using following equations

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

Eq.(2) can be expanded into

$$\begin{cases} 2(x_1 - x_n)x + 2(y_1 - y_n)y = x_1^2 - x_n^2 + y_1^2 - y_n^2 - d_1^2 + d_n^2 \\ 2(x_2 - x_n)x + 2(y_2 - y_n)y = x_2^2 - x_n^2 + y_2^2 - y_n^2 - d_2^2 + d_n^2 \\ \quad\quad \vdots \\ 2(x_{n-1} - x_n)x + 2(y_{n-1} - y_n)y = x_{n-1}^2 - x_n^2 + y_{n-1}^2 - y_n^2 - d_{n-1}^2 + d_n^2 \end{cases} \tag{3}$$

In the matrix form $AX = B$

$$A = \begin{bmatrix} x_1 - x_n & y_1 - y_n \\ x_2 - x_n & y_2 - y_n \\ \vdots & \vdots \\ x_{n-1} & y_{n-1} \end{bmatrix}, B = \begin{bmatrix} d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ d_2^2 - d_n^2 - x_2^2 + x_n^2 - y_1^2 + y_n^2 \\ \vdots \\ d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \end{bmatrix} \tag{4}$$

Coordinate of the unknown node (*x*, *y*) is computed as follows

$$(x, y) = (A^T A)^{-1} A^T B \tag{5}$$

DV-HOP algorithm is similar to the range-based algorithm; that needs to obtain the distance information from unknown nodes to anchor nodes.

III. IV. Optimum DV-HOP

Since WSN may be deployed in hostile environments, they are susceptible to a variety of attacks [5], [6], [7] that could significantly impact the accuracy of the localization process. Optimization in DV HOP algorithm is needed when there are several reference nodes with same hop values.

The localization of one of the unknown nodes denoted as Nu. For the reference node *i*, the hop value between *N u* and reference node *i* is *L i* and the average single hop distance is $Hopsize_i, i = 1,2,....M$ and *M* is the number of the reference nodes. Denote these reference nodes as $v_j, j = 1,2,......M$. Then the distance between *Nu* and the i^{th} reference node is $d_i = L_i \times Hopsize_i$. Let $L = \min\{L_1, L_2.....L_m\}$ [2]. There exist several nodes with same hop value equal to L. From these nodes three random nodes are selected to apply triangulation algorithm [3]. We have simulated this improved DV HOP algorithm to find out the 'Accuracy' for various topologies of sensor network.

Accuracy: It is a percentage of measure of how well the estimated positions of nodes that of the localized network in defined topology match the actual positions.

V. TOPOLOGIES

There are essentially two main categories of sensor network topology, even and random. Even topologies distribute sensor nodes and anchors over the deployment area in an exact grid, whilst random topologies trouble individual nodes positions on the grid with random noise. Random topologies, however, better reflect the deployment scenarios in real-world environments. This is because sensor networks may be deployed in locations where manual placement is either limited (e.g. in a thick forest) or almost impossible (e.g. inside a volcano). In these cases, it is generally assumed that nodes are randomly dropped from some deployment vehicle, and uniform placement cannot be guaranteed. For these reasons, random network topologies are generally more popular. Topologies can be further sub-classed into regular and irregular topologies, according to the regularity of their placement densities and shapes. C-shaped, L-shaped and ring-shaped topologies are typical irregular topology examples, and represent irregular deployment configurations. Rectangular and square topology symbolizes random uniform topologies.

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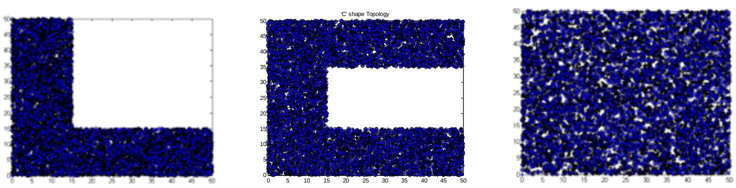
VI. SIMULATION

We have evaluated the location accuracy with respect to radio range of mobile node. The random walk mobility model has been used in different topologies of the sensor network. The simulation is carried out in MATLAB. In the simulation we deploy 100 nodes randomly in a two-dimension area of 100 x 100. The communication radius of each node is assumed to be varied in between 18 to 30. The anchor nodes are selected from all of the nodes proportionally.

Sensors are organized in the following three topologies.

1. 'L' shape Topology
2. 'C' shape Topology
3. Square Topology

Performance of network is evaluated by calculating Average localization error at various values of reference ratio for each of the above mentioned topologies. The simulation results are as follows. Following figures 1 (a) to (c) shows distribution of nodes for 'L' shape, 'C' shape and square topology.



(a) (b) (c)

Figure 1. Three different network topologies: (a) Random deployment in L-Shaped area. (b) Random deployment in a C-Shaped area (c) Random deployment in a square area

We measure the performance of the algorithm with mean location error. It is reported in percentage, normalized by the transmission range. A low error means good performance and better accuracy of the evaluated method.

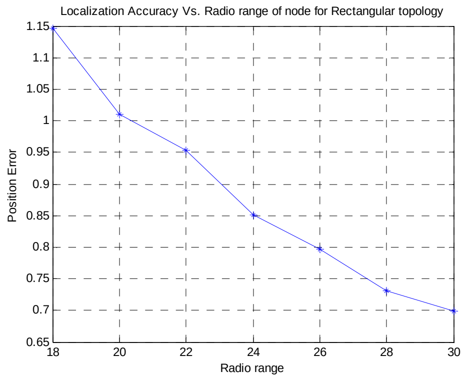


Figure 2. Localization Accuracy Vs. Radio range for Rectangular topology

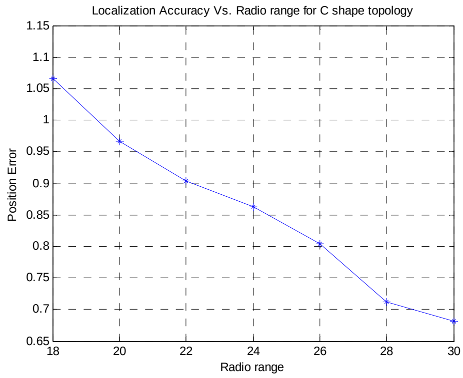


Figure 3. Localization Accuracy Vs. Radio range for C shape topology

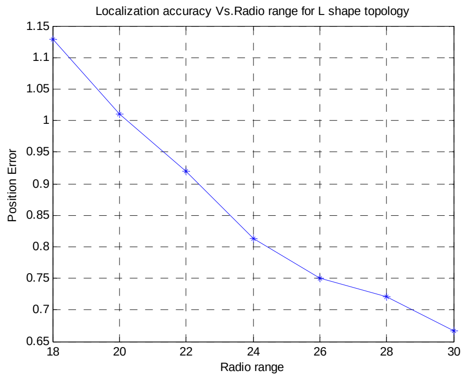


Figure 4. Localization Accuracy Vs. Radio range for L shape topology

VII. CONCLUSION

Defining node deployment topologies in simulations play an important role when comparing the performance of localization algorithms. C shaped, L shaped networks are examples of irregular topologies and square shape is an example of random uniform topology. In this paper we have simulated Improved DV Hop localization algorithm for these three topologies. The simulation results show that as radio range of anchor nodes in the sensor network increase, position error decreases. It means that accuracy increases. In this paper we have compared the localization error for different topologies. Our optimum DV hope localization algorithm gives more localization accuracy for C shape topology which is much harder topology as compared to other topologies.

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