Range Free Localization using Expected Hop Progress in Wireless Sensor Network

Rakshit S.M
ME(VLSI & Embedded System)
G.H. Raisoni College of Engineering
Ahmednagar, India.

Prof. Hate S.G
Electronics and Telecommunication Department
G.H. Raisoni Institute of Engineering & Technology,
Pune, India.

Abstract – Wireless sensor network (WSN) combines the concept of wireless network with sensors. Wireless Sensor Networks have been proposed for a multitude of location-dependent applications. Localization (location estimation) capability is essential in most wireless sensor network applications. In environmental monitoring applications such as animal habitat monitoring, bush fire surveillance, water quality monitoring and precision agriculture, the measurement data are meaningless without an accurate knowledge of the location from where the data are obtained. Finding position without the aid of GPS in each node of an ad hoc network is important in cases where GPS is either not accessible, or not practical to use due to power, form factor or line of sight conditions. So here we are going to used DV-Hop algorithm, i.e. distance vector routing algorithm for finding the position of sensor. Here we summarizes the performance evaluation criteria of the wireless sensor network and algorithms, classification methods, and highlights the principles and characteristics of the algorithm and system representative of the field in recent years, and several algorithms simulation and analysis.

Keywords: Wireless Sensor Network; Localization; DV-Hop; Range-based Algorithms; Range-free Algorithms.

I. INTRODUCTION

Wireless sensor nodes are based on the technology of sensor. Generally, it referred as WSN. It combines the concept of wireless network with sensors. Wireless sensor networks consists of a number of sensor nodes, that are deployed in a large number to monitor environmental condition by measuring physical parameter such as temperature, pressure, humidity etc. Each node in WSN is a small computing device, which has the capability of sensing and they exchange information with the environment through sensors and implement the function of collecting and dealing with data. Wireless sensor networks have been widely used in the fields of environmental monitoring, military applications, disaster management etc. In these large sensor networks systems, we need node to be able to locate themselves in various environments, and on different distance scales. This problem, which we refer to as localization, is a challenging one, and yet extremely crucial for many applications [1].

Localization (location estimation) capability is essential in most wireless sensor network applications. The localization problem has received considerable attention in the past, as many applications need to know where objects or persons are, and hence various location services have been created. Many applications of Wireless sensor networks (WSNs) require sensors to be aware of their physical locations. WSN works properly only when all the nodes in the networks knows their own position. In the environmental monitoring applications such as fire surveillance, water quality monitoring and precision agriculture, the measurement data are meaningless without knowing the location from where the data are obtained. Localization is the ability of wireless sensor nodes to find out its own physical position within a network. Generally, for a sensor node to obtain its location, it needs to be equipped with some sensor that can be used to for inferring this information.

A primary solution for localization is to equip each node with a GPS [1]. Global Positioning System (GPS) is currently the most widely used and most mature positioning system, positioning by satellite timing and ranging to the user node, with a high precision positioning, real time, anti-interference ability, but the GPS positioning applies to block the outdoor environment, the user nodes are usually high energy consumption and large size, the cost is relatively high, fixed infrastructure, which makes it not apply to low-cost self-organizing sensor networks. But this method may be not the right solution because of the following three problems [2].

1. GPSs cannot be used in indoor solutions due to weak satellite signals.
2. GPSs use a lot of energy and reduced the network lifecycle.
3. GPSs are expensive and cannot be used in low-price large-scale sensor nodes.

However, due to the size, price, energy consumption, and coverage problems of GPS receivers, it is often not feasible to equip simple sensor nodes with them. So there is alternative solution for this GPS, we are moving towards algorithm.

II. LOCALIZATION METHODS IN WIRELESS SENSOR NETWORKS

A. Sensor Network Localization Algorithms:

Based on the approach of processing the individual inter- sensor measurement data, localization algorithms can be broadly classified into two categories: *centralized algorithms* and *distributed algorithms*.

Many localization algorithms for sensor networks have been proposed to provide per-node location information. Depending on the positioning mechanism, the existing wireless sensor network is positioning itself to be divided into two categories: Range-Based Localization Algorithms and Range -Free Localization Algorithms. [3][4]

B. Range-Based Localization Algorithms:

Ranging-based positioning mechanisms need to measure the distance or angle information between unknown nodes and anchor nodes, and then use trilateration, triangulation or maximum likelihood estimation method to calculate the unknown node's position. Time of Arrival (TOA), Time Difference of Arrival (TDOA), Angle of Arrival (AOA),
Received Signal Strength Indicator (RSSI), are all popular Range-based methods. They require additional hardware support and thus, are very expensive to be used in large scale networks. RSSI is the most fundamental method.

C. Range-Free Localization Algorithm:

The Range-free algorithms need less sophisticated hardware. They use estimated distance instead of metrical distance to localize, so they have much advantage in power and position cost. The Range-free localization algorithm are cost effective due to the fact that no distance/angle measurement between communicating nodes is required. The centroid, Approximate Point in Triangle Test (APIT), Co-ordinate, DV-hop, and Amorphous and so on are all Range-free algorithms. As far as the tradeoff between location precision and deployment cost is concerned, Range-free localization schemes are more suitable for WSNs than expensive range-based ones [2].

III. IMPLEMENTATION OF DV-HOP ALGORITHM

A distributed, hop-by-hop positioning algorithm (i.e., DV- Hop) has been proposed. This can be interpreted as an extension of both DV routing and GPS positioning so as to provide approximate location information for all nodes in ad hoc networks. DV-Hop introduces a lot of traffic load and communication delay in a WSN, due to the fact that it works in two steps. First, anchors broadcast their location information throughout the network and each sensor keeps track of the hop counts to each of the anchors. Second, any anchor estimates the average hop distance between neighboring sensors after it gets the distances to other anchors. Then, it broadcasts the corresponding average hop distance throughout network.

Position estimation if the node distribution in the network is dense and uniform. The performance and accuracy of DV-Hop deteriorates if the node distribution is sparse or non uniform. DV-Hop propagation method is the most basic scheme, and it first employs a classical distance vector- hop exchange so that all nodes in the network get distances, in hops, to the other anchor nodes. Once the anchor nodes gets hop distances to other anchor nodes, it estimates an average size for one hop, which is then flooded into entire network. When the other arbitrary nodes receive this average hop size then it calculates its own distance from the anchor nodes. This distance can be calculated by multiplying average hop size with the hop distances, in meters, and then at the last we perform trilateration or maximum likelihood estimation method to calculate the position of unknown nodes. The average single hop distance is calculated by anchor nodes i using the fallowing equation [5].

$$\text{Hopsize}=\frac{\sum_{j\neq i}\sqrt{(x_i-x_j)2+(y_i-y_j)2}}{\sum_{j\neq i}Hops_i}$$

Where (x_i, y_i), (x_j, y_j) Anchornode coordinates; Hop the number of hops between the anchor nodes i and j ($i \neq j$).

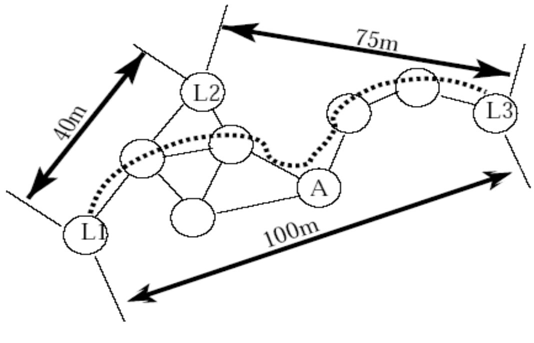

Fig.1 Example of D.V. Hope Algorithm

In [3] the example in figure 4.1, nodes L1, L2 and L3 are landmarks i.e. anchor nodes, and node L1 has both the Euclidean distance to L2 and L3, and the path length of 2 hops and 6 hops respectively. L1 computes the correction i.e. Average hop size $\frac{100+40}{6+2}$ = 17.5, which is in fact the estimated average size of one hop, in meter. L1 has then the choice of either computing a single correction to be broadcasted into the network, or preferentially send different corrections along different directions. In our experiments we are using the first option. In a similar manner, L2 computes its own average hop size $\frac{40+75}{2+5}$ = 16.42 and average hop size of L3 is $\frac{75+100}{6+5}$= 15.90. A regular node whose position has to find out and it gets an update from one of the anchor nodes, and it is usually the closest one, depending on the deployment policy and the time the correction phase of APS starts at each anchor. Hop size are distributed by controlled flooding, meaning that once a node gets and forwards a correction, it will drop all the subsequent ones. This policy ensures that most nodes will receive only one Hop size, from the closest anchor nodes. When networks are large, a method to reduce signaling would be to set a TTL field for propagation packets, which would limit the number of anchor nodes acquired by a node. Here, controlled flooding helps keeping the hop size localized in the neighborhood of the anchor nodes they were generated from, thus accounting for non isotropies across the network. In the above example, assume A gets its Hop size from L2 its estimate distances to the three anchor nodes would be: to L1; 3*16.42 = 49.26, to L2; 2 * 16.42 = 32.84, and to L3; 3 *16.42= 49.26. These values are then plugged into the triangulation procedure described in the next section, for A to get an estimate location. The drawbacks are that it will only work for isotropic networks, The advantages of the DV-Hop method are simplicity and the fact that it does not depend on range or angle measurement error. The drawbacks are that it will work for isotropic networks that is, when the properties of the graph are the same in all directions, so that the average Hop size that are deployed reasonably estimate the distances between hops. It depends entirely on connectivity of the sensor networks. We can improve this method in two aspects.

1. DV-Hop method employs a distance vector-hop exchange protocol, which measured in hop- count, so the minimum hop count between nodes is very important to the equation computing the average single hop distance. In order to make the

Unknown nodes get the shortest hop distances to every anchor nodes, we must establish a mechanism to control routing refer to Spanning

Tree Protocol (STP) in computer networks.

2. When the anchor nodes broadcast the average single hop distance, we can import a variable to control the lifetime of the broadcast information.

Trilateration Positioning Technology:

When one node to the estimated distance of at least three anchor nodes are known, you can use this method. This simple method is to use three anchor nodes as the center of the circle intersection as the location of the unknown node which is shown in following Figure.

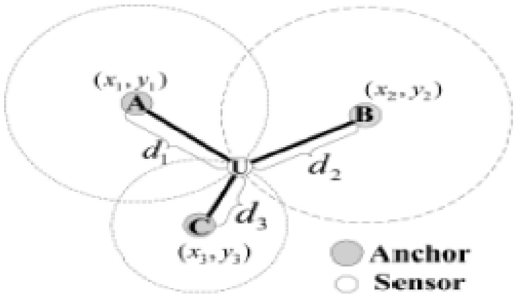

Fig.2. Example of trilateration method.

Positioning of sensors in a WSN can be done by observing the properties of a triangle. The coordinates of any interior point in a triangle can be computed by knowing the coordinates of the three vertices and the corresponding distances to them. More specifically, the location of any interior point in a triangle can be computed by calculating the intersection of three circles. These circles are determined by the vertices' coordinates that act as the centers, and their relative distances to the interior point that act as the radii. Fig.12 shows such an situation, Known A, B, C, The coordinates of three nodes, respectively (x_1, y_1) ,(x_2, y_2) ,(x_3, y_3) And their distance to the unknown node U, respectively d_1,d_2 & d_3 . Assuming the coordinates of the node U(X, Y). Then there exist the following formula: [5]

$\sqrt{(X - x_1)^2 + (Y - y_1}$ =d_1 ---------------------- (1)

$\sqrt{(X - x_2)^2 + (Y - y_2}$ =d_2 ---------------------- (2)

$\sqrt{(X - x_3)^2 + (Y - y_3}$ =d_3 ---------------------- (3)

$(d_1)^2 = (X - x_1)^2 + (Y - y_1)^2$ ---------------------- (4)

$(d_2)^2 = (X - x_2)^2 + (Y - y_2)^2$ ---------------------- (5)

$(d_3)^2 = (X - x_3)^2 + (Y - y_3)^2$ ---------------------- (6)

If we solve the above equation then we get,

$$P = \begin{bmatrix} X \\ Y \end{bmatrix} = (A^T A)^{-1} * (A^T B)$$

Where,

$$A=2 * \begin{bmatrix} (x_1 - x_3) & (y_1 - y_3) \\ (x_2 - x_3) & (y_2 - y_3) \end{bmatrix}$$

$$B=\begin{bmatrix} d_1^2 - d_3^2 - x_1^2 + x_3^2 - y_1^2 + y_3^2 \\ d_2^2 - d_3^2 - x_2^2 + x_3^2 - y_2^2 + y_3^2 \end{bmatrix}$$

IV. SIMULATION RESULT AND PERFORMANCE ANALYSIS

Before positioning algorithm to simulate the first algorithm is based on network architecture and communication model and related parameters to be defined.

Network Structure:

Assuming a two-dimensional wireless sensor network with N sensor nodes, they are uniformly randomly distributed in a square area L*L, in which a small part of the coordinates of the nodes are known by (GPS positioning or manual deployment), known as anchor node (the Beacon node). Suppose communication radius R; the same communications capability of the anchor nodes and unknown nodes, symmetrical communication between nodes to send and receive capability the same.

Simulation with MATLAB software localization algorithm for sensor nodes in wireless sensor networks:

1. Nodes uniformly randomly distributed throughout the network, in accordance with a uniformly distributed random number generator, the coordinates of each node.), (yx).
2. Calculate the hoping between each sensor nodes, then find out the shortest distance between sensors with respect to the hops.
3. Least square method for solving nonlinear equations to obtain the unknown node location.
4. Change the network parameters such as the total number of nodes, communication radius, and anchor node density observation and analysis of the accuracy of DV-Hop algorithm.
5. Once we estimate the coordinates of unknown node, then we can calculate the error value. This is nothing but the difference between estimated locations to the original location. The average error is defined as:

$$error = \frac{\sum_{i=1}^{n}((x_{cal} - x_{real})^2 + (y_{cal} - y_{real})^2)}{n}$$

Case 1:

Border Length = 100;
No. of nodes = 40;
Anchor Nodes = 10;
Unknown Nodes = No. of nodes –Anchor Nodes;
R=60;

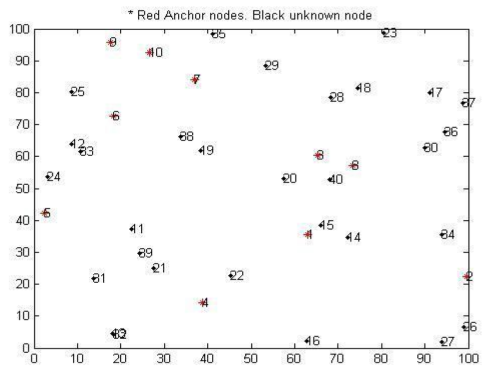

Fig 3. Deployment of 40 nodes in 100*100 meters area

Table 1. Results of Unknown nodes (30) and their corresponding distance (Error)

No. of Un-known Nodes	Error	No. of Un-known Nodes	Error	No. of Un-known Nodes	Error
11	113.44	21	103.25	31	80
12	130.73	22	118.36	32	73.82
13	73.92	23	248.99	33	128.89
14	149.33	24	118.69	34	168.45
15	146.23	25	147.4	35	181.97
16	130.16	26	162.2	36	196.13
17	205.89	27	155.41	37	211.81
18	193.13	28	182.91	38	144.34
19	142.19	29	181.08	39	100.27
20	149.99	30	185.01	40	158.05

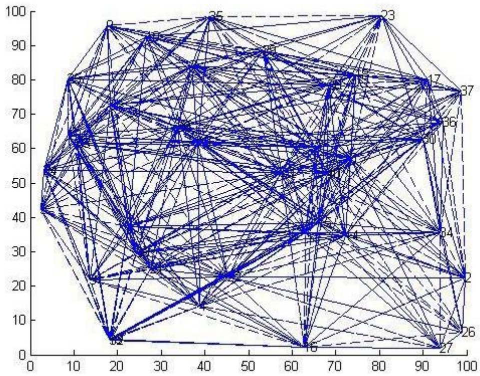

Fig 4. Connectivity of 40 nodes

Now if we take the average of all these error values then, we get the average error , which is near about 149.40

Case 2:

Border Length = 100;
No. of nodes = 100;
Anchor Nodes = 10;
Unknown Nodes= No. of nodes-Anchor Nodes;
R=60;

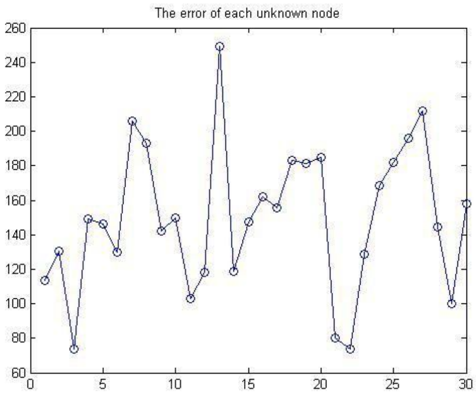

Fig 5. Error of each unknown node

Now if we take the average of all these error values then we get the average error, which is near about 129.68. Therefore, error gets reduced from 149.40 to 129.68 as the number of nodes gets increased.

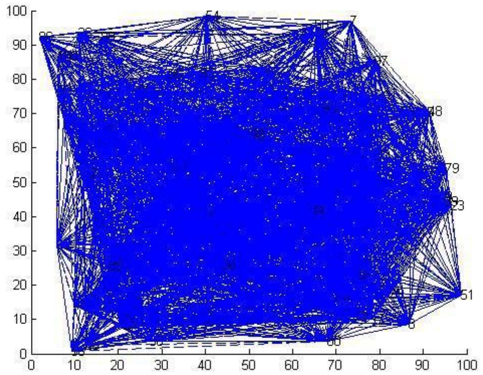

Fig 6. Deployment of 100 nodes in 100*100 meters

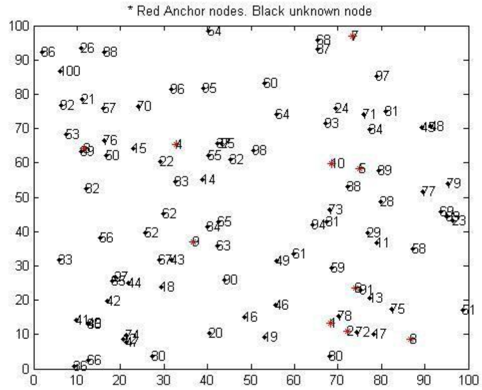

Fig 7. Connectivity of 100 nodes

Table 2. Results of Unknown nodes (90) and their corresponding distance (Error)

No. of Un-Known Nodes	Error	No. of Un-Known Nodes	Error	No. of Un-Known Nodes	Error
71	174.77	81	180.39	91	138.98
72	133.17	82	112.52	92	125.91
73	145.32	83	125.15	93	161.84
74	47.16	84	120.26	94	139.52
75	144.86	85	74.93	95	155.92
76	125.34	86	144.61	96	150.96
77	168.97	87	178.36	97	184.85
78	131.39	88	139.16	98	144.34
79	184.9	89	161.47	99	179.14
80	125.93	90	112.83	100	129.78

No. of Un-Known Nodes	Error	No. of Un-Known Nodes	Error	No. of Un-Known Nodes	Error
11	150.6	31	142.67	51	164.17
12	42.59	32	138.39	52	108.77
13	140.05	33	71.32	53	121.41
14	129.74	34	168.8	54	196.04
15	127.88	35	39.57	55	135.95
16	115.16	36	51.82	56	103.91
17	137.08	37	140.16	57	135.07
18	99.71	38	153.11	58	160.24
19	115.33	39	119.21	59	136.82
20	108.74	40	40.83	60	171.22
21	129.1	41	44.2	61	129.61
22	127.64	42	61.27	62	115.71
23	188.22	43	107.5	63	118.38
24	168.84	44	94.48	64	160.06
25	140.94	45	187.89	65	122.9
26	138.79	46	121.18	66	50.02
27	93.17	47	41.19	67	105.55
28	157.6	48	192.05	68	179.77
29	152.08	49	124.67	69	176.5
30	70.05	50	121.77	70	141.39

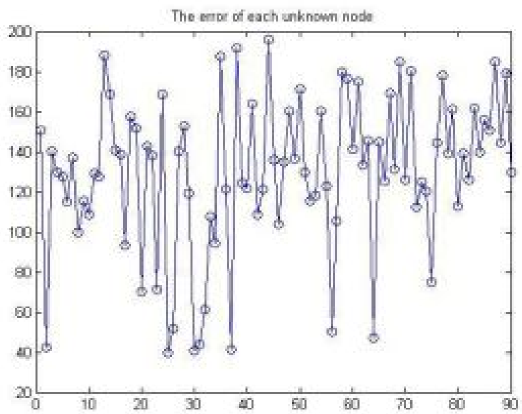

Fig 8. Error of each unknown node

V. MODIFICATION IN DV-HOP ALGORITH

Increased Number of Nodes:

The performance and accuracy of DV-Hop deteriorates if the node distribution is sparse or non uniform. Therefore we increased the total number of nodes and for each total number of nodes we observed the error, which is going to decreased as the number of nodes increased. So Dv-Hop algorithm gives better accuracy for dense network.

Border Length = 100,
No of nodes = 30;% increased the number of nodes by 10 till it reach to 100;
Anchor Nodes = 10; % keep the anchor nodes fixed;
Unknown Nodes = No of nodes –Anchor Nodes'
R=60;

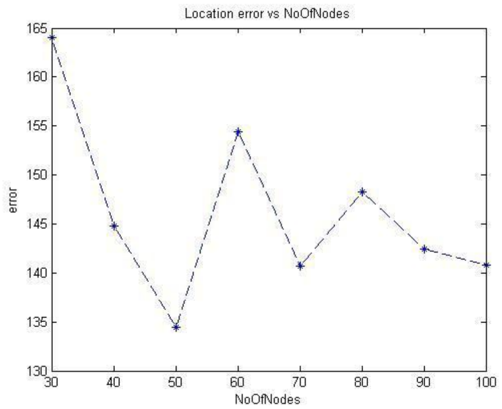

Fig 9. MATLAB result of number of nodes Vs Position error

No Of nodes	position error
30	163.98
40	144.82
50	134.45
60	154.42
70	140.7
80	148.25
90	142.42
100	140.83

No Of nodes	position error
30	163.98
40	144.82

Table.3. Results of Number of nodes and their corresponding position error.

Increased the Anchor Nodes

Increased the anchor node by keeping total number of nodes constant. Therefore, Accuracy is improved as the number of anchor nodes increased. Then calculate the Anchor ratio as fallows.

Observe the graph of position error vs Anchor ratio.

Case 1:

Border Length = 100;
No. of nodes = 100; % keep the number of nodes fixed;
Anchor Nodes = 5; % increased the anchor nodes four times and calculates anchor ratio;
Unknown Nodes = No. of nodes –Anchor Nodes; R=60;

Table 3. Results of Anchor ratio and Position Error

Anchor Ratio	position Error
0.05	158.68
0.1	147.85
0.15	147.14
0.2	147.65

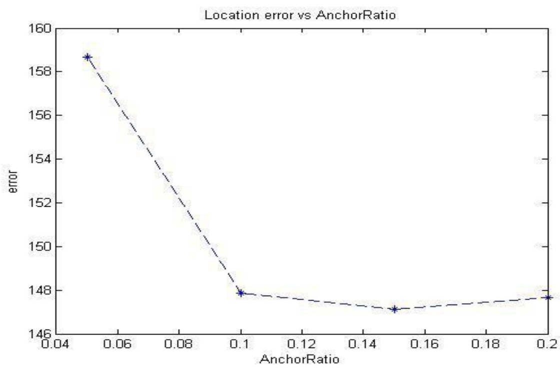

Fig 10. MATLAB result of Anchor Ratio Vs Position error

Case 2:
Border Length = 100;
No of nodes = 30; % keep the number of nodes fixed; Anchor Nodes = 4; % increased the anchor nodes four times and calculates anchor ratio;
Unknown Nodes = No. of nodes –Anchor Nodes;
R=60;
Table 4. Results of Anchor ratio and Position Error

Anchor Ratio	position Error
0.13	158.68
0.26	141.85
0.40	140.14
0.53	136.15

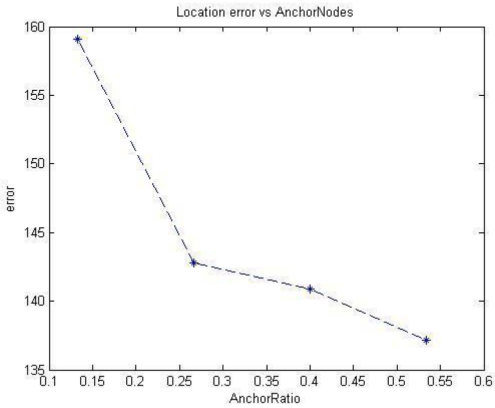

Fig 11. MATLAB result of Anchor Ratio Vs Position error.

VI. CONCLUSION AND FUTURE SCOPE:

For sensed data to be meaningful in a WSN, an estimation of the physical locations for sensors is critical. Here we present Range-free method in that DV-Hop algorithm is used to estimate the position of unknown sensors. A network with a high node density exhibits improved localization performance compared to a sparse network. In sparse WSNs there is a high probability of ill-connected or isolated nodes and in such cases localization accuracy can be degraded substantially. It is always favorable to increase the node density (higher connectivity information means a lower probability of ill-connected networks) to improve the accuracy of localization. There- fore, DV-Hop algorithm is suitable for dense network. However, with increased sensor nodes, the error propagates and accumulates from one hop to the next, which can be a serious problem in WSN localization algorithms. If we increase the anchor nodes it will help to improve the accuracy of localization.

FUTURE SCOPE

The only limitation of DV-Hop algorithm is that, it introduces a lot of traffic load and communication delays in a WSN, due to the fact that it works in two steps. In future scope if we integrates RSSI and DV-Hop algorithm, a new RDV-Hop algorithm is proposed. The new RDV-Hop algorithm makes the unknown nodes which is one hop distance from anchors calculate the distance from it to the neighbor anchors using RSSI method instead of DV-Hop method. Using this method, the estimated error in network is reduced.

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