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An Improvement of Centroid Algorithm Based on Distance in Wireless Sensor Network

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Abstract--In Wireless sensor network (WSN), estimating the exact position of sensor node is an important research problem and its location accuracy impacts the efficiency of localization algorithms. In this paper improved centroid range free localization method is proposed and comparison with conventional centroid is done by varying different parameters such as anchor nodes, communication range and node density. The simulation results show the performance of proposed algorithm is superior to that of the conventional centroid algorithm i.e. proposed centroid algorithm has high position accuracy.

Keywords--Centroid, distance based centroid localization algorithm, range free algorithm, WSN

I. INTRODUCTION

With recent advances in wireless communication and Micro Electro Mechanical System (MEMS) technology, it becomes realistic to construct a tiny sensor node that integrates small size sensor, processor, memory, power supply in it [1]. Sensor node in the WSN is capable of sensing data, collecting and processing it and communicating with other sensor nodes. These small sized sensor nodes are deployed manually or randomly in the area of interest [2]. Such networks have been proposed for many applications such as environment monitoring, habitat monitoring, target tracking, rescue operations etc [3]. For inherent characteristics of these sensor networks make localization an important issue in WSN.

Localization in sensor network is to identify location or position of sensor nodes. Location is required (i) to identify the location from where sensor reading originates, (ii) for communication with other sensing nodes to route data, (iii) when providing other location based services [1, 4]. Nodes in a sensor network are often randomly distributed. To assign measurements to locations, each node has to determine its own position. Many localization techniques have been proposed to provide location information of the unknown sensor node in WSN [5]. We divide these localization protocols into two categories: Range Based and Range Free. For any WSN, the accuracy of its localization technique is highly desired. In range based [6, 10], the location of the sensor node can be determined by the distance or angle estimates. It includes Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA), Received Signal Strength Indicator (RSSI). These methods provide location information with precision but require additional

hardware for computation due to which bulkiness and cost increases [7].

In range free [6, 10], the location is estimated on the basis of hop information. It includes APIT, DV-Hop, Centroid, Amorphous etc. These methods provide approximate location results but are cost effective, consume less energy and do not require any additional hardware due to which more attention is given to range free methods as compared to range based [8].

Centroid, is simple and economic range free localization algorithm [9, 10]. In this method the unknown sensor node localizes itself by calculating the centroid of position of all the adjacent connecting anchor nodes [11], but the estimates of location produces large error [12].

To improve the performance of centroid algorithm, distance based centroid localization algorithm is proposed in this paper. Basic idea behind proposed algorithm is to find distance between the position of anchor nodes and unknown nodes, and with this information location can be estimated with less error. We evaluate the performance of proposed centroid localization algorithm by implementing several simulation experiments by varying different node parameters Here we also compare conventional and proposed centroid algorithm and simulating results demonstrate that the distance based centroid is more efficient and produce less location error.

II. CONVENTIONAL CENTROID ALGORITHM

Bulusu et al. and Heidemann [12] proposed a coarse grained range free localization algorithm, which needs only a minimum of computations. In centroid algorithm, suppose all the nodes know their position, target nodes position should be calculated as the centroid of the nodes' position within their communication range. The main thinking of the algorithm is that the anchor nodes periodically broadcast a beacon signal that contains its own id and localization information to the neighbor nodes. the node determines its own position is the centroid of polygon composed of the anchor nodes.

The algorithm can be implemented as follows [1, 4, 12]:

First: All anchors send beacon periodically to all nodes within their transmission range which contains anchor node id and location information (ID, LocInfo(X_i, Y_i)).

Second: All unknown nodes collect beacon packet received from various reference points or anchor nodes.

Third: All unknown nodes calculate their position coordinates by a centroid determination from all k positions of the anchor (X_i, Y_i) in range using the following centroid formula:

$$(X_{est}, Y_{est}) = \left(\frac{x_1 + x_2 + \dots + x_k}{k}, \frac{y_1 + y_2 + \dots + y_k}{k} \right) \quad (1)$$

(X_{est}, Y_{est}) is estimated location coordinates of unknown node. (x_1, y_1)...(x_k, y_k) is the unknown node that can receive the anchor node coordinate information.

This algorithm is simple in principle with easy realization as well as little communication expense [7], but has high localization error due to this formula stated above in equation (1). In order to solve the problem, the new Centroid algorithm based on distance is presented in next section.

III. IMPROVED DISTANCE BASED CENTROID LOCALIZATION ALGORITHM

The proposed distance based centroid algorithm finds the distance between anchor nodes and the unknown nodes, and uses this distance to calculate weight of the anchor node. With this information, unknown node location can be estimated.

The algorithm can be implemented as follows:
The distance D_i between anchor node and unknown node is calculated. If there is no communication between anchor node and unknown node then the value is zero. We assume that there are n anchor nodes and its position coordinates are (X_i, Y_i) where i ranges from 1 to n. another assumption is that there are m unknown nodes and its position coordinates is (X_j, Y_j) where i ranges from 1 to n.

First: The n anchor nodes send signal that can be received by m unknown nodes. The distance between anchor node and the unknown can be calculated.

Second: The distance based centroid can estimate the coordinates of unknown node by using following formula:

$$X_j = \frac{\sum_{i=1}^n D_i \times X_i}{\sum_{i=1}^n D_i}, \quad Y_j = \frac{\sum_{i=1}^n D_i \times Y_i}{\sum_{i=1}^n D_i}$$

$$(X_i, Y_i) = \frac{d_1 X_1 + d_2 X_2 + \dots + d_i X_i}{d_1 + d_2 + \dots + d_i}, \quad \frac{d_1 Y_1 + d_2 Y_2 + \dots + d_i Y_i}{d_1 + d_2 + \dots + d_i}$$

(2)

(X_i, Y_i) is estimated location coordinates of unknown node. $d_1, d_2, \dots, d_i$ are the weights of n anchor node respectively i.e weight is a function of distance between position of anchor node and unknown node.

IV. COMPARISON SIMULATION AND PERFORMANCE EVALUATION

In our experiment, to evaluate the performance of the proposed algorithm, we have set up the following simulation experiment conditions:

- (i) Unknown sensor nodes are deployed randomly in area of $100 \times 100 \text{ m}^2$.
- (ii) The anchor nodes are distributed grid wise and the number of anchor nodes is set to 49.
- (iii) The radio range of sensor node (r) is set to 30.

Fig 1 represents the position of nodes before and after localization. In this following figure number of anchor nodes are 16, unknown nodes are 50 and communication range is 30m

Fig 1: Node distribution in a network

Here red dots represent UN nodes, blue dots are referred to anchor nodes and red line represents error in calculated location.

In our experiment, we study several system-wide parameters that can affect localization error. These parameters are:

- Anchor Node (AN): These are the nodes whose location is known and in our experiment, values are set to 4,9,16,25,30,49,100 as deployed grid wise.
- Communication Range (R): This is the range or area or the propagation distance to rest of the nodes, and is varied from 20 to 100.
- Node Density (ND): These are total number of nodes in a network. In our experiment, unknown nodes are varied from 50 to 90.

Localization error (e) can be calculated by (3):

$$\text{Error (e)} = \frac{\sqrt{(x_{\text{est}} - x)^2 + (y_{\text{est}} - y)^2}}{R} \quad (3)$$

(x_{est} , y_{est}) is the node's estimated coordinates, (x , y) is the node's real coordinates, R is the communication range.

A. Localization Error when Anchor node is varied:

In this simulation, we analyse the effect of change of number of anchor nodes on the localization error. Localization error is estimated on conventional and proposed centroid algorithm by taking different values of anchor nodes. This is shown in Table 1.

Table 1: Data table of Anchor node v/s localization error (UN=50, R=30)

ANCHOR NODES	LOCALIZATION ERROR	
	CENTROID	WEIGHTED CENTROID
4	1.1419	0.9199
9	0.2849	0.2487
16	0.2219	0.1687
25	0.1492	0.1086
30	0.1166	0.0895
49	0.0906	0.055
100	0.1324	0.0528

Fig 2 shows that estimation error decreases as the number of anchor nodes increases. Centroid localization scheme shows that constantly decrease in localization error as anchor nodes increase. As it can also be observed that proposed centroid algorithm has smaller location error in general with respect to different number of anchor nodes.

Fig 2: Graph represents error w.r.t anchor nodes.

B. Localization Error when communication range is varied:

Table 2 given below shows that how localization error for both the algorithm changes with the change in communication range that is anchor to unknown node range changes.

Table 2: Communication range v/s error (AN=49, UN=50)

COMMUNICATION RANGE	LOCALIZATION ERROR	
	CENTROID	WEIGHTED CENTROID
30	0.1128	0.0509
40	0.1102	0.0548
50	0.1457	0.0629
60	0.1738	0.0815
70	0.1795	0.1045
80	0.2113	0.1225
90	0.2697	0.1397

For above Table 2, Fig 3 is drawn, where graph represents that with the increase in communication range, estimation error increases. This is due to the fact anchor propagation distance result in larger accumulated error. There is significant increase in error with the increase in anchor to node range or communication range (R). Large numbers of anchors nodes are desired for good estimation results. The cost of having such a large percentage of anchors is very high so instead of increasing anchor nodes, we can increase the anchor radio range to which beacons travel. Here we can observe that for proposed algorithm, gained estimation error is least.

Fig 3: Graph represents error w.r.t communication range.

C. Localization Error when node density is varied:

In this, we analyse the effect of node density on the localization error in a network area. Table 3 given below shows the values of node density are varied from 50 to 90 and how change in node density affects the error for both the algorithms of centroid.

Table 3: Data table of Node density v/s localization error (AN=49, R=30m)

NODE DENSITY	LOCALIZATION ERROR	
	CENTROID	WEIGHTED CENTROID
20	0.1184	0.0401
30	0.1057	0.0432
40	0.1022	0.0452
50	0.118	0.0581
60	0.1193	0.0768
70	0.1073	0.0668
80	0.1077	0.0677
90	0.124	0.0663
100	0.1179	0.0718

For above table 3, Fig 4 represents that there is no effect of change in node density on error, as it remains constant throughout, but proposed algorithm has less estimation error as compared to conventional centroid algorithm.

Fig 4: Graph represents node density w.r.t error

V. CONCLUSION

Simulation results are evaluated by varying different node parameters such as anchor node, node density, and communication range. From the simulation curves results we can conclude that our distance based centroid localization algorithm improves the positioning accuracy significantly. The centroid algorithm has large estimation error; it remains independent of node density. In conclusion, improved centroid algorithm demands no additional hardware

VI. SUMMARY AND FUTURE SCOPE

In this paper, we provide the distance based centroid localization algorithm, through appropriate enhance complexity of the original centroid algorithm. It achieves good localization performance, but it remains difficult to realize accurate localization. To reduce the complexity of the algorithm and to save the cost of localization algorithm are the most common problems.

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