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RESEARCH ARTICLE

An Enhancement in Centroid Algorithm in Range-free Grid Based Environment for Wireless Sensor Networks

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Abstract— ***Localization is a prominent part of the Wireless Sensor Networks (WSN), as without the location information, messages are bound to be invalid on network. Various techniques have been introduced to localize the unknown nodes in the network. The efficiency of localization algorithms depend on the accuracy of localizing the nodes, precisely. The anchor nodes are always limited because of hardware restrictions like energy consumptions, cost etc. The primary objective of this task is to achieve the least localization error. In order to achieve this objective, centroid algorithm is refined in the grid environment. The grid environment provides a regular deployment of the anchor nodes. The derived technique uses the concept of weight and distance to improve the accuracy and the simulation results manifest the superior performance.***

Keywords— Localization; Anchor nodes; Centroid; Unknown nodes; Grid deployment

I. Introduction

Wireless Sensor Networks (WSNs) comprises of sensor nodes, competent of gathering information from environment like temperature, humidity, vibrations, sound light etc. In significant applications, to know the node's geographical position as soon as possible is very important to report the incident. There are many node localization algorithms with different accuracies and approaches. An optimal localization algorithm should calculate the position of the sensor node quick and must not be affected by environmental influences and imprecise distances.

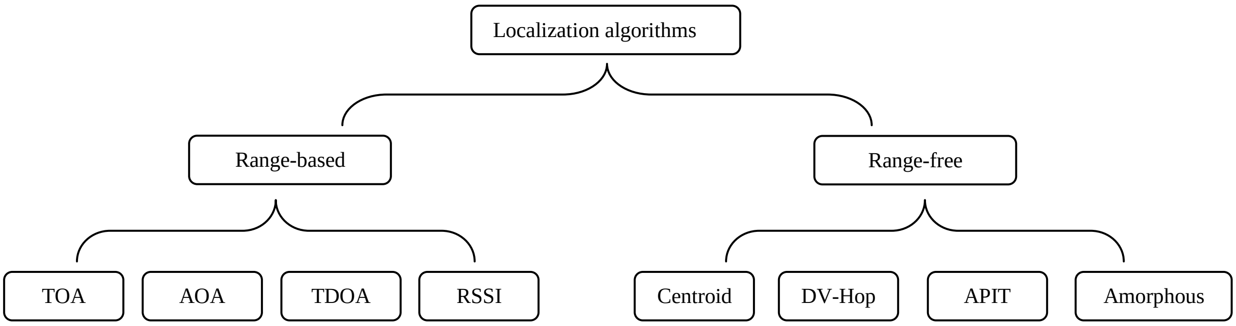


Fig. 1 Categories of localization algorithm

Broadly localization algorithms are classified in two categories: range-based and range-free. The former has highly localization accuracy, but they usually require more hardware in order to measure the distance between sensor nodes so these algorithms are not cost effective. The latter not measure the distance or angle information between unknown nodes and landmarks, which estimate the distance between two nodes by the connectivity information. The range-based algorithms use the TOA, AOA, RSSI [1][8]techniques for the distance measurements, whereas range-free algorithms use only proximity information. Adding hardware to each sensor node for localization is a very expensive solution and impractical. There are severe constraints for using the hardware for the localization purpose.

II. RELATED WORK

Bulusu et. al [2] proposed a range-free node localization algorithm which only needs the proximity information. In his centroid algorithm few anchor nodes are deployed in the network and then anchor nodes periodically broadcast a beacon signal which contains node's ID and other needed information to the neighbor nodes. The unknown node estimates its position by calculating the centroid of the region of those anchors in range of the unknown node.

The algorithm gets the estimated postion by determining centroid of the anchors in range of the unknown node as in the formula (1). Here, $E(x,y)$ is the estimated position of the unknown sensor node, whereas $A(x_i, y_i)$ *re*presents the position of anchor nodes. The number of anchors in the range of unknown node is indicated by *K.*

$$E(x,y) = \frac{1}{K}\sum_{i=1}^{n} A(x_{i,}, y_i) \tag{1}$$

Centroid algorithm is easy and economic range-free algorithm to identify the position of unknown node. It calculates the centroid as the position to localize the unknown nodes regardless of distance between the anchors and unknown nodes, but the estimated position produces high localization error. Sometimes if two nodes at different position communicate with the same group of anchors, the result will calculate the common centroid for both which is not correct.

The localization error is calculated as the difference in the estimated position (X_{est}, Y_{est}) and the actual position (X_{act}, Y_{act}) of the unknown nodes.

$$LE = \sqrt{(X_{est} - X_{act})^2 + (Y_{est} - Y_{act})^2} \tag{2}$$

The centroid algorithm is improved in the various ways. A general technique used to improve the algorithm is of adding the concept of weights. This concept does not blindfolded average the coordinates of the beacon nodes to localize them. It uses weights to ensure an improved localization technique. Beginning from the previous calculation of the centroid, the formula is derived.

In the new derived equation [8], *n* is the number of anchors in the beacon range of unknown node. The estimated position and anchor nodes are presented as earlier $E(x, y)$ and $A(x_i, y_i)$. Here w_{ij} is the weight functions.

$$E(x,y) = \frac{\sum_{i=1}^{n}(w_{ij} \times A(x_i, y_i))}{\sum_{i=1}^{n} w_{ij}} \tag{3}$$

The weight W_{ij} is the function depending on the distance and the other characteristics of the sensor nodes receivers. Each and every environment acquires a different weight to different scenarios and conditions. In this scenario of weighted centroid algorithm shorter distance acquire more weight than the longer ones. Hence the weight (w_{ij}) and distance (d_{ij}) are inversely proportional to each other. In an approximation the correlation is equivalent function of $1/d$. the longer distance are marginally given lower weights with the raised power of *g*. exactly d_{ij} is the distance between beacon and the sensor node. And *g* is the degree [7].

$$w_{ij} = \frac{1}{(d_{ij})^g} \tag{4}$$

III. PROPOSED WORK

In this paper, unknown nodes are not mandatory one hop neighbour to the anchors and also we don't need any measurement technique like AOA, RSSI etc. rather just use the connectivity information that which node is in communication range of the other to calculate the location of the unknown sensor node. In the proposed testing methodology, two assumptions are made for the idealized model on centroid algorithm based on range free localization procedure.

1. Perfect spherical radio propagation.
2. Identical radio range of all sensor nodes.

In the centroid algorithm, we have to deploy anchors or reference nodes within applied field where the unknown nodes deploy randomly in the specified coverage field. After deploying anchor and unknown nodes, anchors start transmission of beacons with a defined range. Within the coverage region non-anchor node receives beacons and process the information handed over by anchors. After that it calculates its centroid by multitrilatration property with the help of anchors coordinated within the closed proximity. The closed proximity depends upon the ranges of neighbour anchors to unknown sensor node.

In the present scenario, we developed a framework for deployment of reference nodes. The anchor nodes are deployed in a regular shape, i.e. in a grid format. The unknown nodes are deployed randomly in the network.

Both of the techniques are applied in the Grid based deployment to check whether the improvement in the weighted centroid algorithm performs better than the conventional centroid algorithm.

IV. SIMULATION RESULTS

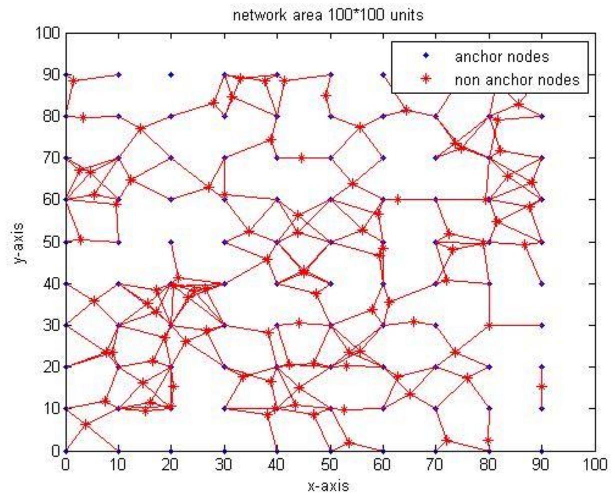
Grid Based Deployment

A framework of regular anchor node is deployed. The anchor nodes are at the grid points. The anchor's communication range is varied with the proximity range for the different scenarios. The same procedure is repeated for various ranges and grid sizes.

We setup the following simulation experiment conditions:-

a) The anchor nodes are deployed on grid basis

b) The unknown nodes are deployed randomly in 100m X 100m network.



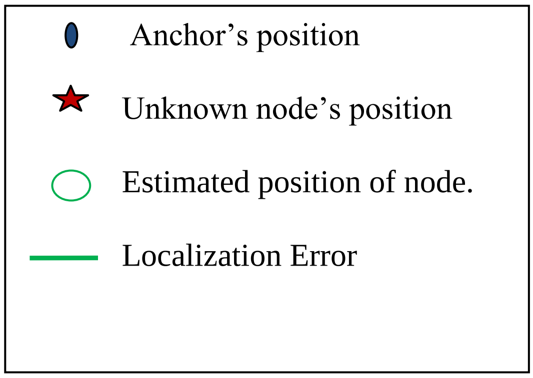


Fig 1. Unknown node's enclosed be surrounding anchors

Fig 1 represents the unknown nodes deployed in the network and nodes in range of the anchors, i.e. which unknown sensor nodes are enclosed by anchor nodes. Here the range of nodes is kept equal to the distance between the adjacent grid point anchor nodes. Different unknown sensor nodes are in the range of different number of anchor nodes. Presently an unknown node is enclosed by maximum four anchors.

Fig. 2 represents the conventional centroid algorithm in which 100 unknown nodes are randomly deployed with same number of anchor nodes with the communication range of 10 units. In the Fig 3, the localization error of conventional centroid algorithm is simulated, the highest error was 0.4347 and the mean localization error of 100 nodes was 0.2271.

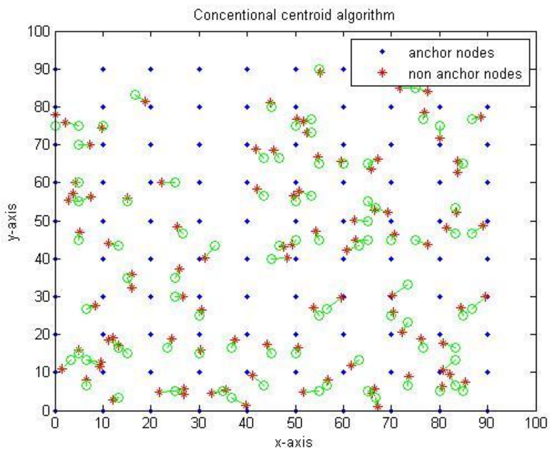


Fig. 2 Conventional centroid algorithm

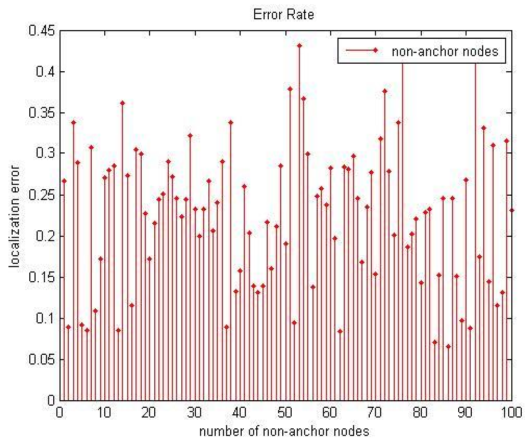


Fig. 3 Error rate of Conventional algorithm

For the higher efficiency this localization error should be minimum. The conventional technique performed simply but there are still drawbacks in it as it cannot separately localize the unknown node under same anchors. This drawback will not be in the enhanced centroid algorithm as the different distance leads to the different weights, so does the localization error.

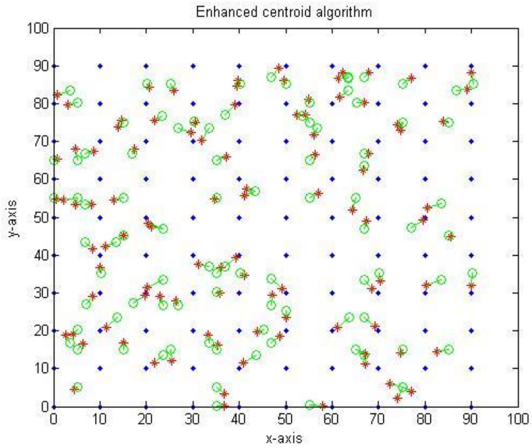


Fig. 4 Enhanced centroid algorithm

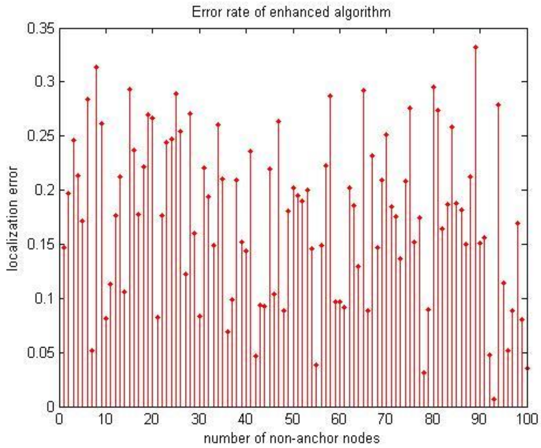


Fig. 5 Error rate of Enhanced algorithm

The enhanced centroid algorithm is simulated(Fig 4) in which the concept of weights are applied to improve the technique and its localization error is simulated in fig 5. Now the maximum error was 0.3319 and the mean was 0.1851. Hence the enhanced approach was better.

The two techniques performed differently under the same scenario and produced different results as the localization error is the key factor in judgement of the result.

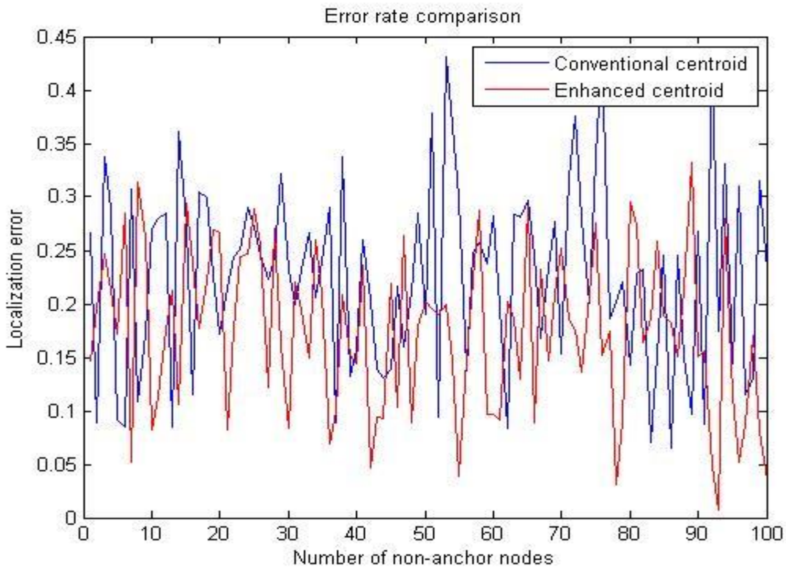


Fig. 6 Error rate comparison

The fig 6 represents the comparison of both techniques and the results shows that enhanced technique performs better in the grid based deployment of anchor nodes. The distance and the degree of the nodes decides the localization error, so the proper weighing functions are to be applied on this.

V. CONCLUSION AND FUTURE SCOPE

In wireless sensor networks, localization is a vital field which is developing. The anchors are deployed in various environments for the validation of the efficiency of the various enhancements in the conventional techniques. In our present scenario the enhanced technique performed better in the grid based deployment. However, there is still scope in the development to mitigate this localization error to further extent. Anchor nodes can also be deployed randomly. In future we would like to simulate the scenario in noisy environment or to add the distance estimation concept with weights.

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