# Combined Circle intersection with Weighted Centroid method for localization of sensor nodes in Wireless Sensor Network

Mohan Kumar. J[1], Jeane Marina D' Souza[2] , Dr. P.R Venketeshwaran[3], Dr. Gopalakrishna Kini[4] and M. Madhusudan Reddy[5].

***Abstract*—** Wireless Sensor Networks (WSNs) are being used for a large number of location-dependent applications, where the measurement data is meaningless without accurate location of its origin. In many of these applications, where coarse accuracy is sufficient, range free localization techniques are being pursued as low cost alternative to the range based localization techniques. Localization in WSNs is to determine the physical position of a sensor node based on the known positions of other sensor nodes having a priori knowledge of their position. In this paper, we present range free Circle weighted centroid localization. It's an effective geometric algorithm for localization. Result of implementation show that this algorithm can be a better substitution for current methods because of lower expense and simple implementation. In these proposed techniques the weights of anchor nodes are obtained according to their proximity to the sensor nodes. We compared the proposed techniques, through extensive simulation with simple centroid and weighted centroid methods. The simulation results demonstrate the effectiveness of proposed schemes.

***Keywords*—**Centroid localization, Edge weight, circle intersection, Range-free localization, Wireless sensor networks.

## I. Introduction

WIRELESS sensor network is a network consisting of thousands of sensors within a particular area. These sensors are able to communicate with each other. They can detect different objects, collect information, and transmit messages. Nowadays, sensor network technologies have become very important especially for applications such as environmental monitoring, military systems, and disaster management. Despite many advantages, these sensors are usually small in size and have many physical limitations. For instance, in many applications it is crucial to know a node's location. Clearly, the most accurate and reliable way to obtain this information is to equip each node with a GPS receiver However, this method is expensive and not feasible for sensor nodes due to the power constraint. To solve this constraint, researchers have developed many localization methods in which instead of requiring every node to have GPS installed, only a few nodes are equipped with GPS hardware. These nodes are called anchor nodes and they know their exact positions. Other normal sensors then obtain distance information through talking to each other and derive their positions based on the information. Two main methodologies of distributed localization are range-based and range-free localization. Range-based localization [1], are hardware intensive methods which localize a sensor node using techniques such as time of arrival (TOA), time difference of arrival of two different signals (TDOA), and angle of arrival (AOA).

Although the range-free approaches [2],[4] normally produce less accurate location results than the range-based approaches, they are more economic and provide simpler estimates. Bulusu et al. presented a range-free, proximity based localization algorithm [2]. In his method, the anchor nodes broadcast their position and each sensor node computes its position as a centroid of the positions of all the connected anchor nodes to itself. This method is simple and economic but it contains a large amount of error. Kim and Kwon [4] proposed an improved version of [2]. In their method, anchor nodes are weighted according to their proximity to the sensor nodes, and each sensor node computes its position as a weighted centroid of the positions of all connected anchor nodes to itself. This method has less error than the previous one but its performance is highly related to the design of the weights while the choice of the weights is heuristic. Sukhyun Yun et al. [5] presented some intelligent localization approaches to improve accuracy of position estimation.

In this paper we propose range free localization techniques for WSNs based on circle intersection combined with weighted centroid algorithm. This algorithm works based on the number of reference nodes having the each sensor node. Circle intersection method is applicable, when the reference nodes of the sensor node are three or more than three. Weighted centroid method is applicable, when the reference nodes of the sensor node are two or less than two. The weights of anchor nodes have been obtained based on the received signal strength information (RSSI), which requires no additional hardware in sensor node as it is available as part of physical layer of sensor node.

Manuscript sent on August 25, 2012. This work was supported in part by the Dept. of Instrumentation and Control Engineering, Manipal Institute of Technology and Manipal Centre for Information Sciences, Manipal.

1- Manipal Centre for Information Sciences, Manipal
2,4 & 5-Manipal Institute of Technology, Manipal
3-Welding Research Institute, Tiruchirappalli.

The rest of the paper is organized as follows: In section 2, centroid method and weighted centroid method is introduced. In section 3 proposed localization techniques is presented. In Section 4, simulation environment and results are discussed. Finally, conclusions are drawn in Section 5.

## II. Background

### 2.1 Centroid Localization

Centroid localization technique uses the knowledge of adjacent connected anchor node position ($X_i$ , $Y_i$) to estimate the location of sensor node . In this method, the anchor nodes transmit a beacon containing their respective location information. The sensor node computes its position as centroid of the positions of all the adjacent connected anchor nodes to itself

$$(X_{est}, Y_{est}) = \left(\frac{(X_1+X_2+\cdots X_n)}{n}, \frac{(Y_1+Y_2+\cdots+Y_n)}{n}\right)$$

Where $(X_{est}, Y_{est})$ represents the estimated position of the sensor node and N is the number of adjacent connected anchor nodes to the sensor node. The method of location estimation using centroid algorithm is very simple and economic, but the results shows that location estimation error is very large in this method and is unacceptable in case of application requiring accurate localization of sensor nodes.

### 2.2 Weighted Centroid Localization

An improved version of centroid algorithm is weighted centroid method [5]. In this method, location of sensor node is calculated by edge weights of anchor nodes connected to the sensor node, and each sensor node computes its position by:

$$(X_{est}, Y_{est}) \left( \frac{W_1.X_1+\cdots+W_n.X_n}{\sum_{i=1}^{n} W_i}, \frac{W_1.Y_1+\cdots+W_n}{\sum_{i=1}^{n} W_i}\right)$$

Where $W_i$ is the edge weight of $i$ anchor node connected to the sensor node. The edge weight is decided based upon the proximity of anchor node to the sensor node. Performance of this approach highly depends on the optimization of edge weights.

## III. Proposed Circle Intersection & Weighted Centroid Method

In the proposed method, we are finding the exact position of sensor nodes using circle intersection method. Anchor node having a limited propagation range, it will be heard from any node inside a circle centered on the emitting anchor node. However, the circle approach is close to the reality. An implemented approach was the circles intersection. Each node listens to the beacons in his neighborhood, and collects their position. As the beacon range is known, the node applies a simple algorithm: the node will here compute the intersection of all the broadcasting circles of the nodes he hears, and computes the intersection of the circles.

### 3.1 Finding the adjacent reference nodes

WSN consists of a set of sensor nodes deployed randomly in vast area to monitor the parameters of interest. These nodes can be categorized as: anchor nodes and normal sensor nodes. Anchor nodes are special type of nodes embedded with GPS or other facility to obtain their position within the network. If feasible these nodes can also be placed manually at known positions within the network. The position of anchor nodes is assumed as ($X_1$,$Y_1$), ($X_2$,$Y_2$),...,($X_n$, $Y_n$). Anchor nodes transmit periodic beacon signals containing their respective positions with overlapped region of coverage. Sensor nodes are deployed in the sensing field, with randomly distributed positions. These sensor nodes locate themselves with the help of beacon signals, transmitted by the anchor nodes. Each sensor node collects the RSS information of all connected adjacent anchor nodes through beacon signal and RSSI is used to obtain the edge weight of the anchor node for weighted centroid localization. Following assumptions have been made:

- The anchor nodes know their positions through GPS or by other means such as pre-configuration.
- TDM technique is used to avoid interference of beacons transmitted by anchor nodes.
- The radio propagation is perfectly spherical and the transmission ranges for all radios are identical

### 3.2 Circle intersection & weighted centroid Method

In this method, the accurate position of the sensor node found out with help of Circle Intersection Method[6]. The distance of the sensor node from the anchor node becomes radius of the circle. Similarly we draw for the other three nearest anchor nodes (reference nodes). The intersection point of these circles will give accurate position of the sensor node. When distance of a sensor node is known only from two anchor nodes, then ambiguity in circle intersection method is removed by weighted centroid method. Circle intersection method shown in Fig1.

Combination of these two methods improves the accuracy of the results.

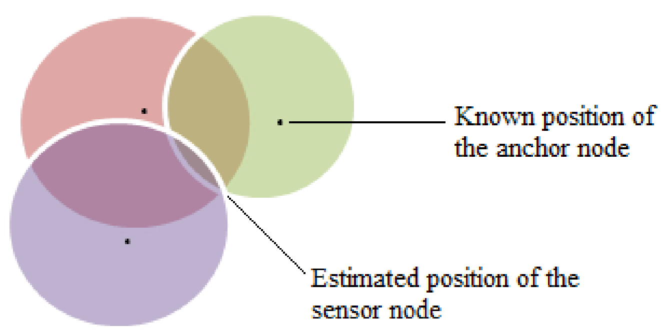


Fig.1.Circle Intersection Method

For example ($X_1$, $Y_1$), ($X_2$, $Y_2$) and ($X_3$, $Y_3$) are the position of the reference nodes. The distance between the sensor node and three reference nodes is less i.e. (<=8.94m). These distances are radius of the circles. The intersection point of these circles is the exact position of the sensor node.

### *3.3 Computing localization error*

We characterize the accuracy of the estimate by localization error *LE*. Let $(X_{est}, Y_{est})$ be the estimated coordinates of the node, and $(X_a, Y_a)$ be its real coordinates. The difference between the estimated coordinate and the real coordinate is:

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

In this paper, the localization error is expressed in meters.

## IV. Simulation Results

MATLAB has been used for performance evaluation of the proposed schemes in the simulation experiments with following primary network parameters:

60 sensor nodes with unknown position and 121 anchor nodes with known position are distributed randomly with in 10mX10m area. The transmission range of all anchor nodes is assumed to be 8.94 m. A sensor node is assumed to be in the proximity of adjacent anchor nodes if its distance from the anchor node is smaller than the transmission range.

In this paper, we have simulated three existing localization techniques for comparison with two proposed localization techniques. Same simulation setup has been used for all the techniques for comparison of results. Following localization techniques have been simulated: A) the simple centroid approach, B) the weighted centroid approach, C) the combination of circle intersection and weighted centroid method approach. Fig 2 shows the simulation setup.

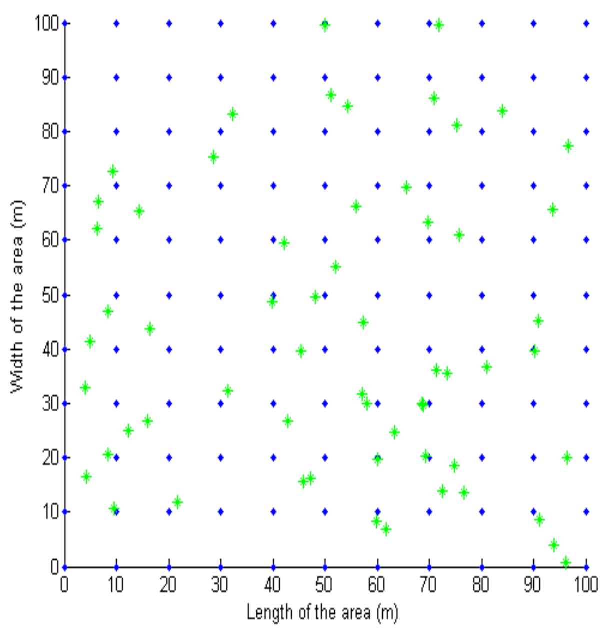


Fig.2.Nodes distribution

Fig. 2.shows the distribution of the sensor nodes and Anchor nodes

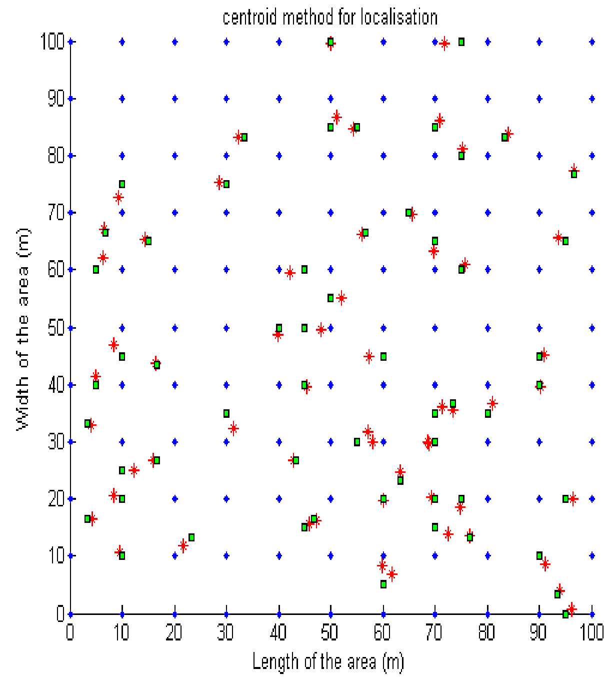


Fig.3 Location Estimation Results (Centroid Method)

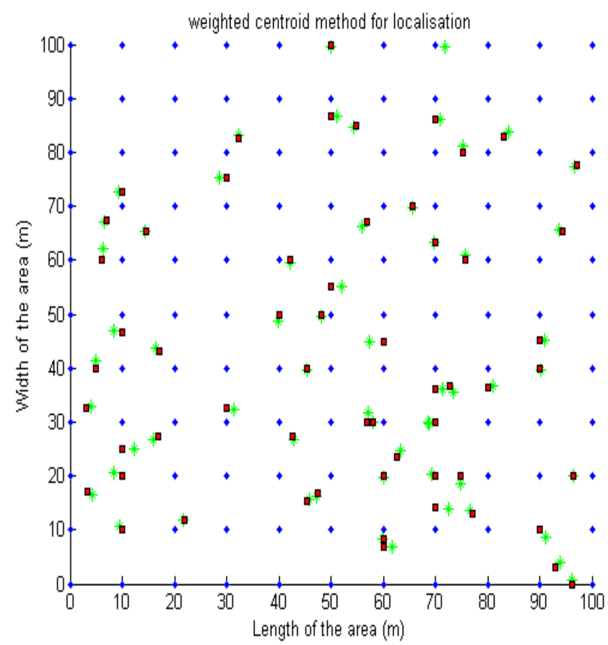


Fig.4.Location Estimation Results (Weighted Centroid Method)

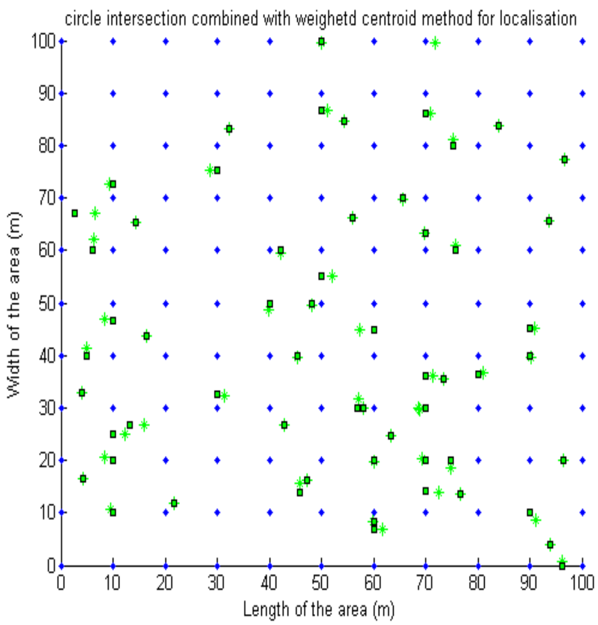


Fig.5.Location Estimation Results (Proposed Method)

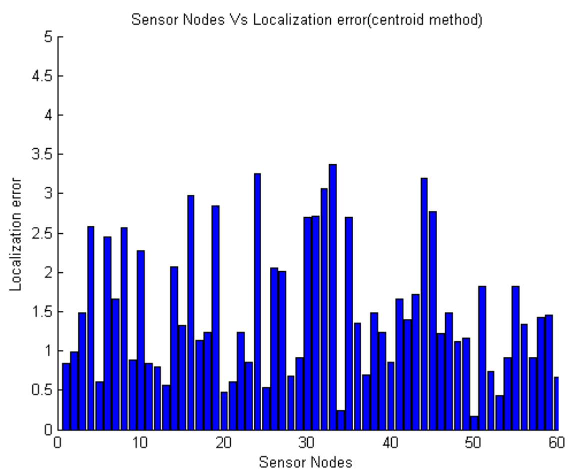


Fig.6. Error Results (Centroid Method)

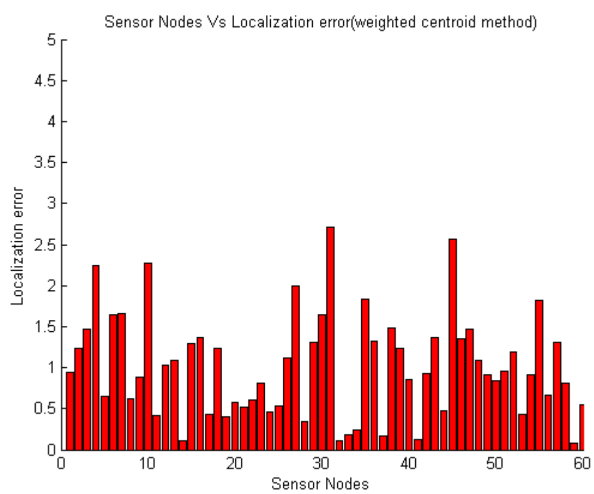


Fig.7.Error Results (Weighted Centroid Method)

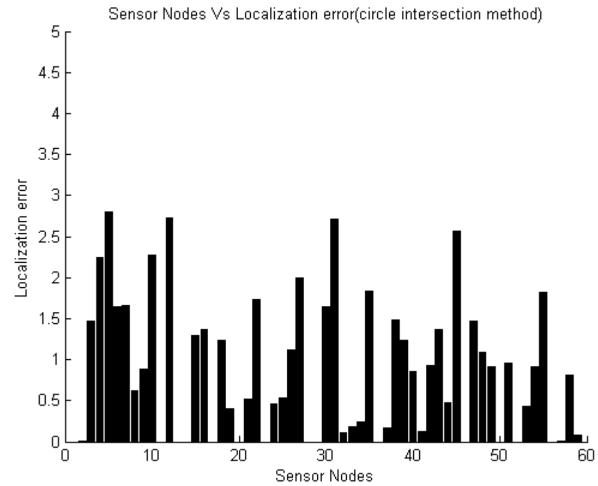


Fig.8.Error Results (proposed method)

TABLE I
COMPARISON OF SIMULATION RESULTS

| Methods | Max. Error | Min. Error | Average Error |
|---|---|---|---|
| Centroid | 3.2531 | 0.2401 | 1.708685 |
| Weighted Centroid | 2.7135 | 0.0797 | 1.015261 |
| Circle Intersection&weighted | 2.7135 | 0.0000 | 0.871842 |

## V. CONCLUSIONS

In this paper, one range free localization scheme for wireless sensor networks (WSNs) is presented. In our proposed method, the sensor nodes do not need any complicated hardware to obtain the distance or TOA/AOA information. The sensor nodes can estimate their positions with the weights of neighbor anchor nodes and intersection of circle (reference node) method.
The above proposed method is very simple and effective. It is an extension of the weighted centroid method.

## REFERENCES

[1].Bahl & padmanabhan, V.N. (2000). RADAR: An in building RF-based user location and tracking system. In proceedings of the IEEE INFOCOM 2000,*tel aviv,isral,march*

[2].N.Bulusu, J. Heidemann, and D. Estrin, "GPS-less low cost outdoor localization for very small devises",*IEEE personal communication Magazine, Vol 7,pp.*28-34, Oct.2008 .[3].Yun, J. Lee, W. Chung E. Kim, "Centroid localization method in wireless sensor networks using TSK fuzzy modelling," *internatuonal symposium on advanced intelligent systems,pp.*971-974,2008.

[4].S.Y.Kim, O.H.Kown, "Location estimation based on edge weights in wireless sensor networks," *journal of korea information and communication society* ,vol.30,2005.

[5].Y.Sukhyun, L.jaehun, and wooyong, "A soft computing approach to localization in wireless sensor networks," *expert system with applications*, Vol.36, pp.7552-7561,2009.

[6].Fatemech.N&Mohammad, "Improved Circles Intersection Algorithm for Localization in WSN", *11th ACIS international conference on Software Engineering*, 2010.

[7].Zhi liu ,Han-xiong , "A probabilistic fuzzy logic system for modeling control." *IEEE Trans. Fuzzy systems, Vol.*13, pp 848-859, 2005.