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Localization in WSN Using Modified Trilateration Based on Fuzzy Optimization

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***Abstract-** Localization is a fundamental problem in Wireless Sensor Networks (WSNs) and is more challenging in the mobile sensor network than in the static sensor network. In a system formed by hundreds of sensors deployed in a large area, it is important to know the position of each sensor. This information can be calculated using either of the several localization algorithms. This paper proposed a novel fuzzy based algorithm to solve the trilateration problem(i.e. when the node is in the overlapping region of circles) in WSNs, with the objective of estimating the location of sensors according to the knowledge of the position of some reference nodes. This algorithm, called modified trilateration (Using fuzzy optimization and centroid technique) is executed along a wireless sensor network formed by hundreds of nodes. The evaluation of Modified Trilateration is led by simulation tests. The result obtained shows that proposed algorithm is a promising method that can easily solve the problem of knowing where the sensors are located with less error as compared to simple weighted centroid technique.*

***Key Words-** GPS, localisation, Wireless sensor network (WSN), centroid, fuzzy logic, received signal strength indicator (RSSI).*

I. Introduction

Wireless sensor networks are often deployed in an ad hoc fashion, that is, their location is not known a priori. Localization is necessary to provide a physical context to sensor readings. Without knowing the position of a sensor node, its information will only tell a part of the story. For example, sensors deployed in a forest to raise alarms whenever wild fires occur, gain significantly in value if they are able to report the spatial relationship between them and the monitored event otherwise information is meaningless. On the other hand, some applications require the position of the node itself, for example, a vehicle tracking system [1]. This is why localization is one of the crucial issues in WSN research. Localization refers to the process of estimating and computing the positions of sensor nodes [2]. The importance of these facts directs researchers to look for a solution for localization problem. One easy way is manual configuration but this is impractical in large scale networks or when sensors are deployed in inaccessible areas such as volcanoes or when sensors are mobile. Another way is to add external hardware- global positioning system (GPS)- to each sensor. In many cases it is impossible to use specific localization devices, like a GPS, because these devices have huge energy consumption and significantly reduce autonomy. Also the additional cost is a setback for these devices to be used on a large scale. In other applications it is necessary to have nodes inside buildings, where GPS technology does not work precisely [3]. Therefore, several localization algorithms have been introduced to solve localization problem. Sensor network localization algorithms estimate the locations of sensors with initially unknown location information by using knowledge of the absolute positions of a few sensors and inter- sensor measurements such as distance and bearing measurements. The sensor nodes with globally known location i.e. equipped with an external hardware (GPS) or by installing sensor nodes at points with known coordinates are known as anchor nodes. In applications requiring a global coordinate system, these anchors will determine the location of the sensor network in the global coordinate system. Because of constraints on the size and cost of sensors, energy consumption, implementation environment (e.g., GPS is not accessible in some environments) and the deployment of sensors (e.g., sensor nodes may be randomly scattered in the region), most sensors do not know their locations. These sensors with unknown location information are called non-anchor nodes and their coordinates will be estimated by the sensor network localization algorithm. Localization algorithms can be divided into two categories: range-based localization methods and range-free localization methods. Range-based localization depends on the assumption that the absolute distance between a sender and a receiver can be estimated by received signal strength or by the time-of-flight of communication signal from the sender to the receiver. The accuracy of such estimation, however, is subject to the transmission medium and surrounding environment and usually relies on complex hardware. In contrast, range-free localization never tries to estimate the absolute point-to-point distance based on received signal strength. As such, the design of hardware can be greatly simplified, making rang-free localization very appealing for WSNs. Reference nodes with pre-knowledge of the locations of themselves are also commonly used in the range-free localization methods. Performance of the localization algorithms can be improved either by using optimization techniques such as fuzzy logic [4-8], Monte Carlo optimization [9], neural network [10,11] etc. or by combining the localization algorithms [12,13]. The main contribution of this paper is the presentation of a novel localization algorithm based on fuzzy logic processing, called Modified Trilateration. The proposed algorithm takes into account the need to keep the average location error low. The rest of this paper is organized as follows: Section II sums up the trilateration, centroid and fuzzy logic. Section III describes Modified Trilateration. The outcome of proposed algorithm performance is developed by simulations in section IV. Finally, in Section V we present concluding remarks and provide discussion for future work.

II. Modified Trilateration

A. Trilateration

Trilateration refers to the process of calculating a node's position based on measured distances between itself and a number of anchor points with known locations. Given the location of an anchor and a sensor's distance to the anchor (e.g., estimated through RSS measurements), it is known that the sensor must be positioned somewhere along the circumference of a circle centered at the anchor's position with a radius equal to the sensor–anchor distance. In two-dimensional space, distance measurements from at least three non collinear anchors are required to obtain a unique location (i.e., the intersection of three circles). In three dimensions, distance measurements to at least four non coplanar anchors are required. In this technique there are two cases:

- The non anchor node may be at the intersection of 3 circles drawn by three non collinear anchors as shown in figure 1.

- The non anchor node may in the overlapping region of 3 circles drawn by three non collinear anchors i.e. three anchor nodes circles are not intersecting at a common point as shown in figure 2.

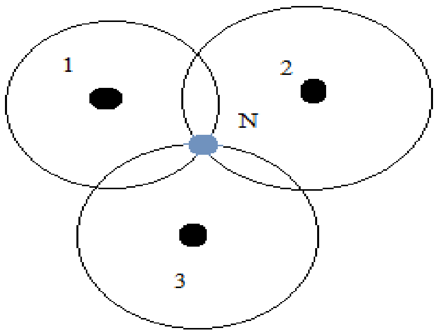

Fig 1: Trilateration

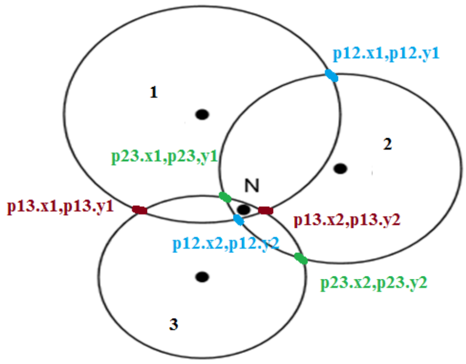

Fig. 2: Trilateration problem [14]

Where 1,2,3 are anchor nodes and N is non anchor node

B. Trilateration Problem

Trilateration problem occur in 2-D WSN localization, when unknown node is not at the intersection of 3 non collinear anchor nodes. A node N is the non anchor node whose position is unknown. Location of node N is estimated with the help of three anchor nodes 1, 2 and 3. The trilateration problem is to find the coordinates of node N= (x_{est} , y_{est}) from the given information. Draw a circle of radius equal to the distance between anchor non anchor nodes estimated through RSSI taking anchor as center of circle. Similarly circles are drawn around anchor 2 and anchor 3. Since the circles centers and radii are subject to measurement errors, the circles will overlap in a (hopefully small) region rather than intersecting at a single point the unknown node location N is somewhere in this region. Each pair of circles yields two intersection points as shown in figure 2. With three circles, there are six intersection points. Three of these points are clustered closely together, while the rest are far apart. The node N is located in the middle of this cluster. Now, to resolve that error centroid technique and fuzzy optimization is used. Their explanations are given the next sections.

C. Fundamental Centroid

After finding the innermost intersection points fundamental centroid technique [15] is applied to calculate the position of non anchor node. The task of the centroid method is to take several node around the unknown nodes as polygon vertices and the unknown node as the centroid of polygon which is indicated in figure 3.

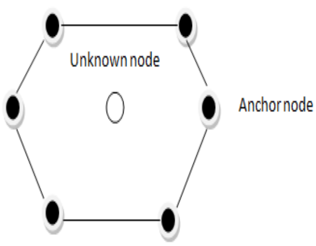

Fig. 3: Centroid technique

After receiving the message, there is a relation for estimating the coordinates of unknown node as given in equation 1:

$$(x_{est,}\, y_{est}) = \left(\frac{x_1 \ldots\ldots x_n}{n}, \frac{y_1 + \cdots y_n}{n}\right) \quad (1)$$

Where ($x_{est,}$ y_{est}) indicates the estimated position of the sensor nodes. Equation 1 is general equation for n nodes; in case of trilateration n is 3 i.e. innermost three intersection points. The result is simple but is not sufficient for correct estimating position so, to optimize the result fuzzy logic is used.

D. Fuzzy Logic

Fuzzy logic is defined as the logic of human thought. Fuzzy logic offers several unique features that make it a particularly good alternative for many control problems. It is inherently robust since it does not require precise, noise free inputs and can be programmed to fail safely [16-19]. Fuzzy logic deals with the analysis of information by using fuzzy sets, each of which may represent a linguistic term like "low", "High", etc. Fuzzy sets are described by the range of real values over which the set is mapped, called domain, and the membership function. A membership function assigns a truth value between 0 and 1 to each point in the fuzzy set's domain. Various types of fuzzy sets can be used such as triangular, beta, PI, Gaussian, sigmoid, etc [20] depending upon the shape of the membership function,. A Fuzzy system basically consists of three parts: fuzzifier, inference engine, and defuzzifier. The fuzzifier maps each crisp input value to the corresponding fuzzy sets and thus assigns it a truth value or degree of membership for each fuzzy set. The fuzzified values are processed by the fuzzy inference engine, which consists of a rule base and a range of methods for inferring the rules. The rule base is simply a series of IF-THEN rules that relate the input fuzzy variables with the output fuzzy variables using linguistic variables, each of which is described by a fuzzy set, and fuzzy implication operators AND, OR, etc. The part of a fuzzy rule before THEN is called predicate or antecedent, while the part following THEN is referred to as consequent. The combined truth of the predicate is determined by implication rules such as MIN-MAX and bounded arithmetic sums. All the rules in the rule-base are processed in a parallel manner by the fuzzy inference engine. There are five step to process the fuzzy inference such as fuzzification of the input values, using the fuzzy operator like AND or OR in antecedent, implication from condition to consequent, aggregation of consequences and in the last part defuzzification.

III. Proposed Algorithm

Modified trilateration algorithm has two phases:

Phase 1: Trilateration.

Phase 2: Error resolving in Trilateration using fuzzy weighted scheme in Centroid technique for points of intersection derived from phase1 of Trilateration. Phase two is explained as:

- Find the distance among all non anchor nodes and distance from sensor to anchors using RSSI value received.
- Then for each sensor node draw circles taking distance between anchor and non anchor node as radius taking anchor as center.
- There are 6 intersection points, two from the intersection of anchor 1 and anchor 2, two from the intersection of anchor 1 and anchor 3 and two from the intersection of anchor 2 and anchor 3.
- Then find the innermost three intersection points as shown in figure 4

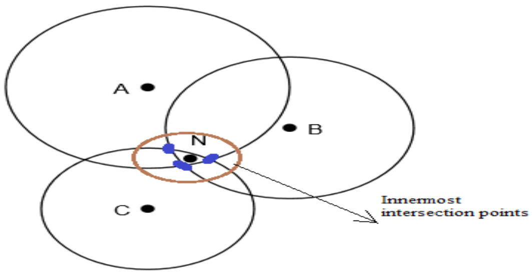

Fig. 4: innermost intersection points

- Weight of each anchor node is calculated using the fuzzy logic applied at the RSSI value received by corresponding anchor nodes from the said sensor node.
- Weight of a point at intersection of anchor 1 and anchor 2 is taken as the average of the weights of anchor1 and anchor2. Similarly weights of other intersection points are calculated.
- Apply formula of weighted Centroid technique for both x-coordinate and y-coordinate.
- Finally calculate the error using the obtained position and the actual position of the sensor node.

IV. Simulation Results

Estimating the location of each sensor node is done by the Trilateration method. To resolve the trilateration error centroid method and fuzzy optimization is used. Hence, the weights are the main variable, which are the outputs of the fuzzy system in the simulation. In fact, the Sugeno fuzzy system receives RSSIs as inputs to map the outputs, which are weights of each GPS equipped (anchor) node to the non anchor node. A WSN consists of sets of anchor nodes and sensor nodes with anchor nodes are located at known and transmit signal strengths containing their respective locations.

Sensor nodes are deployed randomly in the specific region and receive signal strengths from the anchor nodes to estimate their location. The main responsibility of the sensor node is to compute the RSSI information sent by the anchor nodes.

The implementation is been done by Sugeno type fuzzy inference method [21]. The input membership function of the Sugeno method is the RSS from the anchor nodes, which are decomposed into nine triangular membership function such as very very low (VVL), very low (VL), low (L), medium low (ML), medium (M), medium high (MH), high (H), very high (VH), very very high (VVH) that it shown in Figure 5.

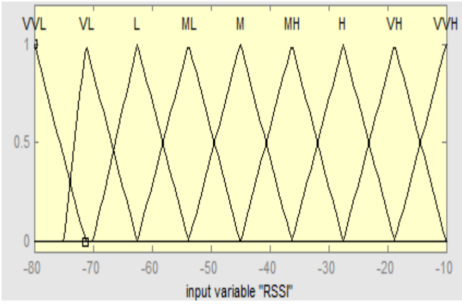

Fig. 5: Input Membership Function

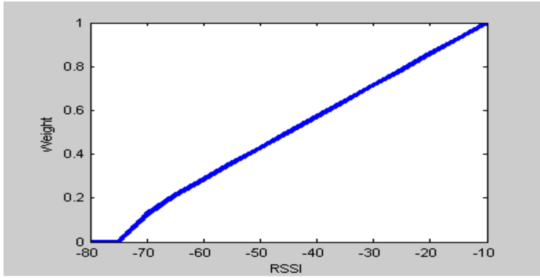

Fig.6: RSSI vs Weight (Surface)

The input membership functions take value [RSS_{min},RSS_{max}], where RSS_{min} and RSS_{max} are the minimum and maximum RSS respectively, which are received by each sensor from each of the anchor node. Now, a rule base is constructed for each input membership function i.e. for 9 input membership functions there are 9 fuzzy rules. After applying the fuzzy rules the output membership function of the Sugeno fuzzy inference is the weight of each anchor node for a given sensor node which takes a value [0,w_{max}], where w_{max} is the weight with a maximum value of one. The output membership function distributes into nine linear functions such as VVL, VL, L, ML, M, MH, H, VH, and VVH. Table 1 shows the rules of sugeno fuzzy system.

Table 1: Rules of sugeno fuzzy system

RULES	IF:RSSI IS	THEN WEIGHT
RULE 1	V V LOW	V V LOW
RULE 2	V LOW	V LOW
RULE 3	LOW	LOW
RULE 4	MEDIUM LOW	MEDIUM LOW
RULE 5	MEDIUM	MEDIUM
RULE 6	MEDIUM HIGH	MEDIUM HIGH
RULE 7	HIGH	HIGH
RULE 8	V HIGH	V HIGH
RULE 9	V V HIGH	V V HIGH

Figure 6 indicates the surface of the fuzzy system, which shows the weights corresponding to the RSSI values. For minimum RSSI weight is minimum i.e. 0 and for maximum RSSI weight is maximum i.e. 1.

A. Calculating RSSI

The algorithms are coded in Matlab where the sensor nodes are distributed randomly in a square region that is 10 meters for each side. The first step is to estimate RSS by the equation (2):

$$RSSI = -(10n\log_{10}(d) + alpha) \qquad (2)$$

Where d is the distance of each sensor node to the anchor nodes which is calculated by the equation (3):

$$d = \left(\sqrt{(x_{anchor} - x_{sensor})^2 + (y_{anchor} - y_{sensor})^2}\right) \qquad (3)$$

Where (x_{anchor}, y_{anchor}) are coordinates of anchor nodes, and (x_{sensor} , y_{sensor}) are coordinates of sensor nodes. On the other hand, in equation (2), n = 3.25 is the path loss exponent, which may take different values and may be affected in different environments. Alpha is constant, and it is the RSSI value of the sensor node that is located in 1-meter distance of anchor node, so alpha is considered to be -40dB for this implementation.

B. Using Localization algorithm

After estimating RSSI for each anchor node and distance between sensor and anchor node then take that distance as radius and anchors as centers draw circles. There are three non collinear nodes so three circles are drawn. Node may at the intersection of these three circles, if it is so then the node position finded out. But their may be the chances that the node is in overlapping region. Three circles intersect at six points, find the innermost three points and apply weight on them. RSSIs are inputs and weights are outputs for the sugeno fuzzy inference. Weight given to each innermost intersection point is average of the weight of the two anchors i.e. if point is because of intersection of anchor 1 and anchor 2 then weight assigned to it is the average weight of anchor 1 and anchor 2 and similarly weight is assigned to other 2 innermost point .

For estimating the coordinates of the sensor nodes in trilateration, weighted centroid formula is used as shown in equation 4

$$(x_{est}, y_{est}) = \left(\frac{x_{13}W_1+x_{12}W_2+x_{23}W_3}{(W_1+W_2+W_3)}, \frac{y_{13}W1+y_{12}W_2+y_{23}W_3}{(W_1+W_2+W_3)}\right) \quad (4)$$

Where (x_{est}, y_{est}) are the coordinates of sensor locations, (x_{13}, y_{13}) are point of intersection of anchor node 1 and 3, (x_{12}, y_{12}) are point of intersection of anchor 1 and 2 and (x_{23}, y_{23}) are point of intersection of anchor 2 and 3. Value of weights W_1, W2, W3 is given in equation 5, 6 and 7.

Weight for the point which is because of intersection of anchor 1 and anchor 3 is:

$$W_1 = \frac{(weig\,ht_1+weig\,ht_3)}{2} \quad (5)$$

Weight for the point which is because of intersection of anchor 1 and anchor 2 is:

$$W_2 = \frac{(weig\,ht_1+weig\,ht_2)}{2} \quad (6)$$

Weight for the point which is because of intersection of anchor 2 and anchor 3 is:

$$W_3 = \frac{(weig\,ht_2+weig\,ht_3)}{2} \quad (7)$$

The simulation result of proposed algorithm is given in figure 6. The region is 10 meter square, where the blue stars are anchor nodes. 100 sensor nodes are randomly deployed in the region. All sensor nodes receive three RSSI from the anchor nodes. After estimating the RSSIs, each sensor node have three average weights that are estimated by the sugeno fuzzy system. The centroid relation is used for estimating the coordinates of the sensor nodes.

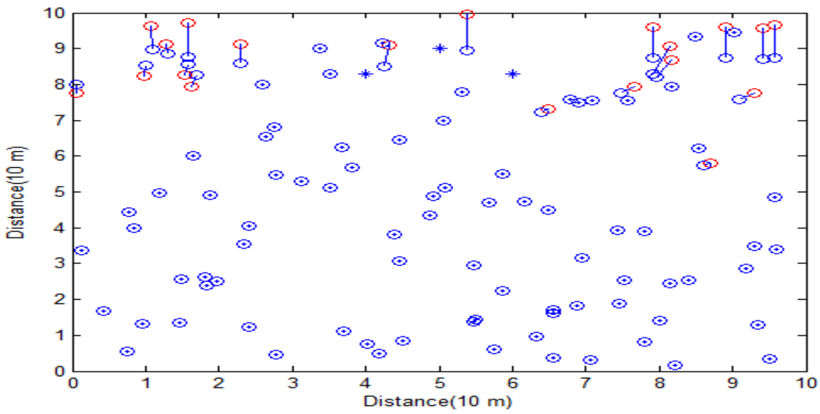

Fig.7: Simulation result of modified trilateration

In Figure 7 the random nodes are the red circles and the estimated nodes are the blue circles. The blue line between the random and estimated nodes is the error of location. Hence, the error in the location between actual and estimated nodes is calculated by equation (8):

$$\text{Location Error} = \sqrt{(x_{est} - x_{sensor})^2 + (y_{est} - y_{sensor})^2} \quad (8)$$

In order to estimate the position errors for all the estimated and actual nodes, the following relation is used given in equation (9-10):

$$\text{Average location error} = \frac{\sum\sqrt{(x_{est}-x_{sensor})^2+(y_{est}-y_{sensor})^2}}{N} \quad (9)$$

Or

$$\text{Average location error} = \frac{\sum Location\ \ error}{N} \quad (10)$$

where N is the total number of sensor nodes. Figure 8 indicates the simulation error results of Modified Trilateration for 100 nodes. Figure 9 indicates the simulation error results of simple weighted centroid localization algorithm for 100 nodes.

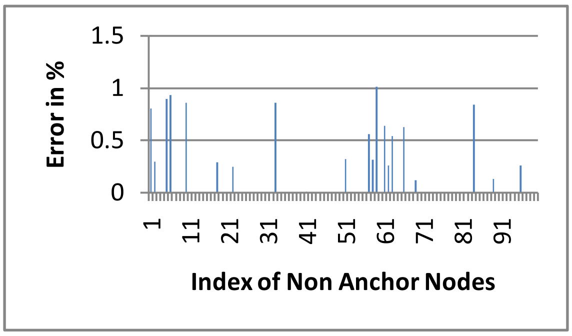

Fig. 8: Error plot for modified trilateration

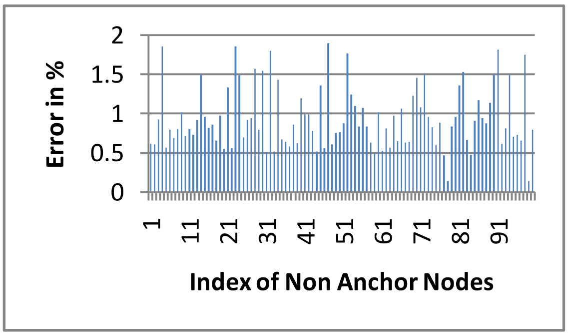

Fig. 9: Error plot for Weighted Centroid

C. **Result Summary**

Perform the above simulation 4 times, for both: proposed algorithm and weighted centroid algorithm and then estimated average location error is given in table 2

Table 2. Comparison Results

Scenario	Average Location Error	
	Proposed algorithm	Weighted Centroid
1	0.0632	1.3353
2	0.1195	1.1620
3	0.0194	1.1756
4	0.1402	1.2302

% average error Calculation For 1st scenario:

$$\% \text{ Avg. error} = \frac{(\text{avg error ofWCT} - \text{avg error for modified trilateration})\times 100}{\text{avg error for WCT}}$$

$$= \frac{(1.1620 - 0.1195)\times 100}{1.1620}$$

$$= 89\%$$

Hence the Proposed algorithm is 85 to 90 % more accurate as compared to weighted centroid technique.

V. Conclusion and Future scope

The node localization is a big challenge in wireless sensor networks. In this paper Trilateration using weighted centroid has been utilized for implementation. The estimation of each sensor node's location has been implemented by RSSI. The sugeno fuzzy inference is used to simulate for estimating the location of each sensor nodes. In fact all the RSSIs are fed to the fuzzy system to achieve the weights to be used in the centroid relation in order to estimate the location of the sensor nodes which is in the overlapping region of three circles drawn by three non collinear nodes. The weights are average of the weights of the two anchor nodes. The weights are the main parameters in the centroid relation, which are the output of the fuzzy system. In fact, the sugeno fuzzy system receives RSSIs as inputs to map to the outputs, which are the weights of each anchor node with respect to the sensor node. After estimating the weights by fuzzy system, the centroid relation estimates the location of each sensor nodes. Hence there is an error in the location between the random and the estimated node. Location error in modified trilateration using weighted centroid is less as compared to the simple weighted centroid technique. Novel algorithm is 85 to 90% more accurate as compared to the simple weighted centroid technique.

Hence, proposed algorithm: Modified trilateration using fuzzy optimization is:

- More energy efficient
- More accurate
- Less no. of anchors used

This model is presently only for static nodes. Further we may work for mobile sensor nodes as well as for mobile anchor nodes model. Also this 2-D model may be further extended to 3-D modelling.

References

[1] M Tubaishat, Z Peng, Q Qi, S Yi. "Wireless sensor networks in intelligent transportation systems", Wireless Commun.Mobile Comput. 9 (2009) 287- 302.

[2] Aspnes,J., T. Eren, D.K. Goldenberg, A.S. Morse, W. Whiteley, Y.R. Yang, B.D. Anderson, and P.N. Belhumeur, "A theory of network localization": IEEE Transactions on Mobile Computing: 2006,1663–1678.

[3] W Ren, "A rapid acquisition algorithm of WSN-aided GPS location", Proc. - Int. Symp. Intell. Inf. Technol. Secur. Informatics, IITSI. (2009) 42-46.

[4] D. F. Larios,J. Barbancho,F. J. Molina,C. Leon, " Locating sensors with fuzzy logic algorithms" 2011 IEEE.

[5] Mostafa Arbabi Monfared ,Reza Abrishambaf, Sener Uysal, "Range Free Localization of Wireless Sensor Networks Based on Sugeno Fuzzy Inference", SENSORCOMM 2012.

[6] Chuanhui Huang, Zhan Xu, Xiu Li Re, "Analysis and Improvement for MDS Localization Algorithm", 2012 IEEE.

[7] Andrija S. Velimirović, Goran Lj. Djordjević, Maja M. Velimirović, Milica D. Jovanović, "Fuzzy Set-Based Approach to Range-Free Localization in Wireless Sensor Networks."

[8] Sukhyun Yun, Jaehun Lee, Wooyong Chung and Euntai Kim. "Centroid Localization Method in Wireless Sensor Networks using TSK Fuzzy Modeling", IEEE 2009,pp. 639–642,.

[9] M.Vasim babu , Dr.A.V.Ramprasad, "Discrete Antithetic Markov Monte Carlo based Power Mapping Localization Algorithm for WSN" , IEEE 2012.

[10] Mohammad Shaifur Rahman, Youngil Park, and Ki-Doo Kim.Localization of Wireless Sensor Network Using Artificial Neural Network

[11] Runjie LIU, Kai SUN, Jinyuan SHEN, "BP localization algorithm based on virtual nodes in wireless sensor network", 2010 IEEE.

[12] Shuang Tian, Xinming Zhang, Pengxi Liu, Peng Sun, Xinguo Wang, "A RSSI-based DV-hop Algorithm for Wireless Sensor Networks" , IEEE 2007.

[13] Yingqiang Ding, Hua Tian, Gangtao Han. "A Distributed Node Localization Algorithm for Wireless Sensor Network Based on MDS and SDP" ,proceeding of International Conference on Computer Science and Electronics Engineering, 2012, pp. 624-628,

[14] Alan Kaminsky "Trilateration" March 8, 2007

[15] N Bulusu, J Heidemann, D Estrin. "GPS-less low-cost outdoor localization for very small devices", IEEE Pers Commun. 7 (2000) 28-34.

[16] G.J. Jordt, R.O. Baldwin, J.F. Raquet, B.E. Mullins, "Energy Cost and Error Performance of Range-Aware, Anchor-Free localisation Algorithms", Ad Hoc Networks, Vol. 6, pp. 539-559, 2008.

[17] E. Elnahrawy, B. Nath, "Poster Abstract: Online Data Cleaning in Wireless Sensor Networks", Proc. of 1st International Conference on Embedded Networked Sensor Systems, 2003 , pp. 294-295,

[18] A.A. Allahverdiyev, "Cargo Transportation Routing Under Fuzzy Conditions", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 6, Vol. 3, No. 1,march 2011, pp. 45-48.

[19] A.A. Allahverdiyev, "Application of Fuzzy-Genetic Algorithm for Solving an Open Transportation", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 7, Vol. 3, No. 2, June 2011, pp. 119- 123.

[20] D. De, "A Distributed Algorithm for localisation Error Detection-Correction, Use in In-Network Faulty Reading Detection: Applicability in Long Thin Wireless Sensor Networks", Proc. of the IEEE Wireless Communications and Networking Conference, April 2009, pp. 1-6.

[21] M. Sugeno, "Fuzzy measures and fuzzy integrals: a survey," Fuzzy Automata and Decision, 1977, pp. 89-102.

