Location Estimation in Wireless Sensor Network using H-PSO Algorithm

Sivakumar.S
Assistant Professor (SG)
Department of Information Technology
PSG College of Technology
Coimbatore, India

Gavya.P.V
PG Scholar
Department of Information Technology
PSG College of Technology
Coimbatore, India

ABSTRACT
Localization has become one of the mandatory services in wireless sensor networks (WSNs) while dealing with critical operations such as coverage, deployment, routing, target tracking and rescue operations. Since the necessity of WSN has increased drastically to provide best solution with accurate results of sensor nodes, it mainly depends on the WSN node localization. This paper initially describes on Mobile Anchor Positioning - Mobile Anchor & Neighbour (MAP - M&N), a range-free localization method, which makes use of the beacon packets of mobile anchor and the location packets of neighboring nodes to estimate the position of nodes and to improve the localization accuracy. The anchor node, which is equipped with global positioning system (GPS), broadcasts its coordinates to the sensor nodes as it moves through the network. The result of MAP-M&N method serves as input to Heuristic Particle Swarm Optimization (H-PSO) algorithm. By using H-PSO algorithm, it can be observed that localization accuracy of the sensor nodes seems to improve significantly than by using only MAP-M&N method for location estimation.

Keywords
Localization, Wireless Sensor Networks, Mobile Anchor, GPS, Heuristic Particle Swarm Optimization algorithm.

1. INTRODUCTION
A Wireless Sensor Network (WSN) essentially consists of spatially distributed autonomous sensors to monitor physical or environmental conditions such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The major motivation behind the development of wireless sensor networks was due to military applications such as battlefield surveillance and in the current scenario such networks are useful in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on. WSNs are useful only if the sensor nodes are aware of the environment surrounding them. For instance, each sensor could only monitor around its region and send the collected data to the sink node [1]. However, the great potential of WSNs lies in its ability to correlate the collected data in time and in space.

1.1 Localization Techniques
Localization is defined as the process of making each sensor node in the sensor network to be aware of its geographic position. The simplest solution is attaching a GPS to each sensor node. But this solution is costly provided the sensor nodes are large in number [2]. Localization serves as one of the most critical issue in wireless sensor networks, because the location information is typically useful for coverage, deployment, routing, location service, target tracking and rescue operations. As the sensor nodes are small, inexpensive, cooperative and deployed in large quantities, there exist unique challenges and opportunities for WSN localization.

Localization algorithms [3] are broadly classified into two categories: range-based and range-free algorithms. The range-based algorithms employ distance or angle estimation techniques to achieve fine-grained accuracy, which require the use of expensive hardware. On the other hand, the range-free techniques depend on the contents of received messages to support coarse-grained accuracy. In recent years, a large number of range-based and range-free algorithms have been proposed for WSN localization. Most of these algorithms share a common feature in that they estimate the locations of the sensor nodes with initially unknown positions (target nodes) using a priori knowledge of the absolute positions of a section of nodes (anchor nodes) and inter-sensor measurements [4].

1. Distance estimation - This phase involves measurement techniques to estimate the relative distance between nodes.

2. Position computation - It consists of algorithms to calculate the coordinates of the unknown node with respect to the location of known anchor nodes or other neighboring nodes. Triangulation, multilateration, and proximity are some techniques that are used for location sensing. It uses the geometric properties of triangles to calculate node locations. Triangulation is classified into lateration, using distance measurements and angulation, using bearing angle information. In 2-dimension to calculate the node location using lateration distance information from 3 reference points is required and using angulation 2 angle measurements and 1 distance information is required.

3. Localization algorithms - It determines how the information concerning distances and positions, is manipulated in order to allow most or all nodes of WSN to estimate their position. Optimally the localization algorithms may involve algorithms to reduce the errors.

In this paper MAP-M&N, a range-free localization algorithm was applied for localizing the sensor nodes and then the proposed meta-heuristic H-PSO algorithm was used along with MAP-M&N. The average error during localization was analyzed using these two algorithms.

1.2 Particle Swarm Optimization
Eberhart and Kennedy developed the PSO in 1995 [5] based on the analogy of bird flock and fish school where each individual is allowed to learn from the experience of its own and from its neighbors. The PSO technique employs a set of feasible solutions within the search space, called a Swarm of particles with random initial locations. Each particle is

allowed to move towards the best position, the particle has come across so far (pbest) and the best position encountered by the entire swarm (gbest) as in equations (1) and (2). In order to get the accurate solution, the whole swarm is subdivided into sub-swarms and the particle with the best fitness with in the local swarm is termed as lbest. The lbest PSO model provides matured but slow convergence, whereas, in our newly proposed PSO variant named H-PSO, i^{th} particle belonging to a sub-swarm feels collective attraction towards its past pbest location, Pi , the locally best location within the sub-swarm Pt and the overall best location Pg.

$$V_{id} = \emptyset_{1_{r_{1(P_{id}-X_{id})}}} + \emptyset_{2_{r_{2(P_{id}-X_{id})}}} \ldots\ldots\ldots \quad (1)$$

$$X_{id} = V_{id} + X_{id} \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

1.3 H-PSO

H-PSO based localization method has very low memory requirements because it has to store only a limited number of variables such as pbest, gbest, lbest and current particle position n at any stage of the search process. The proposed meta-heuristic H-PSO method uses a particle population size of k = 20. Hence, memory requirement of H-PSO based localization technique is very low compared to memory available in current sensor nodes.

2. RELATED WORK

2.1 Range-Based Localization Method

Nabil Ali Alrejeh et al [6] have proposed the range-based and range-free localization techniques. These techniques estimate, point-to-point, the distance between each pair of nodes. With this information and using techniques, such as multilateration, triangulation or other methods, the absolute position of the non-anchor nodes can be estimated. Lovepreetsingh et al. [7], describe about Received Signal Strength Indication (RSSI) [8], Time of Arrival (ToA) [9], Time Difference of Arrival (TDoA) [10] and Angle of Arrival (AoA) [11]. New algorithms continue to appear based on these classical methods for the improvement of accuracy, for example, based on AoA, based on ToA and based on TDoA. Other authors propose new range based algorithms that uses a likelihood calculation for determining the distance.

Received Signal Strength Indication: It requires no additional hardware, and are unlikely to significantly impact local power consumption, sensor size and thus cost.

Time Difference of Arrival: There is a category of localization algorithms utilizing TDoA measurements of the transmitter's signal at a number of receivers with known location information to estimate the location of the transmitter.

Time of Arrival: In this technique cross co-relation method is used to estimate the location of the sensor node.

Angle of Arrival: The beam of the receiver antenna is rotated electronically or mechanically, and the direction corresponding to the maximum signal strength is taken as the direction of the transmitter. Relevant parameters are the sensitivity of the receiver and the beam width.

In general, the range-based ones offer good accuracy, but additional hardware is often needed. Therefore, the weight, the cost and the power consumption of the node devices increase and make these techniques unsuitable for the proposed application.

2.2 Range-Free Localization Method

Range-free or proximity based localization schemes rely on the topological information, e.g., hop count and the connectivity information, rather than range information. Range-free localization schemes may or may not be used with anchors or beacons. A range-free localization scheme does not involve in the use of complex hardware and are cheaper when compared to range-based schemes.

Radio coverage membership

An anchor node detects whether a non-anchor node is in its radio coverage. Using this information, the system can estimate the non-anchor node position as a function of the intersection of the coverage areas of every anchor node that are in its radio coverage and intersection of the coverage areas between the two anchor nodes.

Number of hops to an anchor-node

If there is no connectivity with an anchor node, a non-anchor node can estimate its position knowing the number of hops to every anchor node. An example of that is Node A is at a distance of two hops to anchor node one, three hops to anchor node two and two hops to anchor node three. According to this information and considering the mean distance between the nodes, the absolute position can be calculated applying algorithms, such as triangulation. Some commonly used range free localization techniques are Centroid Algorithm [12] Distance Vector Hop (DV-Hop) [13], Approximate Point-In Triangulation Test (APIT), etc.

Kuo-Feng Ssu et al. [14] presented a range-free algorithm, which uses the following conjecture. A perpendicular bisector of a chord passes through the centre of the circle. When there are two chords of the same circle, their perpendicular bisectors will intersect at the centre of the circle. A mobile anchor moves around the sensing field broadcasting beacons. Each sensor node chooses two pairs of beacons and constructs two chords. The sensor node assumes itself as the centre of a circle and determines its location by finding the intersection point of the perpendicular bisectors of the constructed chords.

W.-H.Liao et al. [15] describes many range free localization techniques. In range-free localization methods neighborhood information such as node connectivity and hop count is used to determine node locations. Range-free methods [16] do not require additional hardware, but they generally only work well when networks are dense. Sparse networks by nature contain less connectivity information and are thus more difficult to localize accurately. These algorithms require that each node knows which nodes interact with each other i.e. in the communication range of each other, their location estimates and ideal radio range of sensors. Range free techniques are most cost-effective because they do not require sensors to be equipped with any special hardware but use less information than range-based.

3. PROPOSED LOCALIZATION APPROACH

The proposed localization approach used in this work can be visualized to work in two phases. In the first phase, a range-free algorithm namely Mobile Anchor Positioning is used for determining the location of the unknown sensor nodes. In the second phase, a Meta-Heuristic evolutionary algorithm namely H-PSO is applied over MAP with Mobile Anchor & Neighbour (MAP-M&N) algorithm for fine-tuning the localization accuracy of sensor nodes.

3.1 Mobile Anchor Positioning (MAP)

The simulation environment is set-up such that the sensor nodes are randomly deployed in the sensing field. Mobile Anchors are location aware nodes that move throughout the field according to the movement file created.

Information Provided By Anchors

When the mobile anchors move they broadcast their positions periodically through the beacons packets, at fixed time intervals, to all the nodes which are at a hearing distance from it. The anchors traverse around the field with a specific speed and their directions are set to change for every 10 seconds.

Visitor list

Visitor list is being maintained by every sensor node in the field. It has the location information that is being extracted from the beacon packets. It collects enough information from the packets sent by mobile beacons before estimating its position.

Beacon points

After collecting enough beacon packets, the node finds first and last beacons packets in the visitor list. The beacon points are considered as an approximate endpoint on the sensor node's communication circle. This is assumed to be the two extremes of a node's communication range. These points are considered to be the center points and two circles are drawn. Two possible locations for the sensor node are the intersection points of the two circles as shown in Figure 1.

Intersection of Two Circles

Given the two centers and the radius, the intersection points are calculated.

CASE 1: If the distance between radius of the two circle is greater than the sum of radius, then the circles have no intersection points.

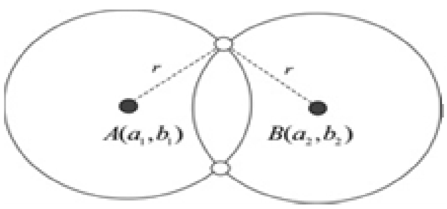
CASE 2: If the distance between radius of the two circle is less than the difference of the two radius, then one circle is within another and there are no solutions.

CASE 3: If distance is zero then circles are coincident and there are infinite solutions.

For example, in Figure 1, the centers of two circles A and B are (a_1, b_1) and (a_2, b_2) respectively. The radii of both the circles are r. The positions (x, y) of the two intersection points of the circles can be calculated by simple algebraic calculation.

$$(\boldsymbol{x} - \boldsymbol{a_1})^2 + (\boldsymbol{y} - \boldsymbol{b_1})^2 = \boldsymbol{r^2} \dots\dots(\mathbf{3})$$

$$(\boldsymbol{x} - \boldsymbol{a_2})^2 + (\boldsymbol{y} - \boldsymbol{b_2})^2 = \boldsymbol{r^2} \dots\dots(\mathbf{4})$$



A(a_1 ,b_1) , B(a_2,b_2)

Figure 1. Basic Idea of Localization

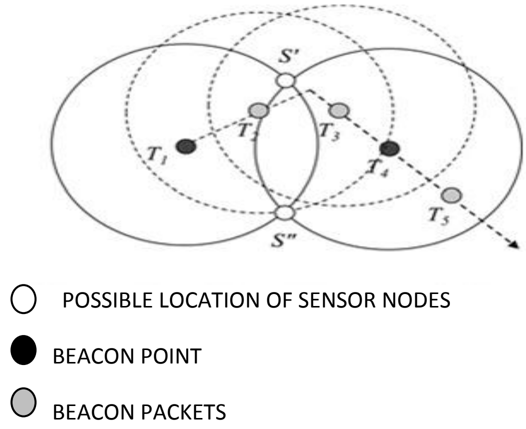


Figure 2. Possible Locations of sensor node

Assume that the sensor node has received and stored four beacons (locations of the mobile anchor) in its list {T_1, T_2, T_3, and T4} (refer Figure 2). From the list, two beacons, which are farthest from each other, are chosen (T_1, T_4). These points are known as Beacon points. These two points are marked as the end of the sensor node's communication range since the sensor node has not received a beacon farther from this point. Hence T_1 and T_4 (Beacon points) represent either two positions of the same mobile anchor or positions of two different mobile anchors when they were at the end of the sensor node's communication range.

With those two points as centers and communication range of a sensor node as radius, two circles are constructed (refer fig 1). Each circle represents the communication range of the mobile anchor which has sent the beacon, and so the sensor node has to fall inside the circle. Since the sensor node has received packets from both the anchors, the node falls inside both the circles. So the circles will intersect each other.

The intersection points of both the circles are determined (S', S'').The intersection points are the possible locations of the sensor node. The reason is as follows. The two farthest points (Beacon Points) are the end points of a sensor node's communication range. The sensor node lies on the circumference of the other circle since it is the same with the other mobile anchor position. Therefore, the sensor node lies on the circumference of both the circles. The only points satisfying the above condition are the two intersection points. Hence, by means of Mobile Anchor Positioning, the location of the sensor node has been approximated to two locations.

The visitor list is searched after identifying the two possible positions i.e. the intersection points. If a node could hear around its range, there is a possibility of a beacon point which can be situated at a distance r from one of the two possible locations. Thus, there is one point in the list, whose distance from one possible location is less than r, and the distance from other possible location is greater than r, then the first possible location is chosen as the location of the sensor node.

It is assumed that the communication range of a mobile anchor is R. The MAP-M maintains the visitors list after receiving the beacon packets from the mobile anchor. The information from the visitor list is used to approximate the location of the sensor node. Let the visitor list of a sensor node S consists of various location information represented as {T1, T2… Tn}. The beacon points are the two extreme points i.e., T1 and Tn. Two circles with radius R and center T1 and Tn are constructed and their intersection points of two circles are found to be S′ and S″.

If there is any Ti (2 ≤ i ≤ n-1), such that the distance between Ti and S′ is less than R and that between Ti and S″ is greater than R, then we can conclude the location of the sensor node is S′. This is because the sensor node should lie inside the communication range of mobile anchor to receive the beacon packets. Consequently, the distance between the sensor node S and beacon packet Ti should be less than R. There is an area named as the shadow region, as shown in Figure 3.

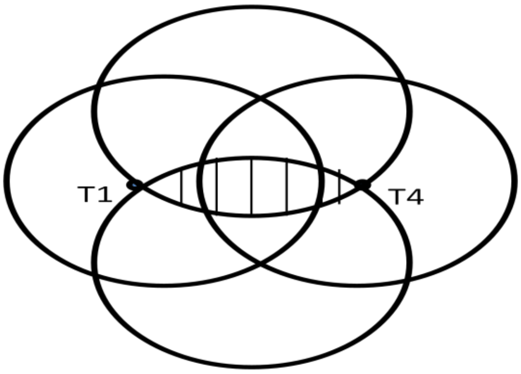
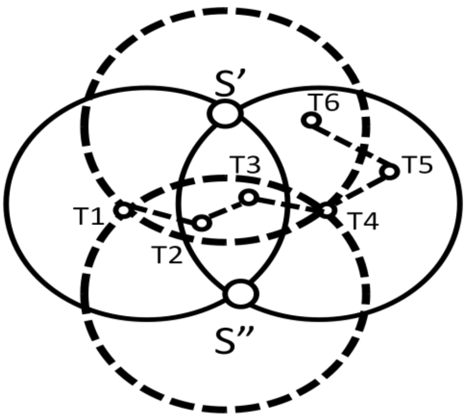


Figure 3. Shadow area

If all the Beacon points lie inside this region, it is not possible to determine the location of the sensor as the shadow region comes under the range of both the intersection points. This could be explained by drawing two circles with S' and S" as centre and the shadow region is the intersection of the two circles. Hence, in order to estimate the location of the sensor node there is a need that at least one of the beacon packets in the visitor list must lie outside the shadow region, as shown in Figure 4.



S' and S'' indicate possible locations of the sensor node

Beacon packets

Figure 4. Node seeking Information from Neighbour Sensors

Therefore, it is not possible to determine the location of the sensor node S using the available beacon packets, thus the node is made to wait until it gets further beacon packets. If no further beacons are obtained, then a single position of sensor node S cannot be obtained. The node will have two positions S' and S". To overcome this problem, the method of Mobile Anchor Positioning-Mobile Anchor & Neighbour (MAP-M&N) is being adopted

3.2 Localization Steps used in MAP-M&N

The localization steps followed while using MAP-M&N algorithm can be represented pictorially as in Figure 5 below:

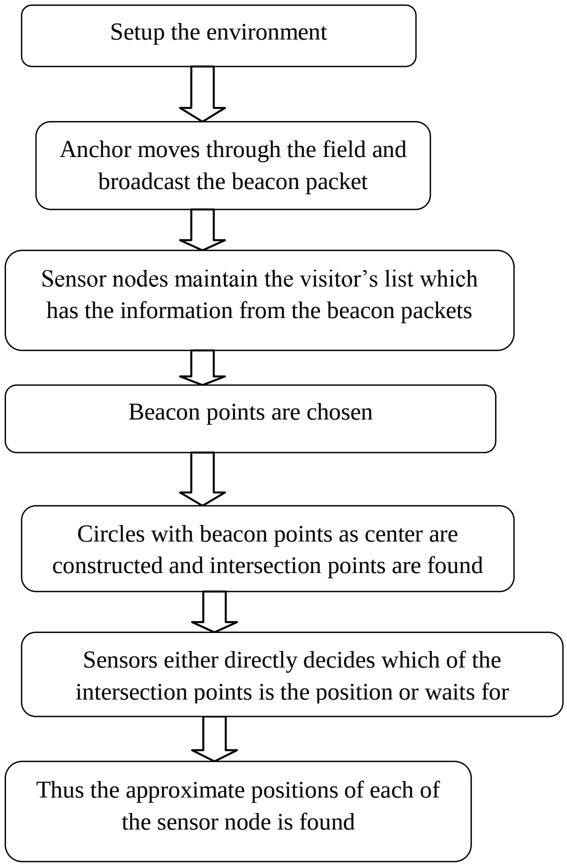


Figure 5. Localization Steps followed in MAP-M&N Algorithm

3.3 Localization Steps used in Mobile Anchor Positioning with H-PSO Algorithm

The following are the steps followed while performing localization with H-PSO algorithm:

1. Initialize a population of particles with random positions. Calculate the fitness value for the given objective function for each particle.
2. Set present particles fitness as "Pbest".
3. Add velocity to initial particles in order to obtain a new set of particles.
4. Find fitness value for each new set of particles. The fitness value is calculated on any function in this find the average distance between nodes
5. Compare each particle's fitness value to find new "Pbest" between the two set of particles
6. Find minimum fitness value by comparing two set of particles and corresponding particle is "Gbest"
   if (Distance(X_{next} , gbestposition)<= λ)
7. Update velocity for the next iteration using the equation (5) as shown below:

$$V_{id} = \theta_1 . r1. (P_{id} - X_{id}) + \theta_2 . r2. (G_{id} - X_{id}) \dots . (5)$$

8. Repeat the iterations until the stopping criteria is met

- The first one has to do with the H-PSO as a whole (when the algorithm finishes)
- No of iterations is 100.Then the best solution is obtained from the H-PSO list
- If the same solution is repeated continuously for three to four iterations,then iterations are stopped.

4. EXPERIMENTAL RESULTS

The topology setting is given as the input. It consists of details like x dimension, y dimension, number of unknown sensor nodes, number of mobile anchor nodes and the routing protocol used. It also includes the simulation period, radio range at different levels.
The following are the simulation parameters used in NS2 for result analysis are as shown in Table 1:

Table 1. Simulation Parameters

S.No	Parameters	Value
1	No. of Mobile anchors	3
2	No. of sensor nodes	100
3	Execution time	200 seconds
4	Area of sensing field	1000 × 1000 m^2
5	Routing Protocol	AODV
6	Number of Iterations	100
7	Transmission Range	200 metres
8	MAC Protocol used	IEEE 802.11

4.1 Performance Metric

The metric that is used to compare the accuracy obtained from MAP-M&N and MAP-M&N with H-PSO Algorithm is Root Mean Square Error (RMSE).

The root mean square error (RMSE) was calculated for both approaches using the formula,

$$RMSE=\frac{\sqrt{\sum_{i=1}^{n}(x_{act(i)}-x_{obt(i)})^2+(y_{act(i)}-y_{obt(i)})^2}}{N}$$

Where,

$x_{act(i)}$,$y_{act(i)}$ - Actual x and y coordinates of sensor nodes

$x_{obt(i)}$, $y_{obt(i)}$- Obtained values of x and y coordinates of sensor nodes

N- Total number of localized nodes

RMSE is calculated for both MAP-M&N and MAP-M&N with H-PSO approaches pertaining to every ten nodes scenario as listed below in Table 2.

Table 2. RMSE for MAP-M&N and MAP-M&N with H-PSO Algorithm

No of Nodes	RMSE for MAP-M&N	RMSE for MAP-M&N with H-PSO
10	538.88	122.88
20	630.44	171.49
30	553.22	85.54
40	505.00	249.48
50	536.60	148.83
60	591.52	192.65
70	588.03	176.61
80	607.49	174.00
90	537.25	169.97
100	518.67	204.78

Figure 6 shows the pictorial representation of RMSE value for MAP-M&N and MAP with H-PSO Algorithm.

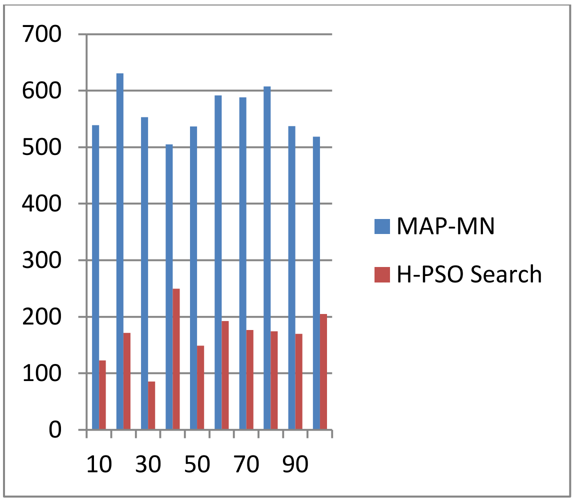


Figure 6. RMSE for MAP-M&N and MAP-M&N with H-PSO Algorithm

It is observed that the Root Mean Square Error is drastically reduced pertaining to 100 nodes scenario on an average when H-PSO optimization algorithm is used along with MAP compared to the RMSE that is being produced using only MAP-M&N.

5. CONCLUSION

Mobile Anchor Positioning method used for localization does not involve the usage of any hardware. Though the percentage of localized nodes obtained using MAP-M&N method is high, it is not much suitable for localization since this method offers only coarse-grained accuracy. H-PSO, a Meta-Heuristic optimization technique is applied over the results of Mobile Anchor Positioning. The experimental results convey the fact that Mobile Anchor Positioning with H-PSO algorithm significantly brings down the average localization error by

80.4% when compared to MAP-M&N. Thus it can be concluded that the localization error was significantly reduced in MAP-M&N with H-PSO algorithm when compared to MAP-M&N. The future work can be applying hybrid H-PSO search algorithm for localization instead of traditional H-PSO algorithm in order to minimize the localization error further.

6. REFERENCES

[1] I.F.Akyildiz,W.Su,Y.Sankarasubramaniam, E.Cayirci, “Wireless Sensor Networks: a Survey”, IEEE Communication. Mag., 2002, Vol.40, No.8, pp. 102 – 114.

[2] Guibin Zhu, Qiuhua Li, Peng Quan, Jiuzhi Ye , “A GPS-free Localization Scheme for Wireless Sensor Networks”, 12th IEEE International Conference on Communication Technology (ICCT 2010), Nov 2010, pp.401-404.

[3] Guoqiang Mao, Barıs¸ Fidan , and Brian D.O. Anderson, “Wireless Sensor Networks Localization Techniques ,” Science Direct, Computer Networks 51, 2007, pp. 2599-2533.

[4] Anil Kumar, Arun Khoslay, Jasbir Singh Saini, Satvir Singh, “Meta-Heuristic Range Based Node Localization Algorithm for Wireless Sensor Networks”, 2012.

[5] Han Bao, Baoxian Zhang, Cheng Li, and Zheng Yao, “Mobile Anchor Assisted Particle Swarm Optimization (PSO) based localization algorithms for Wireless Sensor Networks,” Wireless Communications and Mobile Computing, Oct. 2012, Vol. 12, Iss. 15, pp. 1313-1325.

[6] Nabil Ali Alrajeh, Maryam Bashir and Bilal Shams, “Localization techniques in wireless sensor networks”, International Journal of Distributed sensor networks, 2013.

[7] Love preet Singh, Sukhpreet kaur, “ Techniques of node localization in wireless sensor networks: Review”, International Journal of innovative Research in Computer and Communication Engineering,Vol.2,Issue 5,May 2015

[8] Hoang Q.T., Le T.N., and Yoan Shin, “An RSS comparison based Localization in Wireless Sensor Networks,**”** 8th workshop on Positioning Navigation and communication (WPNC 2011), April 2011, pp.116-121.

[9] Guowei Shen, Zetik R, Honghui Yan, Hirsch O., and Thoma, R.S.,“ Time of Arrival Estimation for range-based localization in UWB sensor networks”, in Proc. of IEEE Int. Conf. on Ultra-Wideband (ICUWB 2010),Sept.2010,Vol.2,pp.1-4.

[10] Pengfei Peng, Hao Luo, Zhong Liu, Xiongwei Ren “ A cooperative target location algorithm based on time difference of arrival in wireless sensor networks”, International Conference on Mechatronics and Automation (ICMA 2009), Aug. 2009, pp. 696-701

[11] Yanping Zhu, Daqing Huang, and Aimin Jiang, “Network Localization using Angle of Arrival,” IEEE International Conference on Electro/Information Technology (EIT 2008), May 2008, pp. 205-210.

[12] Binwei Deng, Guangming Huang, Lei Zhang, and Hao Liu, “Improved Centroid Localization Algorithms in WSNs,**”** 3rd International Conference on Intelligent System and Knowledge Engineering (ISKE 2008), Nov 2008, Vol. 1, pp. 1260-1264.

[13] Zhang Zhao-yang, Gou Xu, Li and Shan-shan Huang, “DV Hop based Self-Adaptive Positioning in Wireless Sensor Networks,” 5th International Conference on Wireless Communications, Networking and Mobile Computing (WiCom 2009), Sept. 2009, pp. 1-4

[14] Kuo-Feng Ssu, Ou, C.-H., Jiau, H.C.: ‘Localization with mobile anchor points in wireless sensor networks’, IEEE Transactions on Vehicular Technol, May 2005, Vol. 54, Iss. 3, pp. 1187–1197.

[15] W-H Liao, Y.C.Lee, and S.P. Kedia, “Mobile Anchor Positioning of Wireless Sensor Networks,” IET communications, 2011, Vol. 5, Issue 7, pp.914-921.

[16] Chi-Chang Chen, Yon Nong Li, Chi Yu Chang, “A novel range-free localization scheme for wireless sensor networks”, International journal on applications of graph theory in wireless ad hoc networks and sensor networks (GRAPH-HOC), September 2012, Vol.4, No.2, pp. 1-13.