Optimized Localization by Mobile Anchors in Wireless Sensor Network by Particle Swarm Optimization

Parulpreet Singh*,Arun Khosla¥, Anil Kumar£, Mamta Khosla§
*¥§Department of Electronics and Communication Engineering
Dr. B.R. Ambedkar National Institute of Technology
Jalandhar,Punjab,India
* parulpreet89@gmail.com
¥ khoslaak@nitj.ac.in
§ khoslam@nit.ac.in
£ Department of Electronics and Communication Engineering
Chandigarh College of Engineering and Technology
Chandigarh, U.T., India

Abstract: - There are various applications which require actual position of the occurring event in a Wireless Sensor Network (WSN) with low location computation cost. Also if some nodes have mobility (either anchor or target), accurate localization process becomes quite challenging. This paper proposes a method based on swarm intelligence for locating nodes in moving anchors WSN environment, which is computationally efficient. The simulation based localization is done for fourteen counts at which the anchor nodes have different positions due to mobility. The advantage of the algorithm used in this paper is that there is only one anchor is required for the localization of a target node (no need for three anchors). The single anchor used for the localization of a target node will make its own two virtual anchor nodes for localization. The nodes which are efficiently localized with its localization error and percentage localization error are observed in this paper. All simulations using different scenarios have been done on MATLAB software.

Index Terms: - Localization, Particle Swarm Optimization (PSO), Anchor Mobility, Wireless Sensor Networks (WSNs)

I. INTRODUCTION

The number of sensor nodes wirelessly communicating, collectively makes a Wireless Sensor Network (WSN) [1, 2]. In most of the applications of WSNs viz. Health monitoring, military, environmental sensing, rescue and biological tracking, the location of sensor node is essential. The process of determining the coordinates of unknown nodes in a network is termed as localization process. The available localization schemes in the literature by which localization process can be done are characterized by set of pairs like static and dynamic localization, centralized and distributed localization, outdoor and indoor localization, two dimensional and three dimensional localization etc. The main objective of these localization schemes is to find the relative coordinates of the concerned node from where the event is occurring in different scenarios. Most of the localization schemes consisting of two phases: Angle/Distance Estimation and Position Computation. In Distance/Angle estimation, measurement techniques which are commonly used are Angle of Arrival (AoA), Time of Arrival (ToA) [14, 16], Time Difference of Arrival (TDoA) and Received Signal Strength Indicator (RSSI) [3, 4]. In position computation phase the computation techniques used are Trilateration, Triangulation, multilateration and proximity [2]. WSN deployments were never be envisioned to be fully static, one should have focus on the mobility aspect of WSNs. In recent years, mobility has become a key area of research for WSNs. In static localization, node position can be determined once during initialization but when those nodes that are mobile, there must be continuous evaluation of the position as these nodes, that navigates through the sensing region. Additional time and energy as well as the availability of a rapid localization service is required for this process. In this paper two anchor nodes are moving parallel in the same direction on the opposite boundaries of a particular area. These anchor nodes localizes the in-range target nodes by making two virtual anchor nodes and then PSO is applied for optimizing the measured location. The algorithm employed for localization and optimization of estimated location runs for fourteen times one after the other.

II. LITERATURE SURVEY

A lot of challenges and difficulties occur in the process of localization when the mobility is introduced in the network. The mobility in the localization process can be divided into three parts: Mobile Targets and Fixed Anchors, Mobile Anchors and Fixed Targets and Both Mobile Targets and Anchors [22, 23]. These all types of mobility involve partial and general movement of either anchor or target nodes. In mobility conditions the re-computation by localization techniques must be performed periodically as the node position will be change after some time. Graefenstein et al. [5] proposed a localization technique in mobile anchor based scenario, which is energy efficient and the distance between moving anchor and target node is calculated by RSSI.

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Then trilateration is applied after getting distances from three reference locations. Sumathi and Srinivasan [6] proposed a single anchor based novel localization algorithm with RSS measurements. The least square method is used for location estimation of fixed target nodes. Guo Z. et al. [7] proposed a Perpendicular Intersection based mobile assisted localization technique. In this technique there is no direct mapping of distances from the RSSI values. The geometric relationship of the perpendicular Intersection has been utilized for node position computation. Sayyed Majid Mazinani and Fatemeh Farnia [8] presented localization in obstacle based scenario by using a mobile anchor which finds the location via GPS. While navigation of mobile anchor through sensing region, the static target nodes receives beacon messages. By using these beacon messages target nodes estimates their coordinates Garg, V. and Jhamb, M. [9] proposed RSS based approach to locate the position of the mobile node. In this scheme the anchor nodes were positioned at the vertices and the target node moves freely inside the square area. The goal of the work was to track the location of mobile node by applying Heron's formula on the triangles formed inside the square. Lee, S. et al. [10] proposed a multi-hop range-free localization algorithm in anisotropic network in which the number of anchors are very less. They proposed a novel distance estimation method to approximate the shortest path based on the path deviation and to estimate their Euclidean distance. Fewer anchors are required for the proposed algorithm, achieving higher localization accuracy in anisotropic networks. Kyunghwi Kim and Wonjun Lee [11] proposed a localization technique which is range based and involves strategy based movement of mobile anchor, termed as MBAL (Mobile Beacon Assisted Localization). The authors considered totally a new scheme which provides path selection during movement, which results low computational complexity. The excessive overhead can be reduced by using this technique. Hu Zhen et al. [12] proposed MACL (Mobile Anchor Centroid Localization) method, in which a single mobile anchor moves into the sensing field and periodically broadcasts its current position. In this technique no extra hardware is required between sensor nodes. According to authors, their technique can improve localization accuracy because the anchor node can move to every point in the sensing field. Also the localization cost can be reduced. The location computation done by above referred localization algorithms might have some error. To reduce these errors optimization based algorithms can be used. The measured and actual position distance can be reduced by using some optimization techniques. For static scenarios, genetic and other stochastic algorithms for optimization are available in the literature. But these optimization algorithms have high computational cost. Kumar A. et al. [17] proposed the application of H-Best PSO (Particle Swarm Optimization) and BBO (Biogeography Based Optimization) for optimization of estimated location of randomly deployed target nodes. The HPSO algorithm was modelled for mature and fast convergence. And BBO was used for more accuracy. Kumar A. et al. [18] proposed 3D node localization techniques for anisotropic WSNs by using the applications of HPSO and BBO termed as Range Free HPSO (RFHPSO) and Range Free BBO (RFBBO). In the proposed scheme, extra hardware is not required for distance calculation between target and anchor nodes. Edge weights between anchor and target nodes are taken to estimate the location of target node. Also the edge weights which are modelled by using Fuzzy Logic System (FLS) can reduce the computational complexity and these weights are further optimized by using the application of PSO and BBO.

The method proposed in this paper has the following advantages.

- Single Anchor is required to localize a target node. The algorithms given in the literature requires at least three anchor nodes for localization
- Localization is a great challenge for mobility based scenarios. The proposed method gives accuracy with fast convergence.

III. PSO BASED NODE LOCALIZATION

An algorithm which is based on a certain phenomenon of the nature that can optimize itself for their requirements and survival, is termed as biologically inspired algorithm. Complex numerical optimization problem can be solved by using biologically inspired algorithm. Some of the bio-inspired algorithms are PSO, BBO, Genetic Algorithm and Firefly Algorithm.

Particle Swarm Optimization:-

An evolutionary computation technique named particle swarm optimization was developed by Kennedy and Eberhart [19, 20]. This technique is based on the behavior of flocking birds. PSO is a computationally efficient algorithm and also it is easy to implement [13]. The solutions named particles are employed in the search space with random locations. The objective function is calculated corresponding to the particles random locations. Then the movement is given to the particles that they can move randomly in the search space [20, 21]. A particle is moved in a search space and collects its particle best 'pbest' and global best 'gbest' position in the space.

$$d_i = \sqrt{(x - x_i)^2 - (y - y_i)^2} \qquad (1)$$

Each localizable node can calculate its distance from the neighboring anchor node by above equation (1)

$\widehat{d_i} = d_i + n_i$ …………………………………….. (2)

Due to effect of noise the distance can be calculated by equation (2). Where n_i is a gaussian noise.

$f(x, y) = \frac{1}{M}\sum(\sqrt{(x - x_i)^2 - (y - y_i)^2} - \widehat{d_i})$……….. (3)

The equation of objective function is given by (3) [20,21].

The algorithm proposed for localization of randomly deployed target nodes by mobile anchor is given in the figure 2.

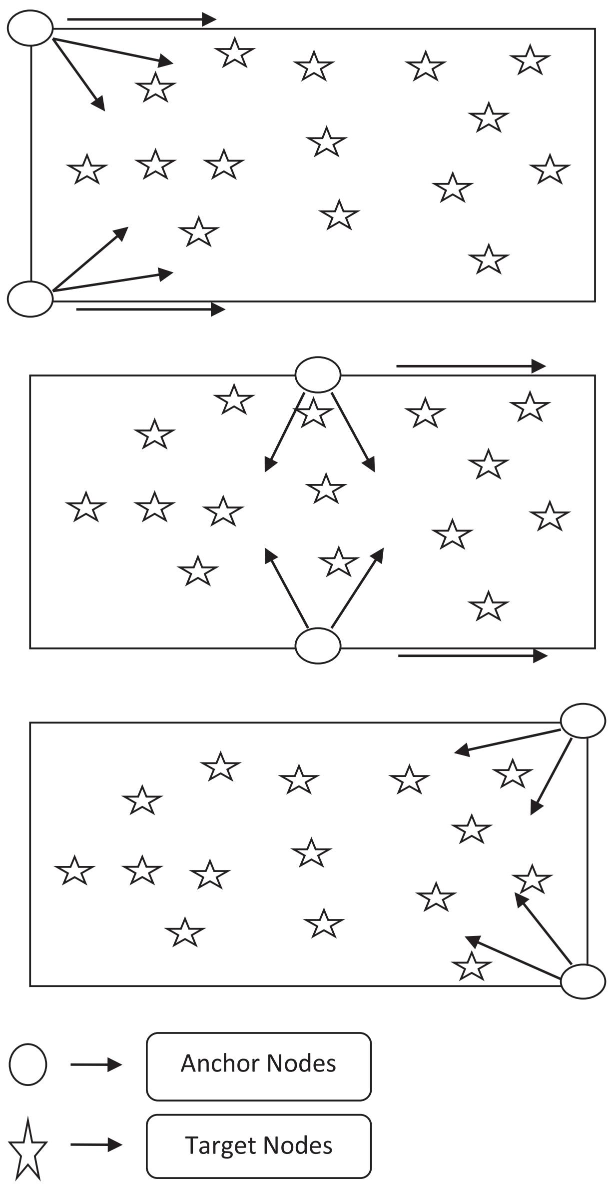

Figure 2: Proposed WSN Scenario

As shown in figure 2, two anchors are moving parallel from one side to another. Once a target node comes under the range of an anchor node, distance will be calculated through RSS measures and two virtual anchor nodes will be projected with some angles inside the area at a distance equal to the anchor and in-range target node (Shown in Figure 2). In this scenario, we have considered the application of conveyer belt in industries. Figure-3 shows the complete flow of localization process used in this paper.

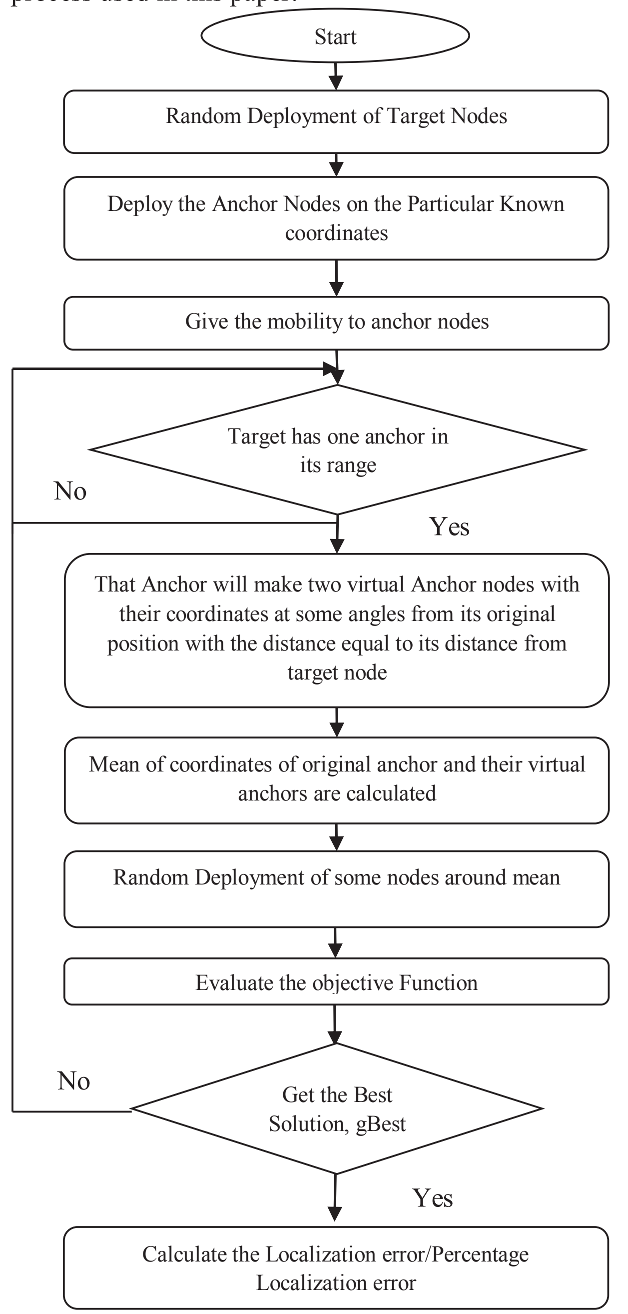

Figure 3: Complete Flow of Localization Process

IV. Simulation Results and Discussions

In order to evaluate the performance of the proposed PSO based algorithm on mobility based scenarios, many simulations were performed on MATLAB software. These simulations were performed on PC having Intel core i3 processor and 4GB of RAM. The simulations have been done on small network of size 15x15 l units. 20 target nodes are deployed in the sensing field and 2 anchor nodes are deployed at the edges of the sensing field (Shown in Figure 2). The Other parameters used for simulation is shown in the Table-1.

Table 1: Simulation Parameters Used for Localization Using PSO

Area	15X15 Units
Anchor Nodes	2
Target Nodes	20
Mobility	Anchor
Range	5 Units
PSO Radius	1 Unit
Virtual Anchors	2 per Anchor

Table 2: Actual Node Coordinates

Node No.	Target Coordinates	
	X	Y
1	0.510549	12.6252
2	6.824778	3.073726
3	1.929088	14.28525
4	4.220646	6.666984
5	14.86397	5.322032
6	3.834701	10.94639
7	9.013321	4.748678
8	13.24391	2.965295
9	14.48758	13.10986
10	11.37607	12.19493
11	10.10498	11.43243
12	2.365491	8.25974
13	13.06688	2.130192
14	0.016545	6.170391
15	13.66697	10.7766
16	4.03132	6.174237
17	3.533918	4.990122
18	11.83521	11.37147
19	14.13156	5.684522
20	10.89578	7.159898

Table 2 shows the actual target nodes coordinates which are randomly deployed in the sensing field. Figure 4 shows the simulation setup in the MATLAB software.

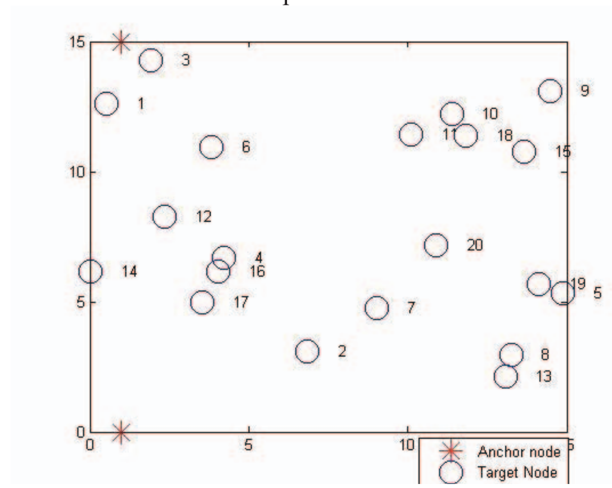

Figure 4: Simulation setup in MATLAB

Table 3: Efficiently Localized Nodes for First Count

Anchors Position for First Count		Efficiently localized Target positions for the second Count		Node Number	Localization Error
		X	Y		
1	0	0.2271	12.8340	1	0.3520
1	15	0.4175	5.9995	14	0.4358

Table 4: Efficiently Localized Nodes for Second Count

Anchors Position for second Count		Efficiently localized Target positions for the second Count		Node Number	Localization Error
		X	Y		
2	0	1.2188	12.4183	1	0.7379
2	15	2.7254	4.8731	17	0.8169

Table 5: Efficiently Localized Nodes for Forth Count

Anchors Position for fourth Count		Efficiently localized Target positions for the fourth Count		Node Number	Localization Error
		X	Y		
4	0	4.3486	6.6778	4	0.1284
4	15	3.3509	6.0981	16	0.6847

In this paper, the results of fifteen positions of the anchor nodes are shown. The position of target node become same. Table-3 shows the coordinates of localized nodes with error for first movement. Similar is the case for next movements. Table- 4,5,6,7,8,9,10 and 11 shows the coordinates of efficiently localized target nodes, Node ID and Localization Error at various anchor positions.

Table 6: Efficiently Localized Nodes for Sixth Count

Anchors Position for sixth Count		Efficiently localized Target positions for the sixth Count		Node Number	Localization Error
		X	Y		
6	0	6.6453	2.9121	2	0.2415
6	15				

Table 7: Efficiently Localized Nodes for Eighth Count

Anchors Position for eighth Count		Efficiently localized Target positions for the eighth Count		Node Number	Localization Error
		X	Y		
8	0	8.0284	4.7470	7	0.9850
8	15				

Table 8: Efficiently Localized Nodes for Tenth Count

Anchors Position for tenth Count		Efficiently localized Target positions for the Tenth Count		Node Number	Localization Error
		X	Y		
10	0	10.5023	12.1883	10	0.8738
10	15	9.6680	11.3488	11	0.4449

Table 9: Efficiently Localized Nodes for Twelfth Count

Anchors Position for twelfth Count		Efficiently localized Target positions for the twelfth Count		Node Number	Localization Error
		X	Y		
12	0	13.0991	2.9581	8	0.1449
12	15	12.2606	12.446	10	0.9194
		12.2383	2.3467	13	0.8564
		12.3779	11.397	18	0.5433

The location error, i.e., distance between actual and estimated target nodes is shown for proposed method. To evaluate the performance of the proposed localization algorithm, performance parameter, i.e., localization error is considered and results are summarized. For mobility based scenarios, the convergence time of the algorithm should be less, i.e., the convergence should be fast. The algorithm used in this paper has very less convergence time. The average convergence time for PSO at particular position of the anchor and target node is 0.0654 seconds.

Table 10: Efficiently Localized Nodes for Fourteenth Count

Anchors Position for Fourteenth Count		Efficiently localized Target positions for the Fourteenth Count		Node Number	Localization Error
		X	Y		
14	0	14.6068	4.8709	5	0.5193
14	15	13.9317	2.7645	8	0.7165
		13.8673	13.358	9	0.6682
		13.6969	2.2957	13	0.6514
		13.5568	5.5346	19	0.5940

Table 11: Efficiently Localized Nodes for Fifteenth Count

Anchors Position for Fifteenth Count		Efficiently localized Target positions for the Fifteenth Count		Node Number	Localization Error
		X	Y		
15	0	12.8522	2.3848	8	0.7003
15	15	11.8686	11.6760	10	0.7154
		10.4778	11.0770	11	0.5151
		12.9328	1.9628	13	0.2144
		11.9451	11.2856	18	0.1395

The simulation results for static environment having at least three anchor nodes are given in the literature [17]. However, due to consideration of less iterations to reduce computational time (For mobility based scenarios computational time should be very less), the accuracy is bit less but the localization is done using single anchor node only (not by three physical anchors) in mobile environment. Also, algorithm used in this paper is better for other challenges like Line of Sight, Localization in mobile scenario and Energy consumption during localization.

V. Conclusion and Future Scope

In this paper, a bio inspired localization algorithm is proposed using application of particle swarm optimization in dynamic wireless sensor networks. The proposed algorithm is divided into two phases. In the first phase, the distance is calculated between anchor and target node, further, virtual anchor nodes are projected inside the sensing field with some angles at a distance equal to anchor and in-range target node. In the second phase, Centroid is calculated and PSO based optimization algorithm is used for location error optimization. The proposed algorithm can be used for the various applications in logistics and military. Further the proposed algorithms may be implemented for 2D/3D centralized localization and range free multi-hop localization for mobile targets or mobile anchors. To achieve more accuracy, a hybrid algorithm can be proposed and different types of trajectories can be used.

References

[1] Akyildiz, Ian F., Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci. "Wireless sensor networks: a survey." Computer networks 38, no. 4 (2002): 393-422.

[2] H. Karl, A. Willig, "Protocols and architectures for wireless sensor networks", John Wiley and Sons, 2007.

[3] Wu, Lingfei, Max QH Meng, Huawei Liang, and Wen Gao. "Accurate localization in combination with wireless sensor networks and laser localization." In Automation and Logistics, 2009. ICAL'09. IEEE International Conference on, pp. 146-151. IEEE, 2009.

[4] Stefano, Gabriele Di, and Alberto Petricola. "A distributed AOA based localization algorithm for wireless sensor networks." Journal of computers 3, no. 4 (2008): 1-8.

[5] J. Graefenstein, A. Albert, P. Biber, A. Schilling, Wireless node localization based on rssi using a rotating antenna on a mobile robot, in: 6th Workshop on Positioning, Navigation and Communication, IEEE, 2009, pp. 253-259.

[6] R. Sumathi, R. Srinivasan, Rss-based location estimation in mobility assisted wireless sensor networks, in: 6th International Conference on Intelligent Data Acquisition and Advanced Computing Systems (IDAACS), Vol. 2, IEEE, 2011, pp. 848-852.

[7] Z. Guo, Y. Guo, F. Hong, Z. Jin, Y. He, Y. Feng, Y. Liu, Perpendicular intersection: locating wireless sensors with mobile beacon, IEEE Transactions on Vehicular Technology 59 (7) (2010) 3501-3509.

[8] Mazinani, Sayyed Majid, and Fatemeh Farnia. "Localization in Wireless Sensor Network Using a Mobile Anchor in Obstacle Environment."International Journal of Computer and Communication Engineering 2, no. 4 (2013): 438.

[9] Garg, Vishal, and Mukul Jhamb. "Tracking the location of mobile node in wireless sensor network." International Journal of Advanced Research in Computer and Communication Engineering 2, no. 6 (2013).

[10] S. Lee, C. Park, M. J. Lee, S. Kim, Multihop range-free localization with approximate shortest path in anisotropic wireless sensor networks, EURASIP Journal on Wireless Communications and Networking (1) (2014) 1-12.

[11] K. Kim, W. Lee, Mbal: A mobile beacon-assisted localization scheme for wireless sensor networks, in: 16th International Conference on Computer Communications and Networks, IEEE, 2007, pp. 57-62.

[12] Z. Hu, D. Gu, Z. Song, H. Li, Localization in wireless sensor networks using a mobile anchor node, International Conference on Advanced Intelligent Mechatronics, IEEE, 2008, pp. 602-607.

[13] Zhang, Xihai, Tianjian Wang, and Junlong Fang. "A Node Localization Approach Using Particle Swarm Optimization in Wireless Sensor Networks." In Identification, Information and Knowledge in the Internet of Things (IIKI), 2014 International Conference on, pp. 84-87. IEEE, 2014.

[14] Mesmoudi, Asma, Mohammed Feham, and Nabila Labraoui. "Wireless sensor networks localization algorithms: a comprehensive survey." arXiv preprint arXiv:1312.4082 (2013).

[15] Yun, Sukhyun, Jaehun Lee, Wooyong Chung, Euntai Kim, and Soohan Kim. "A soft computing approach to localization in wireless sensor networks."Expert Systems with Applications 36, no. 4 (2009): 7552-7561.

[16] Ravindra, S., and S. N. Jagadeesha. "Time of arrival based localization in wireless sensor networks: A linear approach." arXiv preprint arXiv:1403.6697(2014).

[17] Kumar, Anil, Arun Khosla, Jasbir Singh Saini, and Satvir Singh. "Meta-heuristic range based node localization algorithm for wireless sensor networks." In Localization and GNSS (ICL-GNSS), 2012 International Conference on, pp. 1-7. IEEE, 2012.

[18] A. Kumar, A. Khosla, J. S. Saini, S. Singh, Range-free 3d node localization in anisotropic wireless sensor networks, Applied Soft Computingv34 (2015) 438-448.

[19] Kennedy, James. "Particle swarm optimization." In Encyclopedia of machine learning, pp. 760-766. Springer US, 2011.

[20] Kulkarni, Raghavendra V., and Ganesh Kumar Venayagamoorthy. "Bio-inspired algorithms for autonomous deployment and localization of sensor nodes." Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on 40, no. 6 (2010): 663-675.

[21] R. V. Kulkarni, G. K. Venayagamoorthy, Particle swarm optimization in wireless-sensor networks: A brief survey, IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews) 41 (2) (2011), 262-267.

[22] C.-S. Shieh, V.-O. Sai, Y.-C. Lin, T.-F. Lee, T.-T. Nguyen, Q.-D. Le, Improved node localization for wsn using heuristic optimization approaches, in: International Conference on Networking and Network Applications (NaNA), IEEE, 2016, pp. 95-98.

[23] G. Yang, S. Liu, X. He, N. Xiong, C. Wu, Adjustable trajectory design based on node density for mobile sink in wsns, Sensors 16 (12) (2016) 2091.