WIRELESS SENSOR NETWORKS LOCALIZATION AND ITS LOCATION OPTIMIZATION USING BIO INSPIRED LOCALIZATION ALGORITHMS: A SURVEY

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Abstract
This paper describes the concept of localization of the sensor nodes in wireless sensor networks. For overall superior performance of Wireless Sensor Networks, Accurate location of the nodes is highly desirable. In this paper various localization algorithms based on connectivity, range information, anchor information, computational based and mobility based is discussed. For optimizing the results using these algorithms bio-inspired location optimization algorithms like Particle Swarm Optimization (PSO), Biogeography Based Optimization (BBO) and Firefly algorithms are reviewed. A choice between these algorithms is influenced by how precise the localization is expected to be and fast convergence.
Keywords: WSNs, Localization, PSO, BBO, Firefly, Node Location Optimization.

I. INTRODUCTION

WSNs have emerged as a key tool for many applications viz. environmental monitoring, disaster relief and target tracking. A WSN consists of an array of sensors either of same or diverse type. In most of the applications, core function of a WSN is to spot and report events which can be meaningfully assimilated if the exact location of the occurring event is known. To do so, usually, the reporting nodes location has to be known. Manual configuring location information into each node during deployment is not an option. Similarly, equipping every node with a Global Positioning System (GPS) receiver is not feasible because of high cost and deployment limitations [3]. Node location coordinates determination in WSNs is one of the challenging problem which can be referred as localization problem in WSNs. Localization techniques are employed to estimate the location of the nodes whose coordinates are not known. Those nodes are termed as Target Nodes. The coordinates of target nodes can be computed by using a priori knowledge available of a few nodes named as Anchor Nodes. For estimating the distance between two nodes several methods such as Received Signal Strength Indicator (RSSI), Time of Arrival (TOA), Time Difference of Arrival (TDOA) and Angle of Arrival (AOA) has been given in the literature [4]. WSN deployments were never envisioned to be fully static; mobility was initially regarded as having several challenges that needed to be overcome, including connectivity, coverage and energy consumption. However the recent studies in WSNs shows the mobility as a positive light. One of the most significant challenges for mobile WSNs is the need for localization. For proper navigation throughout a sensing region, sensor position must be known. Because sensor nodes may be deployed dynamically (i.e., dropped from an aircraft) or may change position during run-time (i.e., when attached to a shipping container). Thus for determining a position of a node in dynamic scenario is a challengeable task. For static WSNs, this is not as much of a problem because once node positions have been determined, they are unlikely to change.

II. CLASSIFICATION OF LOCALIZATION ALGORITHMS IN WSNS

Sensor localization has become an essential requirement for realistic applications over WSNs. The literature on localization provides detailed explanation about various techniques used for locating the nodes, various range based range free, anchor based anchor free localization algorithms etc. Each sensor node in the network transmits a signal. This signal will be processed on the receiver nodes in order to measure the ranges or in order to count the hops. The Figure 1.1 and 1.2 summaries the taxonomy of the various localization algorithms

A. Single Hop and Multi hop Localization

In single hop Localization the non-anchor node which is to be localized is the one –hop neighbor of a sufficient number of anchors of the known positions. In multi-hop localization the non-anchor node which is to be localized is not the one hop neighbour of the anchor nodes with known location [5]. AoA, ToA/TDoA and RSSI are the few examples of Single hop localization and DV-Hop (Distance Vector HOP), APIT (Approximate point in Triangle) and MDS (Multidimensional Scaling) are the examples of multi hop localization.

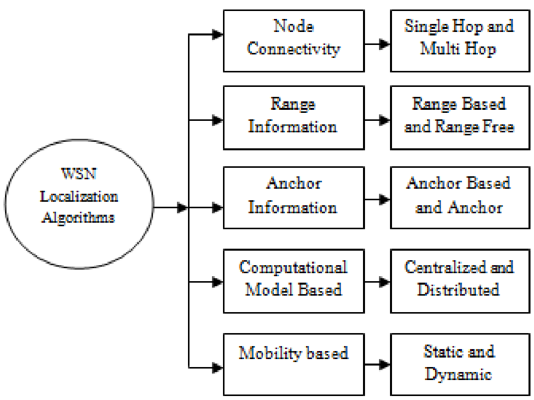


Figure 1.1: Taxonomy of WSNs Localization Algorithms

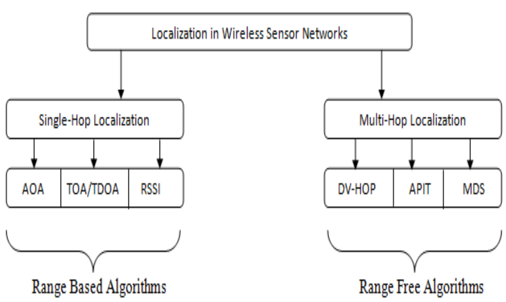


Figure 1.2: Localization Classification

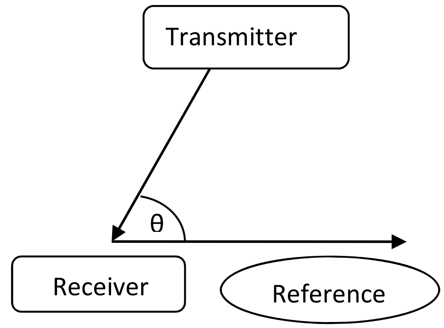
B. Range Based and Range Free Localization

In range based localization, information about the anchor node range is required for localization process whereas in range free localization no range information is required for localization process. Range based method gives fine grained accuracy and range free method gives coarse grained accuracy. Some of the range based and range free algorithms are shown in figure 1.2 [1] [28].

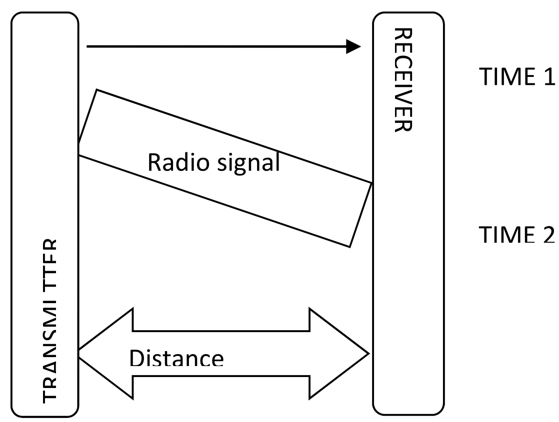
Some of the range based Approaches are

a) AOA:- It is the angle between the line between transmitter and receiver and reference direction.

As shown in the figure 1.3, θ is an angle of arrival of the massage coming from transmitter to receiver. It can also be the angle between two such connecting lines if no reference direction is commonly known to all nodes [28].



a) ToA/TDoA:- Time of Arrival (ToA) also called as ‘Time of Flight’. It exploits the connection between distance and transmission time when the propagation speed is known [30].



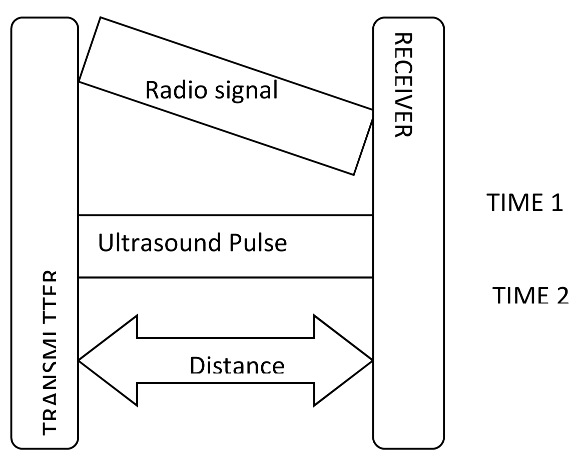


Figure 1.5: Time Difference of Arrival

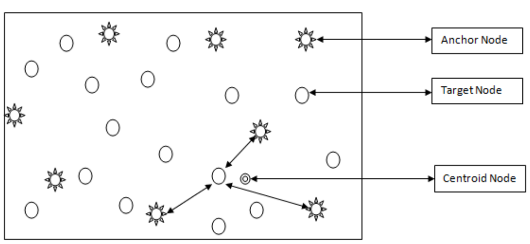
In ToA both sender and receiver know the time when a transmission starts. The speed of the radio signal is known to us and the time of arrival of this transmission at the receiver can be used to compute propagation time and, thus, distance. In TDoA transmission medium of different speeds are used. As shown in the figure 1.5, when a sender starts an ultrasound and a radio transmission simultaneously, the receiver can use the arrival of the radio signal to start measuring the time until arrival of the ultrasound transmission. The arrival time difference between these signals can be used to find out the distance.

RSSI:- Received signal strength indicator is the power measured of the received signal at receiver. The receiver can find out the distance from the transmitter by using the strength of the received signal.

Some of the Range Free Approaches based on anchor information are

Centroid Algorithm:- The Centroid algorithm was proposed by Blusu and Heidemann. In this algorithm the unknown node is located by the location information of the anchor node in range with that node. The equation of Centroid method is

$$(x_{est} \quad y_{est}) = \left(\frac{x(1) + x(2) \ldots x(n)}{N}, \frac{y(1) + y(2) \ldots y(n)}{N}\right)$$



in the range of the particular target node whose coordinated are to be calculated. Figure 1.6 shows the basic idea about Centroid algorithm [25].

a) DV-Hop:- In this method, the number of hops have been calculated between two anchors. By using the information about the number of hops between two anchors the average leanth of single hop can be calculated. Every anchor computes this estimated hop length and propagates it into the network. A node with unknown position can then use this estimated hop length to calculate a multihop range estimate[19].

b) APIT:- APIT empolys a novel area based approach. In this the area is devided into triangular regions. A node which is present inside or outside of these triangular regions allows a node to potentially reside by narrowing the area[18].

d) MDS:- It is also a range free method in which the distance between all pair of nodes are calculated to obtain the distance matrix. After obtaining the matrix, a shotest path algorithm like floyd's or dijkstra's algorithm is applied to complete the matrix[17]. MDS is a energy efficient localization algorithm.when the sensor observation accuracy is poor, this algorithm will give poor results. For refinement of the poor results, trilateration is used in MDS.Trilateration gives better rerults when it is used with MDS.

The table 1.1 shows the comparison with respect to accuracy and cost of various range free algorithms of localization in WSNs.

Algorithm	Accuracy	Communication Cost	Computation Cost	Hardware Cost
Centroid	Low	Low	Low	Low
DV-Hop	Medium	High	Low	Low
APIT	Medium	Low	Low	Low
MDS	High	High	High	Low

Table 1.1: Comparison of various range free Algorithms

C. Anchor Based and Anchor Free Localization

In Anchor based Localization anchor information is required to calculate global coordinates whereas in anchor free localization no anchor information is required. In anchor based localization anchor nodes know their coordinates a priori by use of GPS or manual placement and in anchor free localization relative coordinate are used for localization process.

D. Centralized and Distributed Localization Algorithms

In centralized localization algorithms all the computations are done at a central processor whereas in distributed localization algorithms the computations are done by using inter sensor measurements.

E. Static and Dynamic Localization Algorithms

The Algorithms applied for localization, when the sensor nodes are static or not moving are called static localization algorithms. When the node has some mobility, the algorithms applied for localization are called dynamic localization algorithms

III. CHALLENGES FOR LOCALIZATION IN WSNS [6]

There are some open troubles that need attention and examination to improve the localization process of the WSNs. Some of the challenges for localization are discussed below.

F. Accuracy in Calculating Locations

Accuracy is a most important figure of merit for Localization. Localization Accuracy is the largest distance between the estimated location and actual location of a sensor node [1]. It is a challenge to get accuracy up to the optimum level or get an exact location of a node while applying the localization algorithms. So we have to use some optimization algorithms to get localization accuracy.

G. Localization in MWSNs

Mobile WSNs are much more flexible than static WSNs as they can be deployed in any scenario and deal with rapid topology changes. So Periodic measurement of the location of a node is a challenge which is addressed by mobile devices used in the network [9].

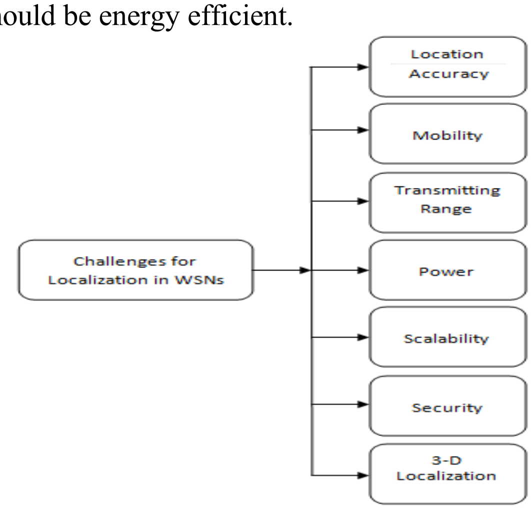
H. Transmitting Range

Transmission range determines how many nodes will come inside a cluster. In that case if transmission range is low there will be less number of cluster members for a cluster leading to less intra cluster traffic and more number of cluster heads which increases the inter cluster head transmission traffic. So one need to appropriately set the transmission radius and it may be dynamically varied to get optimal performance.

I. Energy Efficient Localization

The major design goal of a wireless sensor network is energy efficiency because a WSN is resource constrain in nature. The

Limited energy supplies in sensor node limits the lifetime of the whole system. Due to multiple tasking by a node like communication between nodes, sensing and other applications, a node should be energy efficient.



J. Scalability

The scalability is a key factor to authenticate the localization system. It ensures appropriate evaluation of localization when the network or deployment area gets larger. For range-based schemes, the location performance reduces when the distance between the sender and receiver increases [16]. So appropriate size of deployment area is a challenge for localization process.

K. Secure Localization

Protected localization has always been among the key issues of broadly deployed WSNs. WSNs may be deployed in unfriendly scenarios and the localization procedure is helpless to many localization-specific attacks. So security becomes a challenging task for localization procedure.

L. 3-Dimesional Localization

In many applications such as environmental monitoring, Space monitoring and exploration, study of underwater ecosystem etc., the deployment of WSN nodes are in 3-dimension.So Localization in more than 2-Dimensional environment is a challenging task.

IV.LOCALIZATION IN MOBILITY BASED SCENARIOS OF WIRELESS SENSOR NETWORKS

In this section we consider how to localize individual nodes in a wireless sensor network when some subset of the network nodes can be in motion at any given time. For situations in which it is not practical or cost efficient to use GPS or anchor nodes, An Anchor-Free Mobile Geographic Distributed Localization (MGDL) algorithm for wireless sensor networks has been proposed which obtains better coverage than Anchor Based mobile localization [9]. The MGDL has flexible communication overhead for both high-mobility and low-mobility nodes. Another Method MACL (mobile anchor Centroid localization) [12], a frequency based approach, which uses a single mobile anchor node to move in the sensing field and broadcast its current position periodically. The simulation experiments reveal that the MACL technique can provide accurate localization even when memory limits are severe, the seed density is low, and network transmissions are highly irregular. Garg, V. and Jhamb, M. [10] proposed RSS based approach to locate the position of the mobile node (node that is moving in WSN in Static 2D and Dynamic 2D environment and are not aware of its position in the network). They positioned anchor nodes at the vertices and the target node is moving freely inside the square area. The goal of the work is to track the location of mobile node by applying Heron's Formula on the triangles formed inside the square. They conclude that the communication overhead is less while computation overhead is more in localization process of the mobile target node.

V.OPTIMIZING LOCALIZATION

Almost all the applications of wireless Sensor Networks requires geographic location of the sensor node to know that from where the information is coming. Self-organization and localization capabilities are the most important requirements in sensor networks. To get the exact location of the node, the calculated location optimization can be done by using various algorithms.

VI.LOCATION OPTIMIZATION IN WSNS USING BIO- INSPIRED LOCALIZATION ALGORITHMS

M. Particle Swarm Optimization

An evolutionary computation technique named particle swarm optimization was developed by Kennedy and Eberhart [23]. This technique is based on the behavior of flocking birds. PSO is a computationally efficient algorithm and also it is easy to implement. The solutions named particles are employed in the search space with random locations. The objective function is calculated corresponding to the particles random locations.

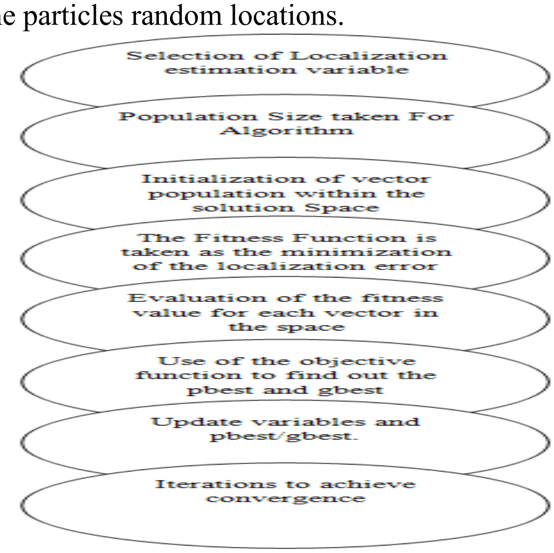


Figure 1.7: Particle Swarm Optimization

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. The basic idea about PSO algorithm is given in the figure 1.7.

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

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

$$\widehat{\boldsymbol{d_i}} = \boldsymbol{d_i} + \boldsymbol{n_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

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

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

The equation of objective function is given by (3) [22].

B. Biogeography Based Optimization

The study of the geographical distribution of biological organisms is termed as biogeography [24]. In biogeography based optimization fitness function is termed as Habitat Suitability Index (HSI). High HSI means a habitat is suitable place for species to live, whereas, low HSI corresponds to lesser appropriate place for the species to live. The characterization of the features of the habitat is termed as Suitability Index Variables (SIV). Low HSI Habitat HSI has high immigration λ and habitat with high HSI has high emigration μ.

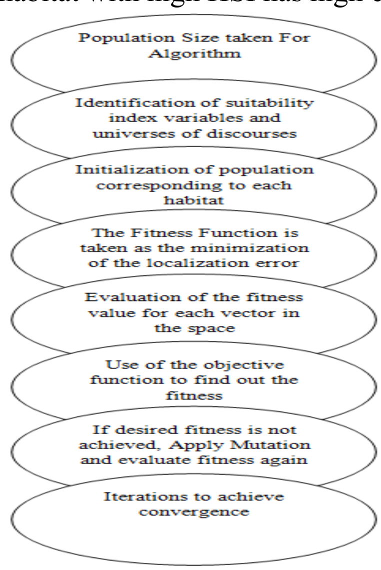


Figure 1.8: Biogeography Based Optimization

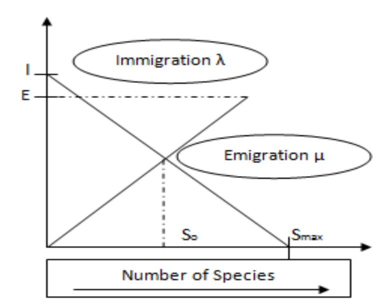


Figure 1.9: Immigration and Emigration rate with respect to Number of Species

The values of immigration and emigration rates are given by equations below [22]

$$\lambda = \mathrm{I}\left(1-\frac{\mathrm{k}}{\mathrm{n}}\right) \text{ and } \quad \mu = \frac{\mathrm{E}}{\mathrm{n}}$$

Where I is the maximum possible immigration rate and E is the maximum possible emigration rate. The basic idea about BBO algorithm is shown in the figure 1.8.

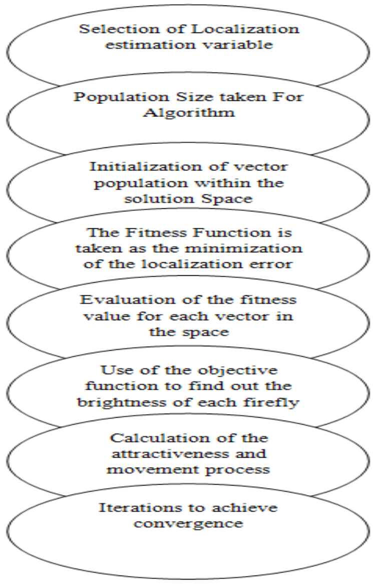
C. Firefly Algorithm

This algorithm named firefly algorithm developed by Dr. Xin-She Yang in 2007 which uses flash light nature of fireflies.

Firefly localization algorithm is based on the following ideal behavior rules of fireflies.

1. All fireflies are unisex. One firefly travel towards another brighter firefly despite of sex [14].
2. Attractiveness is proportional to brightness and inversely proportional to distance. If there is no brighter firefly is found, the firefly movement will be random in nature.
3. The brightness of the firefly is found from the sensor node objective function in the algorithm.

Based on the above rules the firefly localization algorithm is shown in the figure 1.10.



VII.CONCLUSION AND FUTURE SCOPE

The Bio-Inspired algorithms have been applied by many researchers to solve the optimization problems in localizing the nodes in wireless sensor networks because these algorithms are robust and can be used with parallel processing. Multimodal, local optima trapping problems can also be solved by using these algorithms. These algorithms can also adapt solutions for challenging conditions. So Different Bio inspired Optimization techniques can be introduced in mobility based scenarios for future scope. One can use these techniques for mobile 2-dimesional and 3-dimensional environment also. In static environment approximately 96% localization success rate have been achieved. We can also go for optimizing or increasing this success rate.

References:

[1] Karl, Holger, and Andreas Willig. Protocols and architectures for wireless sensor networks. John Wiley & Sons, 2007.

[2] Savvides, Andreas, Chih-Chieh Han, and Mani B. Strivastava. "Dynamic fine-grained localization in ad-hoc networks of sensors." In Proceedings of the 7th annual international conference on Mobile computing and networking, pp. 166-179. ACM, 2001

[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] Mao, Guoqiang, Barış Fidan, and Brian DO Anderson. "Wireless sensor network localization techniques." Computer networks 51, no. 10 (2007): 2529-2553.

[6] Bangash, Javed Iqbal, Abdul Hanan Abdullah, and Abdul Waheed Khan. "ISSUES AND CHALLENGES IN LOCALIZATION OF WIRELESS SENSOR NETWORKS." Science International 26, no. 2 (2014).

[7] Hu, Lingxuan, and David Evans. "Localization for mobile sensor networks." In Proceedings of the 10th annual international conference on Mobile computing and networking, pp. 45-57. ACM, 2004.

[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] Xu, Yurong, Yi Ouyang, Zhengyi Le, James Ford, and Fillia Makedon. "Mobile anchor-free localization for wireless sensor networks." In *Distributed Computing in Sensor Systems*, pp. 96-109. Springer Berlin Heidelberg, 2007.

[10] 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).

[11] Niewiadomska-Szynkiewicz, Ewa, and Michał Marks. "Optimization schemes for wireless sensor network localization." *International Journal of Applied Mathematics and Computer Science* 19, no. 2 (2009): 291-302.

[12] Hu, Zhen, Dongbing Gu, Zhengxun Song, and Hongzuo Li. "Localization in wireless sensor networks using a mobile anchor node." In *Advanced Intelligent Mechatronics, 2008. AIM 2008. IEEE/ASME International Conference on*, pp. 602-607. IEEE, 2008.

[13] Priyantha, Nissanka B., Hari Balakrishnan, Erik D. Demaine, and Seth Teller. "Mobile-assisted localization in wireless sensor networks." In *INFOCOM 2005. 24th Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings IEEE*, vol. 1, pp. 172-183. IEEE, 2005.

[14] Harikrishnan, R., V. Jawahar Senthil Kumar, and P. Sridevi Ponmalar. "Firefly Algorithm Approach for Localization in Wireless Sensor Networks." InProceedings of 3rd International Conference on Advanced Computing, Networking and Informatics, pp. 209-214. Springer India, 2016.

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

[16] Toor AS, Jain AK. Research issues and challenges in wireless sensor networks: a review. Journal of Computer Technology & Applications. 2016; 7(1): 1–6p.

[17] Doremani, F., H. Javadi, and Ahmad Farahi. "A new distributed weighted multidimensional scaling algorithm for localization in wireless sensor networks." International journal of Computer Science and Engineering Survey20, no. 1 (2011).

[18] Wu, Tiezhou, Yishi Zeng, Huijun Zhou, and Biao Li. "Wireless Sensor Network Node Location Based on Improved APIT." Scientific Journal of Computer Science 3, no. 4 (2013): 111.

[19] Yang, Huami, Qi Wang, and Zhuang Liu. "A wireless sensor network DV-Hop localization algorithm." In 2013 International Conference on Information Science and Computer Applications (ISCA 2013). Atlantis Press, 2013.

[20] 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.

[21] Gopakumar, A., and Laura Jacob. "Localization in wireless sensor networks using particle swarm optimization." In Wireless, Mobile and Multimedia Networks, 2008. IET International Conference on, pp. 227-230. IET, 2008.

[22] 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.

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

[24] Simon, Dan. "Biogeography-based optimization." Evolutionary Computation, IEEE Transactions on 12, no. 6 (2008): 702-713.

[25] Liang, Shyi-Ching, LunHao Liao, and Yen-Chun Lee. "Localization algorithm based on improved weighted centroid in wireless sensor networks." Journal of Networks 9, no. 1 (2014): 183-189.

[26] Kumar, Anil, Arun Khosla, Jasbir Singh Saini, and Satvir Singh. "Computational intelligence based algorithm for node localization in wireless sensor networks." In Intelligent Systems (IS), 2012 6th IEEE International Conference, pp. 431-438. IEEE, 2012.

[27] Patil, Shailaja, and Mukesh Zaveri. "Mds and trilateration based localization in wireless sensor network." Wireless Sensor Network 3, no. 06 (2011): 198.

[28] Niculescu, Dragos, and Badri Nath. "Ad hoc positioning system (APS) using AOA." In INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies, vol. 3, pp. 1734-1743. Ieee, 2003.

[29] 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.

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

[31] 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.