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An Investigation of Range-based Localization Methods in Wireless Sensor Networks

Layth Jasim[1*], Bahriye Akay[1]

[1]Department of Computer Engineering/Engineering Faculty, Erciyes University, Turkiye
[*](laithstr@gmail.com) Email of the corresponding author

Abstract – Wireless sensor network (WSN) is a distributed system usually comprising a set of autonomous sensors nodes. These sensors are physically small in size and are capable to communicate with each other and capable of conveying data to recipients. In a large number of applications, information is meaningful only when the locations of sensors are known and the localization is the process that accomplishes the accurate physical coordinate of these nodes. The goal of this work is to investigate the localization algorithms (RSSI, ToA and AoA) for WSN and present a performance analysis of these algorithms in terms of computation of localization error and time of execution.

Keywords –WSN, Localization, RSSI, ToA, AoA. MSE

I. Introduction

The current innovative advances in the fields of wireless communication has made conceivable the improvement of ease, low power, and small-size multi-practical sensors and communication over short distances. A wireless sensor technique is involved distinctive sensor nodes, little in a measure, battery fueled gadgets that can convey and figure signals with different nodes [1]. These days, intelligent sensor networks are used in huge numbers to give chance to check and control homes, urban communities and environment. In the expansion, they have an extensive variety of utilizations in giving new innovation to surveillance, defense field. Sensors joined into machinery, structures and the conditions are joined with the powerful transmission of detected information that can offer tremendous advantages to the guild.

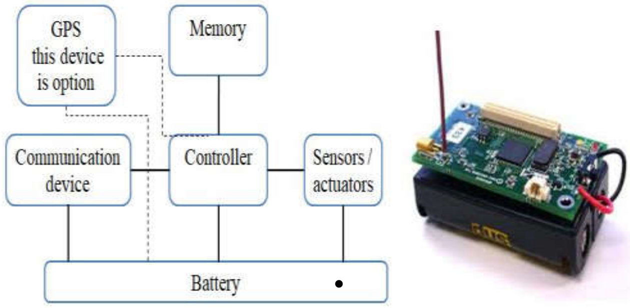
A sensor technique is a foundation comprise of detecting, registering, and communication components that gives an administrator the ability to watch the instrument, also, to respond to occasions and wonders in a predefined environment [2]. A wireless sensor technique (WSN) contains various passage (or "base station") that can pass information with various sensors nodes by means of a wireless association. Information accumulated by the node is compacted and sent to the base station straightforwardly or in the event that required, it utilizes different nodes to exchange information to the base station. The information which is exchanged at that point is used by Base Station link.

The elements of a WSN include: Dynamic technique topology, heterogeneity of nodes, extensive size of node organization, nodes capacity to oppose cruel ecological conditions, nodes should keep running under extremely strict vitality requirements and ought to perform detecting and information handling functionalities. The communication plot is many-to-one (information got together at a base station) instead of shared [3].

II. Hardware of sensor node

When we choose the hardware component for a wireless sensor network node, before determining the hardware components of the node, devices should be investigated depending on the environment beyond to the design node. Then, the application's requirements in terms of the lot to costs, size component, and energy consumption of the nodes are defined and the communication and the computational facilities are often dependent on these factors. But the trade-off between quality and costs is critical [4, 5].

On this basis, there are many research projects that focus on reducing the hardware electronic circuits of the node through reducing the size or costs as well as the rate of energy consumption [4]. The Node sensor consists of five major components, namely as exhibited in Fig.1.



- Fig.1 Overview Hardware f wireless sensor network

A. Controller:

This part is called the "Operations Center", where the process and functions of this part are the collection and aggregate all data analysis and management of data node is capable of implementation of the code.

B. Memory

This section stores the special programs of the node as well as stores all of the data that has been collected and analyses.

C. Sensors and Actuators

This is the main interface of the node where the sensing and control of the physical environment information.

D. Communication

This part is to move data through the sending and receiving information between Nodes or Base Station through the wireless channel.

E. Battery or Power supply

As often, rechargeable part of a device node obtains energy from the environment or through the use of solar cells because one of the most important challenges that the node faces is energy.

F. Global Positioning System (GPS)

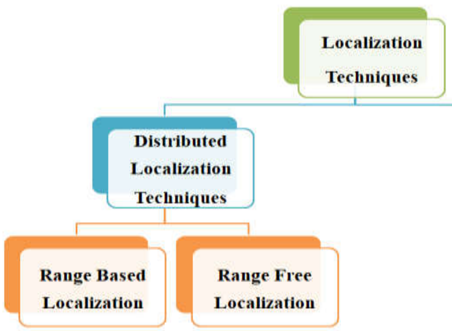
This optional device in the node gives more accuracy in estimating the position of nodes. However, it is expensive in terms of cost and energy of nodes [5].

III. Localization in Wireless Sensor Networks

Research about localization of sensor nodes in wireless sensor networks has turned out to be dynamic since a couple of years and much research has been performed for different applications around this field [7, 9]. This part will present distinctive methods that discover the position of sensor nodes.

IV. Classification of Localization

There are various possibilities on how to allocate the computation between sensor nodes and how to select the localization algorithms. Also based on the calculation model, the localization techniques can be divided as centralized and distributed techniques [15]. The classification of the localization techniques is drawn in Fig.2.



• Fig. 2 Taxonomy of localization techniques [8, 16]

A. Centralized v/s Distributed

In particular, it is critical to understand that any obliged counts should be performed for the most part of the members or all estimations should be represented to a focal station that finds the location of nodes in the technique and appropriates them again to the members [10]. Algorithms are expected to keep running on a focal machine. Each sensor node gathers the estimations of divisions from each neighbor and sends the information to the focal station where the sensor node coordinates are figured. There are two beacon line issues: scaling and effectiveness [11]. Concentrated calculations vanquish the issues of nodes computational containments by enduring the communication cost of streaming information indeed to the central station [12]. It gets less practical as the technique makes more noteworthy, in light of the way that it unduly focuses on vicinity of the base station. Additionally, the information transmitted to the focal station incorporates time defers, so the unified networks cannot be attractive in various orders (e.g., portable nodes) [13, 14].

B. Anchor free v/s Anchor Based

(Also called Beacon nodes/seed) are basic to localize a system in a worldwide coordinate system [17]. Anchor nodes are basically ordinary sensor nodes that have their worldwide position technique in priori and a different node approximates their location from the messages they get from them. This information could be hard coded or increased through some additional gear like a Worldwide Positioning Technique (GPS). On the other hand anchor free nodes are the one without GPS [5]. Here nodes find their positions in the system using degree estimations between them. Each sensor in the technique creates its own specific neighborhood coordinate system by assuming itself as the starting point of this coordinate system and choosing two non-collinear one-hop neighbors to structure axes. By then the places of one-hop neighbors are handled as requirements dictates. At long last it can act on coordinate system to get the node's position in a request to characterize a worldwide technique system. No less than three noncollinear signal hubs are obliged to confine the hubs in two estimations. In the event that three dimensional headings are required, no fewer than four non-coplanar signals must be accessible [18, 19].

C. Range-Free Localization

In range-free localization, there is no supposition about the accessibility of supreme point-to-point distance estimated between sensor nodes. In this way, the location of sensor nodes is evaluated by exploiting the radio availability information or the detecting abilities of every sensor. These calculations may require some reference without nodes. Range-free networks are distance vector (DV) hop, hop terrain, centroid system, APIT, and slope calculation. Range-free networks utilize radio availability to convey location information between sensor nodes. Answer for the range-free localization depends just on the information of reveived messages that are being sent from the reference nodes to all other sensor nodes [20, 21].

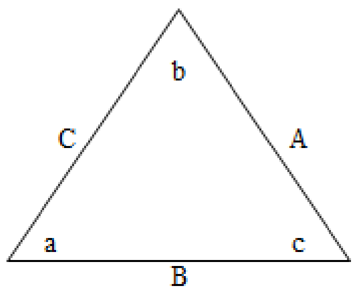
D. Range-Based Localization

Range-based strategies are based on distance estimation and edge estimation. Some of the most imperative networks that are utilized as a part of range based neighborhood localization are gotten flag quality sign (RSSI), point of arrival (AOA), time distinction of landing (TDOA), and time of arrival (TOA).

RSSI [3] has been proposed for equipment obliged networks. The quality of flag got by the node is utilized to quantify its distance from flag source in RSSI. The principle hindrance is in real condition the flag gets hindered by commotion, messes and receiving wire sort, causing a high mistake in localization. The quality of flag got by the node is utilized to estimate its distance from flag source. More noteworthy the distance, bring down the quality of flag when it lands to node. The quality of flag debilitates as the reverse of square distance, hypothetically [20, 21].

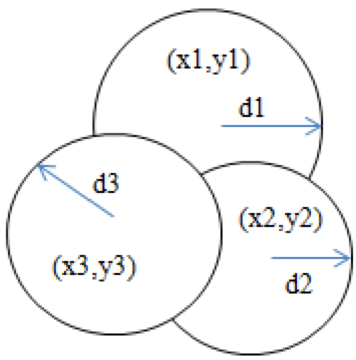
V. MEASUREMENT NETWORKS

A. Trilateration is essentially a method that utilizations distance between one obscure sensor node and three anchor sensors to evaluate the obscure sensor node location. An un-localized sensor location is one of a kind, when no less than three anchor nodes are associated with it in a 2-D space. The coordinate location of the un-localized sensor is recognized by finding the point where three circles cross each other, as shown in Fig.3. In the event that it contains blunder, the point where three circles converge may not be a solitary point.



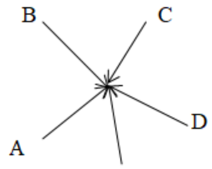
• Fig.3 Triangulation

B. Triangulation is basically a method that utilizes distances between one obscure sensor node and three anchor sensors to appraise the obscure sensor node location. An un-localized sensor location is interesting, when no less than three anchor nodes are associated with it in a 2-D space. The technique location of the un-localized sensor is recognized by finding the point where three circles cross each other, as shown in Fig.4. In the event that it contains blunder, the point where three circles converge may not be a solitary point



• Fig.4 Trilateration

C. Multilateration An un-localized sensor node location may likewise be figured with multilateration with its detachment to more than three anchor sensor node. The assessed sensor node location by the multilateration localization technique is the one that limits the whole of squared distances between conjectured sensor locations to all the anchor locations. For instance, in Fig.5, following capacity can be used to process the location (x, y) of node S [22].



• Fig.5 Multilateration

VI. MATERIALS AND METHOD

The algorithms used for WSN localization were highlighted and three of most common algorithms in the localization process were selected. Various scenarios were adopted to compare the performance between the algorithms used. In this work, range-based WSN localization approaches were chosen, because compared to range-free, range-based can fulfill high accuracy in the localization despite high complexity of implementation. Below, the methods used in this study for localization purpose are listed.

A. Received Signal Strength Indication (RSSI)

The obtained signal power (RSS) is a way to determine the location of a target tool. Relying on a route loss model, the distance between two nodes can be expected by measuring the power of the received signal at one terminal.

To estimate the positioning area of a target node in 3 dimensions (3D) the device desires as a minimum four or more reference nodes with known coordinates. The transmitter forwards control channels or beacon indicators and the target node receives these signs and process them. The measurements of the received signals which might be collected and addressed may be used to decide the position region of a target node [23].

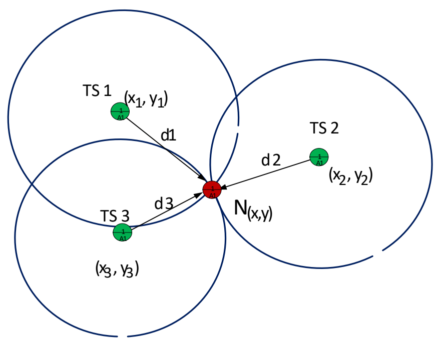
All radio alerts suffer from phenomena called unfastened space loss [4] in which the signal turns into weaker as a feature of distance squared when propagates in the area, in keeping with Fries Equation (1):

$$P_r = \frac{P_t G_t G_r \lambda_2}{(4\lambda)^2 d^2} \quad (1)$$

where Pr is the obtained energy of the tool, Pt is the transmitted power, Gt and Gr are the antenna benefit of the transmitter and receiver, λ (Equation 2) is the carrier wavelength it's miles same to:

$$\lambda = \frac{f}{c} \quad (2)$$

where λ is wavelength of the signal, c is the velocity of the light, and f is the service rate of the signal.



• Fig. 6 RSSI method

The estimation of the position of a goal may be calculated the usage of the information obtained from the radius of circles, which signifies the distance among reference nodes and the vacation spot node. The main idea is that if the harmonics of i reference nodes had been known as (x1,y1), (x2 , y2) ,…, (x_i, y_i), in Fig.6 and their distance from target node n became d1,d2, …,di, (Equation 3) and the following procedure with coordinate (x , y) of the target node [24,27].

$$\begin{cases}(x_1 - x)^2 + (y_1 - y)^2 = d_1^2 \\ (x_2 - x)^2 + (y_2 - y)^2 = d_2^2\end{cases} \quad (3)$$

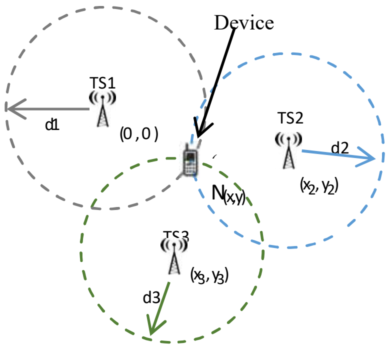
On the solving above equations, we can get the value of U(x, y) and U(x', y'), so we calculate Mean Square Error (MSE) to measure distances of estimated node coordinates (x_i, y_i) and the actual node coordinates (x, y), for i = 1, 2, 3... N , using the Euclidian distance mentioned on the Equation 4:

$$\mathrm{Error}_{rss} = \sqrt{(x - x')^2 + (y - y')^2} \quad (4)$$

B. Time of Arrival (ToA)

The time of arrival method is based on time difference estimation between receiver and sender. By measuring the time taken in one sided communication between sender and receiver, distance is estimated. It has to be taken care that both must be in time synchronization.

Locating Position based on TOA is based on combining the time of arrival estimate measured at several receivers by one transmitter. Fig.7 demonstrates this [24, 25, 27].



- Fig.7 ToA method

The time of flight (TOF) (ti) estimate is used to calculate the distance (di) between transmitter and receiver by using Equation 5:

$$d_i = (t_i - t_o)c \qquad \text{where } i = 1,2,3 \quad (5)$$

Where c is the speed of light, t_i is the TOF, t_o is the actual time instant at which the transmitter device starts transmission and d_i is the distance between the transmitter and the receiver.

To get location of target node, coordinates are found out using Equations 6-9 [27]:

$$d_i^{\,2} = x_i^{\,2} + y_i^{\,2} \quad (6)$$

$$d_1^{\,2} = x_0^{\,2} + y_0^{\,2} \quad (7)$$

$$d_2^{\,2} = (x_2 - x_0)^2 + (y_2 - y_0)^2 \quad (8)$$

$$d_3^{\,2} = (x_3 - x_0)^2 + (y_3 - y_0)^2 \quad (9)$$

On the solving above equations, we can get the value of U(x, y) and U(x', y'), so we calculate Mean Square Error (MSE) to measure distances of estimated node coordinates (x_i, y_i) and the actual node coordinates (x0, y0), for i = 1, 2, 3... N, using the Euclidean distance mentioned on the Equation 10

$$\mathrm{Error}_{ToA} = \sqrt{(x - x')^2 + (y - y')^2} \quad (10)$$

C. Angle of Arrival (AoA)

Angle of arrival is the angle between propagation direction of incident wave and some reference direction. This is also called orientation. This reference direction is always considered north and orientation is considered in a clockwise direction from North. The AOA method uses antenna array at each sensor node. The AOA method is very precise and accurate due to capability of receiving signal by each antenna in the array. The localization of a node by using the information by these antennas is calculated by triangulation method [25-27].

The target node has coordinates (x,y) and with receiver signal has (xi,yi). The orientation angle formed between them is φ_i. This angle will be angle of arrival which is defined as the Equation 11:

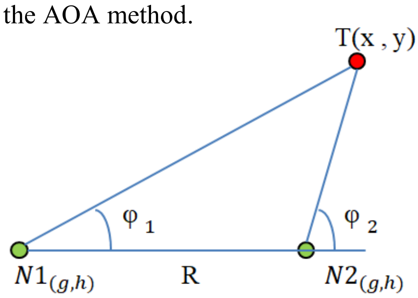
$$\tan \varphi_i = \frac{y - yi}{x - xi} \quad (11)$$

The target node co-ordinates can be determined by using these set of Equations 12-13:

$$x = \frac{R \tan\varphi_2}{\tan\varphi_2 - \tan\varphi_1} \quad (12)$$

$$y = \frac{R \tan\varphi_2 \tan\varphi_1}{\tan\varphi_2 - \tan\varphi_1} \quad (13)$$

where R is the distance between the two reference stations N1 and N2. φ_1 And φ_2 are the angles of arrival at two reference nodes. x, y are the coordinates of the target node. Fig.8 shows the AOA method.



- Fig.8 AOA method

Mean Square Error (MSE) is calculated to measure distance between actual nodes and estimated nodes coordinates, using the Euclidian distance mentioned on the Equation 14:

$$\mathrm{Error}_{\mathrm{AoA}} = \sqrt{(x - x')^2 + (y - y')^2} \quad (14)$$

VII. RESULTS

In this section, simulation results are shown and analyzed. The performance evaluation focuses on the calculation of Mean Square Error (MSE) and calculation of processing time of the algorithms investigated. RSSI, ToA, and AoA schemes are evaluated and compared with each other through MATLAB simulation. A different number of nodes (5, 21, 60, 96,140) are deployed in a sensor field of a 2-dimensional region with (7m×7m, 10m×10m, 20m×20 m, 40×40m square units).

In our scenarios, we used four anchor nodes which are steady on the network corners in a square shape and whose positions are already known. The unknown nodes are deployed in a grid shape in different densities and each unknown nodes calculates the position by these algorithms above schemes.

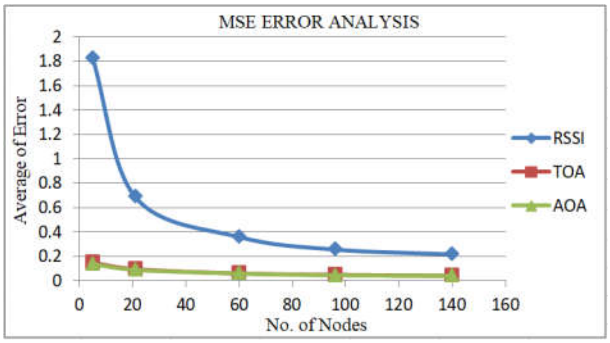
There are two divided cases to show results summary as exhibited below:

A. Case one, Comparison of Mean Square Error (MSE)

In the table below we can see the simulation results of the localization error rate and the AOA is the best one in terms of MSE value.

Table 1. : Summary of comparison (MSE)

Scenario m2	MSE Error		
	RSSI	TOA	AOA
7×7m2	Medium	Low	Low
10×10m2	Medium	Low	Low
20×20m2	Medium	Low	Low
40×40m2	Medium	Low	Low



- Fig.9 density of nodes and Average of error (MSE)

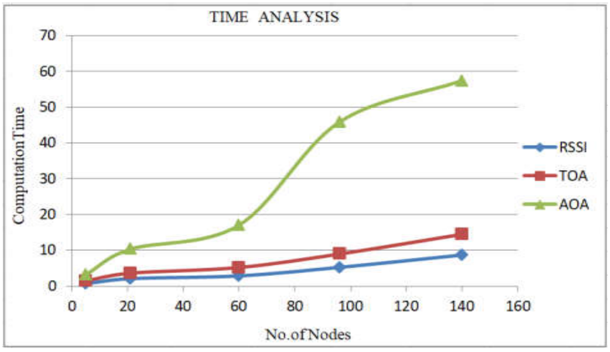
Fig.9 above shows compares the average localization error (MSE) vs. density of nodes.

B. Case two, Comparison of computation time

The table below shows the simulation results of the processing time and the RSSI gives better performance compared to the other algorithms.

Table 2. : Summary of comparison computing time

Scenario m2	Computation Time		
	RSSI	TOA	AOA
7×7m2	Low	Medium	High
10×10m2	Low	Medium	High
20×20m2	Low	Medium	High
40×40m2	Low	Medium	High



- Fig.10 density of nodes and computing time

Fig.10 above shows compares the average computing time vs. density of nodes.

VIII. DISCUSSION

After analyzing the results of all experiments the localization algorithms and running them in different density of nodes and the network size, the following conclusions are obtained:

a. AoA & ToA Algorithms are more accurate in different densities node & size networks and have less mean square error (MSE) than nearest.

b. AoA & ToA algorithms are very efficient in terms od Mean square error (MSE) when using a large density nodes.

c. RSSI algorithm produces higher mean square error (MSE) than AoA & ToA algorithms.

d. RSSI algorithm has the least computing time in different densities.

IX. CONCLUSION

This paper gives a brief idea about the recently popular WSN localization techniques since the sensor node's location is very important in most applications. We presented the various localization algorithms which are commonly used in WSN localization. These algorithms are evaluated in terms of Mean Square Error (MSE) and the processing times. It was seen that in the results from the first case the AoA algorithm has less MSE value compared to the RSSI and ToA algorithms. While the RSSI algorithm generally requires less compuation time compared ToA and AoA algorithms. It can be concluded that the AOA is suitable for applications that need high accuracy, while the RSSI gives better performance in the time critical applications

REFERENCES

[1] A. Sharma,''A Research Review on Segmentation Techniques,'' *(UGC Approved Journal).*, Volume. 5, Issue. 12, August.2017.

[2] C. Perera, C. H. Liu, S. Jayawardena, and M. Chen, "A Survey on Internet of Things from Industrial Market Perspective," *IEEE.*, volume. 2, pages. 1660–1679,2015.

[3] K. Nellore and G. P. Hancke,''A Survey on Urban Traffic Management System Using Wireless Sensor Networks,''*Journal.,*Volume.16, pages.157, 2016.

[4] L. Singh, and S. Kaur,''Techniques of Node Localization in Wireless Sensor Networks A Review,'' *International Journal.,*Volume. 2, Issue. 5, pages. 4143-4148, 2014.

[5] K. Sohrabi, J. Gao, &V. Ailawadhi, ''Protocols for Self Organization of a Wireless Sensor Network,''*IEEE.,*pages.16-27,2000.

[6] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey," *ELSEVIER Computer Networks 2002*, Volume. 38, no. 4, pages. 393–422.

[7] O. Mehta, A. Virparia, J. Patel, and M. Valera, ''A Review on Localization in Wireless Sensor Networks,'' *Journal Advances in Intelligent Systems and Computing June-2016*, Volume 3, Issue 6, pages 2464- 2467.

[8] S. P. Singha, and S. C. Sharmab, ''Range-Free Localization Techniques in Wireless Sensor Networks A Review,''*Conference Elsevier2015.,* Volume.57,pages.7-16.

[9] D. Niculescu, and B. Nath, ''Ad hoc positioning system (APS) using AOA,''*Conference IEEE2013.,*

[10] A. A. Kannan, G. Mao and B. Vucetic, ''Simulated Annealing based Wireless Sensor Network Localization,''*Journal2006.,*Volume.01, pages.15-22, Australia.

[11] C. Alippi, and G. Vanini, ''A RSSI based and Calibrated Centralized Localization Technique for Wireless Sensor Networks,''*IEEE Conference.,*Italy,2006.

[12] K. Langendoen, and N. Reijers, ''Distributed localization in wireless sensor networks a quantitative comparison,'' *Elsevier Journal2003.*, Volume.43, pages. 499-518.

[13] D. Moore, J. Leonard, D. Rus, and S. Teller, ''Robust Distributed Network Localization with Noisy Range Measurements,''*ACM Conference USA.,* 2004.

[14] C. Savarese, and J. Rabaey,'' Robust Positioning Algorithms for Distributed Ad-Hoc Wireless Sensor Networks,*''Annual Technical Conference 2002.*, pp.317-327,USA.

[15] L. Hu, and D. Evans, ''Localization for Mobile Sensor Networks,'' *Annual Conference 2004.,*USA.

[16] M. Farrag, M. Abo-Zahhad, M.M. Doss, and J. V. Fayez, ''Different Aspects of Localization Problem for Wireless Sensor Networks A Review.'' *International Journal 2016.,* Volume.04, Issue.05, pages. 130–140.

[17] N. B. Priyantha, H. Balakrishnan, E. Demaine, and S. Teller, ''Anchor Free Distributed Localization in Sensor Networks,'' *MIT Laboratory 2003,*

[18] N. Mitton, and D. Simplot-Ryl, ''Wireless Sensor and Robot Networks: From Topology Control to Communication,''World Scientific., Singapore, 2014.

[19] A. Mesmoudi, M. Feham, and N. Labraoui, ''Wireless Sensor Networks Localization Algorithms A Comprehensive Survey,'' *Journal 2013.,* Volume.5, page.6.

[20] A. Kumar, and D. Prashar, ''Localization Techniques in Wireless Sensor Networks: A Review,''*Journal.,* Volume.5, Issue.8,pages.268-272, August. 2016.

[21] N. A. Alrajeh, M. Bashir, and B. Shams, ''Localization techniques in wireless sensor networks,''*Journal Hindawi 2013.*,Volume.2013, pages.1-9.

[22] H. Chen1, Q. Shi, P. Huang, H. Vincent Poor and K. Sezaki, "Mobile Anchor Assisted Node Localization for Wireless Sensor Networks,'' *IEEE 2009.,* Tokyo, Japan.

[23] S. Singh, R. Shakya, and Y. Singh, ''Localization Techniques in Wireless Sensor Networks,'' Journal 2015, Volume.6, Issue.1, pages.844-850.

[24] Amitangshu Pal, ''Localization Algorithms in Wireless Sensor Networks: Current Approaches and Future Challenges,''*(macrothink) 2010.*, Volume.2, page.1.

[25] S. Kumar, and R. M. Hegde, ''A Review of Localization and Tracking Algorithms in Wireless Sensor Networks,'' *Networking and Internet Architecture (cs.NI) 9 Jan 2017,* USA.

[26] A. Boukerche, H. A. B. F. Oliveira, E. F. Nakamura, and A. A. F. Loureiro, ''Localization systems for wireless sensor networks,'' *IEEE December 2007.*,'' Volume.14, Issue.6, pages.6-12.

[27] B. Singh, Santosh K. Sahoo, and S. R. Pradhan, ''Performance Evaluation of Anchor-based Range-based Localization Systems in Wireless Sensor Networks,'' *Journal August 2012,* Volume.52, Issue.17, pages.24-29.