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REVIEW OF VARIOUS LOCALIZATION TECHNIQUES IN WIRELESS SENSOR NETWORKS

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Abstract: A network which consist of very small devices known as Sensor Nodes. WSN is a rapidly developing area which is gaining considerable research in scientific community. One of the major issue in WSN is localization of the nodes. It estimates nodes position and information given by nodes is worthless without knowledge of their geographical positions. In different application scenarios including environmental monitoring (like temperature, pressure, humidity etc.), health care, industrial controlling, inventory system, traffic control monitoring, target tracking, in rescuing other emergency situations etc. node localization has significant demand. Localization process is useful in many aspects such as to report the origin of events, routing and network coverage. This paper review and analyze various localization techniques and focus on various open research issues in localization.

Key Words: Sensor Nodes, Localization, Anchor nodes, Location Accuracy, Mobility.

1. INTRODUCTION

Sensor networks consists nodes deployed haphazardly and linked through wireless standard to supervise environmental circumstances i.e. sound, pressure, vibration, temperature etc. and then it intimately send the data to base terminal. Localization [1] is a key mechanics for the evolution and exploitation of WSNs because the location information of sensors is useful for several tasks such as deployment, routing, target tracking and coverage. Localization is done either manly or through GPS. But this is not possible in large scale or in inaccessible areas such as dense forest, volcanoes where sensors are mobile. A simple way is to fix up each node with a GPS but it is impractical because of some factors like cost, energy requirements and environment suppression. Several techniques have been suggested for working out Localization problem, but most of them deal with 2-dimensional network. Hence, a location estimation flaw in three dimensions is a demanding concern area in the research community. Analysis of localization approaches focusing on 3-D space is a significant task as a future research work. This papers starts with the overview of the work done in the various localization algorithms based on the criteria of their application and also address some open issues at the end.

2. LITERATURE REVIEW

Localization [2] is a process of estimating the position and co-ordinates of wireless sensor nodes. Location information is important due to several factors such as the recognition of gathered data,

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node labeling, management and concern of localized nodes in a decided region, impact of node's density and coverage, energy draft formation, topographical routing, entity tracking, and other geographic algorithms.

In Wireless Sensor Networks, Sensor Nodes determine their location by localization. For this purpose localization algorithms [3] are used in WSN. The nodes which are conscious of their positions either from GPS or manly configured are known as Anchor nodes. The nodes which don't know their positions form reference of anchor nodes to measure their positions. For localization algorithms are required that should be cost-effective, energy efficient, robust and scalable localization.

Localization Process [4] consists of mainly two stages which are as follows:

Stage 1: Ranging process, Normal nodes estimate their distance or angle from anchor nodes using strength of signal received and using different methods.

Stage 2: Position Estimation Process, sensor nodes uses estimates based on the distance to compute its actual location.

Localization process locates the sensor nodes based on the input data and other inputs based on localization measurement techniques as shown in Figure 1 below.

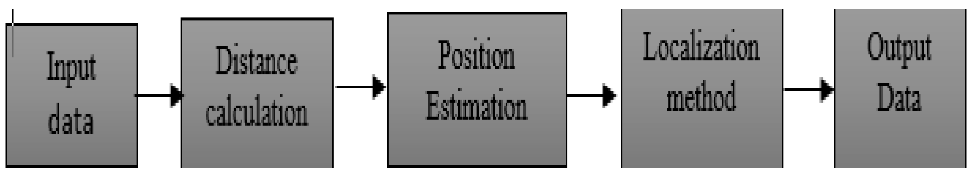

Figure 1. Overview of Localization Process

2.1 Localization Parameters

Localization Parameters [5] are as follows:

- **Accuracy and Precision:** The relevant criterion for localization is accuracy and precision. Accuracy means proximity of the estimated position to the true position. Precision refers to the consistency and reliability of measured position.
- **Scalability:** It is defined as how promptly the localization technique provides the location information. This is also known as responsiveness.
- **Self-organization:** Ability of system to monitor, control and arrange the activities of the elements without help of any external agency.
- **Power:** Power is a necessary parameter in wireless sensor network. Each sensor node has power which is driven from battery.
- **Node Density***:* Performance of algorithms also depend on node density. Some algorithms such as hop-count based require high node density for accurate results.
- **Mobile Nodes:** Wireless sensor networks consist a few number of GPS enabled mobile nodes that are homogeneous in nature. Mobile nodes have more battery power and coverage than the static nodes. Also the mobile nodes are more energy efficient.

2.1 Substantial Evaluation Based Localization

Localization is impractical without the knowledge of physical world, so sensor nodes have to measure their physical co-ordinates. There are several measuring techniques ranging from fine-grained to coarse-grained such as location information, hop value and neighboring information as mentioned in Fig.2.

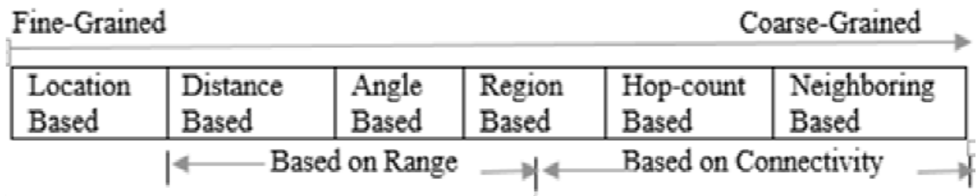

Figure 2. Substantial Evaluation Techniques

GPS is best measurement approach that obtains location directly without any further computation. But addition of GPS to all nodes in the wireless sensor network is impractical because of its high cost, high power usage and environment suppression, which makes it infeasible for indoor applications. Instead of using GPS approach, the position of an unknown node is estimated from reference nodes. The nodes which are aware of their locations either through GPS or manly configured are known as Anchor nodes and the nodes which don't know their positions i.e. unknown nodes form reference of anchor nodes to measure their positions. The distance and angle evaluations are done using some ranging techniques. Hop count and neighborhood measurements make use of radio connectivity information. The area evaluations can use either range or connectivity information based on design of area constraints.

3. CLASSIFICATION OF LOCALIZATION TECHNIQUES

Localization is a process of estimating the position and co-ordinates of wireless sensor nodes. For localization in WSN, hundreds of localization algorithms exist. Therefore these algorithms are classified [6], [7], [8] under different categories which are as follows:

1. GPS Based vs. GPS Free
2. Anchor Based vs. Anchor Less
3. Centralized vs. Distributed
4. Range Based vs. Range Free

GPS Based Localization

In GPS based network all the nodes are fitted with GPS system that provides accurate location estimation to all the nodes. But equipping GPS in all the nodes is impractical because of its inability to work in indoor applications. Its localization accuracy is too high but it very costly from economic point of view.

GPS Free Localization:

GPS free algorithms do not use GPS based systems to localize nodes. Only few nodes are equipped with GPS systems which are known as Anchor or Beacon nodes which begin localization operation and use connectivity information to measure the path length among the nodes corresponding to local network. It is cheaper as compared to GPS based algorithms.

Anchor Based Localization

Anchor nodes are used in these algorithms to compute the position of normal nodes in the network. Anchor-based algorithms generally compute absolute location system. For accuracy of reference point's large number of anchors is required.

Anchor Free Localization:

This approach of localization computes the distance between nodes through the regional map. In these algorithms relative position estimates are made rather than absolute node positions and then relative coordinate map is translated to absolute one using the coordinates of and four according to non-collinear nodes. The shortcoming of these algorithms is recompilation of static nodes with the mobility of reference node.

Centralized Localization:

In Centralized Localization a central sensor node gets all the information in the whole network. Helps to reduces computational overhead of location estimation on respective nodes but increases communication cost. Scalability is another issue in this approach and also not deemed fit in terms of security.

Distributed Localization:

In Distributed localization, sensor nodes execute all significant estimations themselves by communicating with each other to obtain their positions in the network. This approach reduces the communication overhead introduced in the network but raises computational overhead. But in the inter-node communication, there is no concept of using shortest-path method, as it leads to a decrease in output.

Range Based Localization

Range Based Localization [9] algorithms the distance between the nodes is using various parameters like RSSI, TDoA and AoA. It has two subtypes' one-hop and multi-hop estimations. These approaches provide fine-grained localization but increase cost due to requirements of extra ranging hardware.0Range-based localization is generally consisting of two phases which are as follows:

1. Range Computation Method and 2. Range Connecting Technique

1. ***Range Computation Method***: Ranging is the process of calculating distance or angle. Various methods for the computation are:
    - *Time Dependent Methods:* ToA or TDoA methods measures the signal transmission and received time or the difference in the received times.
    - *Angle Based Methods*: They are based on the angles at which signals are received. AoA techniques provide more refined and better results than RSSI techniques. But hardware cost is more in these methods.
    - *RSSI (Received Signal Strength Indicator) Methods*: These methods make estimations for the signal strength value This method generally operates with RF signals.
    - *Network Connectivity methods*: These are also range estimation methods which are used when sensors are not capable of receiving enough signals from access points or the hardware cost of range estimating devices is high. For example, the range is estimated among two nodes by using the hop counts between them.
2. ***Range Connecting Technique***: After computation of range, the localization algorithm tries to locate the node on the basis of range estimations. Some of the known ranges combining methods are as follows:

- *Triangulation*: This method is used in those scenarios where angle estimations are made rather than distance estimations such as AoA techniques. Trigonometry laws of sines and cosines are used to find the location of nodes.
- *Trilateration:* In this method the distance measurements of three anchor nodes to the unknown node are used in form of tuples (x, y, d). The unknown node is located using simple geometric calculations and intersection of three anchor nodes.
- *Multilateration*: This method estimates the location of a node using intersection of hyperbolas rather than circles because it uses more than three anchor nodes. This estimation is based on signal's arrival time or the distance from more than three anchor nodes and provide precise location measurements. The combination of multilateration with RSSI methods meets the requirements of logistic applications.
- *Maximum Likelihood Measurement*: It is one of the popular methods of statistics. It works on the principal of reducing the value of node position based on actual estimation and computed one.
- *Proximity-based*: This method is suitable in those cases where accessibility to range information is almost negligible. Selection of connected anchors is done on the basis messages value with respect to threshold value.

Range Free Localization:

Range Free Localization [10] is an eventual approach. In this approach, every node makes efforts to find precise route to all other nodes in the WSN. Hop count can be converted into distance estimation by multiplying the moderate transmission range of the node. This localization called as Pattern matching, also known to be map-based and Fingerprint algorithm. The benefits of these techniques are simplicity due to use of network's topology information and low cost due to no need of any special hardware. These techniques can be further classified as two ways:

(a) Local methodologies and (b) Hop counting methods.

(a) *Local Techniques:* In these techniques, unknown node gathers information of its neighbor anchors co-ordinates to estimate its own position. The some of the known local range free algorithms for location estimation are: Centroid and APIT.

(b) *Hop Counting Techniques:* In hop-counting methods hop count value is used. Most popular Hop Counting Technique is DV-Hop.

4. COMPARATIVE STUDY ON LOCALIZATION TECHNIQUES

Table 1
Study Based on Different Localization Techniques

Category	*Technique*	*Advantages*	*Disadvantages*
1. Range Based	-Based on Range or Angle Estimation -Fine-Grained Localization -depend upon point-to-point distance estimation	-Anchor Free -Computationally efficient -Fine Resolution	-Degrade localization accuracy due to presence of outliers, ranging noise, Multipath Fading.

2. Range Free	-Based on Connectivity and Topology information -hop count & neighborhood based -Coarse- Grained Localization	-Simple, Cost effective -no additional hardware -applicable in large WSN	-Less accuracy due to ranging errors -Coarser estimations
3. Centralized	Central Base Station performs all computations	-precise locations -solution for computational limitation of nodes	-if central nodes fails whole network collapses -more time delay and traffic congestion -no scalability
4. Distributed	-Each node is responsible for Position estimation	-Good scalability -Reduces traffic congestion -no single point of failure -less storage requirements -computational burden distributed equally	-Localization error is large -no concept of shortest path for inter-node communication that leads to decrease in throughput
5. GPS Based	-Each node is equipped with GPS system	-simple, high accuracy -can use in outdoor applications	-unreliable, sensor nodes required to be small -fails in indoor applications
6. GPS Free	-Location estimation using connectivity information	-used in indoor localization -less error, scalable -supports mobility of nodes	-estimate only relative positions
7. Anchor Based	- use of Anchor nodes having their position estimates	-absolute node positions -simple, effective	-scalability problem -Network-Wide Flooding
8. Anchor Free	-Do not make any assumptions about node locations.	-relative node positions -less convergence time	-Mobility problem

Table 2
Comparison Among Various Localization Techniques

Category	*Range Based*	*Range Free*	*Centralized*	*Distributed*	*GPS Based*	*GPS Free*	*Anchor Based*	*Anchor Free*
Accuracy	Good	Average	High	Medium	High	Medium	High	Medium
Power Usage	Large	Average	Large	Less	Large	Average	Large	Less
Communication Cost	More costly	Low	High	Less	High	Less	Medium	Less
Robustness	Less	Robust	Less	Medium	Medium	Medium	Medium	High
Deploybility & Maintainability	Difficult	Less Difficult	Difficult	Easy	Medium	Easy	Difficult	Less Difficult
Computational Cost	Low	Medium	Large	Fair	Large	Less	Fair	Large
Hardware Cost	Minimum	Minimum	Low	Large	Large	Less	Large	Low
Algorithms	RSSI,TDOA,AOA etc.	APIT, DV-Hop, Centroid etc.	MDS-MAP	APIT,APS, REP, SeRLoc etc.	Weighted Least Square Method	MSPA	APS , N-Hop Multi-Literation	AFL,AFLR etc.

5. STUDY OF SOME OF DISTRIBUTED, ANCHOR BASED RANGE FREE LOCALIZATION ALGORITHMS

Some of the most popular range free algorithms are as follows:

1. APIT: In this network is divided into Triangular regions. To increase the accuracy of location estimations the diameter of the considered area can be reduced using anchor positions.

The APIT algorithm [11] includes the following four steps:

(i) Gather Information from anchors: Unknown nodes listen messages from nearby anchor nodes and record the position, anchors ID and signals strength in form of tables.

(ii) Testing: Testing is performed to check whether unknown node resides inside or outside the triangular region that is formed from three anchor nodes.

(iii) APIT aggregation: Aggregation estimates the overlying regions of the all triangles that contain unknown nodes.

(iv) Computation of unknown node’s position: Centroid of the region is the position to be computed. These steps are applied in distributed manner to individual nodes.

Algorithm of APIT: Location data received from anchor data (Ai, Bi) from M anchors

Inside Set = Null

For (each triangle $\Delta i \in \binom{N}{3}$ triangles)

{

If (PIT-Test (Δi) == TRUE)

Inside Set = Inside Set ∪ {Δi}

If (accuracy (Inside Set) > max) break;

}

/* Computation of Center of gravity */

Computed Position = COG (∩Δi∈ Inside Set);

2. Centroid: Centroid localization algorithm is a range free algorithm [12], [13]. It provides coarse-grained localization estimations. The position of node is find with the help of anchors coordinates (Xi, Yi) information and then centroid is calculated. This algorithm has following three steps.

(a) Anchors broadcast its location to everyone in their range.

(b) Every node receives that information and gathers the messages sent by its anchor nodes in a fixed time interval t.

(c) After that centroid formula determines positions of unknown node.The limitation of this algorithm is high localization error is high.

For improvement of localization accuracy, the weighted centroid localization algorithm came into existence.

Weighted Centroid Algorithm: To provide accurate location estimations as compared to the centroid method where arithmetic centroid is calculated as object's location, WCL makes use of weights.

Distance of node U from three anchors A1, A2 and A3 can be estimated as d1, d2, d3 respectively. Assume d′ as the barycenter of the triangle formed by given three anchors, then d′ coordinate.. At last the unknown node's coordinate d′ can be deduced as per the equation below :

$$(X, Y) = \left(\frac{\frac{d1'X1}{d1}+\frac{d2'X2}{d2}+\frac{d3'X3}{d3}}{\frac{d1'}{d1}+\frac{d2'}{d2}+\frac{d3'}{d3}} \;,\; \frac{\frac{d1'Y1}{d1}+\frac{d2'Y2}{d2}+\frac{d3'Y3}{d3}}{\frac{d1'}{d1}+\frac{d2'}{d2}+\frac{d3'}{d3}} \right)$$

where $\frac{di'}{di}$ refers to the weight of i anchor nodes (i=1,2,3).

3. **DV-Hop:** DV-Hop algorithm [14] is built upon traditional distance based routing schemes. It is a Hop-counting technique in which an unknown node finds minimum hop value. It consists of following three steps:

   Step 1. Beacon Exchange: Each unknown node records hop value that is minimum. Anchors having high hop count value for same packet are discarded. After that hop count is incremented by one, and forwarded to the neighbors..

   Step 2. Calculation of distance between anchor & unknown node: As in first step each beacon node records other beacon nodes position information and hop counts to estimate the average 0hop distance using eq1 as follows:

$$Hop\ Size_i = \frac{\sum_{i\neq j}\sqrt{(x_{i-}x_j)^2 - (y_{i-}y_j)^2}}{\sum_{i\neq j} h_{i,j}} \quad (1)$$

   After the calculation of hop-size, it is flooded in the network and then distance between the unknown node with respect to anchor node is given by Eq. (2)

$$d_{pk} = HopSize_i \times hop_{pk}\ , \quad (2)$$

   Step 3. Unknown nodes use trilateration to estimate its own locations.

Improved DV-Hop: This is the improved version of DV-Hop algorithm [15], [16] to overcome its shortcomings. It make some changes in DV-Hop in second and third steps.

Step1. Anchor nodes broadcast packet and estimate their distances to neighboring nodes. Broadcasted packet contains locations, IDs of anchors, hop counts and priority information.

Step2. Unknown node will get the information. by using Eq.(3)

$$HopSize_{avg} = \sum HopSize_i\ /n \quad (3)$$

Estimated distance between the unknown node and anchor is given by by Eq. (4)

$$d_i = \text{hops} \times HopSize_{avg} \quad (4)$$

Step3. Here unknown nodes calculate their own positions using 2-D algorithm. This algorithm provides location accuracy but increases communication cost.

RNLEDV-Hop (Reduced Local Error DV-Hop): This algorithm [17] contains changes in 2^{nd} and 3^{rd} step of DV-Hop as follows:

Step2. The distances among anchor nodes are estimated by Eq. (5)

$$d_{est}^{i,j} = HopSize_i \times h_{i,j} \text{ ,for all i not equal to j} \quad (5)$$

Distance among the anchor node is computed by Eq. (6):

$$d_{true}^{i,j} = \sqrt{(x_{i-} x_j)^2 - (y_{i-} y_j)^2} \quad (6)$$

Estimation Error = deviation of the estimated distance from the actual distance is calculated as:

$$e^{i,j} = d_{est}^{i,j} - d_{true}^{i,j} \quad (7)$$

Average hop-size find out using this error as:

$$HopSize_{eff}^{i,j} = HopSize_i - \frac{e^{i,j} + e^{i,k}}{h^{i,j} + h^{i,k}} \quad (8)$$

Where ‘k’ is nearby anchor of anchor i.

After all the above estimations, hop-size is flooded and then p is calculated as:

$$d_{eff}^{p,j} = HopSize_{eff}^{i,j} \times h_{p,j} \quad (9)$$

Step3. Unknown node estimates: Accuracy is improved using covariance matrix is used.

Limitation:

(a) Complex computations of hop-size.

(b) Covariance matrix add to overhead.

Advanced DV-Hop: This makes change only in third step of DV-Hop [18], [19]. Instead of using trilateration, maximum likelihood and 2-d hyperbolic location methods it uses a different approach which is improved with the use of Weighted Least Square Method. The third step of this algorithm is as follows:

Step3. To find the location estimation as given below

Position is computed as:

$$\begin{aligned} \sqrt{(x-x_1)^2 + (y-y_1)^2} &= d_1 \\ \sqrt{(x-x_2)^2 + (y-y_2)^2} &= d_2 \\ &\vdots \\ \sqrt{(x-x_n)^2 + (y-y_n)^2} &= d_n \end{aligned} \quad (10)$$

Error can be reducing in the last equation from first $n - 1$ equations and take square.

$$\begin{aligned} \sqrt{(x-x_1)^2 + (y-y_1)^2} - \sqrt{(x-x_n)^2 + (y-y_n)^2} &= d_1 - d_n \\ \sqrt{(x-x_2)^2 + (y-y_2)^2} - \sqrt{(x-x_n)^2 + (y-y_n)^2} &= d_2 - d_n \\ &\vdots \\ \sqrt{(x-x_{n-1})^2 + (y-y_{n-1})^2} - \sqrt{(x-x_n)^2 + (y-y_n)^2} &= d_{n-1} - d_n \end{aligned} \quad (11)$$

Squaring both sides:

$$-2\,(x_1+x_n)\,x - 2\,(y_1+y_n)\,y + 2k = d_1^2 + d_n^2 - (E_1 + E_n)$$

$$-2\,(x_2+x_n)\,x - 2\,(y_2+y_n)\,y + 2k = d_2^2 + d_n^2 - (E_2 + E_n)$$

$$\vdots$$

$$-2\,(x_{n-1}+x_n)\,x - 2\,(y_{n-1}+y_n)\,y + 2k = d_{n-1}^2 + d_n^2 - (E_{n-1} + E_n) \quad (12)$$

where k= $x^2 + y^2$; $E_i = x_i^2 + y_i^2$, $\forall i = 1,2,3, \ldots \ldots .. n$

Matrix Form:

$$A=\begin{bmatrix} -2\,(x_1+x_n)\,x & -\,2\,(y_1+y_n)\,y & 1 \\ -2\,(x_2+x_n)\,x & -\,2\,(y_2+y_n)\,y & 1 \\ \vdots & & \\ -2\,(x_{n-1}+x_n)\,x & -\,2\,(y_{n-1}+y_n)\,y & 1 \end{bmatrix}, \quad (13)$$

$$B=\begin{bmatrix} d_1^2 + d_n^2 & -\,(E_1 + E_n) \\ d_2^2 + d_n^2 & -\,(E_2 + E_n) \\ \vdots & \\ d_{n-1}^2 + d_n^2 & -\,(E_{n-1} + E_n) \end{bmatrix}, \quad C=\begin{bmatrix} x \\ y \\ k \end{bmatrix} \quad (14)$$

Unknown node’s coordinates (x, y) are obtained by solving these matrix equations. To improve the location accuracy, apply WLS method:

$$Z= (Q'W'W\,Q)^{-1}\,Q'\,W'\,W\,H \qquad \text{where } W=\begin{bmatrix} W_{p,1} & 0 \ldots & 0 \\ 0 & W_{p,2} \ldots & 0 \\ \vdots & \vdots & \vdots \\ 0 & 0 & W_{p,n-1} \end{bmatrix} \quad (15)$$

and $w_{p,i}$ is the weight of the unknown node.

6. COMPARATIVE STUDY OF ABOVE MENTIONED APIT, CENTROID AND DV-HOP ALGORITHMS

Table 3
COMPARISION AMONG APIT, CENTROID, DV-HOP

Function	*APIT*	*Centroid*	*DV-Hop*
Algorithm Type	Distributed and Beacon Based	Distributed & Beacon Based	Distributed and Beacon Based
Classified as	Proximity Based	Proximity Based	Network-Connectivity Based
Accuracy	Good	Fair	Good
Scalability	Yes	Yes	No
Overhead	Low	Medium	High
Cost	Low	Low	Medium

7. ISSUES IN LOCALIZATION TECHNIQUES

Sensor network localization has numerous issues [20], so still there is a lot of scope for research community. Some of the issues are:

- *Cost effective algorithms*: During the design of localization algorithm, the cost incurred in hardware and deployment must be considered. GPS is not suitable because of its cost and size of hardware. The use of GPS Devices is not recommended because of higher price and size of hardware.
- *Robust algorithms for mobile sensor networks*: Mobile sensors are much useful in some environments because of mobility and coverage facility. Hence, development of new algorithms must support mobility.
- *Algorithms for 3 Dimensional spaces*: For many WSN applications, accurate location information is crucial. The more of the proposed algorithms are applicable to 2D space. Some of the application needs 3-D positioning of WSNs.
- *Accuracy*: If there is incorrect estimation of node position, then localization accuracy reduces. Accuracy is very much important factor in sensor localization.
- *Scalability*: In large scale deployment, the monitoring area and sensor nodes should be enlarge in size. For checking the scalability of localization techniques it requires careful observation.

CONCLUSION

Wireless sensor network localization is in focus of research community now days. So this paper had provided a review of various distributed localization techniques and also provide complete study on various types of localization techniques with their merits and demerits have been discussed. This paper provides comparative study of the different localization techniques and represents that comparison in tabular form. In this paper the classification of distributed localization algorithms on the basis of range measurements is reported. Regardless of significant research development in this area, some unsolved problems are still there. At the end, we focused on the certain issues need to be addressed. This paper is very useful for the research group those are interested in development, modification and optimization in localization.

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