ISSN:0975-9646

Localization Techniques in Wireless Sensor Networks

Shweta Singh, Ravi Shakya, Yaduvir Singh
Department of Computer Science,
Ideal Institute of Technology, Ghaziabad

***Abstract*— New advances in wireless sensor networks (WSNs) make it a significant technology. Because of its ad-hoc and infrastructure less nature, it has gained the attention of most of the researchers in past few years. In wireless sensor, network sensor nodes are having limited energy and resources. The most important characteristic of a sensor is to collect data, process it and transmit to the destination. For transmitting the data, it is desirable to know the location of sensors. In WSNs, for obtaining this kind of information we need localization techniques. Localization techniques (algorithms) are used to determine the geographical placement (location) of sensor nodes. Localization in wireless sensor network is not only useful for location determination but also it is important to provide the base of routing. It can also be useful for density control, tracking and other communication aspects, so it is very important that every node should reports its location information very accurately. As we know that GPS is very accurate in location determination but it is expensive in terms of cost and energy of nodes, so it is not useful in wireless sensor networks. There are so many localization techniques (algorithms) are proposed for wireless sensor networks. Accuracy of localization techniques is most important before implementing it. Here in this paper our main focus is on the localization error. Localization error is the difference between the actual location and the estimated location of the sensor node. This paper helps the network designers to find out which techniques/algorithms are suitable for their application.**

***Keywords:* Localization, Wireless Sensor Network, Range-Free, Range Based, Anchor node, un-localized node, Beacons, TOA, TDOA, RSSI, AOA, Centroid, HIRLOC, SERLOC, ADLA.**

I. INTRODUCTION

Sensors are low-cost, low-power, multifunctional tiny devices, connected wirelessly and useful in most of the applications for monitoring and controlling environment, homes, cities, health care, target tracking and the defense area. Sensor network node contains many parts like a radio transceiver for transmitting and receiving data, an energy source (battery), a microcontroller, and an electronic circuit. The main function of a sensor network is to collect data, process gathered data and forward it to the destination. The most desirable feature of wireless sensor networks is Self-localization. For most of the applications, the collected data are meaningless if there is no information from where the data is obtained. Localization is necessary for applications such as inventory management, bush fire surveillance, intrusion detection, water quality monitoring, road traffic monitoring, health monitoring, environmental monitoring, and precision agriculture etc. In this paper we mainly focused on range based and range free schemes that are widely used in most of the WSNs applications.

II. LOCALIZATION SCHEMES AND PARAMETERS

There are many schemes available for determining the location of sensor nodes. These can be classified into range based or range free, anchor based or anchor free, stationary or mobile sensor nodes, fine grained or coarse grained, and centralized or distributed as shown in figure 1, other than these schemes GPS based is also one of the technology which can be used for location identification. However, it consumes large amount of energy and is expensive because GPS receiver is required for every node. As compare to other technology GPS provides very high accuracy of localization. But because of limited amount of energy in sensor nodes and very high cost of GPS, it is not suitable for most of the WSN based applications. We discuss here these methods briefly.

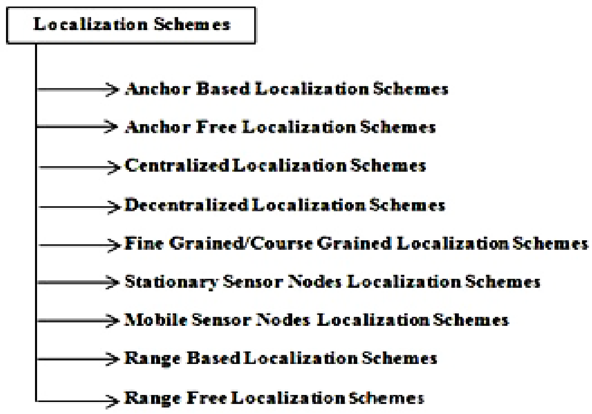


Fig.1. Localization Schemes

- *Anchor Based Localization Schemes*

In this technique the position of few nodes are known. These nodes are known as anchor nodes. With the help of these anchor nodes the location of other un-localized nodes is determined. The accuracy of location is highly depends on the number of anchor nodes.

- *Anchor Free Localization Schemes*

In this technique there is no anchor node available so instead of calculating absolute positions of nodes, algorithms calculate the relative positions of the nodes.

- *Centralized Localization Schemes*

In this scheme all the information is transmitted to one central node. This node is known as base station or sink node. It is responsible of taking care of position computation of all nodes and circulates the information to the respective node. As compare to other schemes its computation cost is less and takes less energy.

- *Decentralized Localization Schemes*

In distributed or decentralized scheme each sensor node is responsible for calculating and estimating their position individually. Because there is no clustering each node communicate directly with anchor nodes.

- *Fine Grained/Course Grained Localization Schemes*

In fine grained schemes localization algorithms use the received signal strength feature of nodes where as in course grained schemes it does not.

- *Stationary Sensor Nodes Localization Schemes*

As we know that there are two types of sensor nodes stationary (static) and mobile nodes. Based on the deployment of sensor nodes algorithms are designed. In stationary sensor nodes all nodes are static and fixed at one place.

- *Mobile Sensor Nodes Localization Schemes*

There are many applications available for which mobile sensor nodes are used. For these application mobile sensors based algorithms are needed.

- *Range Based Localization Schemes*

This scheme mainly focuses on distance estimation and angle estimation.

- *Range Free Localization Schemes*

In range free schemes, nodes communicate with each other through radio connectivity to find out the location of each other. These algorithms do not use distance estimation, angle estimation or any other special hardware.

There are many parameters that need to be considering while implementing any localization techniques. These parameters help to find the difference and similarities between different approaches. These parameters are-

- *Accuracy –*

It is a most important parameter for the localization. There are many applications like military installation for intrusion detection where accuracy is the main concern.

- *Cost*

Cost is another important parameter and is the challenging issue for most of the localization techniques. There are many algorithms available which are not very costly but their accuracy is of very low rate.

- *Power/Energy*

Sensor nodes have the limited power in the form of battery. So power is also the main concern while selecting any localization algorithms.

III. Overview Of Range Based Localization Schemes

Range based localization algorithms mainly focus on estimating the distance and angle between the sensor nodes. These algorithms first calculate the distance between nodes and with the help of geometrical principles they compute the location for the same. These algorithms use sophisticated hardware to find out the range metrics such as AOA (Angle of arrival), TOA (Time of arrival), TDOA (Time difference of arrival) and RSSI (received signal strength indication). There should be communication between localized and un-localized node in its vicinity for determining the geometrical placement or position (location) of un-localized node.

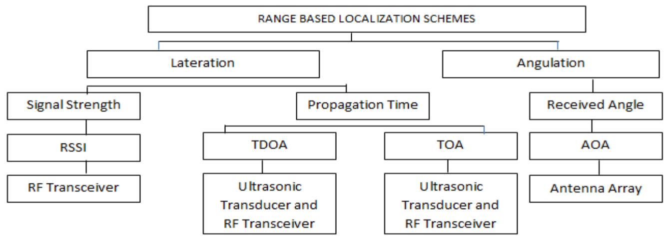


Fig.2. Classification of Range Based Localization Schemes

Range based localization technique can be seen as two-step process –

- *Ranging Step*

In these step un-localized nodes, with the help of signal propagation time or strength of the received signal tried to calculate their anchors. There are so many schemes available like RSSI, TOA, TDOA, and AOA for this step.

- *Position Step*

This step is using ranging information. This ranging information can be evaluated by solving a set of equations. In this step localization procedure is iterated unless all nodes are settled or no more can be localized. Trilateration, Triangulation, Maximum Likelihood (ML) are the techniques used for it.

Here we discuss few concepts that can be used in such kind of localization like-

- *Lateration*

In this mechanism distance is calculated between the sensor nodes

- *Tri-Lateration*

Location of un-localized node is estimated by calculating the distance from three nodes through the intersection of three circles which gives a single point that will be the position of the un-localized node.

- *Multi-Lateration*

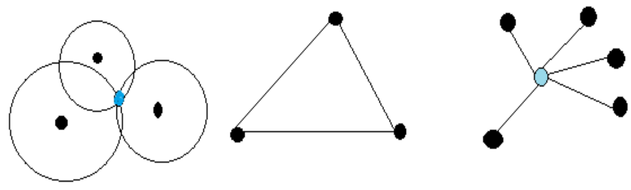
Here we consider more than three nodes for location estimation.

- *Angulation*

In angulation angle between the nodes is consider to determine the location.

- *Triangulation*

For this concept, location of un-localized node is being calculated by measuring at least two angles of un-localized node from two localized nodes.

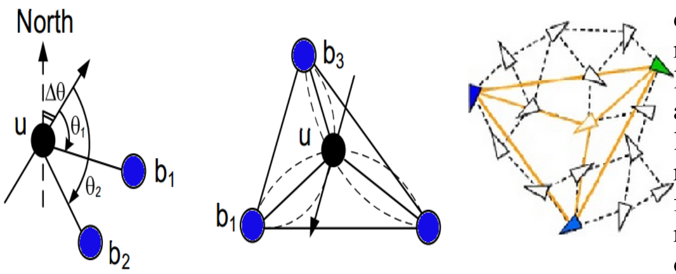


(a) (b) (c)

Fig.3. (a) Tri-lateration; (b) Triangulation; (C) ML estimation

A. *Angle of Arrival (AOA)*

With this scheme the location of un-localized node can be determined by estimating absolute or relative angles between the neighbours. This approach is also known as direction of arrival (DOA). AOA can be defined as the angle between some reference directions (Orientation) and propagation direction of an incident wave. Orientation is a static direction across which the angle of arrival can be measured. It is measured in degree with clockwise direction from the north. For absolute angle of arrival the orientation should be 0◦ and it should point to the north. But if not then it is relative angle of arrival [3] [4]. Un-localized nodes use triangulation method to determine the location [1]. There is another approach which uses antenna array on each sensor node to find out the angle of arrival. Detail description of the techniques to find out the angles between anchor nodes and un-localized nodes are discussed in [2].



(a) (b) (c)

Fig.4. Triangulation in AOA localization: (a) Localization with orientation information; (b) Localization without orientation information; (c) Localization with antenna array

The antenna array is used to find the direction of neighbors. Compass plus GPS is assigned to some anchor nodes or landmarks. These nodes broadcast location information. Un-localized nodes update this information along the way. After getting the information from at least 3 anchor nodes, location is calculated. Since this approach requires additional hardware to transmit and receive location information, it is expensive to use in wide sensor network area.

B. *Time of Arrival (TOA)*

To find the location of un-localized node, this localization metrics calculate the speed of wavelength and the time of radio signals traversed between anchor node and un-localized node [1]. A signal is transmitting from all sensor nodes to their neighbors with the same predefined velocity w. After receiving the signal, each node sends a signal back to the transmitter. A node a can estimates its distance from its neighbor b by using the following formula [5].

$$\mathbf{dis_{ab} = 2^{-1} (t^{a}_{rec} - t^{a}_{tra}) - (t^{b}_{rec} - t^{b}_{tra})} \quad \mathbf{(1)}$$

Where t^arec is the time of receiving and t^atra is the time of transmission of the signal for node 'a' and t^brec and t^btra accordingly for node 'b'. When this distance is being calculated, the tri-lateration method is used to find the location of the sensor. This technique gives the high accuracy but takes a large amount of processing power. It is used in GPS.

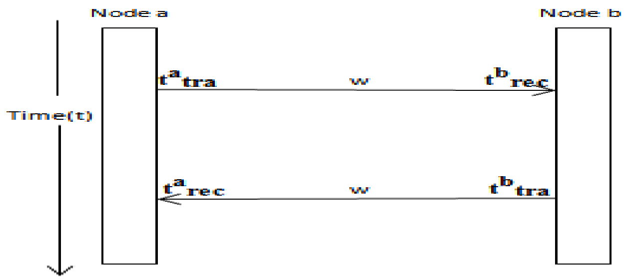


Fig.5. Range Estimation – Time of Arrival

C. *Time Difference of Arrival (TDOA)*

Time of Arrival (TOA) technique suffers from two major limitations. First, there should be synchronization at the microsecond level between all sensor nodes. Second, to determine the distance travelled accurately, all the signals must be incorporated with a timestamp. To overcome these limitations there is another approach time difference of arrival (TDOA) used to estimate the location of un-localized nodes. In this technique the difference of arrival radio and ultrasound signal at different sensor nodes is used for target location estimation. Each node is having microphone and speaker. Anchor node transmits signals to other nodes and waits for some fixed time, and then this node generates "chirps" with the help of speaker. When these signals are received by un-localized node, it turns on its microphone. When microphone identifies chirps it saves the time. This time information is used by un-localized node for determining the distance between anchor node and itself. Figure 6 illustrate the basic idea of TDOA. If there are two references a, b the TDOA measurement tab can be transformed into a distance difference disab by the following formula.

$$\mathbf{dis_{ab} = dis_{a} - dis_{b} = c(t_{a} - t_{b}) = c.\ t_{ab}} \quad \mathbf{(2)}$$

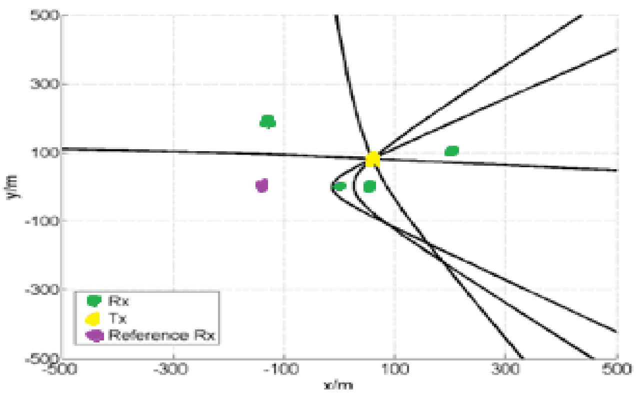


Fig.5. Time Difference of Arrival

The hyperbola shows the distance difference of possible transmitter positions. The transmitter position can be calculated by finding the intersection of hyperbolas from multiple TDOAs.

D. Received Signal Strength Indicator (RSSI)

Radio signal energy can be seen as an electromagnetic wave. These waves' strength decreases as moves forward. This signal strength decrement is reverse proportional to the square of the travelled distance. If d is the travelled distance then signal strength is given by the formula-

Signal Strength $\propto 1/d^2$ (3)

For each transmitted data packet by sensor units Received Signal Strength Indicator (RSSI) value is associated with it. It means RSSI value is the part of the data packet and shows how well the receiver sensor hears the transmitted signal by the access point. RSSI value only shows the relative measurement of the signal. It does not show the absolute measurement. This value fluctuate several dB among different readings. In RSSI approach by determining the signal strength at the receiver end, anyone can estimate the distance between the transmitter and receiver. Its configurable cost is very low in comparison with other approaches but because of the large variation of RSSI value, its error rate is very high. These variations occur due to radio interferences, walls persons, transmission power, and antenna type etc. This variation in RSSI value evaluates inaccurate distance.

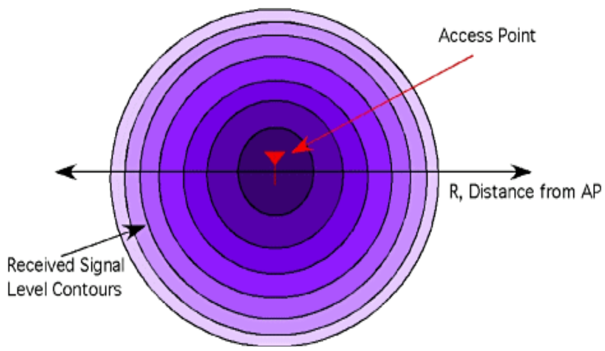


Fig.6. Contour lines show the correlation of received signal strength and separation distance between access points and receivers

E. Comparison of Range Based Localization Techniques

This comparison is based on the localization parameters like accuracy, cost, energy efficiency and size of hardware. TDOA technique gives the high accuracy whereas RSSI is cost effective.

TABLE 1

COMPARISON OF RANGE BASED ALGORITHMS

Technique	Accuracy	Cost	Energy Efficiency	Size of Hardware
TOA	Medium	High	Less	Large
TDOA	High	Low	High	Less Complex, May be Large
AOA	Low	High	Medium	Large
RSSI	Medium	Low	High	Small

IV. OVERVIEW OF RANGE FREE LOCALIZATION SCHEMES

Because of cost and limitation of the hardware many wireless sensor networks applications do not prefer to use of range based localization schemes. These techniques are not suitable for a large- scale sensor network. In many applications course accuracy is sufficient; the best cost-effective alternative is range free schemes for this kind of applications. There is no need to calculate distance or angle in Range free applications. To determine the location of sensor nodes these schemes simply sense the wireless connectivity, localization events or anchor proximity and use a distance-vector flooding technique to calculate the average hop distance and minimum hop count to know the anchor nodes position. These schemes are cost effective but sacrificing the accuracy. Every localized (anchor) node broadcast a packet that contains the location information of the same with initial hop count to one. To identify the minimum hop count distance to each anchor nodes, every node maintains a table for it and increases the hop count as packet is forwarded. Range free localization techniques can be categorized in two ways-

- *Local Technique*

In this technique each localized nodes collect the location information of its neighbour anchor (localized) nodes to determine its own location. Centroid algorithm [7] is an example of this technique where to estimate the position of any un-localized node, that node calculate the centroid of the coordinates of the neighbour anchor nodes. Another approach APIT method [8] divides the whole environment into triangular regions between anchor nodes. Un-localized node determines its location as the centre of gravity of the intersection of all the triangles that the node may reside in.

- *Hop-Counting Technique*

In these techniques un-localized node calculates the hop counting to determine its location. DV-Hop algorithm is an example of this kind of technique. In DV-Hop, un-localized node determine its location by receiving the estimated hop sizes from its neighbour anchor nodes and then find out the smallest hop count. At least three anchor nodes broadcast its location information with hop count across the network from neighbour to neighbour node. This hop count is increased by one after receiving by any node. Un-localized node determines the shortest path from three or more anchor nodes by using the triangulation method and hop count to calculate its location. In Range free algorithms there is no need to calculate the absolute point to point distances among the anchor nods and the un-localized sensor nodes. These algorithms may be-

- Centroid algorithm
- HIRLOC – High-resolution Robust localization algorithm
- SERLOC – Secure Range- Independent localization algorithm
- ADLA – Active Distributed Localization algorithm

A. Centroid Algorithm

N. Bulusu and J. Heidemann proposed centroid algorithm which is a range free, course grained, proximity based localization algorithm. The implementation of centroid algorithm contains below steps.

- All anchor nodes broadcast their location information and identity to all sensor nodes in their transmission range [9]. All nodes listens the signal for a fixed time t and collect the location information from various anchor nodes.
- All un-localized nodes determine their position by forming a polygon shown in figure 7. and calculate the centroid from all positions of anchor nodes in their range by using the below formula-

$$X_{est} = (X_1 + X_2 \ldots + X_n)/n \quad (4)$$
$$Y_{est} = (Y_1 + Y_2 \ldots + Y_n)/n \quad (5)$$

Where $(X_1, Y_1) \ldots (X_n, Y_n)$ are the anchor node's coordinates and (X_{est}, Y_{est}) is estimated coordinates of the node.

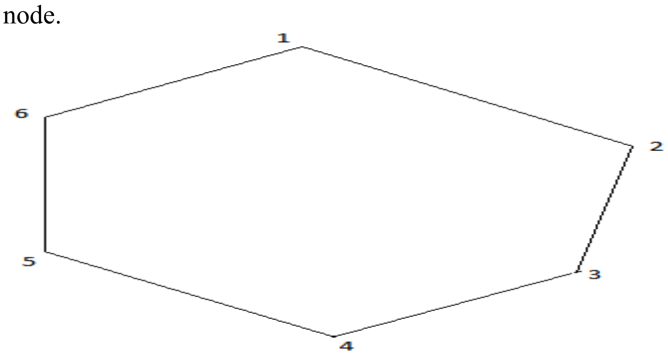


Fig.7. Schematic of Centroid Localization Algorithm

Network connectivity and anchor node's density is the root of this algorithm. Since it is a range free algorithm so the location computed is just rough estimated. Localization error in this algorithm is the main concern and depends on the anchor node's density and distribution. For minimum localization error the density should be maximized. It is a cost effective, less complex and good performance algorithm but the major drawback is it produces large localization error.

B. High-resolution Robust Localization (HIRLOC) Algorithm

In the presence of security threats, HIRLOC scheme is used to determine the high accurate location of un-localized node. This scheme was proposed by Lazos and Poovendran (2004). Accuracy of this algorithm is mainly depend on the information (coordinates of the anchor node, anchor communication range, angle of directional antenna etc.) sent by the anchor nodes. This information gets updated every time and retransmitted to the un-localized node. In HIRLOC, anchor nodes use the directional antennas and their communication range is variable [10]. Every time when anchor nodes transmit its information, they change its direction of antennas, communication range or both. That is why the result is more accurate and robust. Let Si (j) is the anchor (Localized) sector area and LHs (j) is the set of anchor (Localized) nodes heard by a sensor s during the jth transmission round. With the help of collected information from the anchor nodes Li exists in LHs (j), un-localized node determines its location as the region of intersection ROI.

$$ROI(m) = \bigcap_{j=0}^{m} \left(\bigcap_{i=1}^{|LH_s(j)|} S_i(j) \right) \quad \textbf{(6)}$$

ROI is the confined area where un-localized node is located. Location accuracy of any un-localized node depends on the region of intersection (ROI). That is accuracy of localization increases if the size of the ROI decreases ROI. The size of the ROI can be reduced by –

1) *Varying Angle of Antenna* – Anchor nodes can transmit information in all directions by using the multiple directional antennas. By changing the direction of antennas instead of decreasing the size of the intersecting sectors, anchor nodes can retransmit the information with new sector boundaries.

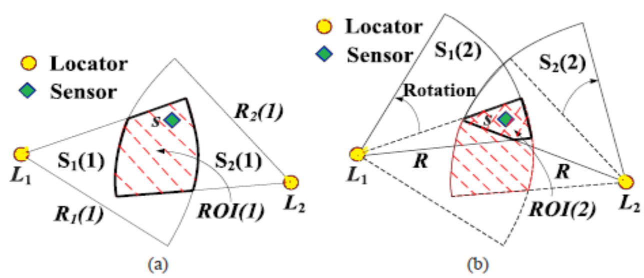


Fig.8. Varying Angle of Antenna – (a) The sensor s is located within the intersection of the sectors S_1 (j), S_2 (j) which defines the region of intersection ROI; (b) The ROI is reduced by the rotation of the antenna sectors by some angle.

2) *Varying Communication Range* – In this approach by reducing the size of the intersecting sectors, ROI (region of intersection) can be reduced. It decreases the

transmission poser of the anchor nodes and rebroadcast the information with new communication range.

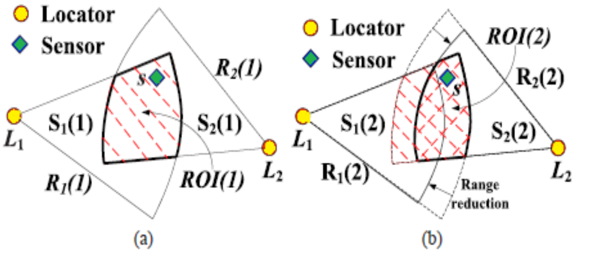


Fig.9. Varying Communication Range – (a) The sensor is located within the intersection of the sectors S_1 (j), S_2 (j) which defines the ROI; (b) the locators reduce their communication range and transmit updated beacons. While s is outside the communication range of A_1, It can still hear the transmission of A_2. The new beacon information leads to the reduction of the ROI.

3) *Hybrid approach* – The combination of the variation of the antenna orientation and communication range is used for this approach.

C. *Secure Range-Independent Localization (SERLOC) Algorithm*

In many of the wireless sensor network applications deployed un-tethered in hostile environment, security in the presence of malicious adversaries is the major concern. Lazos and Poovendran in 2004 proposed a SERLOC algorithm which is the range free distributed localization algorithm and designed to secure the location information of un-localized nodes from various kinds of attacks like Sybil, Wormhole etc. In this algorithm un-localized nodes contain omnidirectional antennas whereas anchor nodes contain directional sectored antennas. Un-localized sensors can estimate their positions with the information like anchor node's coordinates, angle of the antenna, transmitted by the anchor nodes. Any un-localized node can estimate their position by using the below steps-

- Un-localized nodes hear and collect the beacons from the anchor nodes. Each beacon contains the location information of anchor and the angle of sector boundary.
- On the basis of collected coordinates of anchor nodes determines four values (Xmin, Ymin, Xmax, Ymax) among all the anchor location heard.
- Determine an approximate search area inside which un-localized node is located as rectangle (Xmin-R, Ymin-R, Xmax+R, Ymax+R).
- In this step search area is divided into grids.
- For each beacon received do
- Increase the value of a grid point by one if this grid point is within the sector defined in this beacon.
- End for
- Estimated Position = CenterOfGravity(the grid points with the largest values)

$$\tilde{s} : (x_{est}, y_{est}) = \left(\frac{1}{n} \sum_{i=1}^{n} x_{g_i}, \frac{1}{n} \sum_{i=1}^{n} y_{g_i} \right) \quad (7)$$

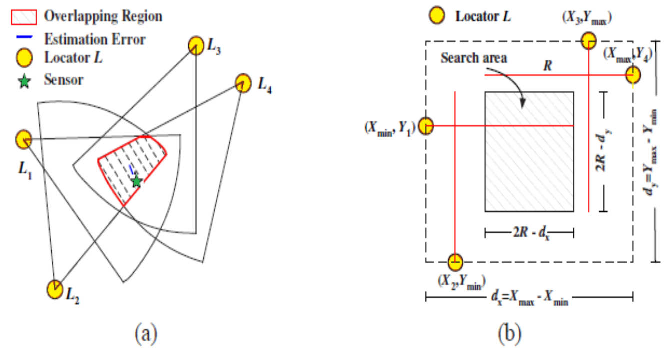


Fig.10. (a) Anchor nodes L_1-L_4 transmit beacons at each sector. Un-localized node s determines its estimated coordinates by calculating centre of gravity (COG) of the overlapping region of the sectors; (b) Determination of the search area.

We can also use this algorithm for those applications where some of the nodes are mobile. For such application, it is required to update the current location information for both anchor and un-localized nodes. To update the information anchor nodes can use GPS signals or GPS enabled fly-over nodes and re-transmit this information to its neighbours. After receiving the location information from its neighbour, node re-estimates their location with new coordinates and sector information.

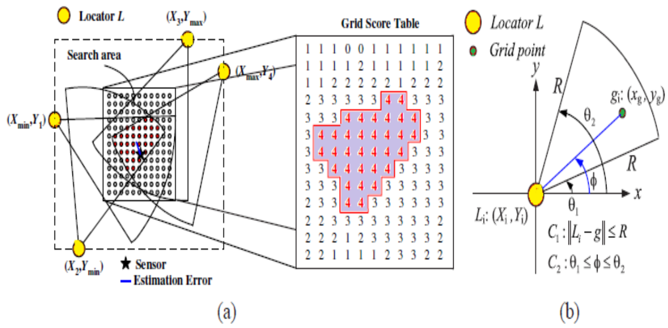


Fig.11. (a) Shows grid placement in the search area and the corresponding grid score table. Un-localized node determines its location as the centroid of all grid points with the highest score; (b) Grid-sector-test for a point g of the search area.

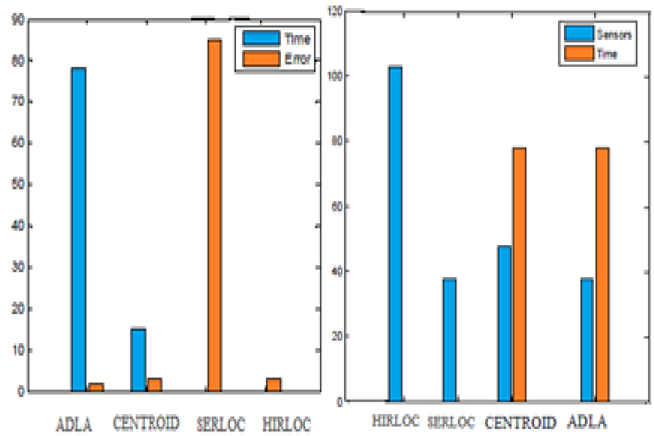
D. *Active Distributed Localization (ADLA) Algorithm*

ADLA is a simple distributed range free algorithm for determining the range of un-localized node. ADLA for sensor node is based on the existing localization schemes and convex programming approach. In this approach for determining the coordinates of node, a grid based structure is used to for capturing the sensor nodes. Let N be the sensor nodes, ρs is the density, A is the area where these nodes are deployed, L be the number of anchor nodes with density ρL be the density for these localized nodes. Over this area 'A' anchor nodes are deployed on fixed position and un-localized nodes are deployed randomly. These anchor nodes are static and contain directional antenna. ROI is calculated to determine the location of sensor nodes. Below is the algorithm with 8 locators-

- Select anchor L_{0-7} having directional antennas.
- Deploy anchors nodes L_{0-7} and un-localized sensor nodes in network area, over grid.
- Define antenna orientation of anchor node node = α, locator range = R and directed gain = Gd
- Determine region of intersection ROI for all anchor nodes
- Determine sector intersection for number transmission rounds if any
- If position of nodes N ⊆ ROI is estimated then calculate average localization error with respect to X and Xi, the coordinates else, go to step 4 end if
- Location of sensor nodes is estimated

E. Comparison of Range Free Localization Techniques

Below is the comparison of above mentioned range free localization algorithms. This comparison is based on the mentioned parameters like localization error, number of anchor nodes used etc.



(a) (b)

Fig.12. (a) Localization error Vs Time; (b) Number of sensor Vs Time

TABLE 2

COMPARISON OF RANGE FREE ALGORITHMS

Technique	Centroid	HIRLOC	SERLOC	ADLA
Localization objective	Self	Self	Self	Self
Encryption key	Used	Used	Used	Used
Use of anchor nodes	Yes	Yes	Yes	Yes
Execution time	0ms	15ms	78ms	7ms
Avg. localization error	85	3	44	33
Observation	Reduced cost	Extra hardware complex	Extra hardware	Hardware based
Number of anchor nodes	103	10	48	85

V. CONCLUSION

In this paper, we have studied the localization problem in wireless sensor network and proposed a series of range based and range free localization techniques such as AOA, TOA, TDOA, RSSI, Centroid, HIRLOC, SERLOC and ADLA to overcome this big issue of localization. We demonstrated HIRLOC, a range free localization technique that improves the position (coordinate) estimation accuracy by varying the angle of antenna or by varying the communication range. We also proposed SERLOC, a range free, decentralized algorithm which determine the location of un-localized node in an un-trusted environment. We compare these algorithms on the basis of localization parameters. This comparison will help to wireless sensor network designer to choose the best method to implement.

REFERENCES

[1] R. Manzoor, Energy efficient localization in wireless sensor networks using noisy measurements [M.S. thesis], 2010.

[2] H. Shi, X. Li, Y. Shang, D. Ma "Cramer-Rao Bound Analysis of Quantized RSSI Based Localization in Wireless Sensor Networks", In Proc. Of International Conference on parallel and distributed systems (ICPAD'05), July 2005.

[3] D. Niculescu and B. Nath, "Ad hoc positioning system (APS) using AOA," in IEEE INFOCOM, Apr. 2003.

[4] A. Nasipuri and K. Li, "A directionality based location discovery scheme for wireless sensor networks," in First ACM International Workshop on Wireless Sensor Networks and Applications, Atlanta, GA, Sept. 2002.

[5] G. Sarigiannidis, "LOCALIZATION FOR AD HOC WIRELESS SENSOR NETWORKS",M.S. thesis TECHNICAL UNIVERSITY DELFT, THE NETHERLANDS, AUGUST 2006

[6] J. Bachrach and C. Taylor, Localization in Sensor Networks, Massachusetts Institute of Technology, Cambridge, Mass, USA, 2004.

[7] N. Bulusu, J. Heidemann, and D. Estrin, "GPS-less low-cost outdoor localization for very small devices,"IEEE Personal Communications, vol. 7, no. 5, pp. 28–34, 2000.

[8] T. He, C. Huang, B. M. Blum, J. A. Stankovic, and T. Abdelzaher, "Range-free localization schemes for large scale sensor networks," in Proceedings of the 9th Annual International Conference on Mobile Computing and Networking (MobiCom '03), pp. 81–95, usa, September 2003.

[9] B.-D. Deng, G.-M. Huang, and L. Zhang. Improved centroid localization algorithm in WSNs. In Proceedings of the 3rd International Conference on Intelligent System and Knowledge (ISK-2008), pages 1260-1264, 2008.

[10] H. Farman, H. Javed, M. Arshad and S. Ullah, "Performance Analysis of High-Resolution Robust Localization and Secure Range Independent Localization in Wireless Sensor Networks", World Applied Sciences Journal, 2012, Vol. 20, no. 5, pp. 709-714.

[11] A. Srinivasan and J. Wu "A Survey on Secure Localization in Wireless Sensor Networks", Florida Atlantic University, Boca Raton, FL, USA