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Research paper

A review on localization techniques in WSN

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Abstract

Wireless Sensor network is a collection of small nodes which collect and send the data for processing. But data is meaningful when its location is known. The area of WSN localization is a developing rapidly by extensive research work. This location information can be achieved using different localization techniques in WSN. The location of events taken place can be determined by knowing the location of sensor nodes. This paper extensively reviews different localization techniques basic and improved one to localize nodes in WSN and also presents some parameter based comparative study. This study is valuable for better understanding of existing methods and improved ones, with the help of this can develop other advanced techniques.

Keywords: *Wireless Sensor Network; RSSI; TOA; TDOA; AOA.*

1. Introduction

Wireless Sensor Network (WSN) area getting popular as it needed by society for variety of application due to its adaptability to the various needful applications areas. Location awareness in many applications is receiving a great demand in cellular, communication, location based applications, services and social networking. In many
Countries providing emergency services it is a great deal itself due to lack of accurate location for providing the services. Wireless Sensor Network is a collection of a homogenous/heterogeneous node equipped with sensor, communication and processing unit which can sense, process and send to the end user using sink node. Sink node is a node connected with more than one network and act as a gateway between outside network and sensor network. The sink node transmits only intended information by the base station It also receives query or messages which need to be run on network to fetch information network parameters, location etc.
WSN is useful in many applications such as animal habitat monitoring,
Management or life critical operations. Once data is sense by sensor node before it sends on network or to any other node it must know the location of its own. So each node detected the event must send the data along with its location to along with sensed information here sink node can use other techniques to find out location of all nodes by sending query over the entire network.
Taylor ET. Al [2] presented even though the location awareness is important and demanding deal but estimates the accurate location is still having challenges. There are different techniques to estimate the correct location nodes. One of the natural and fundamental challenges in WSN is accurate node localization. Even though the Global Positioning Systems (GPS) are provides a correct location information but to equipped all nodes with GPS is rarely practicable and without GPS using localization algorithms are more practical for WSN.

Neal P. ET. Al [1] explained the significant concept in Localization Methods is that some distinctive class of sensor nodes that have prior knowledge about their location coordinates are deployed to find the nodes whose locations
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are unknown. Such nodes are known as anchor nodes. Such nodes can be fitted out with Global Positioning System (GPS) that send beacons messages with their coordinates in order to provide support to other nodes so that they can perform Localization. The GPS is classical approach for localization of nodes but to equip all nodes GPS enable is highly impractical rather to know the locations using localization algorithms. To localize any unknown node it is necessary to know the location of nearest anchor nodes and which measurement techniques to be used.

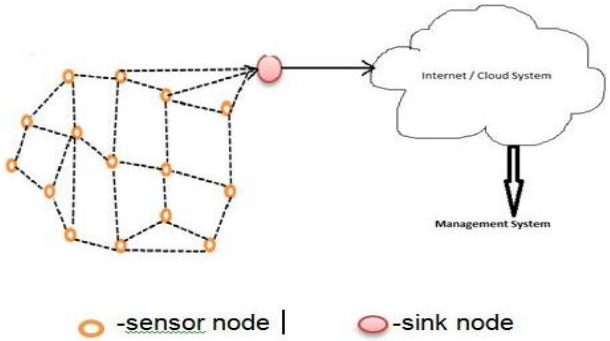

Fig. 1: WSN Scenario Diagram.

2. Classification of localization techniques

To find the correct localization of sensor nodes different localization techniques have been used [3]. It comes in different ranging

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such as AOA, TOA, TDOA, RSSI etc. While estimating the location of sensor nodes the way to distribute computation and how to choose algorithm for localization.

There are different prospects. The localizati on techniques can be largely categorized into centralized and distributed techniques [4].Where the distributed techniques can be again divided as Range Free Techniques and Range Based Techniques.

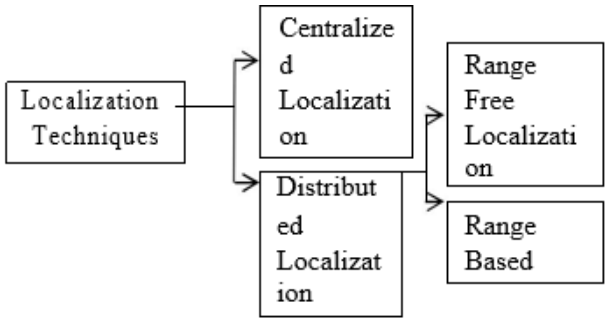

Fig. 2: Classification of Localization Techniques

Anchor Free Vs Anchor Based Nodes

To localize any system in a global coordinate system Anchor Nodes that are also known as Beacon nodes or seed nodes are playing a crucial role. Any normal sensor node can be a anchor node whose location coordinate are pre known and many other node can estimate their location by receiving the messages from anchor nodes.

This anchor nodes can be equipped with some additional hardware which help to locate the exact position like a Global positioning System(GPS).Then anchor free nodes can also be a without GPS where they can found the exact position by using location of other nodes in proximity. GPS enabled anchor nodes simply locate the position of any nodes in coordinate system. But this GPS also has some limitation i.e. it will not work in dense environment or in indoor systems where many obstacles are there and also its power hungry.

i) Cenralized Localization Techniques

In centralized localization centralized algorithm runs on central machine. All sensor node sense the information and otherwise send it to the central machine where processing can be done using localization algorithm. The processing node or machine has information of every requesting nodes location and here network topology of the network is easily known to the central node. Traffic explosion, congestion and computational complexities when larger no of sensor nodes are involved this are few drawbacks in centralized localization System. In centralized approach node only needs to sense the information and send it to central processor no need to store it on node. Let m1 be the message in bits needed to be encode in y1 (k) for some l then total amount of information is need to transported is O(m1nk) bits. When this all bits gone through the multiple hops to reach gateway, let's say worst case K hops. The worst case cost can say as O ($m1nk^2$) bits [11].Semi Definite Programming (SDP), Multi-Dimensional Scaling-Mobile Assisted Programming (MDSMAP), Simulated Annealing based Localization (LBSA) [4].

ii) Distributed Localization Techniques

On other hand in distributed system the algorithms runs on the nodes where computational processing takes place. In this system sensor nodes get help of anchors and localize themselves. Once they localize themselves then they can start making help to localize other nodes too for fixing their positions this node such nodes call as pseudo nodes. Estimation quality of pseudo anchors are based on how many anchors they taken during localization. Link failure and node failure always happen in distributed localization but due to its fault tolerant nature distribute that failure cost in all sensor nodes equally. Distributed Localization is used for large.

Networks whereas centralized localization is used for small networks. When we want to minimize the communication cost between nodes we choose this approach as minimum communication cost between cluster head and gateway. Our main motive to minimize the communication cost which is always higher than the processing cost in WSN.

In WSN Distributed Localization can be broadly classified as Range-based and Range-free localization.

Range Free Localization:

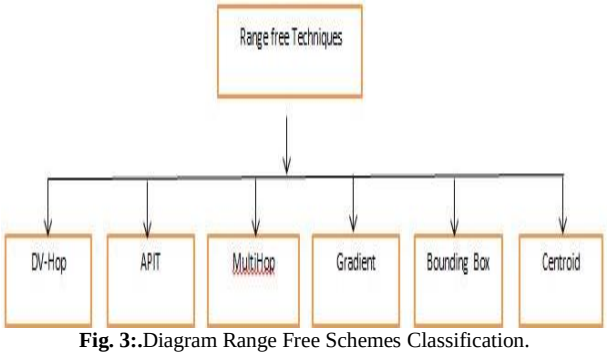

Fig. 3:.Diagram Range Free Schemes Classification.

In this section range free localization techniques by Pal S. et. [4] has been briefly explained. This range free schemes are attracted more attention as its low cost solution due to less hardware is used for estimating distance between sensor nodes. The categorization of the range free techniques as shown in figure 3.

a) DV-Hop Localization Algorithm

DV-hop is identical range-free localization algorithm which was proposed by Niculescu D. et al [5]. The key concept of a DV-Hop algorithm is node transfer information with its neighboring nodes. Every anchor node broadcasts a beacon message which contains the location of anchors with hop count values. Every receipting node keeps the minimum value in hop count field, which it receives and discard the higher values in hop count field. Classical distance vector routing method is also work in same manner. All nodes are receiving other nodes information of WSN; keep the minimum value of the distance and removes higher values.

The hop count value keeps increasing at every intermediate node till it reaches to anchor node. By taking the product of average per-hop distance and the shortest way among the sensor nodes, the distance between unknown node and anchor node can be estimated

The overall single hop /distance can be calculated as a

$$\text{Hop Size} = \frac{\sqrt{(-)2 + (-)2}}{h} \quad (1)$$

Where j is an anchor node with (xj, yj) coordinates and distance between node i to anchor j is a hj. For this algorithm in two planes (2D) minimum 3 anchors are needed where as in three plane (3D) minimum 4 anchors needed. In DV-Hop algorithm after the hop count forwarded by neighbor nodes to reach this to anchor node after adding 1 to the current hop

Count until it reaches to anchor node. But in improved algorithm using anchor position re-estimation, above step is repeated to minimize the ALE (Average location error of anchor) by modifying the hop size value.

This way, the optimal Hop Size improvement is obtained.

b) Approximate Point in Triangle (APIT)

In this range free localization algorithm [4], the main principles of APIT is triangle method, assuming that there are n anchor nodes which able to communicate with the unknown node, the algorithm will traverse number of different triangles, and calculate the centroid of the overlap area of the triangles as the expected location of the unknown node.

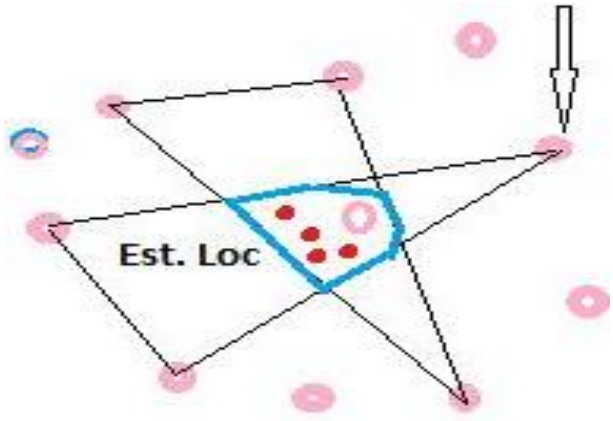

Fig. 4: Apit Algorithm Scenario.

These APIT algorithms mainly work in four steps:

1) The unknown node hears the information of the all near anchors.
2) Every three neighbouring anchor forms triangle by connecting to each other.
3) Test the all unknown node whether node is within the any triangle or not.
4) Finally by computing the center of gravity (COG) of the intersection area of all of the overlap triangles in which the unknown node resides whose position needs to be estimate.

This algorithm is suitable for the unknown nodes are perfectly resides inside the triangle with its anchor but there is deviation in results when node is on the edge or near the edge from inside of a triangle and when it is perfectly outside but neighboring anchors are inside the triangle. To give the remedy to problem Fang Z. et. al [6] proposed an improved version of an APIT algorithm to address an issue. Due to Inside to out error and Outside to in error of the unknown node the major basis of error of procedure is edge effect. Wang solved this edge problem by using backtracking algorithm and also introduced area test to reduce the percentage of error occurrences. An Improved APIT algorithm achieves best while high Node density with less packet loss rate as compare to previous basic APIT algorithms.

c) Multichip

In Multi Hop technique in large sensor Network able to compute connectivity graph [4]. The multi-dimensional scaling (MDS) by using the connectivity information assuming that all nodes are within the vicinity of communication range.

It has three steps as follows:

1) Estimate the distance between each pair of nodes.
2) MDS is used for the position estimation and fit the estimated distance.
3) The optimization is done in last step by using of the known locations.

However in practice present multi-hop localization methods experiences a number of difficulties, such as high computational complexity, less adaptable to irregular topology, less accuracy in positioning, etc. Such issues must be address in localization, so Guo propose a novel approach of improved Multi-hop Localization algorithm.

Guo x. et. al [7] [8] is stated presented improved version of multi-hop algorithm for curtailing influence of specious estimated distances by multi hop on node localization. Where improved multi-hop has a greater computational complexity. This improved Multi hop Localization works in three step:

1) To filter out incorrect estimated distances superior bound restraints are used to filter out and the expected position is determined to the intersection constrained by the accurate distances.
2) To fit the correct distance measurement the appropriate distance is used by arrangement of anchor nodes
3) In the coordinate calculation in node localization can be optimized by using least square (LS),and multilateration, Taylor LS, Weighted Taylor (WLS) and Constrained total least square (CTLS).These methods give guaranteed performance under some constraints and may expose some problems which covers a deficiency of local and global coordinate view of WSN, To process fairly every reference information of nodes in a same manner is needed to improve the accuracy of localization, When high computational overhead the complexity will be more and easy to get caught at local optimum.

d) Centroid

The centroid algorithm originally proposed by Bulusu N. et al. [9]. In this algorithm all sensor node receives location coordinates from all anchors along with communication range. Every unknown node in network listen for some predefined interval t and collects the information receives from messages they received from various nodes. The locations of all unknown nodes calculate using centroid determination from all known positions of anchors is in communication range.

In this localization technique neighboring anchor node positions (xi, yi) acquainted to estimate the location of the sensor node. Here anchor node broadcast beacon message consist their location information using this information sensor node performs computation for their location as the centroid of all anchors nodes connected to the sensor node. Where (xexp, yexp) gives the expected positions of the sensor nodes and N is the no of anchor connected adjacently to the sensor node. This method is very simple and low cost solution but also has some large gap of error in din location estimation of the sensor nodes and it is intolerable in real time applications or critical applications requiring correct localization of sensor nodes.

$$(\quad) = \frac{(1+{}_2+\ldots)}{\quad},\ \frac{((1+{}_2+\ldots)}{\quad}$$

$$,\quad \exp \tag{2}$$

weighted centroid method is an enhanced form of centroid algorithm. The weights of the edges of anchor nodes which are connected to nodes are used to calculate the location of all nodes and every sensor nodes seeking for location computation that can be done as follows:

$$(\exp,) = \frac{(1\quad +{}_{2\,2}+\ldots\quad)\ (++..)}{\quad 1\quad\quad\quad\quad 1\,1\,2\quad 2}\ ,$$

$$\sum \qquad \sum \tag{3}$$

Where the weight of edge of anchor nodes connected to the other nodes. Based on the edge weight the proximity of the anchor node to sensor node decides. Algorithms performs better if the weighted edges are highly optimized.

e) Gradient

In this gradient localization algorithm, using multilateration the location of unknown nodes can be determined. It also maintain the hop count while sending information, initially it sets to zero and it increments as it moves to the other nodes. But this basic gradient algorithm gives less accuracy

Therefore, D. Qiao [10] presented revised descent gradient which present 2 distance-based localization algorithms for WSN. Initially the locations of sensors are unknown and by using beaconing or some other way it fetches the relative locations of sensors. To locate the all nodes need to know information of the absolute locations of three or more sensors/anchors. The gradient descent algorithms achieved excellent localization accuracy and have better performance than existing gradient localization algorithms. The gradient descent algorithms achieved excellent localization accuracy but the same time the high computational complexity need to face and due to that algorithm will be less energy efficient. As this algorithm works in iterative in nature for improvement in accuracy then if more number of anchors use in algorithm slow down the presentation.

Table 1: Performance of Range Free Localization Schemes

Parameter	DV-Hop	API	Multi-Hop	Centroid	Gradient
Node Density	>8	>10	>12	>0	>6
Accuracy	Good	Good	Good	Fair	Average
Anchor Density	>6	>3	>8	>0	>4
Signal Irregularity	Good	Good	Good	Good	Fair
Cost	Medium	Low	High	Low	Low
Scalability	No	Yes	No	Yes	Yes
Overhead	Large	Small	Large	Little	Large

Range Based Localization:

Range based localization schemes are angle estimation based and distance estimation techniques. Angle of Arrival (AOA), Time of Arrival (TOA) and Time Difference of Arrival (TDOA), Received Signal Strength Indicator (RSSI) [2], [3]. Received Signal Strength Indication (RSSI). In RSSI distance between transmitter and receiver is assessed by measuring strength of received signal. A propagation loss is also calculated and it is converted into distance estimation.

i) Angle of Arrival (AoA)

The AoA method is similarly recognized as the direction of arrival measurements [12]. The AOA estimations can be attained either by the receptor antenna's phase reaction or from the receptors antenna's amplitude response. The signal arrives from the anchor node to the un-localize node then using angle calculation node location obtained.

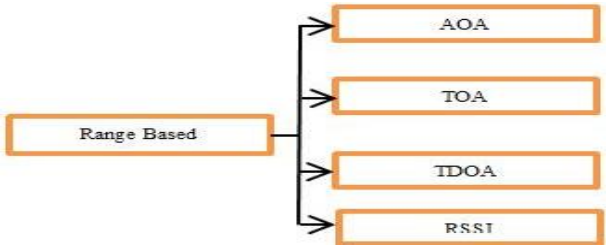

Fig. 5: Range Based Methods.

In this method minimum two anchor nodes are required to compute the location of unknown node by doing angle calculation while signal arrived from location aware node to the location unknown node. The line from an unknown node

Having a certain angle from anchor node. If any small error in measurement then error in localization may be huge.

The accuracy in localization is subject to the direction of antenna and signal reading received. This method can be difficult or erroneous if the shadowing and multipath effect is present during measurement. From the transmitted signal due to a multipath component signal might be appear as a deviation in signal direction and thus results into a huge error in measurement. Thus, AOA technique if it is used with array of large antenna can give better localization otherwise it is of restricted interest in localization. Due to this with small sensor nodes in WSN, this method is not at all energy efficient. This can be computed using h

$$h = (-) \quad (4)$$

ii) Time of Arrival (ToA)

In Time of Arrival (ToA) methods are time of radio signal and speed of wavelength will go together between un-localize node and anchor node. The amount of change between the time of signal received at the receiver end and the starting time of the signal from sender end is called as one way round propagation time measurement or Time of Arrival (ToA).

Here time of radio signal and speed of wavelength will go together between unknown node and anchor node. But the main barrier is to maintain synchronization of same time at Transmitter and receiver end. If both the sensor node i and j with same time difference the time of signal transmission t^i and reception t^j put together can detect the relative distance if the signal propagation speed of medium v is determined.

$$= h(-) + \quad (5)$$

The variance between the time of signal received to the receiver end as well as the starting time of the signal from sender side will be the reason the huge error in assessing distance.

Round trip propagation time measurement: It calculates variation between the times when a signal transmitted by a node and time when it is come back from the receiver node to the transmitted node end. This approach, time synchronization is not needed, while the time difference is calculated at the transmitter node with same timer. While signal received at receiver end then processed and send back to transmitter needs some time and that is delay which is measure threat as error. This delay can be known in advanced by performing calibration. This method also less immune to noise which affect time measurement due to synchronization gets affected.

Here to give correct measurement bandwidth related issues in signal, when line of sight is not clear and multipath environment also a major hurdle for the location estimation. To overcome such restrictions, Ultra-Wide Band (UWB) signals may be apply for correct propagation time calculation.

i) Time Difference of Arrival (TDoA)

Time Difference of Arrival (TDoA) is a normally come with instrument based device. Here, all nodes are fitted out with a microphone and speaker. Systems may use ultrasound and perceptible frequencies. In TDoA, the anchor nodes transmit first a radio message. It delays some predefined interval of time, tdelay and then it creates a kind of beeps on its speaker. A sensor node with unknown location received this signal at time tradio and when the location of unknown node receive the radio signal from anchor node it turns on microphone. When location unknown node listen beeps send by anchor node it saves time as tsound [ref tdoa] Once they have tradio, tsound, and tdelay, the anchor node compute the location using following equation:

$$= (-) * (--) \quad (6)$$

This method work finely when line of site is clear and perform best under echo free scenario.

ii) Received Signal Strength Indicator (RSSI)

In RSSI, signal strength is used to determine the distance between sender and receiver at the receipting end[12]. Signal propagation loss is also computed and converted into distance estimation. The power of signal strength is decreased, as the distance between sender and receiver is increased.

$$() = \frac{^2}{4^{22}} \quad (7)$$

Where

= transmitted power, = transmitter antenna gain, = receiver antenna gain, and = wavelength of the transmitter signal in meters.

Table 2: Measurement Techniques Comparison for Range Based

Parameters	AOA	TOA	TDOA	RSSI
Accuracy	Low	Medium	High	Medium
Energy Efficiency	Medium	Less	High	High
Cost	High	High	Low	Low
Computational Complexity	Low	Low	Low	Low
Hardware Overhead	High	Low	High	Low

Coordinates Determination Strategy:
Localization can be realized by two way:

i) Geometric calculation (Triangulation, Trilateration and Multilateration).
ii) Signal Mapping.

In this coordinate determination techniques [11-12] three main Triangulation, Trilateration and Multilateration Techniques are there. In Triangulation direction of node is used to estimate the distance. This method needs extra hardware setup and has poor ant- interference. So it is used rarely in WSN. In Trilateration position of unknown node for 2D can be determined by using its distance from minimum three anchor nodes which form triangle. It is built on the ground that the position of a point on a 2D plane can be determined by its distances from three non collinear reference points [13]. In WSNs, there reference point is the anchor node. The three non-collinear anchors construct the anchor triangle.

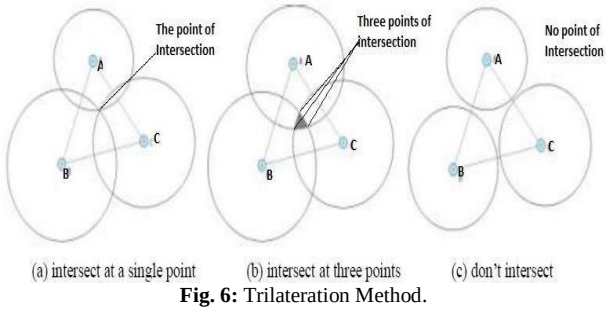

Fig. 6: Trilateration Method.

Assuming the nodes of the triangle formed by anchors are A, B and C. The distances from the unknown node to the three anchors are Ad, Bd and Cd. As per the geometric theory, the location of unknown node is nothing but the intersection point of the three circles. As shown in figure no the intersection point is the position of the unknown node. Due to the estimation errors of the distances, the three circles never intersect at a single point or do not intersect at all. Localization in WSN is a motivating research zone, which is evolving very gradually, and still it has a lot of scope for new research opportunity for researchers.

i) While designing the localization algorithm need to think on Low cost hardware, energy efficiency of the algorithm.
ii) To deploy GPS enable node for localization is not at all the solution for localization because it itself has its several disadvantage such as cost of hardware, size of node and deployment cost, not work in NLOS environment and not energy efficient. Therefore, GPS is not suitable for WSN.
iii) In WSN a resource that we used for localization are very crucial and has very much constraint such as battery life, computational capabilities, low data rates, low memory constraint and small size requirement by the researcher. It is pretty challenging to design a system for localization
iv) In localization schemes, the problem of line of sight (LOS) in range-based approach can lead to erroneous result.
v) In localization more and utmost important is accuracy, if any nodes location computation is performed incorrectly then accuracy of the algorithm will be erroneous because while estimating the nodes location we use cooperative
vi) Approach in network, which gives impact to overall accuracy of network.
vii) Node density is an important issue while designing a localization algorithm.
viii) The nature of algorithm must be universal. Algorithm should fit and work for other environment unless and until no specific technical constraints are there.

3. Conclusion

In this paper a extensive review of different localization techniques in Wireless Sensor Network has been studied and presented with existing and improved one. This new methods give best results along with some new challenges such as Low cost hardware, energy efficient algorithm, location accuracy, NLOS, Node Density, Performance parameter of the algorithm. This paper gives a comparative study of distributed localization methods based on aspects related to performance of an algorithm. But every method has its own beauty. In range based method are due to hardware cost somewhat costly and sometime not fitted to network requirement. Whereas in range free methods less immune with node density. So all this lacuna certainly a scope for research opportunity in the future.

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