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Localization Techniques in Wireless Sensor Networks: A Review

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Abstract: Wireless Sensor Networks have emerged as one of the key research area since last few years containing various challenges. Determining the accurate position of nodes in sensor networks is one of those imperative and tedious tasks. Once the precise location of nodes has been established only then the required functions such as routing, forwarding, information broadcasting can be achieved. To achieve localization, we need some deployed nodes whose position is pre-known. These nodes are called anchor or landmark nodes. With the help of these anchors, locations of sensing nodes are found out. This paper presents an analysis of various localization schemes and contrasts the traditional techniques with modern ones.

Keywords: Sensor networks, anchors, localization, range based, range free, mobile nodes

I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of wireless sensor nodes deployed in large numbers in a particular geographical area. The evolution of Micromechanical Systems (MEMS), chip systems and cellular technologies have led to less power consuming and multi-functionality sensor nodes which are equipped with data collection, data processing, data forwarding, routing and broadcasting capabilities.

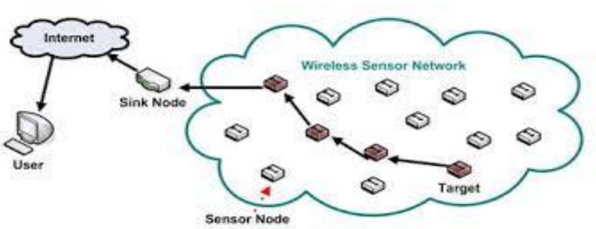

Fig 1: Basic design of WSN
[COURTESY: enroutefiltering.blogspot.com]

Each sensor node has a transceiver, a microcontroller, analog to digital convertor and a battery. The node where a particular event is generated is called target node. The data is forwarded through other nodes to a gateway which ultimately delivers it to a sink node. This sink node passes the data over the internet. Each sensor node can act as an information source capable of sensing and collecting data samples from the environment in which it is deployed. The scale of sensor networks is quite large in magnitude as compared to ad-hoc wireless networks. The number of nodes in sensor networks is in range of several thousands.
Furthermore, sensor networks tend to be dynamic in the sense that they require addition or deletion of nodes in order to extend or shrink the network. Based upon its features, WSN has umpteen number of applications in health monitoring, military, security, disaster prevention and weather forecasting.

II. LOCALIZATION

The term localization refers to determining the position of sensor nodes with the help of landmarks (equipped with GPS technology). Localization poses a challenging problem because of the limited resources available with the sensors such as low computation abilities, limited power etc. To make localization practically tractable, we need to make certain assumptions regarding network topology, protocol design parameters, cost/accuracy trade-offs, performance evaluations, and security [1].
On the most fundamental level localization algorithms can be divided into two broad categories: Range based and Range free techniques.

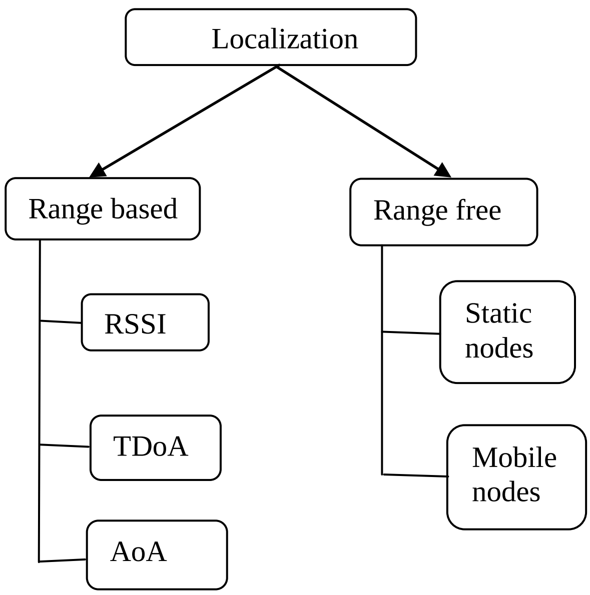

FIG 2: LOCALIZATION CLASSIFICATION

In whole, any position determination technique must fulfil following criteria [7]:

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1. The localization algorithm must be a distributed algorithm. It eliminated a single point of failure and takes the load off from one node.
2. It must be durable and continue to localize currently available nodes even if some nodes fail.
3. Cost trade-offs must be kept in mind
4. It matters whether the nodes are static or mobile. Based upon the mobility of sensing nodes or anchors, different algorithms must be deployed.
5. The algorithm must be in accordance with density of nodes, security needs and routing methods.

III. RANGE BASED TECHNIQUES

Range based techniques are primarily used in network model consisting of static nodes and static anchors. These localization algorithms determine the position of unknown static sensors by using information regarding absolute position of few anchors by deploying techniques such as Trilateration or multilateration. They use inter sensor calculations such as distance calculations, time measurements. RSSI [2] uses received signal strength profiling for location estimation. The receiving unknown node has to calculate signal attenuation to estimate its distance to anchor. Angle of Arrival (AoA)[3] measurements rely on Line of Sight communication predominantly and thus have low accuracy. It is due to the fact that LoS communications can be inhibited by signal fading, diffractions, and multipath propagation. Time Difference of Arrival (TDoA) [4] relies on time measurements. The time difference between sending a signal at transmitter end and receiving the signal at receiver end is calculated. However, the prerequisite is that the local time at both ends must be synchronised.

Table 1: Comparison of Range based techniques

Parameters for comparison	RSSI	TDoA	AoA
Additional hardware required	No	Yes	Yes
Attenuation/Fading problem	Yes	No	Yes
Accuracy	Average	Better	Low
Cost	Less costly	Costly	Costly
Security concern	Very high	High	Average

IV. RANGE FREE TECHNIQUES

Range based techniques have various limitations in terms of cost, computational overhead, energy expenditures, accuracy, small range, reliability etc. To overcome these shortcomings various range free techniques have been proposed. These algorithms estimate the position of an unknown node by harnessing the connectivity information instead of calculating time and distance measurements. These algorithms have been subdivided into two categories: anchor based and anchor free [5][6][8]. But anchor based schemes are less complex, have less computational overhead and hence are more desirable. Here we assume that anchors are static and sensing nodes can be either static or mobile.

Table 2: Range free techniques sub-categories

Static anchors, static nodes	Static anchors, mobile nodes
1. Centroid based 2. Connectivity based 3. region Overlap	1.cluster based 2.Historicalinformation based

A. Centroid Based
The basic centroid algorithm was proposed by Bulusu[9]. It deploys a set of anchors with overlapping coverage area and computes the estimated position as centroid of the polygon.

Based upon the work of [9] various attempts have been performed to scale the technique in 3-D and maintain its efficiency [14][17]. H.Chen [10] proposes a localization scheme with tetrahedron having four landmarks. It computes the centre of gravity of each tetrahedron and averages them out to find the estimated location. Its accuracy is much higher as compared to traditional centroid scheme and localization error rate is reduced significantly.

B. Connectivity Based
Connectivity based localization schemes exploit the connectivity information to localize a node using Graph Theory. One such algorithm is DV-Hop [18]. The working of DV-Hop is as follows: Nodes exchange distances vector information packets so that each node is appraised of minimum hops and coordinates of all available anchors. Each anchor broadcasts its distance to each hop. When an unknown node receives this information, it computes average distance to each anchor using its own recorded hop information. Although having an acceptable accuracy, it is less favoured because it requires each node to maintain a database/table of hops, which puts an additional burden on power of nodes.

Original DV-Hop algorithm has been improved upon to propose new algorithms [19]. These algorithms have low localization error rate and better accuracy both in case of regular and irregular topologies. It achieves high localization accuracy by tracting the bounded least square problem.

Localization Collaborative Body (LCB) [20] is another connectivity based localization scheme. In this, first all anchors broadcast their location information. The unknown nodes receiving that information transform their network model into a BN-tree in which only the root node must have at least three children and other parent nodes can have at least two children. The unknown node is then localized using position of anchors and relative location relationship between unknown nodes and anchors.

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C. Region Overlapping

HiRLOC algorithm [11] minimizes the overlapping region by tweaking the transmitting power and directional sectoral antennas of unknown sensing nodes. Each anchor node forms a region and location of unknown node is estimated as centroid of overlapped sectors. It is an evolved form of SeRLOC [15] which uses omnidirectional antennas.

Another scheme, Vornoi Graph algorithm [12] first arranges the RSSI values in decreasing order and then computes the Vornoi region of each landmark using Unit Disk Graph. The centre of gravity or centroid of overlapping region is the estimated position of unknown node. The localization accuracy is very high at the expanse of computational overhead and localization error decreases with increase in density of anchor nodes.

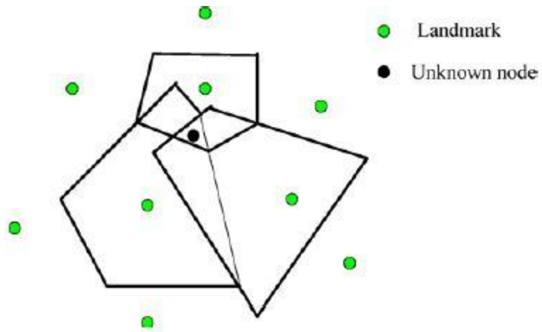

Fig 3: Vornoi region overlapping algorithm [21]

APIT [16] is a region based range free localization scheme. Anchor nodes equipped with GPS technology transmit beacons using which the deploying environment is isolated to construct a triangular region between anchor nodes. All possible combinations of anchors are tried out. The overall area is narrowed down based upon whether an unknown node resides inside or outside of the triangle. It the computes the centroid of the overlapping triangles as the estimated position of the unknown node.

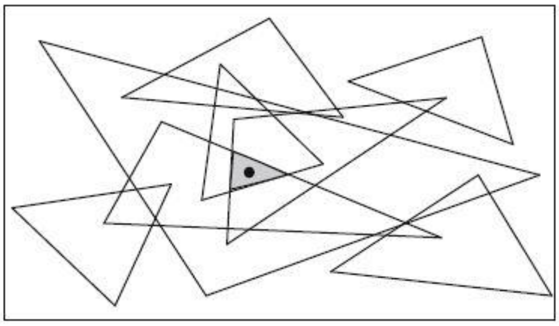

Fig 4: APIT localization scheme overview

VN-APIT [13] is an improvised APIT algorithm which eliminates the defects induced by uneven distribution of nodes in APIT scheme. It logically deploys virtual nodes in sensor networks to determine whether an unknown node is inside or outside of the triangle. It is more robust than traditional APIT scheme and has low localization error rate.

D. Cluster Based Algorithms

In cluster based localization schemes, the wireless sensor network is partitioned into several clusters. Each anchor is responsible for localizing the unknown node in its own cluster. Then the location information is combined in each cluster to get the estimated location.

One such technique is Distributed Target tracking localization algorithm [23] .In this, whenever a mobile node transitions from one cluster to another, the anchor in that cluster determines its position. Each anchor broadcasts a beacon to unknown node and receives a feedback beacon. The distance between anchor and unknown node is computed and coordinates of unknown node is determined using trilateration method.

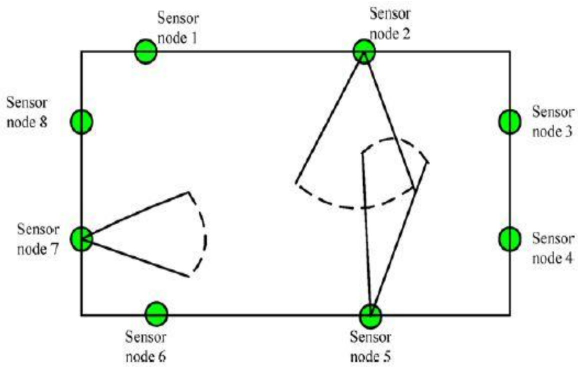

Fig 5: Target tracking localization [21]

Since the probability of interference of beacons from different anchors is high, each anchor should work in turn for fixed short time intervals.

E. Historical Information Based

These algorithms estimate the location of unknown sensing nodes using recorded historical information. They have low computational complexity and low power consumption.

[24] Is a distributed mobile localization algorithm. It tends to use mobility as an advantage and predictability of movement to localize the nodes. Each node maintains a queue containing last three locations. A linear motion equation is then deployed based upon those historical information to predict the position.

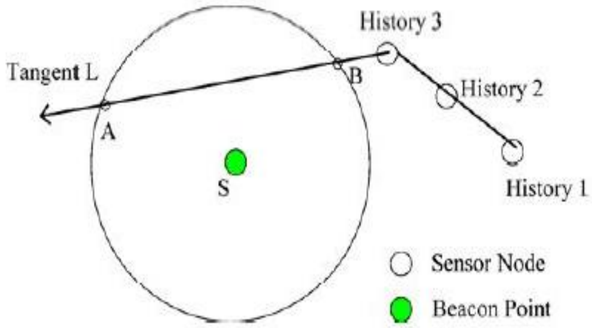

Fig 6: Distributed mobile localization [21]

Table 2: Comparison of Range free localization schemes

Localization algorithm	Localization accuracy	Localization coverage [22]
Centroid	Average	Smaller
3-D Centroid	Better	Smaller
DV-Hop	Average	Average
Idv-Hop	Better	Average
LCB	Average	Average
HiRLOC, SeRLOC	Average	Smaller
Vornoi graph	Average	Average
APIT	Smaller	Smaller
VN-APIT	Better	Average
Distributed target tracking	Average	Smaller
Distributed mobile localization	Better	Average

V. ARTIFICIAL INTELLIGENCE TECHNIQUES

A. Computational Intelligence

Computational intelligence is the study of adaptive mechanisms that enables or facilitates intelligent behaviour in complex or changing environments. It consists of paradigms to learn from new environments, adapt to new conditions, to generalize, abstract, discover and associate. It takes as input the raw numerical sensory data and processes them to exploit descriptive parallelism in order to generate time bound responses.

It encompasses techniques such as neural networks, swarm intelligence, fuzzy logic, reinforcement learning, evolutionary algorithms etc. Computational intelligence techniques can play pivotal role in solving the localization problem in sensor networks as they grow more dynamic in nature.

B. Machine learning

Machine learning techniques have solved the localization problem with low computational complexity in recent past. They can be put into two broad classifications: supervised and unsupervised. In supervised learning, there are predefined class labels and test set is constructed from available training data set. On the other hand, in the case of unsupervised learning, there are no predefined class labels. It is a learning from experience [25].

[26] Demonstrates how Support vector machines can be applied to solve the localization problem. It caps the localization error using appropriate training data set. It offers a distributed and fast localization with optimum use of resources.

C. Fuzzy Logic Inference

Fuzzy logic takes crisp inputs and fuzzifies them to generate fuzzy sets. These fuzzy set members are aggregated and then defuzzified to get a crisp output.
Fuzzy logic inference is a method of deducing mappings from input to output using concepts of fuzzy logic. It can be of two types: Mandami type [27] and Sugeno type [28].

[29] Proposes a localization algorithm based on Sugeno inference logic. The achieved localization accuracy is better with very low computational complexity.

VI. CONCLUSION

With the wireless sensor networks getting more scaled up and growing dynamic in nature, determination of accurate location information of nodes becomes a decisive task. In this review, we analysed the various available localization techniques to demonstrate how range free techniques hold edge over range based techniques. The future work in area of localization algorithms can be on mobility of anchor nodes, or proposing a technique for the combination of mobile and static nodes, scaling the existing algorithms to 3-D model and to obtain a secured verifiable localization technique with low overhead and computational complexity.

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