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An Overview of Localisation Techniques in Wireless Sensor Networks

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Abstract - Localization is a means to find the location of sensor nodes deployed in wireless sensor networks. Identity and location both are very important information. An obvious and interesting method to obtain these two types of data is to find the location of wireless sensors deployed in the network. Basically objects can be located by various localization techniques discussed in this paper. However, signals in indoor environments are generally severely impaired which may pose many challenges for positioning them.

Key Words: wireless senor network, localisation, GPS, angulation, lateration, sensor nodes, anchor nodes.

1. INTRODUCTION

Development of low-cost, low-power, smaller in size and multi-functional sensors has been possible due to the recent progress in the field of wireless communications and electronics. Economical and smart sensors that are networked through wireless links and deployed in large number provide extraordinary prospects for monitoring and controlling various devices at homes, cities, and even the environment.

The most desirable characteristic of wireless sensor networks is self-localization. The data obtained from sensors is of no use without the knowledge about the position from where the data is obtained. The most fundamental method for localization of node is GPS (global positioning system), but if large number of nodes exists in the given network then it becomes very expensive. With the intention to solve the issue of localization many algorithms have been proposed.

2. Overview of Localisation

Localization is broadly used in Wireless Sensor Networks (WSNs) to spot the position of the sensor nodes. A WSN in which several nodes are present, setting up of GPS on each sensor node is very costly and furthermore GPS is not able to provide exact location in an indoor environment. Following are basic techniques used in various algorithms in order to localize a sensor:

A. Angulation

This method makes use of angle between two nodes to estimate location.

B. Triangulation

In order to estimate the position of non-localized node, this method measures minimum two angles of a non-localized node from two localized nodes. For the estimation of node position trigonometric laws are used [16].

C. Lateration

This method makes use of distance between nodes to estimate location of unknown node.

D. Trilateration

In this method, distance measurement from three nodes is used to find out the location of node. In this model, the position of the node which is to be localized is found by the meeting point of three circles.

E. Multilateration

In this method of location estimation more than three nodes are used.

3. Localisation Schemes

Localization schemes can be categorized as GPS based or GPS free, stationary or mobile sensor nodes, anchor based or anchor free, centralized or distributed, fine grained or coarse grained, and range based or range free.

A. *GPS Based and GPS Free*
Since each node is equipped with therefore GPS-based schemes are quite expensive. Localization accuracy needs to be very high as well. Algorithms which are GPS- free, they do not use GPS and also are less expensive as they estimate the relative distance between the nodes and local network [9, 10]. The nodes that start the localization process are called anchor or beacon nodes and they need to be localized through GPS [4].

B. *Stationary and Mobile Sensor Nodes*
Most applications use static nodes that are fixed at one place. Several localization algorithms are created for static nodes. Not many applications use mobile sensor nodes and hence few algorithms are designed for it [11].

C. *Anchor Based and Anchor Free*
The positions of some nodes are known in anchor-based mechanisms. The positions of these known nodes help to localize the non-localised node. The number of anchor nodes decides the accuracy of the new found location of non-localised node. Anchor-free algorithms, instead of computing exact node positions, approximate relative positions of nodes [4].

D. *Centralized and Distributed*
In centralized designs, all information is sent to 'sink node or base station' which is actually a central point. Sink node calculates position of nodes and forwards information to respective nodes. Computation cost as well as energy in case of centralized algorithm is low as compared to that at individual node. In distributed designs, position of sensors is computed individually and then communicated to anchor nodes directly. Clustering is not done in distributed designs, and each node estimates its own position [5–8].

E. *Coarse-Grained and Fine-Grained*
When localisation is carried out with help of received signal strength it is known as fine grained localization mechanism whereas when received

signal strength is not used it is known as coarse-grained localization mechanism.

F. *Range-Free and Range-based Methods*

Range-free methods use radio signals to communicate between nodes to deduce their location. These methods include distance vector (DV) hop, hop terrain, centroid system, APIT, and gradient algorithm. In this method, distance measurement, angle of arrival and special hardware are not used [12, 13]. Range-based Methods are distance- and angle-estimation based techniques. Important techniques used in this localization are received signal strength indication (RSSI), angle of arrival (AOA), time difference of arrival (TDOA), and time of arrival (TOA) [15–21]. Range based and range free methods are discussed below:

1) *DV Hop:* Hop count is used to compute range between nodes. A minimum of three anchor nodes share their coordinates with hop count with all other nodes across the network. This information circulates across the network from one node to another. The hop count is increased by one whenever a node receives such information [12]. Consequently, non-localized node can find information about the number of hops away from anchor node [3]. Shortest path from other nodes is computed by anchor nodes and non-localized nodes compute shortest path from anchor nodes [14]. Average hop distance is given as: distance between two nodes/number of hops [3].Location of non-localised nodes from anchor nodes is computed by triangulation method [14].
2) *Hop Terrain:* Hop terrain finds the distance between anchor node and non-localized node, just like DV hop method. In this method, firstly, non-localized node computes its position from anchor node by using formula: *distance between two nodes/total numbers of hop,* known as average hop distance formula. After this initial position estimation, next step is to broadcast initial estimated position to neighbour nodes. This information with distance information is received by neighbour nodes. A node refines its position until final position is found by using least square method [3].
3) *Centroid System:* Centroid system uses grained localization algorithm based on proximity that uses several anchor /nodes that broadcast their locations with (X_i, Y_i) coordinates. Non-localized nodes estimate their positions after receiving this information [24]. Anchor nodes localize themselves through GPS receiver as they are randomly deployed in the network area [3].
4) *APIT:* In APIT (approximate point in triangulation) method, anchor nodes receive location details from GPS or transmitters. Overlapping triangles give the location information of the non-localized node. [3].
5) *Gradient Algorithm:* In gradient algorithm, non-localized node gets its location by multilateration. Gradient begins by anchor nodes. By using multilateration of three anchor nodes non-localized nodes compute their positions [3]. It also makes use of hop count value that is initialised to 0 and incremented when it propagates to other neighbouring nodes [3]. The information of the shortest path is taken by every node from anchor nodes.
6) *Received Signal Strength Indication (RSSI):* In RSSI, distance estimation between transmitter and receiver is done by measuring signal strength at the receiver [4]. Distance estimation can be done by calculating the propagation loss. With the increase in distance between transmitter and receiver decrease in power of signal strength is observed.
7) *Angle of Arrival (AOA):* By using angle at which the anchor signals are received by the non-localized nodes, location of non-localized node can be computed [16]. Non-localized nodes use triangulation method to compute their locations [3].
8) *Time Difference of Arrival (TDOA):* The time difference between the arrival of radio signal and ultrasonic signal is used in this technique. Each node has a microphone and a speaker [2] [22].
9) *Time of Arrival (TOA).* In this method to compute the location of non-localized node, time and wavelength of radio signals moving between anchor node and non-localized node is measured [3]. Although it requires high processing capability, still this extremely accurate technique is used by GPS.

4. CONCLUSION

In Wireless Sensor Networks, it is certainly essential to consider constraints like node size, energy, and cost etc. before working on localization mechanism. Communication between nodes and transmission of data consumes more energy. Most of the proposed localization algorithms are application specific. Localization algorithm designed for one application might not necessarily work for other applications in wireless sensor networks. The table below clearly presents a comparative analysis of various localization techniques discussed above:

Table -1: Comparison of Localisation Techniques

Localisation Techniques	Energy	Cost	Hardware Size	Accuracy
GPS based	Less	High	Large	High
GPS free	Medium	Low	Small	Medium
RSSI	High	Low	Small	Medium
TOA	Less	High	Large	Medium
TDOA	High	Low	Might be large	High
AOA	Medium	High	Large	Low
DV Hop	High	Low	Small	Medium
APIT	High	Medium	Medium	Medium
Centralised	Less	Depends	Depends	High
Decentralised	High	Depends	Depends	Low

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