Imperial Journal of Interdisciplinary Research (IJIR)
Vol-2, Issue-9, 2016
ISSN: 2454-1362, http://www.onlinejournal.in

A Review on Node Localization Techniques for Wireless Sensor Networks

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***Abstract**: Recent advances in radio and embedded systems have enabled the proliferation of wireless sensor networks. WSN's are greatly being utilized as a part of various situations to perform different observation undertaking, for example, research, rescue, disaster management, target finding and various tasks in smart environments. In various tasks, node localization is one of the most important system parameters. Node localization is essential to report the origin of tasks, support group query of sensors, routing and to answer questions on the network exposure. So, one of the basic challenges in wireless sensor network is node localization. In this paper, we discuss sensor node architecture and its applications, different localization techniques, and few possible future research directions.*

***Keywords**- Wireless Sensor Networks, localization, RSSI.*

I. INTRODUCTION

With the new era of technology in integrated circuitry, computational devices become smaller, faster and cheaper. Along with the sensible wireless communication technology, a new networking epitome, wireless sensor network, is introduced. Many researchers and industries put their attention toward wireless sensor network because it provides an unexampled application scope for users and challenges for researchers. A sensor network is a network composed of hundreds or thousands of nodes that are capable of sensing one or more physical entity in the environment, e.g. Temperature, humidity, light intensity, seismic waves, etching Wireless sensor network information is exchanged between various sensors through wireless communication link, and processed at central node. Life time of a sensor depends on batteries attached to it, recharging is difficult and sometimes impossible for networks deployed in unfriendly environment.

Any wireless sensor network has four basic components:

(1) An assembly of sensors.
(2) An interconnecting network.
(3) A central point for collecting information.
(4) A set resources at the central point for computing to handle status querying, data correlation, event trending, and data mining.

The sensors in a wireless sensor network are self organizing and do some of the computing in the network by itself. Some algorithmic methods are used for managing potentially huge quantity of data in the sensor network. The communication and computation substructure associated with sensor networks is often specific to their environment and embedded in the device and application-specific nature of these networks. [1].

The rest of the paper is organized as follows. Localization of WSN and their techniques are explained in section II. Concluding remarks are given in section III.

II. LOCALIZATION IN WSN

Localization is a way to determine the location of sensor node. It is highly desirable to design low-cost, scalable and efficient localization mechanisms for WSN's.

Localization in wireless sensor networks is to determine the geographical positions of sensors in a wireless sensor network. The most trivial solution is manual configuration. The location of each sensor is predetermined before deployment. Sensors are installed to the assigned locations by human. Obviously, this solution is in scalable as much labour is required for the installation. Furthermore, it is sometimes infeasible to have manual configuration as the location information of sensors is unknown before actual deployment. Recalled the previous example of habitat monitoring, sensors are dropped from an aeroplane which exact locations are only known when sensors land on the forest.

Localization is estimated through communication between localized node and unlocalized node for determining their geometrical placement or position. Location is determined by means of distance and angle between nodes. There are many concepts used in localization such as the following.

(i) Lateration, occurs when distance between nodes is measured to estimate location.
(ii) Angulations, occurs when angle between nodes is measured to estimate location.

(iii) Trilateration, occurs when Location of node is estimated through distance measurement from three nodes.

In this concept, intersection of three circles is calculated, which gives a single point which is a position of

unlocalized node.

(iv) Multilateration, in this concept, more than three nodes is used in location estimation.

(v) Triangulation, in this mechanism, at least two angles of an unlocalized node from two localized nodes are measured to estimate its position. Trigonometric laws, law of sins And cosines are used to estimate node position.

Localization schemes are classified as anchor based or anchor free, centralized or distributed, GPS based or GPS free, fine grained or coarse grained, stationary or mobile sensor nodes, and range based or range free. We will briefly discuss all of these methods.

2.1 Anchor Based and Anchor Free

In anchor-based mechanisms, the positions of few nodes are known. Unlocalized nodes are localized by these known nodes positions. Accuracy is highly depending on the number of anchor nodes. Anchor-free algorithms estimate relative positions of nodes instead of computing absolute node positions.

2.2 Centralized and Distributed

In centralized schemes, all information is passed to one central point or node which is usually called "sink node or base station". Sink node computes position of nodes and forwards information to respected nodes. Computation cost of centralized based algorithm is decreased, and it takes less energy as compared with computation at individual node. In distributed schemes, sensors calculate and estimate their positions individually and directly communicate with anchor nodes. There is no clustering in distributed schemes, and every node estimates its own position.

2.3 GPS Based and GPS Free

GPS-based schemes are very costly because GPS receiver has to be put on every node. Localization accuracy is very high as well. GPS-free algorithms do not use GPS, and they calculate the distance between the nodes relative to local network and are less costly as compared with GPS-based schemes. Some nodes need to be localized through GPS which are called anchor or beacon nodes that initiate the localization process.

2.4 Course Grained and Fine Grained

Fine-grained localization schemes result when localization methods use features of received signal strength, while coarse-grained localization schemes result without using received signal strength.

2.5 Stationary and Mobile Sensor Nodes

Localization algorithms are also designed according to field of sensor nodes in which they are deployed. Some nodes are static in nature and are fixed at one place and the majority applications use static nodes. That is why many localization algorithms are designed for static nodes. Few applications use mobile sensor nodes, for which few mechanisms are designed.

2.6 Range-Free and Range-Based Localization

Range-Free Methods

Range-free methods are distance vector (DV) hop, hop terrain, centroid system, APIT, and gradient algorithm. Range-free methods use radio connectivity to communicate between nodes to infer their location. In range-free schemes, distance measurement, angle of arrival, and special hardware are not used.

i. DV Hop

DV hop estimates range between nodes using hop count. At least three anchor nodes broadcast coordinates with hop count across the network. The information propagates across the network from neighbor to neighbor node. When neighbor node receives such information, hop count is incremented by one. In this way, unlocalized node can find number of hops away from anchor node. All anchor nodes calculate shortest path from other nodes, and unlocalized nodes also calculate shortest path from all anchor nodes. Average hop distance formula is calculated as follows distance between two nodes/number of hops.

Unknown nodes use triangulation method to estimate their positions from three or more anchor nodes using hop count to measure shortest distance.

ii. Hop Terrain

Hop terrain is similar to DV hop method in finding the distance between anchor node and unlocalized node. There are two parts in the method. In the first part, unlocalized node estimates its position from anchor node by using average hop distance formula which is distance between two nodes/total numbers of hops. This is initial position estimation. After initial position estimation, the second part executes, in which initial estimated position is broadcast to neighbor nodes. Neighbor nodes receive this information with distance information. A node refines its position until final position is met by using least square method.

iii. Centroid System

Centroid system uses proximity-based grained localization algorithm that uses multiple anchor nodes, which broadcast their locations with coordinates. After receiving information, unlocalized nodes estimate their positions. Anchor nodes are randomly deployed in the network area, and they localize themselves through GPS receiver. Node localizes itself after receiving anchor node beacon signals.

iv. APIT

In APIT (approximate point in triangulation) scheme, anchor nodes get location information from GPS or transmitters. Unlocalized node gets location information from overlapping triangles. The area is divided into overlapping triangles. In APIT, the following four steps are included.

(i) Unlocalized nodes maintain table after receiving beacon messages from anchor nodes.

The table contains information of anchor ID, location, and signal strength.

(ii) Unlocalized nodes select any three anchor nodes from area and check whether they are in triangle form. This test is called PIT (point in triangulation) test.

(iii) PIT test continue until accuracy of unlocalized node location is found by combination of and three anchor nodes.

(iv) At the end, center of gravity (COG) is calculated, which is intersection of all triangles

Where an unlocalized node is placed to find its estimated position.

v. Gradient Algorithm

In gradient algorithm, multilateration is used by unlocalized node to get its location. Gradient starts by anchor nodes and helps unlocalized nodes to estimate their positions from three anchor nodes by using multilateration. It also uses hop count value which is initially set to 0 and incremented when it propagates to other neighboring nodes. Every sensor node takes information of the shortest path from anchor nodes. Gradient algorithm is as follows:

(i) In the first step, anchor node broadcasts beacon message containing its coordinate and

Hop count value.

(ii) In the second step, unlocalized node calculates shortest path between itself and the anchor

Node from which it receives beacon signals. To calculate estimated distance between

Anchor node and unlocalized node. Where is the estimated distance covered by one hop?

(iii) In the third step, error equation is used to get minimum error in which node calculates its Coordinate by using multilateration.

Range-Based Localization

Range-based schemes are distance-estimation- and angle-estimation-based techniques. Important techniques used in range-based localization are received signal strength indication (RSSI), angle of arrival (AOA), time difference of arrival (TDOA), and time of arrival (TOA).

i. Received Signal Strength Indication (RSSI)

In RSSI, distance between transmitter and receiver is estimated by measuring signal strength at the receiver. Propagation loss is also calculated, and it is converted into distance estimation. As the distance between transmitter and receiver is increased, power of signal strength is decreased. This is measured by RSSI using the following equation:

$$P_r(d) = \frac{PtGtG_r\lambda^2}{(4\lambda)^2 d^2}$$

Where p_t = transmitted power, G_t = transmitter antenna gain, G_r = receiver antenna gain, and λ= wavelength of the transmitter signal in meters.

In theory, the energy of a radio signal diminishes with the square of the distance from the signal's source. As a result, a node listening to a radio transmission should be able to use the strength of the received signal to calculate its distance from the transmitter. RSSI suggests an elegant solution to the hardware ranging problem: all sensor nodes having radios are used to compute ranges for localization.

In practice, however, RSSI ranging measurements contain noise on the order of several meters. This noise occurs because radio propagation tends to be highly non-uniform in real environments For instance; radio propagates differently over asphalt than over grass. Physical obstacles such as walls, furniture, etc. reflect and absorb radio waves. As a result, distance predictions using signal strength have been unable to demonstrate the precision obtained by other ranging methods such as time difference of arrival. However, RSSI has garnered new interest recently. More careful physical analysis of radio propagation may allow better use of RSSI data, as might better calibration of sensor radios. An extensive analysis of radio signal strength has been done, in which noticeable improvements in localization were shown. Thus, it is quite possible that a more sophisticated use of RSSI will eventually prove to be a superior ranging technology, from a price/performance standpoint.

ii. Angle of Arrival (AOA)

Unlocalized node location can be estimated using angle of two anchors signals. These are the angles at which the anchors signals are received by the unlocalized nodes .Unlocalized nodes use triangulation method to estimate their locations.

iii. Time Difference of Arrival (TDOA)

In this technique, the time difference of arrival radio and ultrasound signal is used. Each node is equipped with microphone and speaker. Anchor node sends signals and waits for some fixed amount of time which is then it generates "chirps" with the help of speaker. These signals are received by unlocalized node at time. When unlocalized node receives anchor's radio signals, it turns on microphone. When microphone detects chirps sent by anchor node, unlocalized node saves the time .Unlocalized node uses this time information for calculating the distance between anchor and itself.

iv. Time of Arrival (TOA)

In TOA, speed of wavelength and time of radio signals travelling between anchor node and unlocalized node is measured to estimate the location of unlocalized node [13]. GPS uses TOA, and it is a highly accurate technique however, it requires high processing capabilities. Some interesting results are obtained by comparing few localization techniques. The results are based on observations and analysis. Figure 4 shows cost of four localization techniques, and it is observed that GPS- and TOA-based systems are more expensive as compared with DV hop and RSSI.

Table-1 Comparison of Range based techniques

Type of Measurement		Cost	Accuracy	Energy efficient	Hardware size
Distance	RSSI	Low	Medium	High	Small
	TDOA	Low	High	High	Less Complex, May be large
	TOA	High	Medium	Less	Large
Angle	AOA	High	Low	Medium	Large

Table-2 Comparison of Range Free techniques

Type of measurement		Cost	Accuracy	Energy efficient	Hardware size
Distance	DV Hop	Low	Medium	High	Small
	Hop Terrain	Low	Medium	High	Small
	APIT	Medium	Medium	High	Medium
	Centroid system	Depends	High	Less	Depends

III. CONCLUSION

In this paper we have discussed various localization techniques discuss the advantages and disadvantages of these techniques. In this paper localization algorithms were classified based on key features like Anchor Free, Anchor Based, Range Based, Range free, GPS Based, GPS Free etc. Range Based RSSI provides less accurate estimate of distance still it has been favoured by researcher because of its low cost as compared to any other measurement techniques.

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