Localization Techniques in Wireless Sensor Network: A Survey

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Abstract – Wireless Sensor Networks are widely used in many environment and conflicting environments. The important function of a sensor network is to collect and forward data to destination. Alertness of location is one of the important and serious issue and challenge in wireless sensor network. The location of collected data is obtained by using localization techniques in Wireless Sensor Networks. Localization is the process of finding the position of a senor node. In this paper, we discuss the problem localization and review has been done on the localization techniques.

Keywords—Wireless Sensor Networks; Localization techniques; GPS; Anchor node; Sensor node.

1. INTRODUCTION

Wireless sensor networks that consist of thousands of low-cost sensor nodes have been used in many promising applications such as health investigation, battle field surveillance, and environmental monitoring. Sensors are tiny devices, low costing and having low processing capabilities. Sensor in wireless sensor network collects the information, store the information and forward the computed data to other devices [1]. Localization is the most important issue in wireless sensor network because the location information is useful in deployment, routing, target tracking, coverage and rescue.

Localization is the process of finding the position of nodes as data and information are useless if the nodes have no idea of their geographical positions. Sensor node can determine its location by extracting the information received from the infrastructure, by making node to send signal periodically [2]. Global positioning system (GPS) is the simplest node localization method, but it becomes very expensive if large number of nodes exists in a network and also these devices have huge energy consumption [2]. Therefore, several localization algorithms have been introduced to solve localization problem. Almost all existing localization schemes consist of two phases: 1) distance/angle estimation: this is used to estimate distance or angle between two sensor nodes such as TDOA (Time Difference Of Arrival, RSSI (Received Signal Strength Indicator); 2) position computation: the position of the unknown node is estimated based on the available information of distance or angle of references nodes such as lateration, trilateration, triangulation, multilateration [6]. Most of the localization algorithms can be classified into two categories: 1) range-based localization and 2) range-free localization. The accuracy of range-free localization is lower than that of range-based localization, range-free localization is easily implemented and is suitable for large WSNs in which a large number of sensor nodes are deployed [3]. In this paper, we will present the survey of node localization algorithms.

In this paper, Section I describes the introduction to wireless sensor network and localization, Section II gives the classification of localization techniques, Section III describes performance comparison of techniques, and Section IV concludes the discussion and explain the future work.

2. CLASSIFICATION OF LOCALIZATION ALGORITHM

The existing localization schemes can be classfied into two major categories: the range-based approaches and the range-free approaches. The range-based schemes are based on using range measurement techniques for location estimation. The range-free schemes are distance-estimation and angle-estimation based techniques [2]. Range-based and range-free schemes may or may not use anchor nodes (which know their own location also called beacon node).

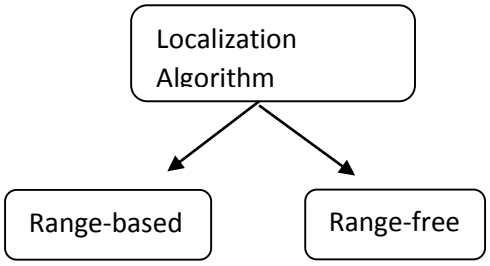

Fig.1. Classification of localization schemes

Range-based and range-free techniques are discussed below:

2.1. Range-free methods

Techniques used are distance vector (DV); hop count, APIT and centroid system [3].

2.1.1. Distance vector (DV) hop:
DV -Hop is the hop-count based localization. It does not need to measure the distance between the beacon node and unknown node. It uses the average hop distance to estimate the actual distance [13].
2.1.2. Hop count:

This method is used to approximate the distance between anchor node and blind node. Hop count method is easy to implement and it is energy efficient but accuracy is very less [13].

2.1.3. APIT:

Approximate Point in Triangulation (APIT): In this algorithm three anchor noes formed a triangle and blind node determines whether it is inside that triangle or not by analysis RSS value of each anchor node. This is called the point in triangulation test (PIT). APIT has more accuracy i.e. More the number of anchor nodes more the triangle formed around blind node and hence more the accuracy. Error occurs in estimating the blind node is inside the triangle or not [5].

2.1.4. Centroid System:

Blind nodes estimate their location by using centroid formula. Anchor nodes transmit their location using GPS method to the blind nodes. This method is simple but localization error is high [3].

2.2. Range-based methods:

Important techniques used in range-based methods are received signal strength indicator (RSSI), angle of arrival (AOA), time difference of arrival (TDOA), time of arrival (TOA) [10].

2.2.1. Received signal strength indicator (RSSI):

In RSSI, distance between transmitter and receiver is estimated by measuring signal strength at the receiver. RSS varies as the inverse square of the distance d between the transmitter and the receiver. As the distance increased, power of signal strength is decreased. This is measured using free space propagation model:

$$P = \frac{PtGtGr\lambda^2}{(4\pi)^2 d^2} \quad (1)$$

Where P_t is the transmitter power, G_t is the transmitter antenna gain, G_r is the receiver antenna gain, is the wavelength of the signal.

2.2.2. Angle of Arrival (AOA):

Angle of Arrival is the angle between a signal's propagation and some reference direction. Blind node (Unlocalized) estimated their location using angle of two signals. Blind nodes use triangulation method to approximation their locations.

2.2.3. Time of Arrival (TOA):

Speed of wavelength and time of signals travelling between anchor node and blind node is measured to estimate the location of blind node. TOA is a highly precise method. The distance to the source can be calculated as follow:

$$S = (T_2 - T_1)\, V_p \quad (2)$$

Where T1 is the time at which signal is sent, V_p is the signal propagation speed in the medium and T2 is the time of arrival (TOA).
2.2.4. Time Difference of Arrival (TDOA):
Anchor node sends signal and waits for some time, $t_{delay.}$ Blind node receives these signals at time $t_{sound.}$ Blind node uses this time information for calculating the distance between anchor node and itself using the following equation [7]

$$D = (S_{radio} - S_{sound}) * (t_{sound} - t_{radio} - t_{delay}) \quad (3)$$

There are many conceptions used in localization. Node Localization is approximated over communication between anchor nodes and blind nodes. Location is estimated through distance estimation and angle estimation.

2.3. Triangulation:
Triangulation is the process of determining the position of the blind node by measuring the angle of blind node to the anchor node. Triangulation is an angular distance between three anchor nodes forming a triangle and blind node inside the triangle [4].

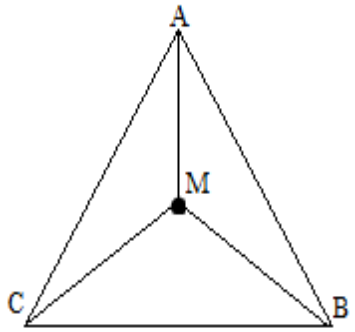

Fig 2: Triangulation

2.4. Trilateration:
Trilateration is the process of finding the position of a blind node by measuring the distance from atleast three anchor nodes. The intersection point of three circles gives the single point which is the position of blind node [4].

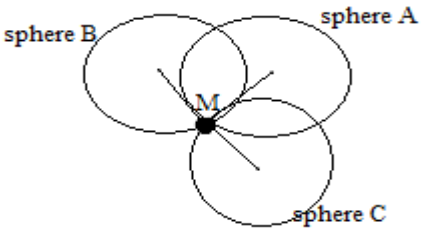

Fig 3: Trilateration

2.5. Multilateration:

In multilateration, more than three anchor nodes are used to find the position of blind node.

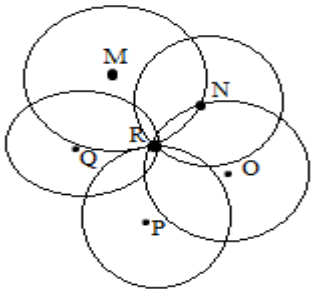

Fig 4: Multilateration

3. PERFORMANCE COMPARISON

In this section comparative study for range-based and range-free localization techniques is done on the bases of some parameters that are accuracy, energy efficiency, hardware cost and hardware size. We will review this comparison in table 1. We will also discuss the parameters for localization [3].

Table 1: Comparison of different localization techniques [3]

Technique	Accuracy	Energy efficient	Hardware cost	Hardware size
GPS	High	Less	High	Bulky
DV hop	Medium	High	Low	Small
APIT	Medium	High	Medium	Medium
RSSI	Medium	High	Low	Small
AOA	Low	Medium	High	Large
TOA	Medium	Less	High	Large
TDOA	High	High	Low	Large

We here present the parameters to distinguish between different techniques of localization [6].

1. **Accuracy**: Accuracy is very important in WSN for localization of nodes. Most applications require higher accuracy. Range-based schemes have more accuracy than range-free schemes. The accuracy of techniques is reduced due to obstacles present in the environment. When a node estimates its wrong position and broadcasts that information over the network, accuracy of the localization procedure is decreased. Accuracy depends on few factors like cost, number of anchor nodes and node density.
2. **Hardware cost**: Cost is a very challenging dispute in localization of nodes in WSN. Range-based scheme requires more hardware than range-free scheme. The algorithm with less cost doesn't give high rate of accuracy. Hardware cost comprises node density, anchor density and equipment.
3. **Energy efficient**: Localization techniques should be energy efficient in WSN. A sensor node requires maximum energy in data transmission and reception.

Range-based offers high accuracy but requires additional hardware. Table 2 gives the comparison of range based techniques [5].

Table 2: Comparison of Range-based Techniques [5]

Techniques	Type of measurement	Accuracy		Overhead
		LOS	NLOS	
RSSI	Distance	Low	Very Low	Low
AOA	Angle	High	Very Low	High
TOA	Distance	High	High	Low
TDOA	Distance	Very High	High	High

4. CONCLUSION

There are many applications of WSN in which sensor nodes gather the data and information from the specific location and forward it to the destination. Localization is the process by which sensor nodes know the location from where the data is collected. Localization is the process of finding a sensor node's position in space. Localization is a significant dispute in wireless sensor network. In this paper, we explain different localization techniques in detail. Range-based schemes and range-free scheme are intensely studied. This classification of localization techniques is useful to understand the maneuver of various techniques and for implement of new localization algorithms.

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In additional, some estimation issues were introduced to authenticate new proposed methods and to compare different existence techniques in order to find the best one for a specific application. Many algorithms can be design to resolve the problem of localization of nodes. All the efforts are designed to improve the performance and to development of techniques to work on large scale of applications.

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