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# A Survey on Localization for Wireless Sensor Network

Ripal Patel[1], Rutvij Joshi[2], Paras Gosai[3], Jitiksha Patel[4]
Electronics and communication department, Dr. S & S.S Ghandhy. Engineering College,
Surat-India

**ABSTRACT**
Wireless sensor networks (WSN) contain tiny, lightweight nodes that are highly distributed and organized in large number through wireless links that cooperate with each other in order to sense phenomena, collect and process data and transmit sensed information to the user. Many applications of WSNs require the knowledge of nodes location. Therefore, algorithms that can compute the location of sensor nodes within a WSN are needed. The process of determining the geographical positions of sensors is known as localization. This Paper presents a survey on localization techniques. Here in this paper Range based techniques are discussed in detail. The comparison of various range based techniques is also discussed here.
***Keywords* —** WSN (wireless sensor network), Localization, Range based method

## I. INTRODUCTION

WITH the advancement in electronics and wireless communication technology has led the way to the development of small, low-power, low-cost sensor nodes that communicate over short distances. In wireless sensor network (WSN), a large number of these sensor nodes are deployed across a geographical region through wireless link to detect phenomena, collect and process data and transmit sensed information to the user. Now a day sensor network are used in many applications which require continuous check and detection of unambiguous actions such as Military application, Environmental application, Health applications, Home application, Multimedia application etc. The important challenge in the design of wireless systems for WSN is the communication bandwidth and energy which are limited. There is sudden burst of data when any event takes place in sensing environment. Due to high volume of sensed data and limited memory, sensor node experience congestion which leads packet loss and hence retransmission of packets becomes necessary.

Wireless sensor networks consist of different types of sensor nodes such as seismic, thermal, visual, and infrared, and they monitor a variety of ambient conditions such as temperature, humidity, pressure and characteristic of object and their motion [17]. These WSNs create smart environments by providing access to information regarding the environment through collecting, processing, analysing, and disseminating data whenever required.

In wireless sensor networks the positions of individual nodes are unknown as the nodes are deployed arbitrarily in a geographical region. Identifying the location of the nodes in a WSN is of great importance, given that in some applications such as animal habitat monitoring, brush fire surveillance, water quality monitoring and precision agriculture, the measurement data are meaningless without an accurate knowledge from where in the network the collected data is coming from. Therefore, we would not make effective use of WSN. Many network protocols and middleware services rely on location information, such as geographic routing protocols, context-based routing protocols, location-aware services, and enhanced security protection mechanisms require the knowledge of node's location information for that [15].

Due to the context of the application and the potential for a high number of wireless sensor nodes, either manually configuring location information into each node or equipping every node with a GPS receiver becomes expensive and infeasible. The GPS can require high power consumption which is not feasible in WSN as the node have limited battery power. Therefore various localization techniques are developed for finding nodes location in WSN. The process of determining the geographical positions of sensors is known as localization. The nodes who know their geographical location are known as anchor node. Localization algorithms use the location information of anchors and estimates of distances between neighbouring nodes to determine the positions of the rest of the sensors by RSSI, TOA, TDOA and AOA.

This paper is organized as follows. Classification of Localization techniques are described in section II. In section III different range based methods are described to calculate distance and after that different methods of finding position are described in section IV. Section V represents the conclusion of the study.

## II. CLASSIFICATION OF LOCALIZATION TECHNIQUES

Localization techniques are classified into four categories as follow:

### A. Centralized versus Distributed algorithm

Localization algorithms can be classified as centralized [7][12] or distributed [2][14] algorithms based on their computational organization. In centralized algorithms, nodes send data to a central location where computation is performed and the location of each node is determined and sent back to the nodes. The drawbacks of centralized algorithms are their high communication costs, high power consumption and intrinsic delay. In most cases, the intrinsic delay of centralized algorithms increases as the number of nodes in the network increases, thus making centralized algorithms inefficient for large networks. As a result, distributed algorithms that distribute the computational load across the network to decrease delay and to minimize the amount of inter sensor communication have been introduced [19]. In distributed algorithms, each node determines its location by communication with its neighbouring nodes.

Generally, distributed algorithms are more robust and energy efficient since each node determines its location locally with the help of its neighbours, without the need to send and receive location information to and from a central server. Distributed algorithms can be more complex to implement.

B. **Range Free versus Range Based Localization Techniques**

For determining the location of a sensor node, two types of techniques exist: range-free[5][7] and range-based[1][4][5][7]. Range-free techniques use connectivity information between neighbouring nodes to estimate the nodes' position. Range-based techniques however require ranging information that can be used to estimate the distance between two neighbouring nodes. On the one hand, range-free techniques do not require any additional hardware and use proximity information to estimate the location of the nodes in a WSN, and thus have less accuracy. On the other hand, range-based techniques use range measurements such as time of arrival (TOA), angle of arrival (AOA), received signal strength indicator (RSSI), and time difference of arrival (TDOA) to measure the distances between the nodes in order to estimate the location of the nodes.

C. **Anchor Based versus Anchor Free Localization Techniques**

Another classification of localization algorithms for WSNs is based on whether or not external reference nodes are needed. These nodes, called anchor nodes (or simply anchors for short), usually either have a GPS receiver installed on them or know their position by manual configuration. They are used by other nodes as reference nodes in order to provide coordinates in the absolute reference system being used.

Anchor-based algorithms[3][5][7][9] use anchor nodes to rotate, translate and sometimes scale a relative coordinate system so that it coincides with an absolute coordinate system. In such algorithms, a fraction of the nodes must be anchor nodes or at least a minimum number of anchor nodes are required for adequate results. For 2-dimensional spaces, at least three no collinear anchor nodes and for 3-dimensional spaces, at least four no coplanar anchor nodes are required. The final coordinate assignments of the sensor nodes are valid with respect to a global coordinate system or any other coordinate system being used. A drawback to anchor- based algorithms is that another positioning system is required to determine the anchor node positions. Therefore, if the other positioning system is unavailable, for instance, for GPS-based anchors located in areas where there is no clear view of the sky, the algorithm may not function properly. Another drawback to anchor-based algorithms is that anchor nodes are expensive as they usually require a GPS receiver to be mounted on them. Therefore, algorithms that require many anchor nodes are not very cost effective. Location information can also be hard-coded into anchor nodes, however, in this case careful deployment of anchor nodes is required, which may be very expensive or even impossible in inaccessible terrains.

In contrast, anchor-free localization algorithms [19] do not require anchor nodes. These algorithms provide only relative node locations, i.e., node locations that reflect the position of the sensor nodes relative to each other. For some applications, such relative coordinates are sufficient, however. For example, in geographic routing protocols, the next forwarding node is usually chosen based on a distance metric that requires the next hop to be physically closer to the destination, which can be perfectly expressed with relative coordinates.

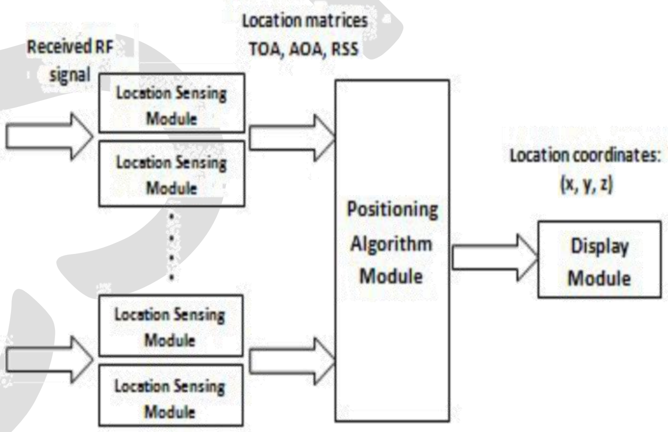


Figure 1 Range based localization method [16]

D. **Mobile versus Stationary Node Localization**

As the number of applications that require mobile sensor nodes has increased, the problem of mobility in WSNs has recently gained much interest. Studies conducted on introducing mobility in WSNs have resulted in an overall improvement in the network by not only increasing the overall network lifetime, but also by improving the data capacity of the network as well as addressing delay and latency problems[19]. Some authors have proposed algorithms in which mobile anchor nodes are used in order to aid with the localization of stationary sensor nodes[5][13]; One of the example of a such approach is an inventory management. In other scenarios however, some or all of the sensor nodes are mobile [5][7][9]; In this type of scenarios mobility creates the problem of locating and tracking moving sensors in real time.

## III. RANGE ESTIMATION TECHNIQUE

Range based Localization process is divided in to two parts as shown in figure:

- Estimation of range(distance) or angle
- Estimation of position of node

As shown in figure 1 Range based system is composed of three different blocks. The first is location sensing where the location sensing module sense the signal and desired location metrics such as Angle of Arrival (AOA), Received Signal Strength (RSS) or TOA (Time of Arrival) are extracted from propagation channel. Second, with a certain accuracy, these parameters are fed into the positioning algorithm block where it produces the (x, y, z) co-ordinates of the node by using Trilateration and Triangulation method.

### E. Received Signal Strength Indicator (RSSI)

Received Signal Strength Indicator (RSSI) is defined as the amount of power present in a received radio signal. Due to radio propagation path loss, received signal strength (RSS) decreases as the distance of the radio propagation increases. Therefore, the distance between two sensor nodes can be determined using the RSS value at the receiver by equation 1, assuming that the transmission power at the sender is either fixed or known.

$$p_r = d^{-n_p} \qquad (1)$$

Where, $p_r$= Received power
d = distance
$n_p$ = path-loss exponent typically between 2 and 4

An advantage of this technique is that no additional hardware is required as it uses a standard feature found in most wireless devices, namely the received signal strength indicator. Also it does not significantly impact local power consumption or sensor size and thus cost. The disadvantage of this technique is its inaccuracy and unreliability because the multipath environment creates constructive and deconstructive interference so that a user's location will not be correlated with signal power. This effect is frequency dependent as well, so a measurement at one carrier frequency will be uncorrelated with a measurement at another carrier frequency. For example, if the sensor network is deployed indoors, walls and other obstacles would severely reduce the precision of the method due to nonlinearities, noise, interference, and absorption.

### F. Time of Arrival

Time of arrival is defined as the earliest time at which the signal arrives at the receiver. It can be measured by adding the time at which the signal is transmitted with the time needed to reach the destination (time delay). This method requires an additional hardware at the receiver to measure the arrival time of signal. Distance or range is calculated by using standard formula of speed as shown below.

$$D = S \times T \qquad (2)$$

Where, D=Distance Between transmitter and receiver
S=Speed of signal
T=Time to reach the signal to the receiver

In TOA, the nodes have to be synchronized and the signal must include the time stamp information [3]. To overcome these limitations, Round-trip Time of Arrival (RTOA) and Time Difference of Arrival (TDOA) are developed.

### G. Time Difference of Arrival

The Time Difference of Arrival (TDOA) technique requires the nodes to transmit two signals that travel at different speeds. This is based on the fact that radio waves travel much faster than sound in air. In this technique, each node is equipped with a microphone and a speaker. Most systems use ultrasound while some use audible frequencies as a second signal and RF signal as a first signal. In TDOA, a RF signal and ultrasound signal are sent by the transmitter at the same time. The receiver nodes receive the Radio signal and note the current time, and then they turn on their ultrasound receiver to receive the ultrasound signal and again note the current time. Once they have the different times, the nodes can compute the distance between themselves and the transmitter from the following equation.

$$s_1 - s_2 = \frac{d}{t_1} - \frac{d}{t_2} \qquad (3)$$

Where, $s_1$ = speed of radio signal
$s_2$ = speed of ultrasound signal
d = distance
$t_1$ and $t_2$ = time take to reach the radio and ultrasound signal at the receiver

If line-of-sight conditions are met and the environment is echo-free, TDOA techniques perform extremely accurately. The advantage of TDOA method is that synchronization between nodes is not required. The disadvantage of such systems is that they require special hardware which must be built into the sensor nodes. Also, the speed of sound in air varies with air temperature and humidity, which can introduce inaccuracies. Lastly, it is very difficult to meet line-of-sight conditions in many environments such as inside buildings or in mountainous terrains.

### H. Angle of Arrival

Angle of Arrival (AoA) techniques [6][8] gather data using either radio or antenna arrays. These arrays allow a receiving node determine the direction of a transmitting node. Optical communication techniques can also be used to gather AoA data. In these techniques, a single transmitted signal is received by several spatially separated antenna array elements. The phase or time difference between the signal's arrivals at different elements of array is calculated and thus the AoA of the signal is found.

This technique is accurate to within a few degrees but the downside is that AoA hardware is bigger and more expensive than TDOA ranging hardware, since each node must have the antenna array [3]. Another important factor is the need for spatial separation between array elements which will be difficult to accommodate as the size of sensor nodes decreases.

## IV. POSITION ESTIMATION TECHNIQUE

There are various methods to estimate the position of node or co-ordinate of the node. Some of them are listed below.

### A. Trilateration

This method determine the position of a node from the intersection of 3 circles of 3 anchor nodes that are formed based on distance measurements between its neighbours. The radius of the circle is equal to the distance measurement between the anchor node and the unknown node as shown in Fig 3.3. However, in a real environment due to the multipath, the distance measurement is not perfect.

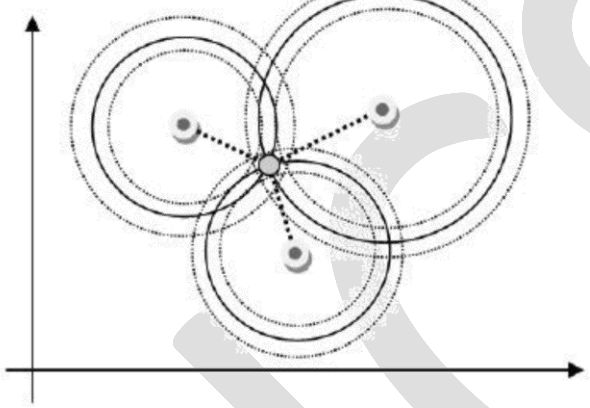

Figure 2 Trilateration [16]

### B. Triangulation

This method is used when the direction of the node rather than the distance is estimated. It uses trigonometry laws of sine's and cosines to calculate the nodes position based on the angle information from two anchor nodes and their positions as shown in Figure 3.

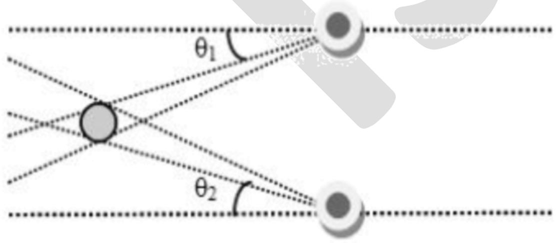


Figure 3 Triangulation [16]

### C. Maximum Likelihood Multilateration

Trilateration technique cannot accurately estimate the position of a node if the distance measurements are noisy. A possible solution is to use the Maximum Likelihood (ML) estimation, which includes distance measurements from multiple neighbour nodes as in Figure 3. This method intends to minimize the differences between the measured distances and estimated distances. [4]

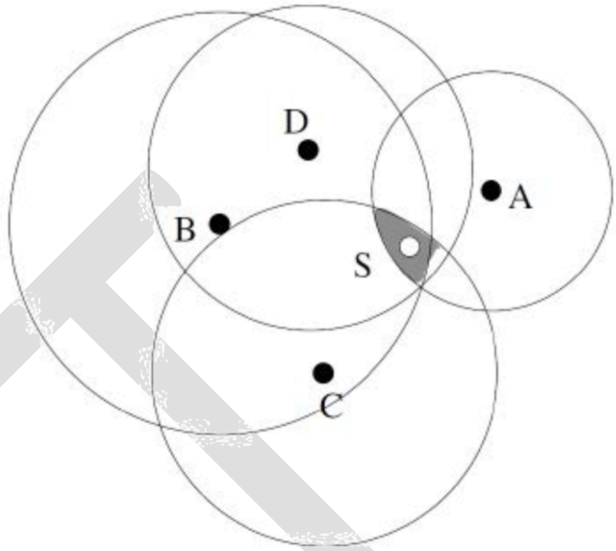


Figure 4 Maximum Likelihood Multilateration

## V. CONCLUSION

After studying various range based techniques, from table 1, we have conclude that TOA/TDOA method gives more accuracy in distance measurement as compared to RSS method, but in TDOA/TOA method, extra hardware is needed in the node while in RSS method no extra hardware is needed.

| Geometric Methods | Advantages | Disadvantages |
|---|---|---|
| RSS | • Simple to implement (most wireless devices report power)<br>• Not sensitive to timing and RF bandwidth | • Not accurate<br>• Requires models specific to application case and environment |
| AOA | • Only requires 2 anchors for localization | • DP blockage and multipath affects accuracy<br>• Requires use of antenna arrays/ smart antennas<br>• Accuracy is dependent on RF bandwidth |
| TOA/TDOA | • Accurate ranging/localization can be obtained<br>• Can be scaled to multitude of applications | • Accuracy is dependent on RF bandwidth<br>• DP blockage might cause large errors |

Table 1 Comparison of range based method

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