



Localization Techniques for Mobile Wireless Sensor Networks

Bhavini Gautam*, Dr. Trilok Chand Aseri**

Department of Computer Science*, Department of Computer Science, Chandigarh**
PEC University of Technology *, PEC University of Technology **
Chandigarh, India

Abstract: — Over the past decade Wireless sensor networks (WSNs) have been a widely used paradigm for observing various environmental phenomenon via sampling. Mobile wireless sensor networks (MWSNs) are regarded as the ascendants of wireless sensor networks in which mobility plays a vital role. Adding mobility in WSN is very crucial as it may be either an incidental side effect and may prove to be detrimental for the network performance, or it may prove out to be a desired property and as a result may enhance network performance. The need for robustness and scalability in a sensor network alleviates the need for accurate, fast and cost effective localization. Localization i.e., estimating sensor position is one of the significant challenges of MWSNs. This paper presents a survey of current localization methods for mobile wireless sensor networks. In this survey we present the entire localization process, classification of localization methods and algorithms, summarized their advantages and disadvantages. Finally, localization problems are discussed which affect localization process and application areas of mobile wireless sensor networks are covered.

Keywords: Anchor nodes, localization algorithm, Mobile sensor, Mobile wireless sensor networks, Range

I. Introduction

With the ever increasing need to monitor various physical phenomena wireless sensor networks have been of great usability. Localization is critical for many applications in WSN as it helps in estimating the location (absolute or relative) of a sensor node [1], [2].

In recent years, WSN have been surveyed a lot as an active area of research [4], [5] and recently mobility has become an important area of research for the WSN community. Mobile sensors must frequently estimate their position, which takes time and energy, and consumes other resources needed by the sensing application. Localization algorithm for static WSNs [11] are ineffective for MWSNs [13], [15].

A trivial method for sensor localization is for the sensors to be equipped with *Global Positioning System* (GPS) [17]. However, there are several arguments against this architecture. To mitigate issues with GPS deployment on sensors many people suggest using some special sensor nodes, which already know their absolute location via GPS or manual placement viz., *anchor nodes*, *seeds*, *landmarks* or *infrastructure nodes* [18]. Other nodes estimate their location based on the information derived from the anchor nodes.

The rest of the paper is organized as follows section II explains the entire localization process that how nodes initiate to communicate and finally estimate the location of mobile nodes. Section III classifies the various localization process and algorithms depending on different classifiers and we draw our conclusion in section IV.

II. Localization Process

The localization techniques use extensive hardware, algorithms and signal modalities, which are categorized. We start by describing the three phases typically used in localization: (A) *coordination*, (B) *measurement*, and (C) *position estimation* [24].

The localization process is illustrated below in the figure:-

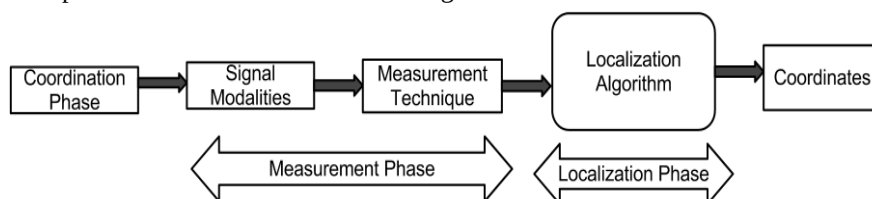


Figure 1- Localization Process

A. Coordination Phase

Before signal transmission, nodes participating in the localization coordinate with one another in order to have a sync amongst themselves indicating that coordination process is about to begin. *Reference broadcast synchronization* (RBS) and *elapsed time on arrival* (ETA) have been the favorable methods since their coordination methods have microsecond accuracy and require transmission of only a single message.

B. Measurement Phase

The measurement phase includes the transmission of a signal by at least one node, followed by signal processing by all other participating nodes.

1) Signal Modalities

The choice of signal modality used by sensor nodes is important for accurate localization, and depends on node hardware, the environment, and the application. Signal modality has high effect on the accuracy of location estimation. The use of signal modality is constrained by factors such as environmental conditions, the application for which modality is to be used for. Commonly used signals are *radio signals* based on RF, it is a low on cost modality because all wireless sensor nodes have onboard radio hardware. However in humid environments, for example, radio signals performance is degraded. The *acoustic modality* typically employs either ultrasound or audible wave propagation. *Infrared (IR) signal* is an ideal modality for indoor localization since attenuation in IR is relatively high [24].

2) Range based algorithms.

Range-based localization methods normally require either of the distance or angle approximates between nodes to obtain unknown node's location. Distance estimates and angle measurements are used in order to locate nodes [12].

a) Time based Methods

These methods record certain time properties of the received signal and convert it into distance approximate. *Time of arrival (ToA)* and *time difference of arrival (TDoA)* [3] methods in which propagation time can be directly translated into distance estimate, based on known signal propagation speed. These methods can be applied to many different signals such as RF, acoustic, infrared and ultrasound. Time based methods are very accurate under line of sight conditions, but this line of sight condition is difficult to meet in some environments. Moreover, the speed of sound varies with air, temperature and humidity and acoustic signals exhibits multipath signal propagation that again impacts the accuracy of signal detection.

b) Angle of Arrival (AoA)

This method estimates the angle at which signals are received and use simple geometric relationships to calculate node positions. This method provides accurate localization measurement but is constrained by the cost of the hardware [25].

c) Received Signal Strength Indicator (RSSI)

RSSI measures the strength or power of the signal at the receiver and based on the known transmit power, the effective propagation loss can be calculated. Then by using certain methods this loss is translated into a distance estimate. This method used RF signals. It is a relatively cheap and most popular solution, as no extra device is to be used, since all sensor nodes are likely to have radio transceiver. This technique yields inaccuracy due to multipath propagation of radio signals [16].

3) Range free algorithms

The range-free algorithms use the connectivity and the proximity information to calculate the position of a node [7]. These algorithms eliminate the need of extra hardware to estimate the position of the mobile node.

C. Localization Phase

The signal data obtained in the measurement phase is then used to approximate the position of the target node. Since, due to many factors range data often gets attenuated by noisy signal measurements, optimization methods are to be employed to filter the noise and arrive at a more definite position estimate.

1) Trilateration

When ranges between anchor nodes and the mobile node can be determined, trilateration is used to estimate position [21]. For two-dimensional localization, three range measurements from known positions (anchor nodes) are required. Each range can be represented as the radius of a circle, with the anchor nodes as center. In ideal situation, three circles should intersect at a point and that intersection point is the location of the target node. However the intersection point gets deviated due to interference and is attenuated by measurement noise, so the three circles will overlap, and the target node will most likely lie in that region.

2) Angulation.

When anchor bearings or angular separation between anchors and the mobile node is available, angulations can be used to determine the position of the mobile node. When two anchors are used, the

target position will be identified as the third point in a triangle of two known angles (the bearings from each anchor), and the length of one side (the distance between anchor nodes) this is known as triangulation.

III. Localization Classification

The available algorithms [13] are classified in taxonomy. They can be classified under different aspects such as range, scenario, coordinates, anchors, calculation etc. They are categorized into two main groups based on learning criteria: *Learning based* and *Non- Learning based* approaches, which are described below.

A. Non-learning based localization algorithms

Most of the localization algorithms are non-learning based. These groups classified into *Anchor based* and *Anchor free* classes.

i. Non-learning anchor based localization algorithms

Under this set of algorithms are included the algorithms which use range, angle or these algorithms depend uniquely on information and here the efficiency of the algorithm depend greatly on the number of the anchor nodes [20]. These algorithms can be implemented either in a centralized manner or in a distributed manner and are referred to as *Centralized* and *Distributed* localization.

a) Centralized localization

The centralized localization algorithm runs on a *base station* and it requires it to gain the measurement data from all the participating nodes. Base station determines the location of each node by collected measurement data and transport them back into network. The advantage of the centralized approach is an algorithm can be designed that has more accuracy, precision, and can process greater amounts of data with very less amount of localization error. On the other hand, base station processing suffers from the common pitfalls of centralization, such as poor scalability, single point of failure, data routing complexity, and greater power consumption.

b) Distributed localization

The distributed localization algorithm is such that all the computations are done by the sensor nodes themselves and the nodes communicate amongst themselves with one-hop or multi-hops neighbor nodes to get their positions in the network.. It has the characteristics of small traffic, equal calculation burden of each node, similar storage requirements and good scalability. However, due to the lack of global information, location accuracy is susceptible to the number of anchor nodes and the distribution of nodes [14].

When nodes are mobile, the decision to use centralized or distributed processing becomes even more crucial. Mobility requires continuous and rapid localization. Centralized localization algorithms exist for MWSN but they are not fast enough for applications such as navigation. For example, mTrack [10] reports a latency of approximately 5 seconds; dNav on the other hand, is distributed, and takes less than 1 second on average to return position and velocity estimates.

ii. Non-learning anchor free localization algorithms

In contrast to anchor based, this category has not even one anchor node. In these schemes instead of finding the nodes' position, the algorithm finds relative positions of the nodes in the coordinate system by a reference group of nodes referred to as *reference nodes* [19]. The multi-dimensional scaling (MDS-MAP) technique uses data analysis and information visualization to display distance-like data in geometrical visualization. This algorithm computes the shortest distance between all pairs of nodes and then makes a distance matrix and applies MDS to construct relative location of nodes. If there was sufficient anchor numbers available, it can estimate absolute nodes' location by transforming relative locations. MDS requires global information and it has high communication and computational cost.

B. Learning based localization algorithms

This section will classify a number of localization techniques that employ the concepts from machine learning. Localization techniques based on learning approaches are simple because of having easy implementation and fewer requirements. Generally machine learning algorithms are implemented in two phases: - *Offline* and *Online* phases [23].

In the first phase, the training information gathers from the network. Learning approach runs on the information and the result is a predicted model. After that, in the online localization phase, any sensor can use this model to localize itself without knowledge about other sensors. This property makes the learning based localization

algorithms cost efficient, fast and low computation. However, it has its own limitation; the accuracy of algorithm depends on the number of training data which is produced by beacons. Examples of this type of algorithm are *Monte Carlo* method and *fingerprinting* technique.

1) Monte Carlo Method

The Monte Carlo method has been extensively used in robotics. Then later this method was extended to support the localization of sensors in a free, unmapped terrain. Using sequential Monte Carlo for mobile networks helps in reducing the number of anchor nodes used and yields higher levels of accuracy. Localization takes place in two steps, *prediction* and *filtering*. First, the prediction step leads to choosing a set of samples representing the belief of the node regarding its location i.e., the set of samples contain all the possible positions of a node's location. During the prediction step, a node picks random locations within the deployment area, possibly constrained by its maximum speed and the previous location samples. Second, the filtering step aims at removing the impossible locations from the set of samples in order to reduce the set. The filtering is done using information obtained from the environment, such as the location of the anchors in the case of a sensor. The process repeats and the sensor or is able to update its position. *Monte Carlo boxed* is another variant where the major difference lies in the way anchor information is used and method employed to draw node's position samples [22].

2) Fingerprinting

The location fingerprinting technique connects location-dependent characteristics such as received signal strength (RSS), from known access points to a location, and uses these characteristics to infer the location [8]. Locations within the entire area of interest are usually expressed as a set of rectangular grid points. Fingerprinting based positioning is divided into *offline* and *online* phases. In the offline phase (also known as *training* phase), by site surveying, the RSS from multiple access points (APs) at different grid points are collected and stored in a fingerprint database called a radio map or fingerprint database. The vector of mean RSS values at point is called the location fingerprint of that point. In the online phase, a mobile sensor measures a sample fingerprint vector of RSSs from different APs at its position. The sample fingerprint is then compared with fingerprints stored in the radio map for determining the location of the mobile sensor in the distribution area of nodes. The Euclidean distance between the measured sample and each fingerprint in the radio map is commonly used for location estimation. The coordinate associated with the fingerprint that yields the smallest Euclidean distance is selected as the estimate of the position [9].

As different classes of localization algorithms have been discussed, thus the systems for localization in a MWSN can be classified under different aspects such as based on the anchor nodes, learning process as shown in the figure2.

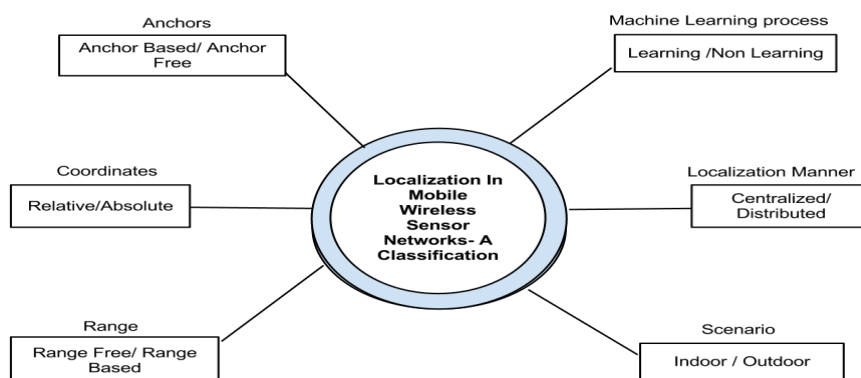


Fig 2: Classification of Localization algorithms

IV. Conclusion

In this paper, we proposed a new classification for localization techniques. In this classification, localization algorithms were classified based on different key features like learning, anchor existence, range, calculation etc. This classification is usable to understand the operation of various localization methods. However with these localization methods there are certain issues which need attention in this area such as 3D localization and secure localization.

REFERENCES

- [1] Ekici, E., Gu, Y., Bozdog, D, "Mobility-based communication in wireless sensor networks", Communications Magazine, IEEE 44(7), 56–62 (2006).
- [2] Aspnes, J. E., D.K. Goldenberg, A.S. Morse, W. Whitley, Y.R. Yang, B.D. Anderson, and P.N. Belhumeur, 2006. "A theory of network localization," *IEEE Transactions on Mobile Computing*, pp.1663–1678.
- [3] J. Caffery, J. Heidemann, and D. Estrin, "GPS-less low cost outdoor localization for very small devices", IEEE Personal communications, vol.7, no.5, pp.28-34, October 2000.
- [4] H. Liu, H. Darabi, P. Banerjee, J. Liu, "Survey of Wireless Indoor Positioning Techniques and Systems" in IEEE Transactions on System, Man and Cybernetics Vol, 37, No, 6, Nov. 2007.
- [5] G. Mao, B. Fidan and Brian D.O. Anderson, "Wireless sensor network Localization techniques", The Int. Journal of Computer and Telecommunications Networking 2007.
- [6] N. Patwari, A. O. Hero III, M. Perkins, N. Correal, and R. J. O'Dea, "Relative location estimation in wireless sensor networks," IEEE Trans. Sig. Proc., vol. 51, no. 8, pp. 2137–2148, Aug. 2003.
- [7] T. He, C. Huang, B. M. Blum, J. A. Stankovic, T. Abdelzaher, "Range Free Localization Schemes for Large Scale Sensor Networks" in Proc. Int. Conference on Mobile Computing and Networking, San Diego, California, USA, 2003
- [8] N. Swangmuang and P. Krishnamurthy, "An effective location fingerprint model for wireless indoor localization", Pervasive and Mobile Computing, pp. 836-850, 2008.
- [9] H. Lemelson, S. Kopf, T. King, and W. Effelsberg. "Improving for 802.11-based location fingerprinting systems", International Conference on computer software and application, 2009.
- [10] K. Lorincz and M. Welsh, "Motetrack: a robust, decentralized location tracking system for disaster response," in *Proceedings of the international Workshop on Location- and Context-Awareness (LoC 2005)*, vol. 3479, pp.63-82, Oberpfaffenhofen, Germany, May 2005.
- [11] B. Azzedine, A. Oliveira, F. Nakamura, and A. Loureiro, "Localization system for wireless sensor networks", IEEE Wireless Communications, December 2007.
- [12] L. Lazos and R. Poovendran, "SeRLoc: Secure range-independent localization for wireless sensor networks", International conference on web information systems engineering, October, 2004.
- [13] J. S. Tilak, V. Kolar, B. Abughazaleh, and K. Kang, "Dynamic localization protocols for mobile sensor networks", International Conference on mobile ad-hoc and sensor systems, 2004.
- [14] X. Chen, P. Han, Q. He, S. Tu, "A viable localization scheme for dynamic wireless sensor networks", International conference on multisymposiums on computer and computational sciences, 2006
- [15] J. K. Langendoen and N. Reijers, "Distributed localization in wireless networks: A quantitative comparison", Computer Networks, no 43, pp. 500-518, 2003.
- [16] J. S. Chen, Y. Chen, W. Trappe, "Exploiting Environmental Properties for Wireless Localization and Location Aware Applications" in Proceedings of the Sixth Annual IEEE International Conference on Pervasive Computing and Communications, Hong Kong, March 2008.
- [17] P. Zhang and M. Martonosi, "LOCALE: Collaborative localization estimation for sparse mobile sensor networks", International conference on information processing in sensor networks, April 2008.
- [18] K.F. Su, C.H. Ou, and H.C. Jiau, "Localization with mobile anchor points in wireless sensor networks," IEEE Trans, vol. 54, no. 3, pp. 1187-1197, May 2005.
- [19] N.B. Priyantha, H. Balakrishnan, E. Demaine, S. Teller "Anchor-Free Distributed Localization in Sensor Networks" MIT Laboratory for Computer Science, Tech. Report #392, April 2003.
- [20] G. Yu, F. Yu, and L. Feng, "A three dimensional localization algorithm using a mobile anchor node under wireless channel", IEEE World congress on computational intelligence, June, 2008.
- [21] B. Zhang and F. Yu, "An energy efficient localization algorithm for wireless sensor networks using a mobile anchor node", International conference on information and automation, June 2008
- [22] F. Dellaert, D. Fox, W. Burgard, and S. Thrun. "Monte Carlo localization for mobile robots", IEEE International Conference on Robotics and Automation (ICRA99), Detroit, Michigan, USA, May 1999.
- [23] A. Baggio, "Monte-Carlo localization for mobile wireless sensor networks". Technical Report PDS-2006-004, Delft University of Technology, June 2006
- [24] Isaac Amudson and X.D. Koustoubos, "A Survey on Localization for Mobile Wireless Sensor Network," (Eds.): MELT 2009, LNCS 5801, pp. 235–254, 2009.
- [25] Bekris, K.E., Argyros, A.A., Kavvaki, L.E, "Angle-based methods for mobile robot navigation: Reaching the entire plane". International Conference on Robotics and Automation (2004).