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Survey on Various Localization Techniques in Wireless Sensor Networks

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Abstract— *Recent improvements in Micro-Electro-Mechanical Systems (MEMS) have made it both technically possible and economically feasible to produce and use hundreds of wireless sensor nodes in a network for industrial applications. One of the challenges in a Wireless Sensor Network (WSN) is localization; meaning to assign coordinates to nodes, according to their actual positions and their premises. Localization has always been a challenge to human beings; from the early times of estimating the width of a river or distance to a ship, to the newly faced challenges of GPS positioning or Molecular structure estimation. WSN localization has been widely studied recently. But there is yet lots of work to do in the field. Localization strategies vary by the capabilities of the nodes and environmental issues; e.g., nodes might be able to measure internode distances or even may be mobile, each of which provides its own design challenges. However, one thing that is usually common among approaches is that they assume that all nodes have identical physical capabilities, all having the same radio range and that nodes know their maximum range initially.*

Index Terms— Centralized, Distributed, Localization, Range-free, Range-based, Wireless sensor networks

1. Introduction

Wireless sensor networks become apparent for military needs and found its way into civil applications. Today, wireless sensor networks has become a key equipment for different types of ”smart environments”, and an intense research effort is currently in process to enable the application of wireless sensor networks for a wide range of industrial problems. Wireless networks have more importance when a large number of sensor nodes have to be deployed, and/or in unsafe situation.

“A WSN is a collection of small and inexpensive devices, with limited sensing, computing and communication capabilities acting together to provide measurement of physical parameters or to identify events in known or unknown environment. The motivation is because of the low power and small size sensor nodes used in the network [3].

1.1 Architecture of WSN

Most common architecture for WSN follows the OSI Model. Mainly in sensor network we need five layers: application layer, transport layer, network layer, data link layer and physical layer. With these five layers, three cross layers planes are added as shown in Fig. 1 [2].

Application layer: This layer is responsible for traffic management and translates the data in usable and understandable form or sends queries to obtain certain information with the help of software. Sensor networks deployed in different fields for various applications, for example; military, medical, environment, agriculture fields.

Transport layer: This layer is specifically needed when a system is organized to access other networks. This layer provides reliability and congestion avoidance. For providing these functionality, a lot of protocols designed which are either applied on the upstream, or downstream. These protocols use different methods for loss detection and loss recovery. In general, Transport protocols can be divided into: Packet driven: all packets sent by source must reach destination. Event driven: the event must be detected, but it is necessary that one notification message reaches the sink.

Network layer: This layer has a lot of challenges which depend on the application but the major challenges are in the energy saving, limited memory, sensor does not have a global identification number and have to be self organized. So, this is not computer networks with IP address and central device for controlling. The major function of this layer is routing. There are many routing protocols which can be categorized into; flat routing and hierarchal routing or can be divided into time driven, query driven and event driven.

Data link layer: It provides various functions such as data frame detection, multiplexing data streams, MAC, and error control. Errors or unreliability comes from: Co- channel interference at the MAC layer which is solved by MAC protocols. Multipath fading and shadowing occurs at the physical layer. Forward error correction and automatic repeat request solved this problem.

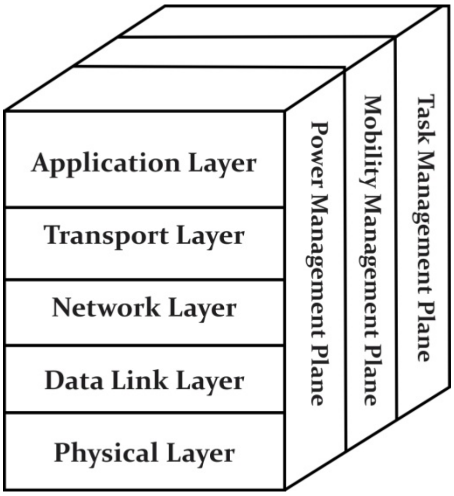

Fig 1: WSN Architecture [2]

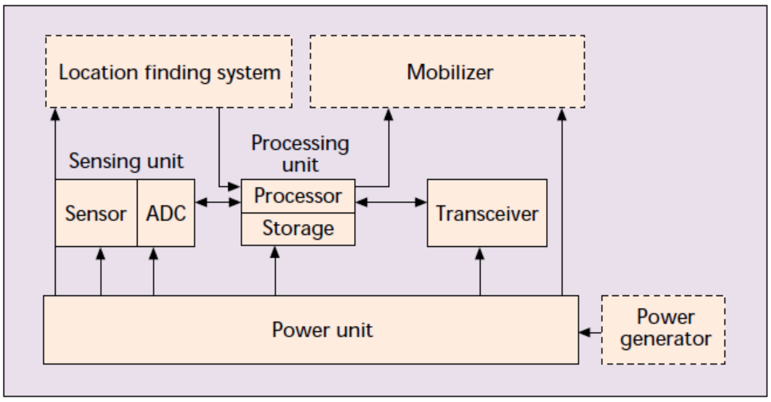

Fig 2: The components of a sensor node [1]

Physical Layer: It can provide an interface to transmit a stream of bits over physical medium. It is also responsible for generation carrier frequency, frequency selection, signal detection, modulation and data encryption.
Cross layers: The three cross layers are: power management plane, mobility management plane and task management plane. These management planes are responsible for network management and make the sensors work together in order to increase the lifetime and overall efficiency of the network [2].

1.2 Sensor Nodes

Low cost, low-power, multifunctional sensor nodes that have small size and communicate in short distances. Sensor nodes have sensing, data processing, and communicating components, leverage the idea of sensor networks [1].

Components of sensor node

A sensor node consists of four basic components, as shown in Fig. 2:
Sensing Unit: Sensing units are composed of two subcomponents: sensors and analog-to-digital converters (ADCs). The analog signals produced by the sensors based on the observed events are converted to digital signals by the ADC, and then fed into the processing unit.
Processing Unit: It is associated with a small storage unit, manages the procedures that make the sensor node work with the other nodes to carry out the required sensing tasks.
Transceiver Unit: Transceiver unit connects the node to the network.
Power Unit: Power units may be supported by power scavenging units such as solar cells. There are also other subcomponents that are application-dependent.
They may also have additional application-dependent components such as a power generator, location finding system, and mobilizer.

2. Issues of WSN

The major issues that affect the design and performance of a wireless sensor network are as follows: [9]

i. **Medium Access Schemes**: Communication is a major source of energy consumption in WSNs and MAC protocols control the radio of the nodes directly in the network. MAC protocols should be designed for regulating energy consumption, which in turn affects the lifetime of the network. So the design of the MAC protocol should have switching mechanism to decide how frequently the on and off mechanism should be done. MAC protocol should avoid collisions, overhearing, control packet overhead and idle listening. Scalability, Adaptability and Distributed work are another important criterion in designing a MAC protocol. When the sensor networks are deployed in critical applications then minimum latency and high throughput are important factors for MAC protocols.

ii. **Deployment:** Sensor nodes can be deployed either structured or random (unstructured) by dropping it from a plane. Various issues which need to be taken care during the deployment are: When sensor nodes are deployed pratically, Node death either by normal battery discharge or due to short circuits which may lead to wrong sensor readings. Deployment of sensor networks results in network congestion due to many concurrent transmissions by several sensor nodes. Low data yield is another common problem in real world deployment of sensor nodes.

iii. **Routing:** It is a very challenging issue in sensor network. Various issues at the network layer are: Energy efficiency is a very important factor. We need to discover energy efficient routes so that we can optimize the network lifetime. Routing Protocols should include multi-path design technique so that when the primary path fails an alternative path can be used. Path repair is desired in routing protocols whenever a path break is identified. Fault tolerance is also a desirable property for routing protocols.

iv. **Localization:** Determining the physical location of the sensors after they have been deployed is known as localization. Location discovery for a sensor network should have localization algorithm which satisfy the following requirements: The localization algorithm should be distributed because centralized approach requires high computation at specific nodes to estimate the position of nodes which increases signaling bandwidth. Localization algorithms should be robust to locate the failures and loss of nodes. Localization algorithm should be accurate, scalable and support mobility of nodes.

v. **Synchronization**: Time Synchronization in a sensor network aims to provide a global timescale for local clocks of nodes in the network. Clock synchronization for a sensor network has many challenges that are significantly different from those in infrastructure based networks. The synchronization protocol should be more robust to handle failures and communication delay because sensor nodes have higher degree of failures. Sensor nodes need to coordinate and cooperate with each other to achieve a complex sensing task like data fusion. If the sensor nodes have lack of synchronization then the data estimation will be inaccurate. The algorithm for sensor network clock synchronization needs to achieve multi-hop synchronization due to multi hops span with higher jitter of sensor networks.

vi. **Data Aggregation:** The sensors periodically sense the data from the adjoining environment, process it and transmit it to the base station or sink. But the data generated from many sensors is redundant and also the amount of data generated may be very large for the base station to process it. Hence we need data aggregation for combining the sensed data into high quality information. We can eliminate transmission of redundant data using meta- data negotiations. We can use improved clustering techniques for data aggregation to conserve energy of the sensors and improved In-Network aggregation techniques to improve energy efficiency.

vii. **Architecture:** The key issues that must be addressed by the sensor architecture are: Like continuous channel monitoring, data encoding and transferring of bits to the radio need to be performed in parallel. A scalable and durable architecture would allow dynamic changes to be made for the topology with minimum transfer of update messages. The architecture must provide precise control over radio transmission timing.

viii. **Security:** Security in sensor networks is very important factor as performance and low energy consumption is important in many applications. Following are the basic security requirements for every WSN application should have: Confidentiality is needed to ensure sensitive information is protected and not open to unauthorized third parties. Authentication techniques verify the identity of the members in a communication. It is essential for each and every sensor node to have the ability to verify that the data which is received was really sent by a trusted sender. One of the many attacks originated against sensor networks is the message reply attack. So sensor network should be designed for freshness.

3. Related work

Localization is required to report the source of events, routing, help group querying of sensors and to answer questions on the network coverage. So, one of the primary challenges in wireless sensor network is to find out the position of node. The importance of localization information arises from various factors of WSNs. These factors include the identification and correlation of collected data, node addressing, management and query of nodes localized in a determined region, evaluation of nodes' density and coverage, energy map generation, geographic routing, object tracking, and other geographic algorithms.[4]

Components of Localization Systems:

Localization systems can be divided into three distinct components: [4]

i. **Distance/angle estimation:** This component is responsible for estimating of the distances and/or angles between two nodes. This estimated information will be used by the other components of the localization system.

ii. **Position computation:** It is used for computing a node's position based on available information of reference nodes such as distances/angles and position.

iii. **Localization algorithm:** This is the main component of a localization system. It determines how the previously available information will be manipulated in order to allow the nodes of a WSN to estimate their positions.

T. Kawazoe et al. [15] implemented an indoor localization system that uses RSSI in a sensor network based on the ZigBee standard. The amount of collected data could be controlled by changing the RSSI threshold. We evaluated the system's position estimation accuracy. To achieve an autonomous system, it would be preferable if a sensor node could decide an appropriate threshold by judging its wireless environment through the mutual exchange of RSSI information.

A. Pal [14] proposed localization algorithm based on the computation position. Localization algorithm broadly categorized in Centralized algorithms and Distributed algorithm. Centralized localization is basically migration of inter-node ranging and connectivity data to a powerful central base station where computation is performed. These algorithms more accurate position but communication costs are also important for sensor networks. In Distributed localizations, all the required computations are done on the sensor nodes and potentially have better scalability. There are many research activities going on to improve localization in wireless sensor networks. But there are also some interesting open problems that need further attention such as robust algorithm for mobile sensor networks, attack the challenges of information asymmetry, finding localization algorithms in 3D space etc.

G. Mao et al. [11] discussed localization scheme based on hop count. These localization algorithms were classified into one-hop localization algorithms and multi-hop localization algorithms. A thorough investigation on connectivity-based and distance-based localization algorithms was presented.

V. Obado et al. [13] proposed a localization based technique to detect wormhole attack in underwater wireless sensor networks. Our localization technique utilizes the Lambert W function and received signal strength (RSS) between sensor nodes to measure distances between these nodes accurately. This is a two-level hybrid computation approach that allows the nodes to make a coarse estimation of their positions using distributed approach while the sink with more resources, calculates accurate positions using centralized approach. The accuracy is important to which will proceed by using the nodes positions, distance and connectivity with their neighbors.

O. Demigha et al. [7] discussed energy-efficiency in collaborative target tracking instead of single node tracking. WSNs are often of a dense network, and redundant data can be received from various sensors help at improving tracking accuracy. By using limited sensing and communication ranges, we can reduce energy consumption. Energy-efficiency in a collaborative WSN-based target tracking scheme used two methods: i) sensing-related methods ii) communication-related methods.

H. Chen et al. [5] proposed an improved DV-Hop positioning algorithm aiming at the positioning problem of wireless sensor network node location, together with its basic principle and realization issues. Without increasing hardware cost, the proposed method can improve location accuracy for sensor node. Not only the placement of anchor nodes, but also the number of anchor nodes could affect average error of localization and location coverage of the algorithm.

A. Mesmoudi et al. [12] proposed localization scheme based on the dependency of the range measurements. Theses proposed schemes are classified into two categories: range-based and range-free schemes. Range-based techniques use distance or angle estimates in locations estimations. Range-free techniques use information about connectivity between unknown nodes and landmarks. Range-based schemes and range-free schemes are further divided into two types: fully schemes and hybrid schemes.

T. H. Lee et al. [6] have developed and proposed the mechanism and procedure for the location estimation for object tracking in large-scale WSNs. The designed modeling uses range -free-positioning technology and centralized data processing technology with data aggregation to reduce the time which is required for data processing and traffic loads. The proposed positioning model is suitable for practical use in large-scale WSNs which are constrained by energy consumption, computation power and device cost.

In [8], the author proposed a WSN location algorithm CDDVHOP which uses neighbor node close degree to build mathematical model and then calculate the single hop distance instead of average single hop distance in DV-HOP. This algorithm used one hop distance and two hop distances. A path record is added in the process for multi-hop distance calculation. The smallest number of hops is calculated using path record, then the smallest anchor hop path can be informed and therefore the multi-hop distance calculation can be decomposed into a series of single-hop and two-hop nodes.

In [16], a thorough analysis for approximate point-in-triangulation test (APIT) algorithm is done, and an improvement of APIT is proposed. The improvement algorithm reduces the In-To-Out Error and Out-To-In Error probabilities. Once the individual APIT tests finish, APIT aggregates the results using a grid SCAN algorithm. In this algorithm, the grid array nodes that may exist on behalf of the largest regional. Once all triangular regions are computed, the resulting information is used to find the maximum over lapping area to calculate the center of gravity for position estimation.

4. Review of Different Categories of Localization Algorithm

Localization algorithms can be classified into different categories based on place of computation of nodes' location, range measurement, anchor nodes etc. Now we will discuss three categories of localization algorithm.

4.1 Based on Place of Computation

Location of node can be computed at powerful node or at node itself. So, there are two places where we can calculate the location.

Centralized Localization: Centralized localization is migration of inter-node ranging and connectivity data to a powerful central base station and then the migration of resulting locations back to respective nodes. Centralized algorithms eliminate the problem of computation in each node but the limitations lie in the communication cost of moving data to the base station [14].

Distributed Localization In Distributed localizations, all the significant computations are done on the sensor nodes themselves and other to get their positions in a network the nodes communicate with each. Distributed localizations can be categorized based on different parameters such as Relaxation-based distributed algorithms, Beacon-based distributed algorithms, Coordinate system stitching based distributed algorithms etc [14].

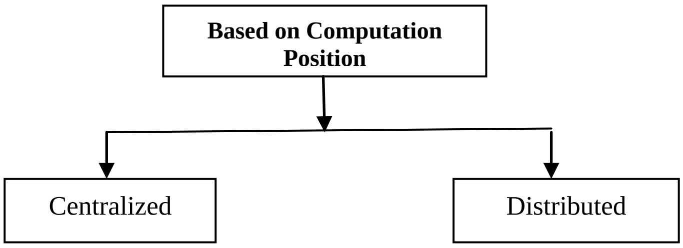

Fig 3: Categorization of localization algorithm based on computation position

4.2 Based on Range Measurement

According to the dependency of range measurements, the localization schemes can be classified into two categories: i) range-based ii) range-free approaches.

Range Based Localization: Range-based techniques use distance or angle information in their locations estimations. These techniques have used Received Signal Strength Indication (RSSI), Angle of Arrival (AoA), Time of Arrival (TOA), or Time Difference of Arrival (TDoA) [10].

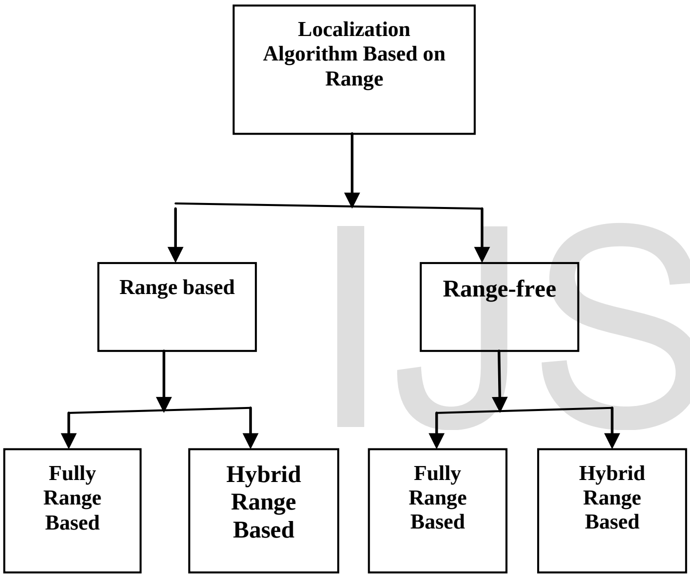

Fig 4: Categorization based on range measurement

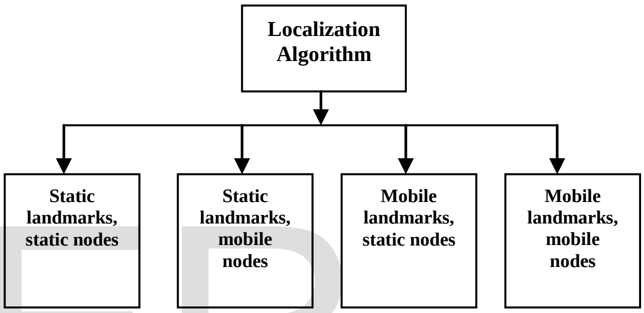

Fig 5: Categorization based on mobility of nodes

Range-free Localization: Range-free techniques use information about connectivity between unknown nodes and landmarks eg. DV-Hop, Centroid [10]. Range-based schemes and range-free schemes can be classified into two sub-categories: fully schemes and hybrid schemes. Fully schemes algorithms use only one method either range-based or range-free but hybrid schemes use combination of two or more methods of range-based or range-free [12].

4.3 Based on Mobility of Nodes

In this [10], localization algorithms are categories into four categories as shown in fig 5: (i) static landmarks, static nodes, (ii) static landmarks, mobile nodes, (iii) mobile landmarks, static nodes and (iv) mobile landmarks, mobile nodes. All these categories need landmarks to locate the unknown node.

Static landmarks, static nodes: Localization algorithms of static landmarks and nodes are useful in WSNs, where all the nodes are static. The algorithms can be classified into two categories according to whether they need physical measurements to obtain distance or angle information. Localization algorithms within each category can be further classified based on range measurement as range-based or range-free.

Static landmarks, mobile nodes: In the real application of WSNs, such as monitoring the living of human or animal, many unknown nodes are mobile. The application of unknown nodes which are mobile is closely related to our life. Static landmarks and

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mobile nodes localization algorithms can be divided into historical information localization algorithms and cluster localization algorithms.

Mobile landmarks, static nodes: Some localization algorithms use mobile landmarks to locate static nodes by using a specific trajectory. The algorithms are classified into two categories: geometric localization algorithms and path planning localization algorithms.

Mobile landmarks, mobile nodes: Unknown nodes and landmarks are mobile in a WSN. The localization process of these algorithms is complicated, because it is of great significance to special environment. We have further classified these algorithms into two categories: probability distribution localization algorithms and time based localization algorithms.

Table 1: Comparison of localization algorithm

Category of algorithm	**Objective**	**Node density**	**Accuracy**	**Cost(messaging and computation)**	**Power consumption**
Centralized	Eliminates the problem of computation in each node	Less	High	High	High
Distributed	Improve life time of nodes and network because there is no need of communication with base station which consumes more energy.	High	Low/High (depend on algorithm used)	Low	Low
Range based	Use distance or angle in locations estimation.	Medium	High	High	High
Range free	Use connectivity information between unknown nodes and landmarks.	High	Low	Low	Low

Table 2: Comparison of localization algorithm

Category of algorithm		**Objective**	**Node density**	**Accuracy**	**Power consumption**
Static landmarks, mobile nodes	Historical information based	i)Use recorded historical information to locate mobile unknown nodes. ii)Save energy computation	No effect	Better	Average
	Cluster based	To reduce computation complexity.	No effect	Average	Smaller
Mobile landmarks, static nodes	Geometric localization	Use specific trajectory to locate static unknown nodes	Average	Better	Average
	Path planning based		Smaller	Average	Average
Mobile landmarks, mobile nodes	Time based localization	i) To calculate the positions of unknown nodes in a very short time interval. ii) To get the high localization coverage.	Greater	Average	Greater
	Probability distribution	Predict location using the prior distribution probability method which can reduce the cost.	Smaller	Smaller	Greater

5. Conclusion and Future Scope

Wireless sensor devices have a wide range of application in surveillance and monitoring. Most of the devices or nodes in wireless sensor network are made up of off-the-shelf materials and deployed in the area of surveillance and monitoring. The responsibility of each sensor node is to identify the changes in its particular region or area. There is a considerable rise in the use of wireless sensor network because of their cost and size. The localization techniques discussed in this paper, help in reducing the deployment cost of dense wireless sensor networks. Through wireless sensor networks we can identify the location information of each node with additional hardware support, which makes a node expensive in terms hardware and power consumption during its deployment. Several techniques with abridged hardware which can identify their current location have been discussed in this paper along with their key features and drawbacks. For future works, we suggest using more informed but yet simple methods in probability aggregation phase of the algorithm, which has a direct impact on the accuracy of positioning. Better methods could be used for position estimation in a final square with the highest probability of containing the node. Boundary nodes and nodes residing in parts of the network, for which there is no anchor, require a more special way to be dealt with; this is also a subject worth investigating.

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