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Survey of Localization Techniques in Mobile Wireless Sensor Network

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***Abstract*— Wireless sensor network (WSN) is employed to gather and forward information to the destination. It is very crucial to know the location of the event or collected information. This location information may be obtained using GPS or localization technique in wireless sensor networks. Localization is a technique to obtain the location of sensor nodes in the network. Localization of nodes in sensor network is a motivating analysis space, and lot of works are done to this point. It is highly required to design energy aware, economical and scalable localization techniques for WSNs. In this paper, we have done analyse of various localization techniques, and few possible future research directions.**

I. Introduction

In WSNs, sensor nodes are deployed in real geographical environment and observe some physical behaviors. WSNs have many analytical challenges. Sensors are small device in size, low cost accounting, and having low process capabilities. WSN's applications attracted great attention interest of researchers in recent years [1]. WSNs are different from ad hoc and mobile networks in many ways. WSNs have various applications; so, the protocols designed for ad hoc networks don't suit WSNs [2]. WSNs have different application such as: monitor environmental aspects and physical phenomena like temperature, audio and optical data, habitat monitoring, traffic control monitoring, patient healthcare monitoring, and underwater acoustic monitoring. WSNs have many technical limitation that affect architecture and performance of overall network like hardware and operating system [3], medium access schemes [4], deployment [5], time synchronization [6], localization, middleware, wireless sensors and actors networks [7], transport layer, network layer, quality of service, and network security [8]. WSN's applications have opened inspiring and innovative analysis areas in telecommunication world particularly in recent years. Localization of nodes is very crucial to find location of nodes in sensing space [9]. Data collection without their geographical positions would be useless. Localization of nodes, can be achieved by using GPS (global positioning system) but it becomes very expensive if number of nodes are large in a given network. so far Many algorithms have been come up to solve the localization issue but due to their application specific nature most of the solutions are not suitable for wide range of WSNs [10]. Ultra wide band techniques are useful for the indoor environment while extra hardware would be require for acoustic transmission-based system. Both are accurate techniques but expensive in terms of energy consumption and processing. Unlocalized nodes calculate their location from anchor nodes beacon messages, which needs much power. Many algorithms have been proposed to reduce this communication cost. If one node calculates its wrong location, then this error propagates to overall network and further nodes and this will lead wrong information of anchor nodes location is propagated [11]. To find the location of nodes is mainly based on the distance between anchor node (with known location) and unlocalized node (with unknown location). Sensor nodes are used in industrial, environmental, military, and civil applications [12].In this paper, we study sensor node localization schemes having different features used for different applications. For static and mobile sensor nodes Different algorithms of localization are used. The rest of the paper is organized as follows. Section 2 discusses components of sensor nodes. Section 3 describes WSNs applications. Section 4 provides an overview of localization in WSNs. Section 5 presents range-free and range-based localization techniques. Section 6 covers analysis and discussion. Section 7 concludes the paper.

II. Components of Sensor Nodes

Sensor nodes have hardware and software components.Hardware components include processors, radio-transceiver sensors, and power unit. The software's used for sensor nodes are TinyOs, Contiki, and Nano Rk. In this section, we discuss hardware components briefly.

A. Sensors

There are two types of Sensors nodes: digital sensors and analog sensors. Analog sensors gives data in continuous or in waveform. The data is further processed by the processing unit that converts it to human readable form [12].Digital sensors directly generate data in the discrete or digital form. Once the data is converted, it directly sends it to the processor for further processing [12].

B. Memory

Microprocessors use different types of memory for processing data. The memory and input/output devices are integrated on the same circuit. Random-access memory (RAM) stores data before sending it, while read-only memory (ROM) stores operating system of sensors nodes [13].

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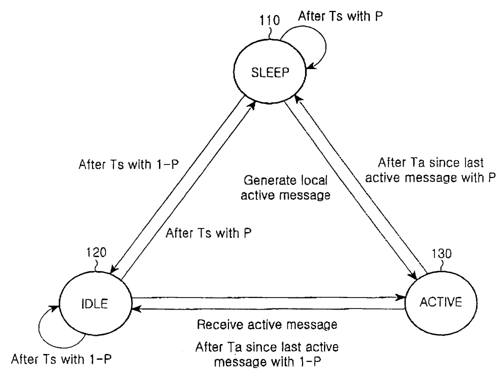

Fig. 1. Transition of a sensor node

C. Processors

Microprocessors of sensor nodes are also known as small scale CPUs which is related about the CPU speed, voltage, and power consumption. Sensors operations run at low CPU speed.Most of the time, sensors remain in sleep mode. In sleep mode processor is involved in other activities like time synchronization and consumes small amount of the power [12].

D. Radio Transceiver

The transceiver receives and sends data to other sensor nodes [12]. The radio frequency is used to connect sensors with other nodes. Data transmission process consume most of the energy in transceiver section.The transceiver has four operational modes such as sleep, idle, receive, and send [13].

1) Sleep Mode: In sleep mode, nodes turn off their communication devices or modules so that there are no more transmission and reception of data frames. In sleep mode, nodes can listen to data frames. This is listening stage of sleep mode. When nodes listen to the data frame, it turn in to the active mode; otherwise, it remains in sleep mode.

2) Active Mode: In active mode, data is transmitted normally. Nodes communication devices are in active state and can send or receive data.

3) Idle Mode: It is also one of the sleep modes. In this stage, sensor nodes are in low-power mode and remain in this mode for agreed amount of time. When sensor nodes go back to the awake or active mode from the idle mode, they again connect to the networks and start communication [13].The transition of a sensor node in sleep, active, and the idle mode is presented in Figure 1.

E. Power Unit

It is the most important part of the sensor node. Sensor node cannot perform any work without this unit [13]. The lifetime of the sensor node is defines by the Power unit. Typical architecture of sensor node is given in Figure 2.

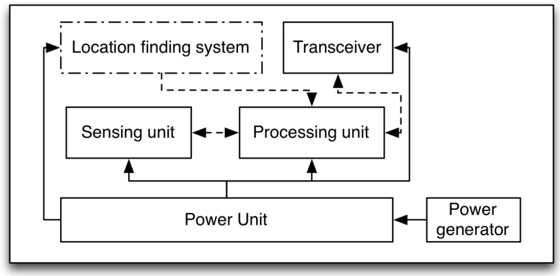

Fig. 2. Typical architecture of sensor node

III. Applications

Sensor nodes gather and forward data for the particular application whenever some kind of physical change occurs, such as change in temperature, sound, and pressure. WSNs have many applications such as military, civil, and environmental applications. Some important applications are discussed below.

A. Area Monitoring

Sensor nodes are deployed in the area where some actions have to be monitored; for instance, the position of the enemy is monitored by sensor nodes, and the information is sent to the base station for further processing. Sensor nodes are also used to monitor vehicle movement.

B. Environmental Monitoring

WSNs have many applications in forests and oceans, and so forth. In forests, such networks are deployed for detecting fire.WSNs can detect when the fire is started and how it is spreading. Senor nodes also detect the movements of animals to analyses their habits. WSNs are also used to analyses plants and soil.

C. Industrial Monitoring

In industries, sensors monitor the process of making goods. For instance, in manufacturing a vehicle, sensors detect whether the process is going right. A response is produce if there is any manufacturing fault [12]. Sensor nodes also monitor the grasping of objects by robots.

D. Medical and Healthcare Monitoring

Medical sensors are used to monitor the conditions of patients. Doctor scan monitor patient's conditions, blood pressure, sugar level, and so forth,review ECG and change drugs according to their conditions[12]. Personal health-monitoring sensors have special applications. Smart phones are used to monitor health, and the response is generated if any health risk is detected. Medical sensors store health information and analyze the data obtained from many other sensors such as ECG, blood pressure, and blood sugar [13].

E. Traffic Control System

Sensor nodes monitor traffic flow and number plates of traveling vehicles and can locate their positions if needed. WSNs are used to monitor activities of drivers as well such as seat-belt monitoring [12].

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F. Underwater Acoustic Sensor Networks

Underwater special sensors can monitor different applications of numerous oceanic phenomena; for instance, water pollution, underwater chemical reactions, and bioactivity. For such purposes, different types of 2D and 3D static sensors are used. 3D dynamic sensors are used to monitor autonomous underwater vehicles (AUVs) [12].

IV. LOCALIZATION OVERVIEW

Localization of nodes need distance between localized node and unlocalized node . The 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 calculate location.
(ii) Angulation occurs when angle between nodes is measured to estimate location.
(iii) Trilateration. Location of node is calculated 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 theory, more than three nodes are used in location estimation.
(v) Triangulation. In this mechanism, minimum two angles of an unlocalized node from two localized nodes are measured to calculate its position. Trigonometric laws, law of sines and cosines are used to estimate node position [14].

Localization schemes are categories as anchor based or anchor free, centralized or distributed, GPS based or GPS free, fine grained or coarse grained, static or mobile sensor nodes, and range based or range free. We will briefly analyze all of these schemes.

A. Anchor Based and Anchor Free

In anchor-based mechanisms, the positions of few nodes are known. Unlocalized nodes get there location by these known nodes positions. Accuracy is highly depending on the number of anchor nodes. Anchor-free algorithms calculate relative positions of nodes instead of computing absolute node positions [14].

B. 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. In distributed schemes there may be clustering scheme for localization or every node can calculate its own position [15][16].

C. GPS Based and GPS Free

In GPS-based schemes GPS receiver has to be added with every node which makes it very costly but it gives very high localization accuracy.In GPS-free algorithms GPS is not used, and they calculate the distance between the nodes to compute relative position in local network and it is comparatively less costly with GPS-based schemes [17] Some application required global position of sensor nodes [14].

D. Coarse Grained and Fine Grained

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

E. Static and Mobile Sensor Nodes

Localization algorithms are also designed according to area 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 the main reason why many localization algorithms are designed for static nodes. few mechanisms are designed for the Few applications use mobile sensor nodes applications [18].

V. RELATED WORK

Recently, a large number of localization techniques and algorithms have been proposed for WSNs, and simultaneously many studies have been done to analyze existing localization techniques and algorithms. For example, in [19], Mao et al. first provide an overview of measurement techniques that can be used for WSN localization, e.g., distance related measurements, angle-of-arrival (AOA) measurements and RSS profiling techniques. Then the one-hop and the multi-hop localization algorithms based on the measurement techniques are presented in detail, respectively, where the connectivity-based or range free localization algorithms and the distance-based multi-hop localization algorithms are particularly discussed due to their prevalence in multi-hop WSN localization techniques. In addition, based on the analysis, the open research problems in the distance-based sensor network localization and the possible approaches to these problems are also discussed.

In [20], Amundson et al. present a survey on localization methods for mobile wireless sensor networks (MWSNs). First, the authors provide a brief taxonomy of MWSNs, including the three different architectures of MWSNs, the differences between MWSNs and WSNs, and the advantages of adding mobility. The MWSN localization discussed in [20] is consists of three phases: 1) coordination, 2) measurement, and 3) position estimation. In the coordination phase, sensor nodes coordinate to initiate localization, including clock synchronization and the notification that the localization process is about to begin. In the second phase, the measurement techniques, e.g., the angle-of-arrival (AOA) and the time-difference-of-arrival (TDOA) methods are presented. The measurements obtained in the second phase can be used to determine the approximate position of the mobile target node based on localization

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algorithms, e.g., the Dead Reckoning, the maximum likelihood estimation (MLE) and the Sequential Bayesian estimation (SBE). To the best of our knowledge, the reference [20] is the first survey focusing on MWSNs localization.

In [9], an overview of localization techniques is presented for WSNs. The major localization techniques are classified into two categories: centralized and distributed based on where the computational effort is carried out. Based on the details of localization process, the advantages and limitations of each localization technique are discussed. In addition, future research directions and challenges are highlighted. This paper point out that the further study of localization technique should be adapted to the movement of sensor nodes since node mobility can heavily affect localization accuracy of targets. However, the localization techniques proposed for mobile sensor nodes are not discussed in [9].

In [21], localization algorithms are classified into target/source localization and node self-localization. In the target localization, Single-Target/Source Localization in WSNs, Multiple-Target Localization in WSNs and Single-Target/Source Localization in Wireless Binary Sensor Networks(WBSNs) are mainly introduced. Then, in node self-localization,range-based and range-free methods are investigated. With the widespread adoption of WSNs, the localization algorithms are very different for different applications. Therefore,in the paper, the localization in some special scenarios are also surveyed, e.g., localization in non-line-of-sight (NLOS) scenarios, node selection criteria for localization in energy constrained network, cooperative node localization, scheduling sensor nodes to optimize the trade-off between localization performance and energy consumption, and localization algorithm in heterogeneous network. Finally, the evaluation criteria for localization algorithms are introduced in WSNs.

In [22], the distance-based localization techniques are surveyed for WSNs. It is impossible to present a complete review of every published algorithm. Therefore, ten representative distance-based localization algorithms that have diverse characteristics and methods are chosen and presented in detail in [22]. The authors outline a tiered classification mechanism in which the localization techniques are classified as distributed,distributed-centralized, or centralized. Generally, centralized localization algorithms produce better location estimates than distributed and distributed-centralized algorithms. However, much more energy is consumed in the centralized algorithms due to high communication overheads for packet transmission to the base station. Distributed-centralized localization algorithms are always used in cluster-based WSNs, which can produce more accurate location estimates than distributed algorithms without significantly increasing energy consumption or sacrificing scalability.

In [23], the classification of localization algorithms is first studied based on three categories: range-based/range free, anchor based/anchor-free, distributed/centralized. Then, the localization algorithms are compared in terms of node density, localization accuracy, hardware cost, computation cost, communication cost, etc. Based on the analysis of exiting localization algorithms, the authors try to find positions of mobile nodes in harsh environments by designing a distributed RSSI based, range-based and beacon-based localization technique.

In [24], a survey on multidimensional scaling (MDS)-Based Localization is presented for WSNs. Several typical MDS based localization algorithms, e.g., MDA-MAP(C) [25], MDSMAP(P) [26], Local MDS [27], dwMDS(G) [28] and HMDS [29] algorithms, have been introduced and analyzed. MDSMAP(C) is a centralized and the earliest usage algorithm of MDS in node localization for WSN. MDS-MAP(P), Local MDS, and dwMDS(G) are distributed algorithm. They are improved localization algorithms based on MDS-MAP(C).HMDS is a localization scheme for cluster-based WSNs. HMDS consists of three phases: clustering phase, intra-cluster localization phase, and merge phase. In the first phase, the WSN is partitioned into multiple clusters by a clustering algorithm. In the second phase,distance measurements from all cluster members are collected by cluster heads and local MDS computation is performed to form a local map. Finally, in the merge phase, the local map is calibrated to a global map.

In [30], sensor node architecture and its applications, different localization techniques, and few possible future research directions are presented. Localization techniques 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. All the classification methods are briefly introduced, but the details of localization algorithm are not discussed. In the paper, only some traditional localization algorithms, e.g., GPS, RSSI, ToA, TDoA, AoA, Dv-hop and APIT are compared without considering new improved algorithms. Existing localization algorithms are always classified into two major categories: range-based and range-free. However, it is difficult to classify all the localization algorithms as range-based or range-free.

Therefore, in [31], range-based and range-free schemes are further divided into two sub-categories: fully schemes and hybrid schemes. That is fully-range-based, hybrid-range-based, fully-range-free, and hybrid-range-free. It is pointed out that hybrid localization algorithms can achieve a better localization performance compared with fully localization ones. However, in hybrid localization algorithms, large computations are required to estimate locations and the time complexity of them is relatively high.

In [32], the localization algorithms in WSNs are surveyed and reclassified with a new perspective based on the mobility state of sensor nodes. A detailed analysis of the representative localization algorithms are presented according to the following four subclasses: 1) static landmarks, static nodes,2) static landmarks, mobile nodes, 3) mobile landmarks, static nodes and 4) mobile landmarks, mobile nodes. However, only anchor-based localization algorithms are studied in the paper without considering any anchor-free localization algorithms. In most localization algorithms, localization is carried out with the help of neighbor nodes. Therefore, in [33], the localization algorithms are classified as known location based localization, proximity based localization, angle based localization, range and distance based localization. In known location based localization, sensor nodes can obtain their locations in prior either by manually configuring or using GPS. While in proximity

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based localization, a WSN is always divided into several clusters, and each sensor node can find out the nearness or proximity location by using Infrared (IR) or Bluetooth. All the algorithms studied in [33] are used in 2D static WSNs. They are not suitable for 3D scenarios or mobile WSNs.

In [34], M.S. Aruna1 et al. have presented a detailed survey on various localization techniques and path planning mechanism for the mobile beacon node in order to reduce the collinear problem and localization error and with less path length and localization time. Various results show that proposed trajectory has less localization error when compared to existing trajectory.

In [35] Mustafa Ilhan Akbas, et al. proposed a localization algorithm for wireless networks with mobile sensor nodes and stationary actors. The proposed localization algorithm overcomes failure and high mobility of sensors node by a locality preserving approach complemented with an idea that benefits from the motion pattern of the sensors. The algorithm aims to retrieve location information at the actor nodes rather than the sensors and it adopts one-hop localization approach in order to address the limited lifetime of the WSAN. The accuracy of the proposed algorithm can be further improved with RSS or other measurement techniques at the expense of increased energy consumption. In proposed scheme [36], a subsurface current mobility model is adopted and tailored according to the requirements of the scenario. The result presented Through extensive simulations shown that the localization estimation can be realized using local multihop information. In overall, as the multi-hop chains are allowed to become longer, more positions can be estimated with the cost of lower accuracy. The selection of the maximum hop number is therefore an issue depending on the requirements of network.

In [37] CamLy Nguyen et al. proposed a maximum-likelihood based multihop localization algorithm called kHopLoc for use in wireless sensor networks that is strong in both isotropic and anisotropic network deployment regions. Compared to other multihop localization algorithms, the proposed kHopLoc algorithm achieves higher accuracy in varying network configurations and connection link-models. The algorithm first runs a training phase during which a Monte Carlo simulation is utilized to produce accurate multihop connection probability density functions (described later). In its second phase, the algorithm constructs likelihood functions for each target node based on their hop counts to all reachable anchor nodes which it then maximizes to produce localization information. The main advantage of the algorithm is the use of a Monte Carlo initial training phase to generate the multihop connection probability density functions. These are then used to build likelihood functions whose maxima estimate each target node location. Since the algorithm uses full statistical information for the multihop connection probabilities, localization results are significantly more accurate for both in isotropic and anisotropic networks.

In [38] Slavisa Tomic, et al. addresses node localization problem in a cooperative 3-D wireless sensor network (WSN), for both cases of known and unknown node transmit power by investigating the target localization problem in a cooperative 3-D WSN, where all targets can communicate with any node within their communication range. In this by using RSS propagation model and simple geometry a novel objective function derived which is based on the LS criterion, which tightly approximates the ML one for small noise. The results show that the derived non-convex objective function can be transformed into a convex one by applying semidefinite programming (SDP) relaxation technique and the generalization of the proposed SDP estimator is straightforward for the case when the node's transmit power is not known. Cooperative localization is a very difficult problem, particularly useful for large-scale WSNs with limited energy resources. the proposed scheme involves an efficient estimator based on SDP relaxation technique to estimate the locations of a number of target nodes simultaneously. The new estimator exhibited excellent performance in a variety of scenarios, as well as robustness to not knowing.

In [39] Juan Cota-Ruiz et al. have presented a routing algorithm useful in the realm of centralized range-based localization schemes which is capable of estimating the distance between two non-neighboring sensors in multi-hop wireless sensor networks. This scheme employs a global table search of sensor edges and recursive functions to find all possible paths between a source sensor and a destination sensor with the minimum number of hops. Using a distance matrix, the algorithm evaluates and averages all paths to estimate a measure of distance between both sensors. In this scheme a recursive algorithm to estimate distances between any two sensors. The algorithm finds all possible combination routes with the minimum number of hops between a sender and a target node. To find all possible routes between two sensors, the algorithm uses a data structure in each sensor that contains all neighboring sensors that are at one-hop of distance. In the searching process, each child node is expanded going forward looking for a target node. If an expanded node has no children, the searching process returns back to the parent node to continue exploring new sensors. After that, the algorithm evaluates the path distance of each found route with a weighted distance matrix. Finally, a distance estimate is computed as the mean of all path distance. The proposed algorithm is then analyzed and compared with classical and novel approaches, and the results indicate that the proposed approach outperforms the other methods in distance estimate accuracy when used in random and uniform placement of nodes for large-scale wireless networks. Moreover, due the nature of this approach to provide all multiple-trajectories between two non-neighboring nodes with the minimum number of hops, our method can be easily applied in a variety of fields, i.e., transportation, vehicle routing, web mapping, communications, geography, artificial intelligence, and/or GIS-Network analysis, to name only a few.

In [40] Shikai Shen et al. proposed an improved DV-Hop localization algorithm to ensure the accuracy of localization. this localization algorithm first employ distortion function to select the beacon nodes that can estimate average hop distance, and then adopt two-dimensional hyperbolic function instead of the classic trilateration/least square method to determine the locations of unknown nodes, which are very close to their actual locations. Remarkably, the average localization error of

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proposed localization algorithm is lower than those of DV-Hop algorithm and its improved algorithm, under both the uniform and non-uniform node distributions and Proposed algorithm takes full consideration of the bad impact that the distant node exerts on the necessary average hop distance in positioning, and the impact that the neighboring node density of k-hop exerts on the improvement of the positioning accuracy.

In [41] Xihai Zhang et al. proposed An efficient path planning approach in mobile beacon localization for the randomly deployed wireless sensor nodes. The proposed approach can provide the deployment uniformly of virtual beacon nodes among the sensor fields and the lower computational complexity of path planning compared with method which utilizes only mobile beacons on the basis of a random movement. The performance evaluation shows that the proposed approach can reduce the beacon movement distance and the number of virtual mobile beacon nodes by comparison with other methods. In this scheme, a path planning algorithm based on grid scan which is the entire traverse in sensor field is proposed. In order to improve the localization accuracy, the weighting function is constructed based on the distance between the nodes. Furthermore, to avoid decrease in the localization accuracy an iterative multilateration algorithm and the start conditions of localization algorithm is also proposed. To evaluate the proposed path planning algorithm, the results of the static beacon randomly deployed and RWP mobile path in sensor field are also provided. It is obtained that proposed scheme by a mobile beacon is significantly better than localization scheme by beacon deployment randomly in localization effects.

In [42] Dexin Wang et al. discuss the benefit brought by cooperation in the context of robust localization against malicious anchors. Cooperation provides improved detection about the existence of malicious anchors, as well as the ability to estimate their true locations. This scheme investigate various loss functions and propose an accelerated cooperative robust localization algorithm based on Huber loss function. The proposed algorithm offers accuracy comparable to existing cooperative robust localization methods but at significantly reduced computational complexity. an accelerated algorithm FARCoL was proposed based on its characteristics. Compared with CARSDP, FARCoL significantly reduces the computational complexity of the algorithm while preserving similar accuracy.

VI. Evaluation Criteria for Localization in Wireless Sensor Network

The localization errors are unavoidable in the estimations. In this section, we describe some common metrics: average localization error, root mean square error, and geometric mean error. And the Euclidean distance and Manhattan distance are two widely used metrics that are computed considering a two-dimensional coordinate system [43]. The Euclidean distance is describe as a shortest distance between two coordinates. The Manhattan distance is describe as a distance between two coordinates measured along International Journal of Distributed Sensor Networks 9 the axes at the right angles. The metrics are described as follows.

1) Average Localization Error. The average localization error for Euclidean distance can be computed as follows:

$$error = \frac{1}{N_t}\sum_{i=1}^{N_t}\sqrt{(x_i^{'}-x)^2+(y_i^{'}-y)^2} \quad (1)$$

where N_t is the number of trails. (x, y) is the true location of the unknown node or source. $(x^{'}, y^{'})$ is the estimated location.
The average localization error for Manhattan distance can be computed as follows:

$$error = \frac{1}{N_t}\sum_{i=1}^{N_t}(|x_i^{'}-x|+|y_i^{'}-y|) \quad (2)$$

2) Root Mean Square Error. The root mean square error for Euclidean distance can be computed as follows [44]:

$$error = \sqrt{\frac{1}{N_t}\sum_{i=1}^{N_t}(x_i^{'}-x)^2+(y_i^{'}-y)^2} \quad (3)$$

The root mean square error for Manhattan distance can be computed as follows:

$$error = \sqrt{\frac{1}{N_t}\sum_{i=1}^{N_t}|x_i^{'}-x|+|y_i^{'}-y|} \quad (4)$$

3) Geometric Mean Error. The geometric mean error for Euclidean distance can be computed as follows:

$$error = \sqrt[N_t]{\prod_{i=1}^{N_t}(x_i^{'}-x)^2+(y_i^{'}-y)^2} \quad (5)$$

The geometric mean error for Manhattan distance can be computed as follows:

$$error = \sqrt[N_t]{\prod_{i=1}^{N_t}|x_i^{'}-x|+|y_i^{'}-y|} \quad (6)$$

VII. Conclusion

In this paper, we presented a survey and taxonomy on localization for mobile wireless sensor networks. Localization in MWSNs entails new challenges that result from integrating resource-constrained wireless sensors on a mobile platform. The localization methods and algorithms that provide greater accuracy on larger-footprint mobile entities with fewer resource restrictions are no longer applicable. Similarly, centralized and high-latency localization techniques for static WSNs are undesirable for the majority of MWSN applications. There are several directions for future work in MWSN localization. Currently, a tradeoff exists between the rapid execution of an algorithm and its accuracy. Additional work is needed that focused on reducing run-time latency, while maintaining positioning accuracy. In addition, the majority of localization algorithms to date are centralized. For mobile sensor localization, this is often a poor design choice, due to the additional latency and energy costs incurred. The development of more distributed localization techniques would be a welcome addition to MWSN localization.

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