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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].

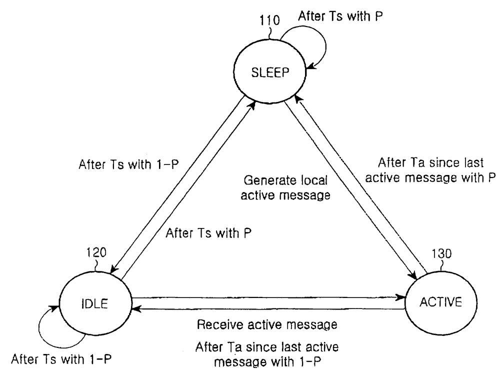

Fig. 1. Transition of a sensor node

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.

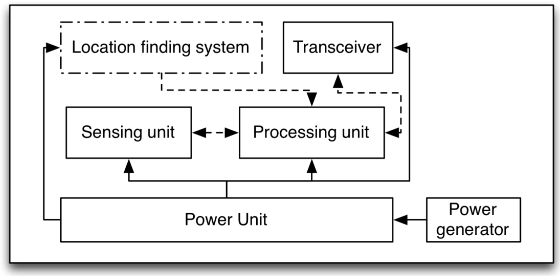

Fig. 2. Typical architecture of sensor node

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