A Survey: Localization and Tracking Mobile Targets through Wireless Sensors Network

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***Abstract*— Wireless sensor network applications have been deployed widely. Sensor networks involve sensor nodes which are very small in size. They are low in cost, and have a low battery life. Sensor nodes are capable of solving a variety of collaborative problems, such as, monitoring and surveillance. One of the critical components in wireless sensor networks is the localizing tracking sensor or mobile node. In this paper we will discuss the various location system techniques and categorize these techniques based on the communication between nodes into centralized and decentralized localization techniques. The tracking techniques are categorized into four main types. Each type will be compared and discussed in detail. We will suggest ways of implementing the techniques and finally carry out an evaluation.**

***Index Terms*—** *Wireless Sensor, Localization, Tracking.*

I. INTRODUCTION

Wireless sensor networks have become a vital research area nowadays. Sensor nodes are used widely. The first research in this area was motivated by military applications with DARPA funding a number of prominent research projects such as Smart Dust, and NEST. Recently, civilian applications of wireless sensor networks have been considered including environmental and species monitoring, water, air, soil chemistry, agriculture, production and delivery, healthcare. Wireless sensor networks are composed of sensor nodes, which collaborate to perform specific tasks. Sensor nodes have the ability to sense, process, and communicate data. The main goal of wireless sensor networks (WSN) it to permit multiple applications to run on top of the same sensor network.

Sensor networks are considered as a system of many small and simple devices deployed over an area in order to sense and monitor events of interests or track objects or people as they move. As shown in Figure 1, sensor nodes are tiny electronic devices equipped with a battery for an energy source. They have a sensor for detecting physical characteristics and a processor for performing computations. A wireless transceiver is fitted for two way communications with other sensors. They are equipped with a memory for storing information. A sensor node has the following characteristics: (1) a small physical size, (2) low power consumption, (3) limited processing power, (4) short-range communications and (5) a small amount of memory storage.

Fig. 1. Wireless Sensor (Jennic)

The potential applications of wireless sensor networks involve environmental monitoring, military surveillance, search-and-rescue, tracking soldiers and cars. The wireless sensor network applications involve target tracking, which had been widely deployed to secure military areas from intruders or for wildlife animal monitoring. Target tracking applications have become one of the major uses of wireless sensor networks. According to [1], target tracking using wireless sensor networks was initially investigated on 2002. Sensor localization involves finding the location of an object with high accuracy, using a mobile sensor or stationary sensor.

Localizing wireless sensors and tracking mobile targets through wireless sensor networks have become two important areas in the use of wireless sensor networks. Localization involves determining the location of the sensor node based on other sensor nodes with known locations. Tracking mobile targets involves finding out the location of mobile targets based on wireless sensor nodes with known positions. In this paper, we are concentrating on tracking mobile objects using sensor nodes with in fixed locations. The main problem is to detect the presence of mobile targets based on the distributed sensor nodes without using any additional hardware. The technique must be inexpensive and power efficient.

This paper is organized as follows: Section 2 reviews the existing localization techniques. Section 3 reviews the existing tracking techniques. Section 4 involves comparisons between the existing techniques. In section 5, implementation and evaluation are involved. And Finally, Section 6 involves a conclusion.

II. LOCALIZATION TECHNIQUES

According to [2], localization techniques can be divided into two categories based on the communication between

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nodes: Centralized localization and Decentralized localization techniques, as shown in Figure 2.

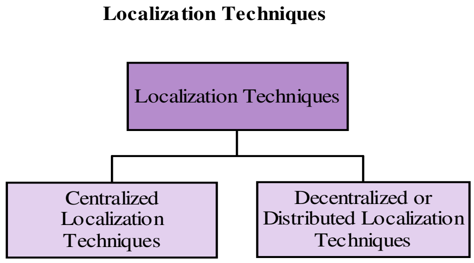

Fig. 2. Localization Techniques

A. *Centralized Localization Techniques*

Centralized localization techniques involve transmitting data to a central node in order to compute the location for each node. In [3], Doherty L. et al. proposed a method for finding the location of the unknown sensor nodes based on a centralized localization. Also in [4], Shang Y. et al. proposed a MDS-MAP technique for calculating the positions of nodes with only basic information that is likely to be already available.

Centralized localization techniques involve locating the sensor node based on transmitting data to a central node, in order to calculate the position there. Both of works [3] & [4], involves transmitting data to a central node. Transmitting data to a central computer is quite expensive, since the power supply for each node is limited. Consequently, communication with a centralized computing is expensive, and sending time series data within the network introduces latency, and it also consumes energy and network bandwidth

B. *Decentralized Localization Techniques*

Decentralized or distributed localization techniques depend on each sensor node being able to determine its location with only limited communication with nearby nodes. Distributed localization techniques do not require centralized computation. Distributed localization techniques involve two kinds of techniques as shown in Figure 3: Range-based and Range-free localization techniques.

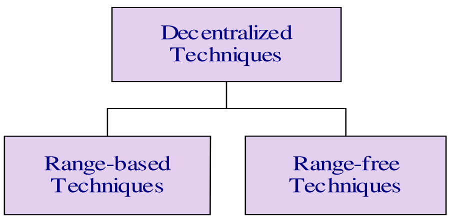

Fig. 3. Decentralized Techniques

1) Range-based Localization Techniques: Range-based localization techniques involve finding the location of the target sensor node using absolute point-to-point distance estimates or angle estimates. Range-based localization techniques involve many techniques such as Time or Arrival (TOA), GPS, RADAR, AHLoS, Calamari, and CRB.

- ***TOA***: is commonly used as a mean of obtaining range information via signal propagation time, and it's depend on the time difference to compute the location of the sensor nodes. TOA needs a high clock resolution to obtain accurate position estimates as shown in Figure 4.
- ***GPS***: is the most widespread positioning technique, and its based on a set of satellites which offer three dimensional positioning with accuracy of around 3 m.
- ***RADAR***: is a localization technique proposed in [5], which developed by a Microsoft Research group. It's a radio frequency based system for tracking users inside buildings and its based on IEEE.11 WaveLAN wireless networking technology. RADAR operates by recording and processing signal strength information at multiple base stations positioned to provide overlapping coverage in the area of interest.
- ***AHLoS***: is a localization system in wireless sensor networks, its based on a set of distributed iterative algorithms. AHLoS technique depends on limited fraction of nodes with known positions and its deploys TOA as the primary ranging method for AHLoS.
- ***Calamari***: is an ad hoc localization technique proposed in [6], it aims to consume a few resources as possible, including energy, computational power, and componentry. It involves estimating distance between sensor nodes based on a fusion or RF received signal strength information (RSSI) and acoustic time of flight (TOF).
- ***CRB***: is a localization technique proposed in [7], and it involves estimating the location when sensors measure received signal strength (RSS) or time of arrival (TOA).

Range-based techniques are a decentralized technique and give accurate and precise localization information. The proposed range-based techniques require extensive hardware, in order to calculate the target's location. The additional hardware is expensive and energy-consuming, which makes these techniques less suitable for low-power sensor network devices.

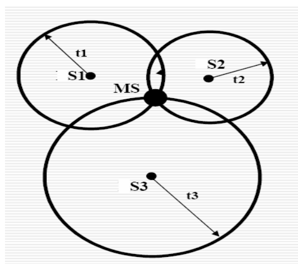

Fig. 4. TOA Technique

2) Range-free Localization Techniques: Researchers have sought alternative range free solutions for localization problems in wireless sensor networks. Range free localization involves using regular radio modules as a basis for localization and is dependent only on the content of the received message. They, therefore, they do not require any additional hardware. Range free localization techniques are regarded as cost effective and energy efficient. They provide adequate solutions for localization in wireless sensor networks.

- ***Local Techniques***: These techniques rely on a high density of beacons, so that every sensor node can hear from several beacons. As in [8], Bulusu N. et al. proposed a Centroid localization technique for every small, low cost devices and no need for GPS. It's based on spherical radio propagation assumption and it's simple. This technique involves that each node estimates its location by measuring the centre of the location of all nodes it hears. In [9], He T. et al. propose APIT range free localization technique, which needs a heterogeneous network of sensing devices where a small percentage of beacon nodes. APIT involves dividing the environment into triangular regions to allow a node to narrow down the area in which it can potentially reside in order to get its position as shown in Figure 5. And finally, in [10], Bulusu et al. propose two techniques HEAP increment beacon placement algorithm and STROBE adaptive density algorithms applicable to high density regimes of beacon placement.
- ***Hop Counting Techniques***: These techniques rely on flooding a network and involve providing localization in network where nodes density is low. As in [11], Niculescu D. & Nath B. propose DV-HOP technique, which involves that each node maintains a counter of denoting the minimum number of hops to each node, and then update the counter based on the received message. And in [12], they propose an algorithm which takes the advantages of the ad hoc wireless sensors to find the position information. The proposed technique relies on distributed simple computation and local communication only, and it does not require any additional hardware.

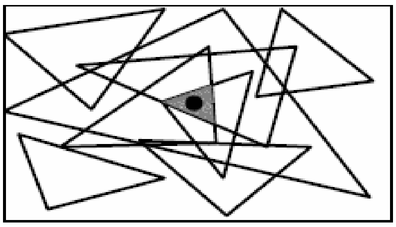

Fig. 5. APIT Technique

III. LOCATION TRACKING TECHNIQUES

Most of the previous techniques involved finding the location of the stationary wireless sensor nodes. In this section we discuss the techniques which involve tracking mobile targets through wireless sensor areas. One of the greatest challenges for developing sensor networks for target tracking is battery power conservation. Each sensor node is usually powered by batteries which might, in the field, be difficult to replace. In this article, the key objective is to track a mobile target based on distributed wireless sensor nodes with known positions.

In this section, we describe the techniques which related directly to our work, and categorize them into four main groups as shown in Figure 6.

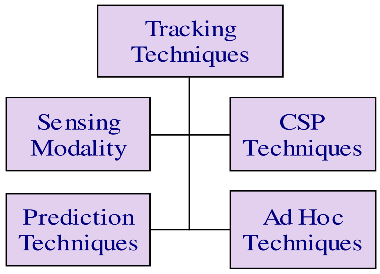

Fig. 6. Tracking Techniques

1) *Prediction-based Techniques:* Recently, the prediction-based techniques have been deployed widely using wireless sensor nodes, in order to predict the future movement of the mobile target, and consequently reducing the power-consumption in wireless sensor nodes. Such as in [13], Guo Z. et al. proposed a prediction-based technique called Predictive Accuracy-based Tracking Energy Saving (PATES), to reduce the power consumption in wireless sensor networks by limiting the sensor active time. In [14], Yang H. & Sikdar B. proposed a distributed predictive tracking technique for tracking mobile targets. In [15], Xu Y. & Lee W. proposed a prediction-based approach called Localized Prediction for Power Efficient Target Tracking Sensor Networks. In [16], Zhang W. & Cao G. proposed a Dynamic Convoy Tree-based Collaboration (DCTC) technique. Figure 7 depicts the prediction technique.

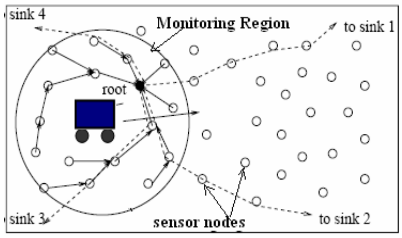

Fig. 7. Prediction Technique

2) *Sensing Modality-based Techniques:* Sensing modality-based techniques involve detecting and tracking the mobile targets based on sensing modalities such as acoustic or seismic. These techniques have received much attention recently, because they offer accurate and precise location information, Figure 8 involves an image of an acoustic sensor with a microphone. In [17], Kushwaha M. et al. proposed a mobile acoustic beacon based the sensor node localization method. In [18], Mechitov K. et al. proposed a cooperative tracking technique to track mobile targets. In [19], Galstyan A. et al. proposed an online distributed algorithm in which sensor nodes use geometric constraints induced by both radio connectivity and sensing to decrease the uncertainty of their positions. In [20], Gupta R. & Das S. developed a technique for detecting and tracking mobile targets. And finally in [21], Aslam J. et al. propose a binary sensor method.

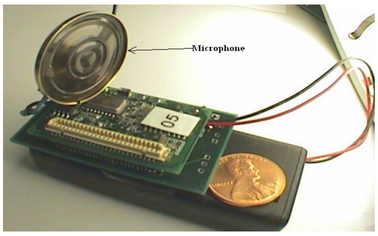

Fig. 8. Acoustic Sensor

3) Collaborative Signal Processing-based Techniques: In this section, we summarize the techniques which employ the Collaborative Signal and Information Processing (CSIP). According to [22], the concept underpinning the information driven approach is to base the decision for sensor collaboration on information constraints as well as those on cost and resource and consumption. Each sensor in the network can exploit the information content of the data already received to optimize future sensing actions, and so efficiently managing the scarce communication and processing resources. In [22], Zhao F. et al. introduced the information driven approach in Ad-Hoc sensor networks. In [23], Li D. et al presented a technique for tracking multiple targets. In [24], Brooks R. et al. proposed a Collaborative Signal Processing technique for target classification and tracking in distributed sensor networks.

IV. COMPARISONS

The main purpose of our work is to design a tracking technique for detecting and tracking mobile targets in wireless sensor network areas. There are many tracking techniques that have been mentioned above. In this section, the localization and tracking techniques are evaluated based on five main factors. Table 1: involves a comparison between centralized and decentralized techniques based on five factors, Table 2: involves a comparison between range-based and range-free localization techniques, and finally, Table 3: involves a comparison between tracking techniques.

- ***Cost***: is an important factor, which involves the installation of and the system's administration needs together with capital costs which involve factors such as the price per mobile unit or infrastructure element.
- ***Accuracy***: the main goal for any tracking technique is to be able track the mobile target. The tracking technique must be accurate with a low fault tolerance.
- ***Power-consuming***: it is an important factor, because each sensor node has limited power and it is hard to change the sensors' battery frequently.
- ***Dependence on Special hardware***: the tracking technique depends on the sensor's characteristics. A reduction in the need to deploy additional hardware leads to lower power consumption and less expensive sensor nodes.
- ***Deployment:*** the tracking technique must be easy to deploy with little "setting up".

TABLE 1
CENTRALIZED AND DECENTRALIZED TECHS.

Comparison	Centralized Techniques	Decentralized Techniques
Cost	Expensive	Inexpensive
Power-consuming	Power-consumed	Power-efficient
Accuracy	75 %	75-90 %
Dependence on Special hardware	Does not require additional hardware	Do require additional hardware
Deploy ability	Hard to deploy	Easy to deploy

TABLE 2
RANGE-BASED & RANGE-FREE TECHS.

Comparison	Range-based Techniques	Range-free Techniques
Cost	Expensive	Inexpensive
Power-consuming	Power-consumed	Power-efficient
Accuracy	90 %	75 %
Dependence on Special hardware	Require additional hardware	Do not require additional hardware
Deploy ability	Hard to deploy	East to deploy

TABLE 3
TRACKING TECHNIQUES

Comparison	Sensing-based Techniques	CSP Techniques	Prediction-based Techniques
Cost	Expensive	Inexpensive	Inexpensive
Power-consuming	Power-consumed	Power-efficient	Power-efficient
Accuracy	90 %	70-85 %	90 %
Dependence on Special hardware	Require additional hardware	Do not require additional hardware	Do not require additional hardware
Deploy ability	Hard to deploy	Easy	Easy

V. IMPLEMENTATION

The presented work is a part of a SafetyNet project, a 3 years ongoing work, which involves designing and developing wireless fire sensors to replace the traditional sensors. This work aims to provide a low-power, small-size, and very low cost wireless sensors. Battery-powered sensors can be easily fixed and moved, with no need to wiring installations which costs thousands of pounds. In this project, I'm working on designing and developing algorithm to detect and track mobile targets based on wireless sensors. The tracking system must be inexpensive, and power-efficient.

As described before, four tracking techniques are being used in order to track and detect mobile targets through wireless sensor networks. Sensing modality-based techniques need additional hardware to track and detect and mobile target, which might be expensive and power-consuming. Ad-hoc techniques work efficiently in ad-hoc topology. Therefore, sensing modality-based and ad hoc based techniques are not efficient solution for our project.

Prediction techniques involve predicting the future movement of the mobile targets, in order to conserve battery-life. On the other hand, Collaborative Signal processing techniques base the decision for sensor collaboration, in order to reduce the bandwidth consumption and consequently minimize power consumption. Therefore, tracking techniques which employ predictive and collaborative processing techniques are accurate and power efficient.

In our project, we will employ prediction and collaborative signal processing techniques. We will use NS2 simulator.

VI. CONCLUSION

Tracking mobile targets through wireless sensor networks is a vital area in wireless sensor applications. In our work, we need to investigate and design a technique for detecting and tracking the position of fire-fighters in a building, based on distributed sensor nodes. The technique must be inexpensive, accurate, power-efficient, and does not require any additional hardware. The location tracking techniques have been categorized and evaluated in the previous section. As seen before, most of the proposed techniques are based on additional hardware, in order to detect and track the position of the mobile targets, and consequently increasing the cost of the sensor nodes.

Prediction-based techniques will be used as a part of our project, because they predict the future position of the mobile target, in order to conserve the battery. Collaborative signal processing techniques are useful, as they are based on the decision of sensors collaboration

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