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A Review paper on Object Tracking Techniques in Wireless Sensor Networks.

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Abstract

A wireless sensor networks (WSNs) consist of autonomous sensors which are spatially distributed to control and monitor physical conditions of the environment. The most interesting applications of WSNs which is also considered as a killer application is Object Tracking Sensor Networks (OTSN). Generally, OTSN is used to track the object moving in the monitored area and to report the locations of objects to base-station, it has wide variety of applications such as field of surveillance, military applications, wild-life monitoring and commercial applications. In this paper, a survey has been carried out and different techniques are discussed for object tracking. The survey promotes overview of some recent research on object tracking techniques.

1. Introduction

Recent advances in integrating electronic components have been made possible by microelectronic mechanical systems (MEMS) is cost-effective, energy efficient and has contributed significantly to a large amount of research and development in the field of wireless sensor networks (WSNs). The sensor nodes which are the major building blocks involved in WSNs consist of three main components mainly: Sensing component, MCU and RF component. These nodes are deployed with a very low cost, energy consumption savings and yet with high level of sophistication for computing power when compared to previous deployment of sensor nodes. Usually, WSNs are deployed with large number of sensor nodes to form certain area which is to be considered as a monitored region for monitoring. The nodes are interconnected and are used for monitoring purpose and reporting device to acquire specific types of data as per application requirement.

Object tracking sensor networks is a major field of research in wireless sensor networks and also known as a target tracking. Many protocols and techniques have been developed in recent years by considering several important factors. The object tracking approaches that can be applied to different architectures (as shown in figure 1) is Hierarchical networks, Peer-to-Peer networks and other(Hybrid) networks in which many techniques have been developed a protocol for object tracking which are mainly classified based on the following as shown (see Figure 2). The hierarchical networks consists of Tree-based methods, Cluster based methods, hybrid methods and Activation based methods while the peer-to-peer networks has methods like embedded filter based which includes distributed kalman filter algorithms and the other networks includes prediction based methods which are briefly discussed in this paper.

The rest of the paper is organized as follows: Section 2 defines the general problem that is to be followed by OTSN principle based on design factors. Section 3 gives a review of some of the object tracking techniques used in the literature. In Section 4 we conclude the paper.

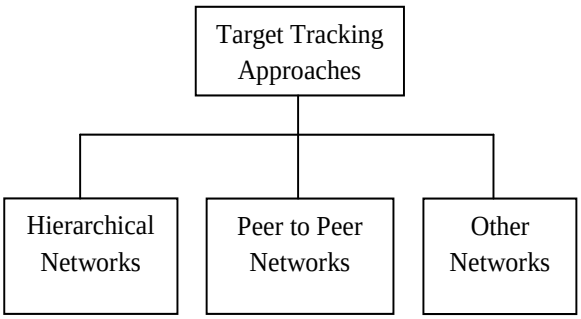

Figure 1.Target tracking approaches.

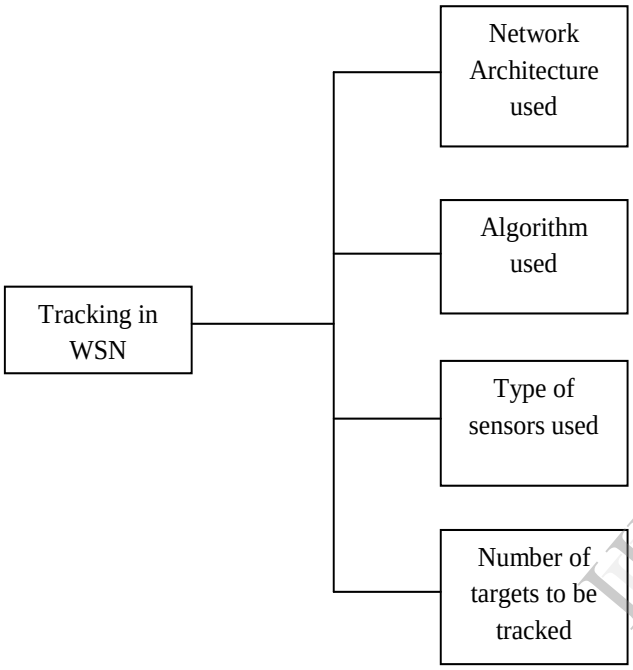

Figure 2. Basic classification of tracking in WSN.

2. General definition problem in object tracking sensor networks.

Problem Scenario: We know that OTSN consist of *n* wireless sensor nodes in the region in a distributed manner for tracking *m* (where m>=1) mobile objects [9]. Generally the nodes are placed randomly in the network if they are to be deployed dynamically, according to the application requirement. Sensor nodes has the ability to detect the presence or absence of object in its monitored area by sampling the sensed signals. Each object whether entering the monitored area or exiting from it moves randomly at any given period of time say *t* and stay for some duration with probability say *p* [9].

Objectives: As OTSN is considered to be the most energy consuming kind of application, so the main aim should be about to reduce the energy consumed by the sensor nodes. It is often desirable to determine the location of the objects, so performing this periodically we can track the area in which the object is located. In this case the number of sensor nodes that are to be activated should be less in order to minimize the energy spent and thus maximizing the network lifetime. Furthermore, there is another important parameter in OTSN of missing reports, it determines the number of reports done to the total number of reports and in case of losing the track of target there should be some recovery mechanism so that the missing reports are minimized. The region where the sensor nodes need to remain active is considered to be monitoring region [2]. When we are using the methods like prediction, there we are supposed to activate that nodes where the target is more likely to move on, thus that is known as forwarding region [2].

3. Various techniques for object tracking

In 2006, Guang-yao Jin *et.al* [1], presented a cluster-based and prediction-based approach for tracking the object in WSNs. In dynamic clustering, the network is formed with the help of powerful CH (Cluster Head) nodes and having low-end sink nodes.

At the first stage, the Powerful CH node having the strongest sensed signal of target becomes the cluster head and then forms a cluster consisting all the nearby sink nodes. Now the sink node in the cluster transmits the sensed data to the CH and there after data aggregation is formed on that data, thereon sends the data to the base station. Here in this method to avoid the missing of target the cluster head (CH) needs to monitor the target continuously. If the CH are sparsely distributed then it becomes very difficult to track the particular object and thus if the object travels with higher speed then the energy consumed by the cluster head would also increase. This paper had proposed a mechanism based on 3 functionalities which are Initial clustering, cluster reforming and cluster head election.

In initial clustering, at initial time all sensors are in the sleep mode then after receiving tracking command all the sensors wake up for a short period of time and the sensor node which can detect the target will form a cluster while the rest of others will go to sleep mode. In cluster reforming step, as new cluster head is already been elected, a new cluster will be formed according to it. This new cluster head selected by former cluster after broad casting a confirming packet, the sensor nodes of the old cluster will check whether they are the neighbour nodes of the new cluster just formed, if they, then they will remain in listening modes while the

others go to sleep mode immediately. So now the newly formed cluster head will wait for a for a short random time and as soon as time expires it will broadcast re-clustering command packet which contains the new scheduling information and thus the neighboring nodes will used that schedule to form a new cluster. In the cluster head selection, the node is selected based on the next possible location of the target gained by prediction. In the current cluster when the predicted location is at the boundary, the cluster head will send a packet and select the first one which replies the message to be the new cluster head by sending a confirming packet. Thus, this process is held every time before a cluster is formed.

In 2008, Suganya.S [5] suggested a cluster based approach for collaborative target tracking. This approach consists of various modules. Firstly the scenario generation where the location of sensor nodes are known priori and the sensor nodes are deployed in monitored region. Secondly the detection of target which is based on the strength received by the sensor nodes of the target. As the signal strength is estimated, if it is exceeding the threshold range then the noise in the signal will be modeled by the Gaussian random variable and if the signal detected is low than the threshold then it is assumed that signal consist of noise only. The third module is clustering of nodes in which it includes the size of cluster, area covered and the number of nodes. The steps included in this module is already described as in [1]. Fourth module involves energy based target localization which is constrained within two dimensions that is target is assumed to be in a plane and it is expressed in terms of (x, y) coordinates. The final step involves the estimation of target tracking error and energy consumption by making comparison with the true locations and consumption of energy is calculated on each sensor node based on number and size of packets transmitted, and size of messages exchanged between nodes.

In 2012, D.Charanya [4] proposed a work which is energy efficient prediction based method in a clustered network consisting of nodes at same energy level and communication range. The steps involved in this method is described as a block diagram as shown in (figure 3). The first step involves the clustering of nodes to increase the life time of sensor network by reducing the energy consumption. It uses the LEACH-R algorithm in clustering of nodes where a CH nodes is being selected based on the target detection as a leader node. Target detection is done based on the Received Signal Strength Indicator (RSSI). After this step the prediction based algorithm is to be used that predicts the next location which is based on linear prediction. This prediction method with current (x_i, y_i) and previous location (x_{i-1}, y_{i-1}) can be used to calculate next location. The selected nodes sense the target and current target location is calculated using trilateration algorithm where three sensor nodes are selected each time and the two nodes calculates its distance from the moving object and send it to leader node and thus calculates the location of moving object.

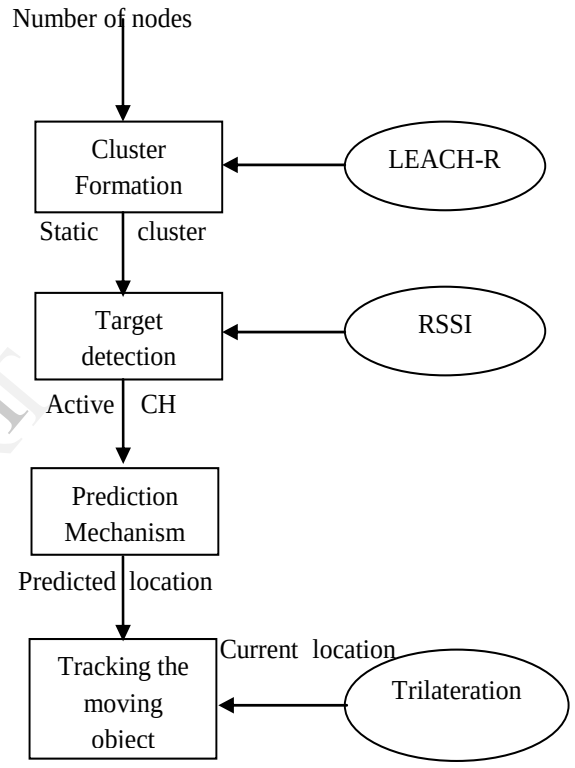

Figure 3. Block Diagram

In 2004, Yingzi Xu *et.al* [2] proposed a Prediction-based energy saving scheme called PES in which the number of participating nodes are minimized and inactivate the other nodes into sleep mode. These energy saving scheme consist of prediction model, wake-up mechanisms and recovery mechanism. With the help of this method only those sensor nodes are being activated which are needed to track the object, while the other sensor nodes into low power mode. Prediction model is based on the observation that the movement of object remains constant for certain amount of time. By this assumption, without considering the variance of speed and direction the current node will predict the sensor node and the object movement in (T - X) second. This model uses three

main heuristics for selecting speed and direction Heuristics INSTANT, Heuristics AVERAGE, Heuristics EXP_AVG. Next, the wake up mechanisms is used to accommodate prediction errors so that the chances of losing the track of object reduces to great extent. For this there are three heuristics used commonly known as Heuristic DESTINATION, Heuristic ROUTE and Heuristic ALL_NBR. At last the recovery mechanisms are used so that the missing rates that have been occurred due to prediction model and wake-up mechanism can be overcome when the object is not found by the current and target nodes. Thus PES results into the reduction of energy consumption on MCU and sensor components.

In 2004, Yingqi Xu *et.al* [3], once again proposed a method known as Dual Prediction-based Reporting (DPR) in which energy is conserved at the reporting stage of object tracking sensor network which is usually done at the reporting time from sink node to base station. The reporting mechanism of DPR consist of two main components: *location models* in which the system requires the granularity of location information and *prediction models* in which the model predicts the future movements based on the moving history. Basically, this mechanism is deployed at both sensor nodes as well as the base station and by using the data, both sensor nodes and base station make the same prediction for the moving objects. If the prediction of both came to be same then there is no need to transmit data from sensor node to base station otherwise the sensed data has to be transmitted to base station in order to update its cache for predicting the future movement of object. Hence the transmissions from the sensor nodes to base station are avoided as long as the predictions are correct and thus reduces extra communication overhead. Prediction models as described [2] which comprises of the heuristics, is used for making the prediction of the object's future movement. In location models the author has given description about the precision of the historical data which indirectly affects the accuracy of prediction models. Location models are categorized into two different modules: *geometric* and *symbolic*, thereon studied several possible location models such as Sensor cell, Triangle, Grid and Coordinate for overall performance of DPR. Thus DPR is able to minimize energy usage of OTSNs, the energy savings achieved under the ranges of mobile object dynamics and granularity is also less due to dynamics of mobile object.

In 2011, Samer Samarah *et.al* [6], in this paper the author has proposed a prediction-based tracking technique using sequential pattern (PTSP) which is an object tracking technique that has the ability to predict the future movements in order to track with the minimum number of sensor nodes while the rest of the others are to be kept in sleep mode as it reduces the energy consumption of the entire network. Basically, this technique (PTSP) is especially based on inherited patterns of the object's movement in the network and making the use of sequential patterns (data mining technique) to which sensor node that the moving object will be moved to. The proposed PTSP technique is based mainly on two stages: 1) Sequential pattern generation and 2) Object tracking and monitoring. In the first stage which is a sequential pattern generation, the prediction model is develop from a log of data that is being collected from the sensor network, after aggregating at the sink in a database which produces inherited patterns in the monitored area of moving object. Therefore, with the help of this data, sequential patterns can be easily generated that will be deployed by the sink to sensor node in the network. So with the help of this patterns it will become easy to predict the future movement of a particular object in the network in its detection area. The second stage consist of actual tracking of moving objects and it consist of two steps. 1) activation mechanism which will be making use of sequential patterns to predict the node(s) that is to be activated keep tracking the moving object and 2) missing object recovery mechanism, that is used to find the missing objects when the activated node is unable to locate object in its monitored area. In this paper they have proposed a novel approach for energy efficient technique which is PTSP in its prediction mechanism that reduces the energy consumption by considering the number of active node and sleep node in the network as well as the missing rate according to missed report to total number of reports.

In 2013, Thangarajan et al [7], had used a technique prediction-based tracking using sequential pattern generation (PTSP) as described in [6]. As this provides minimum energy consumption by object tracking sensor networks and maintaining acceptable

Table 1. Comparison of various tracking methods

missing rates. But the problem was the technique deals with the object tracking even when sensor node routing fails. It comprises of two stages energy calculation and route finding, so all nodes will not participate in the forwarding process and packets dropping will also be decreased which indirectly reduces the retransmission and thus the lifetime of the network will be increased. In addition to sequential pattern generation, it takes longer time to predict the future movements of objects which is based on huge log of data aggregated at the

Techniques	Reduce energy consumption	Missing rate	MTT Support	Recovery Mechanism	Deactivating non-necessary nodes	Prediction accuracy	Increase Network lifetime
DCOT[1]	✓	✓	×	×	✓	×	✓
PES[2]	✓	✓	✓	✓	✓	✓	✓
DPR[3]	✓	✓	✓	✓	✓	✓	✓
Prediction based clustering using LEACH-R[4]	✓	✓	×	×	✓	×	✓
CCTT[5]	✓	✓	×	×	✓	×	✓
PTSP[6][7]	✓	✓	✓	✓	✓	✓	✓
CPBP[8]	✓	✓	×	×	✓	×	✓

sink in a database. Markov decision precision or learning techniques can be used to predict the object which also reduces the missing rates. As Markov decision precision is based on current data and thus makes the prediction accuracy more perfect in case where the probability of missing objects is more.

In 2013, Vahid Hosseini et al [8], had proposed a clustering and prediction-based protocol for target tracking (CPBP). This technique has been a combination of clustering and prediction making, where first some assumptions are made regarding base station for tracking the moving objects which is the basis for performing tracking application. Firstly the assumptions for the network model which determines the base station, the sensing range, the type of sensors used. Secondly the sensing and communication model is described giving the details about the sensing range of particular sensor used for the given protocol, communication between base station and the sensor node.Then next is about the localization which gives the details about the coordinates of sensor located. Here in this protocol base station (BS) is in charge of cluster formation so it has a good knowledge about energy of each and every sensor used in the network. Prediction-based protocols are used to predict the next location of the target which is a linear prediction method that is dependent on the current and previous location of the target and mathematical equations are used for speed and directions. Thus this protocol considers both the distance and energy parameters for clustering which has an improvement on the number of transmitted packets, network lifetime and the number of target miss.

4. Conclusion and future work

From the review of the above papers, it can be concluded that many different techniques can be used for object tracking in wireless sensor networks. Looking into this techniques it is required to cluster the sensor nodes in the network and applying prediction methods to activate the next node through which the object is to be moved in an energy efficient manner. Table I gives the brief comparison between all the methods used for object tracking in sensor networks.

Thus in the future work, many other prediction models can be constructed to increase the accuracy of predicting the nodes through which the object is to be moved and reducing the communication between the sensor nodes and the base station. Other area is that we can include the concept of other fields like data mining, image processing so that the results obtained consist of reduced errors.

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