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A Survey on Target Tracking Techniques in Wireless Sensor Network

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Abstract

Wireless Sensor technology is rapidly spreading all around the world. One important use of sensor networks is the tracking of a mobile target (point source) by the network. Mobile target tracking in wireless sensor networks has gained a lot of attention in the recent years due to the special characteristics of these WSNs. Considering the wide application of tracking WSNs, varied issues of data aggregation, scheduling, routing and energy conservation have been revisited and new solutions have been projected recently. Due to the importance of this topic, a detailed survey becomes necessary and helpful. In this paper we present a survey of the progressive mobile target tracking techniques in WSNs and the target tracking techniques available so far in wireless sensor networks.

Keywords: Wireless Sensor Networks, target tracking, Network architecture.

Introduction

In recent years, Wireless sensor networks have found rapidly growing applications in areas such as surveillance, environmental monitoring, automated data collection, and environmental monitoring. One important use of sensor networks is the tracking of a mobile target (point source) by the network. The network employs the object tracking techniques to continuously report the position of the object in terms of Cartesian coordinates to a sink node or to a central base station. With wireless sensor networks, objects can be tracked by simply tagging them with a small sensor node [1]. The nodes can be used as active tags that announce the presence of a device. A database can be used to record the location of tracked objects relative to the set of nodes at known locations. With this system, it becomes possible to ask where an object is currently, not simply where it was last scanned.

Unlike sensing or security networks, node tracking applications will continually have topology changes as nodes move through the network. While the connectivity between the nodes at fixed locations will remain relatively stable, the connectivity to mobile nodes will be continually changing. Additionally the set of nodes being tracked will continually change as objects enter and leave the system. It is essential that the network be able to efficiently detect the presence of new nodes that enter the network [2].

The techniques are mainly classified based on following [2] [3]. Those are

- Network architecture used
- Algorithm or technique used
- Type of sensors used
- Number of targets to be tracked
- Technology used for implementation

Each of these categories has been described carefully in section 2, 3, 4, 5 and 6 respectively.

Network Architecture

The following are the main types of network architectures that can be used for target tracking in Wireless Sensor Networks [8] [11].

- Cluster based architecture
- Decentralized architecture
- Tree based architecture

Cluster Based Architecture

In cluster based architecture there are several sensor nodes are available. This architecture assigns a cluster leader or cluster head for a certain group of nodes. The ordinary nodes just sense the reading and send that information to the cluster head thereby the ordinary nodes are reducing their burden. So, that the cluster head is normally a high energy and high resource node. The introduction of the cluster head can reduce the sufficient cost of network as one can deploy low cost and low energy sensor nodes.

The cluster based architecture of WSN can be classified as follows.

- Static clustering
- Dynamic clustering

Static Clustering

In Static clustering the cluster heads are assigned to the particular sensor node at the time of formation of the network and they cannot be changed. That is throughout the working of WSN the nodes remain to the same cluster head as they were pre assigned.

Dynamic Clustering

There are also two types in the dynamic clustering. Those are following

- Prediction based or Proactive clustering
- Non Prediction based clustering

Prediction based or Proactive Clustering

This prediction based clustering scheme is mostly employed in a network of sleep sensors, where most of the sensors stay in the sleep mode. In this scheme when a target moves from the region of one cluster head to the other, the current cluster head has to make an estimation or prediction about where the target is moving [13].

Non Prediction Based Clustering

This Non prediction based clustering is also similar to the scheme of the dynamic clustering. This scheme is used in a network of non-sleep sensor nodes. In this scheme energy saving is not an issue instead the proper selection and the life time of cluster head is an issue. So based on some application environment a cluster head selection algorithm is run on each individual node and the nodes collaboratively select the cluster head.

Decentralized Architecture

In the decentralized architecture, there is no cluster head node in the network. In this case all the network nodes are at the same level in terms of work responsibility. So the information sent to the target localization travels through the network to a central base station that is not the part of the wireless sensor network. The base station can be a computer or some computation entity. It runs an algorithm through which it can estimate the current location of the target.

Tree Based Architecture

The Tree based architecture is maintained across the network. The tree is rooted at the closest node to the target. Thus as the target moves some nodes get deleted and some nodes get added [6] [7]. This scheme reduces the overhead of energy and information flow,

as the information flows from the root to the end or periphery of the network through a particular route, as the information flow is controlled. So energy consumption automatically gets controlled.

While tracking a target, the nodes that detect the target and communicate with each other. It selects a root node. The root node collects all the information from the nodes through a distributed spanning tree. If the root node is far away from the target, the tree will be reconfigured. The centralized target tracking approaches are both time and energy consuming. To avoid this limitation tree based tracking methods are proposed. Those are given below.

Scalable tracking using networked sensors (STUN)

The scalable tracking using networked sensors, the cost is assigned to each link calculated by Euclidean distance between two nodes. The leaf nodes are used to track the moving objects and then send the collected data to the sink node through the intermediate nodes. The intermediate nodes keep a record of detected objects and whenever a change in the record, the nodes send updated information to the sink. The performance of STUN is determined by the structure of its message-pruning hierarchy and the tracked objects mobility patterns. The STUN relies on "Drain and Balance Tree" structure. This DAB method constructs the tree in bottom-up fashion. That is from leaves to root, through a series of DAB steps. Within each DAB step, a subset of the sensors is merged into balanced subtrees. The effectiveness of the method comes from properly choosing the nodes to merge in each of these steps. The STUN has some drawbacks, those are DAB tree does not replicate physical sensor network as it is a logical tree. Hence an edge may consist of multiple communication hops. So it may increase the communication cost and DAB tree does not consider query cost.

Dynamic Convoy Tree-based Collaboration (DCTC)

The Dynamic convoy tree includes sensor nodes around the moving objects and also the tree is designed to add some nodes and delete some nodes as the target moves. DCTC first detects the target and monitors it by tracking the surrounding area of the target. The target first enters into the detection region. Sensor nodes which will find the target collaborate with each other to select a root node and construct an initial convoy tree. The root node uses some classification algorithms to obtain complete and accurate information about the target. A big challenge of implementing the DCTC framework is reconfiguration of the convoy tree in an energy

efficient way, when the target is moving. But it has some drawback. DAB tree is a logical tree. It cannot reflect the physical structure of the sensor network. Communication cost is high due to edges consisting of multiple communication hops. The construction of DAB tree does not consider the query cost.

Deviation Avoidance Tree (DAT)

This Deviation Avoidance Tree is constructed to overcome the drawback of the Drain and Balance tree structure. In this DAT method treats each node as a singleton sub tree. More links can be used to connect all sub trees together. At the end all the sub trees will be connected into one tree. DAT has two stage approaches. The primary stage aims at reducing the update value, while the second stage aims at reducing the query cost.

Zone-based Deviation Avoidance Tree (Z-DAT)

This Zone-based Deviation Avoidance Tree is also similar to the DAT but Z-DAT examines links in a different order. The DAT and Z-DAT almost reduce the update cost but sometimes fails to reduce the query cost. To overcome these issues Query Cost Reduction (QCR) is designed. It reduces the total update and query cost by adjusting the object tracking tree obtained by DAT/Z-DAT.

Dynamic Object Tracking (DOT)

DOT is one of the protocol that reports the tracking information of moving object to moving source. In Target tracking, sources nodes sends request to the sensor nodes and the node closes to the target replies back. To identify the moving target continuously, the spatial neighbors of near sensor nodes are waken up. In this method source send query to beacon node which keeps the track of information and reply back target's next location. Then the source node moves towards next beacon node. This process is repeated until the source node catches the target

Optimized Communication and Organization (OCO)

This OCO is also a tree based method for target tracking. It provides self-organizing and routing capabilities with low computation overhead on sensor nodes. OCO consists of four phases. Those are position-collecting, processing, tracking, and maintenance. The position-collecting phase involves in collecting position of all the nodes in the network. The processing phase involves in cleaning up the redundant nodes, routing and detecting the border nodes.

The tracking phase detects all objects coming from outside the perimeter of the sensor network. Normally, only the sensor modules of the border nodes are ON. If a border node detects an object, it periodically sends its position information to the base sensor node by using its father's ID. When it has lost the object, it sends a message to turn on the all the sensor modules. If a neighbor detects the object, it will continue to send the position information of the object to the base sensor node. Right after it has lost the object, it turns the sensor modules of all it's of all its neighbors to ON and so on.

If no one activated neighbors detect nothing, they automatically turn the sensor module OFF after a short time interval. This is the way for tracking the object as long as it remains within the network. The maintenance phase is started when the network detect a dead node. In this case, the base sensor node deletes the dead node from the list and then reorganizes the network by starting the four phase procedure again. The main drawback of this method is high energy consumption.

Algorithm or Technique

According to the algorithm or technique used the tracking techniques can be classified as following [10].

- For the network of sleepy sensors
- Target reporting
- Target chasing

For the Network of Sleep Sensors

As all the sensors are in sleep mode. Thus there needs to be a mechanism through which the sensors can be woken up when the target approaches in the region of sleepy sensors. To wake up either Prediction heuristics or Sensor scheduling.

Prediction Heuristics

In this case most of sensors stay in sleep mode. The current node predicts the future movement and location of the target and correspondingly wakes up the nodes in the region where the target is moving. The critical performance parameters for prediction based reporting are the miss rate and energy consumption. The network or the regions where the current wireless sensor nodes were active. The heuristics reflect the prediction model that can be used for the prediction based object tracking in WSN. The prediction heuristics that can be used can either of Heuristic INSTANE is assumed that the target's future speed and direction will be the same as it is currently having. Heuristic assumed that the future direction and movement of the target will be equal to the average of previous direction and movement.

Heuristic EXP_AVG also the average of past readings is carried out except it is exponential weighted average, which means that more weight is assigned to near future reading than the far future readings.

Sensor Scheduling

Instead of incorporating prediction based scheme sensors can be scheduled for their wakeup and sleep time. In this scheme it is to be determined that which sensors stay in awake over the time in order to have an appropriate tradeoff between the tracking performance and the overall sensor usage. The objective is to minimize the estimation errors while still reducing the sensor usage over a period of time.

Target Reporting

In target reporting only the information target location in terms of Cartesian coordinates is sent to a sink node or some central entity. Thus the data continuously travels through the network. The main task here is to devise efficient routing and target location calculation techniques in order to minimize the overall energy consumption by the network and minimizing the tracking error.

Target Chasing

In target node the sink node has to physically follow the target. Thus the sink node has to continuously consult the neighboring nodes and the information of target has to be disseminated in the network for sink to follow the target.

Type of Sensors

The tracking techniques are widely different depending on the type of sensors used [9]. Those are

- Ordinary sensors
- Binary sensors

Ordinary Sensors

The ordinary sensor network consists of the type of sensor nodes that operate on original values of signals. Thus the distance, speed and direction of target have to be calculated on the basis of signal strength measured by the sensor nodes.

Binary Sensors

The binary sensors work only on two binary values [4]. They can just detect the presence or absence of the target in their sensing range by signaling either by 1 or 0. The tracking mechanism in this case is more complicated than ordinary sensor networks.

Number of Targets Used

The tracking technique can be either for single target tracking or multiple target tracking. Tracking in single target is relatively simple

[5]. Less data is produced that results in a low traffic in the network. Less traffic is easier to handle and the routing mechanism is not complex. Multiple Target Tracking, the location of multiple targets has to be tracked simultaneously. Increasing the number of targets to be tracked increases the network traffic and thus more complex routing schemes and energy minimization techniques have to be incorporated to compensate for the network performance.

Technology Used for Implementation of Tracking in Wireless Sensor Networks

Various technologies can be used for implementation of tracking techniques in wireless sensor networks including Zigbee, Bluetooth etc., [12]. Mostly the technology which uses Omni directional antennas can be used for the implementation of tracking in wireless sensor networks. This is because the presence of target has to be felt, whatever the direction of motion of target is. The Omni directional antennas solve the purpose of tracking.

Conclusion

A wide range of technologies, network architectures and types of sensors are available for tracking in wireless sensor networks. There is a performance tradeoff in energy, tracking error and other performance parameters. To design a wireless sensor network for object tracking or to do research in proposing new techniques the classification of techniques has to be kept in mind with their relative tradeoffs to achieve affective results.

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