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Target Tracking in Wireless Sensor Network: A Survey

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***Abstract*: In this work we have discussed applications and various issues of target tracking in wireless sensor networks and made a survey on related works. Our survey identifies some open research problems which can be addressed for achieving energy efficient target tacking in wireless sensor networks.**

Keywords— **wireless sensor network, target tracking methods, protocols, metrics, research issues.**

I. INTRODUCTION

Wireless Sensor Networks (WSN) comprises of smart sensor nodes capable of collecting, processing, storing and communicating information from one node to another. Sensors can monitor a wide variety of conditions like - temperature, pressure, humidity, soil makeup, vehicular movement, noise levels, lightning, the presence or absence of certain kinds of objects, mechanical stress levels on attached objects and so on[1]. Sensors node deployment may be tri-angular, square or irregular sensor deployment. As sensor nodes have some intelligence, data can be processed as it flows through the network. Depending on environment where they are placed WSN may be categorized as - Terrestrial WSN, Underground WSN, Underwater WSN, Multimedia WSN, Mobile WSN etc [3]. Depending on the environment, a sensor network faces different challenges and constraints. As sensor nodes operate on limited battery power, energy usage is a very important concern in a WSN and there has been significant research that focuses on harvesting and minimizing energy [3].

Target tracking is concerned with approximating the trajectory of one or more moving objects based on some partial information, usually provided by sensors [2]. Target tracking protocols can be mainly classified into five schemes, which are: tree - based tracking, cluster-based tracking, prediction-based tracking, mobicast message-based tracking and hybrid methods [2]. Sensor networks used in target tracking face two kinds of major problems [5] – efficient networking & energy-saving techniques (as sensors have to communicate with one another or with a base to transmit results of local computation) and efficient processing of information gathered by sensors.

Wireless Sensor network (WSN) has great potential to be employed in critical situations in military, environmental, commercial and other applications. Detection and tracking of Targets has become an increasingly important application for sensor networks. Designing efficient target tracking methods to track moving objects is essential due to its increasing need in various fields.

The rest of the paper is organised as follows. Section II presents a review of related works in wireless sensor network with the focus on various target tracking methods, protocols and metrics for analysing the target tracking methods. In Section III we discuss various issues in wireless sensor network. In Section IV, we have proposed some open research problem that can be addressed. Section V presents conclusion and future work.

II. LITERATURE SURVEY

A. Sensors and Sensor Networks

A Sensor Network is composed of a large number of low-cost, low-power, multifunctional sensor nodes of different types that are used to monitor a wide variety of conditions like- temperature, humidity, vehicular movement, lightning condition, pressure, soil makeup, noise levels, the presence or absence of certain kinds of features, mechanical stress levels on attached objects, and characteristics related to a target such as speed, direction, and size of an object etc[4]. A sensor node usually consists of four sub-systems: -

1. *A computing subsystem*: In a sensor node, the microcontroller unit is responsible for functions such as control of sensors and execution of communication protocols.
2. *A communication subsystem*: This comprises of short range radios used to communicate with neighboring nodes and the outside world. These devices operate under the Transmit, Receive, Idle and Sleep modes having various levels of energy consumption.
3. *A sensing subsystem*: This subsystem consists of sensors and actuators and is responsible for the sharing of information between the sensor network and the outside world.
4. *A power supply subsystem*: It consists of a battery which supplies power to the node.

B. Characteristics of WSN

Some unique characteristics of a wireless sensor networks include -

1. Limited power & processing capabilities
2. Heterogeneity of nodes
3. Mobility of nodes
4. Large scale of deployment
5. Dynamic network topology
6. Ability to withstand harsh environmental conditions
7. Ability to cope with node failures etc.

C. Applications of WSN

Wireless Sensor Network finds in a wide variety of application in several fields –

1. *Military Applications* -Monitoring Friendly Forces, Equipments and Ammunition, Battlefield Surveillance, Targeting, Battle Damage Assessment, Nuclear, Biological and Chemical Attack Detection
2. *Environmental Applications* - Environmental control in office building, Forest Fire Detection, Flood Detection, Monitoring Biodiversity
3. *Habitat Monitoring Applications* – monitoring of wild animals,
4. *Health Applications*- Tele-monitoring of Physical Data, Tracking and Monitoring Doctors and Patients in a Hospital, Drug Administration in Hospitals
5. *Home and Office Applications* - Smart Homes, Home automation, Inventory Control
6. *Other Applications like*- Target Tracking, Monitoring Nuclear Reactor, Suspicious Individual detection, Fire Fighting etc and many more.

D. Target Tracking Methods

Tracking moving objects using WSN is an important application. Several methods for efficient target tracking have been proposed [5]. Kalman Filter approaches (discretization approaches over the configuration space), Particle Filtering (a technique introduced in the field of Monte Carlo simulations), Probabilistic methods (used in robotics for simultaneous localization and mapping-SLAM in which the robot attempts to track itself using the sensed position of several landmarks) and many others.

Traditional target tracking methodologies make use of a *centralized approach.* As the number of sensors rise in the network, more messages are passed on towards the sink and will consume additional bandwidth. This approach is not fault tolerant as there is single point of failure and it also lacks scalability. Also in traditional target tracking methods, sensing task is usually performed by one node at a time resulting in less accuracy and heavy computation burden on that node. Target tracking in the course of maintaining a balance between network resources like energy, bandwidth, and overheads is challenging. Traditional tracking methods lack the ability to optimistically deal with identification of multiple targets and their tracking. Though, some protocols are competent in terms of energy efficiency, additional research is required to tackle issues such as quality of service posed by video sensors and real time applications.

A *minimalist approach* is the binary sensor network model [5] in which a sensor node consists of sensors that can detect only one bit of information (indicating whether the object is approaching or moving away) and broadcast this bit to a base station. This minimalist binary sensor network with only one bit gives reliable direction information for tracking, but an additional bit provided by a proximity sensor is necessary to determine the exact location of object.

E. Classification target tracking protocols

Target tracking protocols may be classified into following major categories [2] –

1. *Tree-based target tracking protocols*: nodes in a network may be organized in a hierarchical tree or represented as a graph in which vertices represent sensor nodes and edges are links between nodes that can directly communicate with each other.
2. *Cluster based architecture*: clusters are formed statistically at the time of network deployment and the properties of each cluster are fixed such as number of members, area covered, etc. Cluster-based methods provide scalability and better usage of bandwidth than other types of methods. If cluster head is formed via local network processing, extra messages are reduced and fewer messages are transmitted towards base station thus providing security as well as less usage of bandwidth. Clustering may be static or dynamic
3. *Prediction-based tracking protocols*: rely on tree-based and cluster-based tracking in addition to prediction. These models assume that moving object will continue the current speed and direction for the next few moments and process historical data to deduce subsequent movement of a mobile object. These methods allow limited number of sensors to track the moving object.
4. *Mobicast message-based tracking protocols*: depends on prediction. It is a spatiotemporal multicast method in which message is delivered to a group of nodes that change with time according to estimated velocity of moving entity. The mobicast message contains location and time of discovery of mobile entity.
5. *Hybrid protocols*: employ clustering, prediction and scheduling mechanism such as DPT, PES, etc thus giving better performance in terms of energy consumption as compared to other approaches.

F. Metrics for analysing target tracking protocols

Metrics for analysing target tracking protocols [2] vary depending on the objectives of the protocols.

Metrics such as *cluster formation*, *tracking accuracy* and *missing track recovery* are proportional to energy utilization in target tracking sensor network. If message communication is high for cluster formation, more energy is consumed. High tracking accuracy demand requires additional energy usage. Similarly missing track recovery will increase overheads and energy consumption.

Other metrics for target tracking protocols may be

- *error ratio*
- *number of change of directions*
- *missing time*
- *varying speed of target*
- *remaining energy of sensor nodes*
- *distance between source and object*
- *network life time*
- *cluster head life time*

- *effect of number of clusters*
- *effect of active radius*
- *total energy consumption of the network*
- *total packet overhead*
- *time before the first node dies*
- *impact of sampling duration*
- *impact of sampling frequency.*

The total energy consumption analysis during target tracking is the key concern in the majority of the protocols as sensor nodes are constrained in energy. The energy consumption of a sensor node can be divided into three main domains, radio communication, sensing and data processing.

III. OPEN RESEARCH ISSUES

Though a lot of research has been already done in the area, however, application of WSN in a variety of application areas brought many open issues to researchers. Open research issues for target tracking applications include [2]

1. Dealing with moving object direction changes and varying speeds,
2. Energy efficient missing target track recovery
3. Performance comparison of static and dynamic network,
4. Relationship between energy consumption with cluster formation,
5. Tracking Precision & Prediction Accuracy,
6. Designing well organized computing and nominal transmission of messages without degradation of performance as message transmission consumes a lot of energy
7. Sensor node fault tolerance - For many applications the sensor nodes are deployed in harsh environments so various nodes may fail, may be attacked or node energy may be depleted due to obstacles. Therefore, fault tolerant target tracking algorithms and protocols must be designed for wireless sensor networks as the fault tolerant approaches developed for traditional wired or wireless networks are not well suited for WSN because of various differences between these networks.

Energy Consumption is the key concern in target tracking protocols [5]. When a sensor node is depleted of energy, it will die and get disconnected from the network which can significantly impact the performance of the application. Sensor network lifetime depends on the number of active nodes and connectivity of the network, so energy must be used efficiently in order to maximize the network lifetime. Energy harvesting involves nodes replenishing its energy from an energy source. Potential energy sources include –solar cells, vibration, fuel cells, acoustic noise, a mobile energy supplier etc. In terms of harvesting energy from the environment, solar cell is the most popular technique that harvest energy from sunlight. There is also work in using a mobile energy supplier such as a robot to replenish energy. The robots would be responsible in charging themselves with energy and then delivering energy to the nodes.

Energy conservation in a WSN maximizes network lifetime and is addressed through efficient reliable wireless communication; intelligent sensor placement to achieve adequate coverage, security and efficient storage management; and through data aggregation and data compression. These approaches aim to satisfy both the energy constraint and provide quality of service for the application. For reliable communication, services such as congestion control, active buffer monitoring, acknowledgements, and packet-loss recovery are necessary to guarantee reliable packet delivery. Communication strength is dependent on the placement of sensor nodes. Sparse sensor placement may result in long-range transmission and higher energy usage while dense sensor placement may result in short-range transmission and less energy consumption.

Coverage is interrelated to sensor placement. The total number of sensors in the network and their placement determine the degree of network coverage. Depending on the application, a higher degree of coverage may be required to increase the accuracy of the sensed data.

Implementation of protocols at different layers in the protocol stack can significantly affect energy consumption, end-to-end delay, and system efficiency. It is important to optimize communication and minimize energy usage. Traditional networking protocols do not work well in a WSN since they are not designed to meet these requirements. Hence, new energy-efficient protocols have been proposed for all layers of the protocol stack. These protocols employ cross-layer optimization by supporting interactions across the protocol layers. Specifically, protocol state information at a particular layer is shared across all the layers to meet the specific requirements of the WSN.

A sensor node cannot store large amount of data like a server in the Internet, and acknowledgements are too costly for sensor networks. Therefore, new schemes that split the end-to-end communication probably at the sinks may be needed [4]. Protocols need to be improved or new protocols need to be developed to address higher topology changes and higher scalability. Also, new internetworking schemes should be developed to allow easy communication between the sensor networks and external networks. Though some medium access schemes have been proposed for sensor networks, the area is still largely open to research. So is the mainly unexplored domain of error control in sensor networks. Key open research issues include - MAC for mobile sensor networks, Determination of lower bounds on the energy required for sensor network self-organization, Error control coding schemes, Power saving modes of operation etc. The physical layer is a largely unexplored area in sensor networks. Open research issues range from power efficient transceiver design to modulation schemes. A few of these are - Modulation schemes, Strategies to overcome signal propagation effects, Hardware design Power efficient hardware management etc.

IV. Research Problems to be addressed

Though a lot of work has been done and is going on in wireless sensor network we would like to highlight some open research problems which can be addressed.

1. Work may be done to reduce cost of infrastructure still maintaining the efficiency by reducing the number of sensors or considering sparse deployment of sensors or by using low cost binary sensors.
2. Efficient use of energy to maximize the network lifetime. Energy conservation in a WSN maximizes network lifetime and Energy harvesting replenishes energy from an energy source. Work may be done in this area to satisfy both the energy constraint and provide quality of service for the application.
3. Protocols need to be developed to address higher topology changes and higher scalability. New internetworking schemes should be developed to allow easy communication between the sensor networks and external networks. One of the unexplored domains is error control in sensor networks The physical layer is another largely unexplored area in sensor networks with various issues like power efficient transceiver design, modulation schemes, strategies to overcome signal propagation effects etc. Thus work may be done for developing technologies needed for different layers of the sensor networks protocol stack.
4. Message transmission consumes more energy than local processing, thus, work may be done for designing target tracking method with the consideration for well organized computing and nominal transmission of messages without degradation of performance.
5. Though there are target tracking protocols competent in terms of energy efficiency, they lack the ability to optimistically deal with identification of multiple targets, tackle issues such as quality of service posed by video sensors and real time applications. So work may be done to address issues such as - dealing with moving object direction changes and varying speeds, fault tolerant target tracking algorithms, energy efficient missing target recovery and performance, comparison of static and mobile network, relationship between energy consumption with cluster formation, tracking precision, prediction accuracy etc.
6. Designing randomized target tracking techniques.

V. Conclusions and future work

This work surveys the related research works on wireless sensor networks as far as the target tracking is concerned. Some of the open issues research problems are proposed which can be taken up in future research of target racking in wireless sensor networks.

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