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A survey on Object Tracking Techniques in Wireless Sensor Network

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Abstract - *WSN (Wireless Sensor Network) is a collection of battery powered tiny sensor nodes which has ability of collecting, processing, storing and transferring the sensed data from one node to another. These capabilities make sensor network to be used for many applications like environmental monitoring, intruder detection, object tracking and many more. Due to several resource constraint designing tracking algorithm in terms of tracking quality and energy efficiency is challenging issue in WSN and has gained worldwide attention in recent years*

In this survey paper, we overview object tracking methods based on network architecture.

***Key Words*: wireless sensor network, object tracking, clustering, prediction**

1. INTRODUCTION

Wireless Sensor Networks (WSN) is group of small sensor nodes connected by wireless media. They are low cost, battery powered, placed randomly to form a sensor field. The sensors are distributed to monitor physical or environmental conditions, such as temperature, sound, vibration, motion, pressure or pollutants. It has an ability to work cooperatively and pass their data through the network to the Base Station (BS) or a sink node. WSN has the ability to dynamically adapt to changing environments.

Object tracking is one of the challenging application for Wireless Sensor Network in which group of wireless sensors nodes are involved in the task of tracking a moving object. It consists of mainly two phase: 1) Detection of object 2) Monitoring and tracking of object. Object Tracking is widely used in many applications like military application, commercial applications, field of surveillance, intruder application and traffic applications.

There are various metrics for analysing object tracking such as cluster formation, tracking accuracy, cluster head life time, miss rate, total energy consumed, distance between the source and object, varying speed of the object, etc. The open issues in object tracking are detecting the moving object's change in direction, varying speed of the object, object precision, prediction accuracy, fault tolerance and missing object recovery. In all tracking process, more energy is consumed for messages or data transmission between the sensor nodes or between the sensor and sink. [16]

In traditional object tracking all the sensor node pass their sensed data to the one node (base station or a sink node) therefore computation burden increases at that node, results in less accuracy and reduction in energy efficiency of that network and if number of sensor increases in the network, more number of messages are passed to Base station which consumes more bandwidth. Therefore, this approach lacks scalability. Also, if that one node fails due to reduction in energy whole network collapse. It is called as centralized approach. In WSN, each node has very limited power and consequently traditional tracking methods based on complex signal processing algorithm are not applicable.

In an object tracking application, the sensor nodes which can sense the object at a particular time are kept in active mode, while the remaining nodes are to be retained in inactive mode so as to conserve energy until the object approaches them. To continuously monitor mobile object, a group of sensors must be turned in active mode just before object reaches to them. The group of active sensor nodes varies depending on the speed of moving object. Those group of active sensors are scheduled by cluster head. The sensor nodes detect the moving object and transmit the information to the sink or the base station. [15]

The object tracking algorithm should be designed in such a way that it results in good quality tracking with low energy consumption. The good quality tracking extends the network lifetime and achieves a high accuracy.

2. Related Work

In this section we review different approaches used in object tracking based on network architecture. Object tracking in WSNs has been studied with different perspectives. Some of the object tracking algorithms are proposed to improve the energy efficiency, localization accuracy, tracking quality. Some are designed to give solutions for challenges in object tracking. Fig. 1 depicts classification of network architecture used in object tracking.

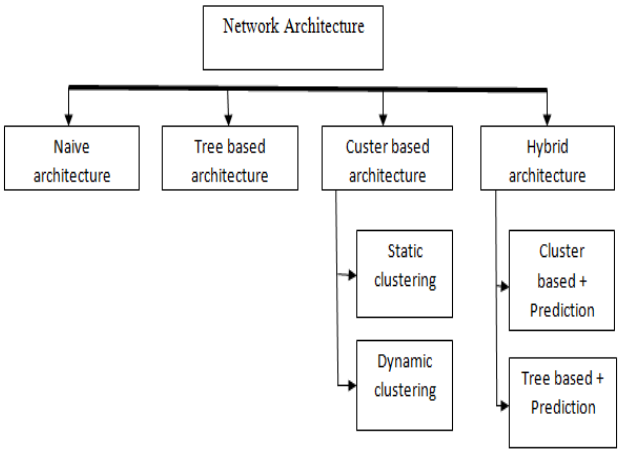

Fig-1: Classification of network architecture

2.1 Naive architecture

Naive architecture (or centralized) based tracking method is the simplest approach, in which all nodes are in tracking mode all the time. In this case all the network nodes are at the same level in terms of work responsibility. All the sensor nodes always try to intercept and monitor object which comes within their sensing range and pass monitored information to centralized sink node or base station. Sink node solely execute the entire computation burden for processing gathered data received from network nodes and locating object. More sensor nodes the network has, the more messages are relayed onto sink node which results in heavy computation and increasing bandwidth consumption. This makes the naive architecture method not robust against sink node failure especially for the case of link failure and channel congestion.

2.2 Tree based architecture

Tree-based methods organize the network into a hierarchy tree. Some algorithms are Scalable Tracking Using Networked Sensors, Dynamic Convoy Tree-based Collaboration and Optimized Communication and Organization.

H. T. Kung et al. Have proposed STUN [6] where construction of the tree is based on the costs. Cost is computed from the Euclidean distance between the two nodes and assigned to each link of network graph. The leaf nodes are used for tracking the moving object and then sending collected data to the root node through intermediate nodes. Distance travelled by the tracking object is limited here.

Wensheng Zhang has proposed DCTC [12] algorithm, dynamically constructs a tree for mobile object tracking and depending on the object location, a subset of nodes participate in tree construction. The tree in the DCTC is a logic tree which means it does reflect the physical structure of the sensor network.

Sam Phu Manh Tran *et al.* Have proposed, OCO [10] is a tree-based method for object tracking that provides self-organizing and routing capabilities. Advantage of this method is low computation overhead on nodes. Disadvantage is it does not consider Authentication and security features.

2.3 Cluster based architecture

Cluster based architecture is used to facilitate collaborative data processing, in which large network is divided into small regions called cluster. Each cluster has a cluster head (CH) and slave nodes (members). Clustering is particularly useful for applications that require scalability to hundreds or thousands of nodes.

Any clustering algorithm consists of four stages:

- Geographical formation of clusters
- Selection of cluster heads (CH) which has high capabilities than other sensor nodes. The selection depends on various parameters such as residual energy, processing capabilities, location from object.
- Data aggregation in order to send gathered data sensed by member nodes to cluster heads.
- Data transmission stage in which cluster head transmit aggregated data to sink node.

Based on how clusters are formed they are classified into two types: Static clustering, Dynamic clustering.

2.3.1 Static clustering

In static clustering, clusters are formed manually at the time of network deployment. The attributes of each cluster, such as the size of a cluster, the area it covers, and the members it possesses are fixed throughout the network lifetime. In spite of its simple architecture, the static cluster architecture suffers from several drawbacks. First, static membership is not robust from the perspective of fault tolerance. If a CH dies due to power depletion, all the sensors in that cluster render useless. Second, static attributes prevents sensor nodes in different clusters from sharing information and collaborating on data processing.

Formation of a cluster is triggered by certain events of interest (e.g., detection of an approaching target with acoustic sounds). Unlike static clustering approaches, in dynamic clustering approach sensors are not static members of a particular cluster throughout network lifetime, they may support different clusters at different times.

2.3.2 Dynamic clustering

Examples of dynamic cluster-based tracking are but not limited to RARE, Dynamic Clustering Tracking Algorithm DCTA and Adaptive Dynamic Cluster-based Tracking (ADCT).

Wei-Peng Chen *et al.* have proposed, Dynamic clustering algorithm [11] for acoustic object tracking in WSNs, constructs a voronoi diagram for CHs and nearest CH to object in each interval time is selected as active CH. Then

active CH broadcasts a message and nodes that receive this message reply and send the information that have sensed from object for it. Active CH, calculates current object's location and sends it to the sink. Conflict may occur when more than one CH has the same pre-determined threshold, which lead complication in CH selection.

A cluster-based algorithm for tracking by Khin Thanda Soe has proposed [5] consists of three main phases, object detection, acoustic source localization and object state estimation and tracking.

Olule, E. *et al.* have proposed [9] is based on two algorithms, RARE-Area (Reduced Area REporting) and RARE-Node (Reduction of Active node REdundancy). RARE-Area reduces number of nodes participating in tracking and RARE-Node reduces redundant information.

Dan Liu, Nihong Wang *et al.* have proposed, Dynamic cluster based algorithm [7] wake up or slept the sensing nodes though predicting the moving track of the object, reduce the number of tracking nodes to minimize network energy consumption. Selecting the optimal nodes to conduct the tracking task along the predicted moving track will also guaranty load balancing and extends network lifetime.

2.4 Hybrid architecture

Hybrid architecture generally combines one of the previously mentioned architectures with some prediction mechanism.

Examples are PES (Prediction-based Energy Saving), DPR (Dual Prediction-based Reporting) and DPT (Distributed Predicted Tracking). These methods focus on increasing energy efficiency by keeping most of nodes in sleeping mode.

Yingqi Xu *et al.* have proposed, DPR [14], where the next location of object is calculated at both sensor nodes and sink. When the difference between real location and predicted location is acceptable, no update message sends to sink and therefore less packets are transmitted to the sink which results in less utilization of communication bandwidth.DPR reduces the energy consumption of radio components by minimizing the number of long distance transmissions between sensor nodes and the sink node with a minimal overhead. In DPR, both the base station and sensor nodes make identical predictions about the future movements of mobile objects based on their moving history. Disadvantage of this method is Error in sensor detection and communication collisions in network is not recoverable. Computation cost is greater because prediction is done at base station as well as sensor nodes.

Mohammad-Taghi Abdizadeh *et al.* have proposed, Adaptive Prediction-based Tracking (APT) [8] scheme is proposed that enables tracking in the sensor network to achieve a certain level of self-cognition for modifying the tracking time interval based on movement patterns with acceleration. Therefore this algorithm significantly decreases the network power consumption and achieves a smaller miss probability.

H. Yang *et al.* have proposed, Distributed Predictive Tracking [DPT] [13], uses separate algorithms for nodes and CHs. The protocol uses a clustering based architecture for scalability and a prediction based tracking method to provide a distributed and energy efficient solution. The CH uses the object descriptor to identify object and predicts its next location. Advantage of this protocol is it is robust against node or prediction failures which may result in temporary loss of the object and recovers from such scenarios quickly with very little additional energy use. To achieve low miss rate, the DPT algorithm should be extended.

An auction based adaptive sensor activation algorithm for target tracking in WSNs is presented in (Zhenga et al., 2014) [17] where the authors used an auction mechanism for selecting the cluster head. In each iteration of the tracking operation, the cluster head predict the region where that target may move. Based on this predicted region, only nodes within this region are activated and the rest remain in sleeping mode. Algorithm has proven itself in terms of the network lifetime, energy efficiency and accuracy of tracking.

3. CONCLUSIONS

Based on the survey, we found that all the object tracking methods aim to minimize number of active sensor nodes to minimize energy consumption. There is always tradeoff between energy efficiency and accuracy. Most of the algorithms try to maintain balance between them.

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