Methods for Target Tracking in Sensor Networks with Energy-Efficient Approach

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Abstract

The target tracking methods can be categorized into tree-based, clustering, prediction and Mobicast methods. In The tracking algorithm based on clustering, the cluster member nodes detect the target and send the data to cluster head. One of the important advantages of clustering-based methods is that it increases the network lifetime while keeping energy consumption. In the tracking algorithm based on prediction, the next position of target is predicted according to the current target speed and direction. These algorithms make use of sleeping nodes. As a result, they reduce the energy consumption and increase the lifetime of network.

Keywords: Sensor Network, Target Tracking, Energy Consumption, Clustering.

1. Introduction

Wireless sensor networks have many interesting applications. These fields can refer to target detection and tracking, environmental monitoring, industrial process monitoring, and planned systems. Since the optimization of energy consumption determines the lifetime of used sensor network, this is an important topic of research in wireless sensor networks. Target tracking is an important application in wireless sensor networks and energy efficient target tracking algorithms are used for precise tracking. Wireless sensor networks consist of a large number of inexpensive wireless sensor nodes. Each of these nodes can collect the process and store the environmental information and also they have the ability to establish connections with neighboring nodes. Mobile target tracking is one of important fields that can be used in the wireless sensor networks. For example, some cases could be mentioned as following: embedding the military survivor's surveillance systems, environmental and industrial monitoring, systems monitoring to staff and wildlife are needed for tracking programs. The energy source of Sensor nodes in wireless sensor networks is usually a battery whose recharging and replacement is impossible and even harmful. Thus the main challenge in the researches about tracking methods in the wireless sensor networks is optimization of energy consumption and maximization of network lifetime by reducing the energy consumption in every node and balancing the energy consumption of all
nodes. Energy economy is an important matter in the applications of wireless sensor networks. In this field, selecting the type of sensor nodes is an important principle at target tracking applications in sensor networks. For the correct choice of sensor nodes has a significant impact on increasing the efficiency of target tracking. Usually the sensor nodes are selected according to the type of targets.

II. Challenges for Target Tracking in Sensor Networks

Advantages of target tracking system in wireless sensor networks include: qualitative and correct observations, accurate signal processing, tracking accuracy, and strength increase of system. Sensor networks challenges include issues such as: a power supply and limited communication bandwidth, algorithms and distributed control, and control of performance limitations of sensor nodes, especially when the network size becomes large. Wireless sensor network has its own limitations in terms of design and supply. Limited energy, low-bandwidth, short-range communication, and limited processing and storage capacity of each node are of supply limitations. Limitation of design depends on network usage and is controlled based on environment. Environment plays an important role in determining the size of network, how to deploy the path and installation of a network. Energy consumption is an important design factor in wireless sensor networks.

III. The Methods of Target Tracking in Wireless Sensor Networks

Target tracking methods can be classified into methods based on tree (tree-based), clustering, prediction, and Mobicast. The nodes are classified into two groups i.e. cluster member and cluster head with clustering in the network. In the tracking algorithm based on clustering, the cluster member nodes detect the target and send the data to cluster-head. The Cluster head collects all information from the members and calculates the target position and sends this information to the Sink node (central receiver). One of the most important advantages of clustering-based methods is that it increases the network lifetime while keeping energy consumption. In the tracking algorithm based on prediction, the next position of target can be predicted according to the current target speed and direction. These algorithms make use of sleeping nodes. As a result, they have reduced the energy consumption and increased the lifetime of network. Mobicast routing protocols for Sink nodes are means for delivering messages as rapid and reliable. It also provides a strong relational extraction (isolation) for internal coordination and data aggregation in sensor networks. When an object (target) is identified, the group works. Then the group leader will receive the message Mobicast (including location estimation and target detection time) and sends it to the region. And it moves with respect to the estimated speed of target.
IV. Tree-based Tracking Methods

Some tree-based tracking methods include (Ramya et al., 2012):

- STUN (Scalable Tracking Using Networked Sensors)
- DCTC (Dynamic Convoy Tree-based Collaboration)
- OCO (Optimized Communication & Organization)
- DAT (Deviation Avoidance Tree)
- Z-DAT (Zone based-Deviation Avoidance Tree)

A. STUN method

In this method, some cost is awarded to all links in the network graph. This cost is calculated according to the Euclidean distance between two nodes. The tree is constructed on the basis of costs. Leaf nodes are used to detect the moving target and to send the collected data to a central receiver (sink) via intermediate nodes. Intermediate nodes hold the record (record) of identified targets on their own. And they send new information (updated) to the central receiver (sink) whenever a change occurs in the history (record). STUN efficiency is determined by the message prune hierarchical structure and tracking pattern of moving objects (Ramya et al., 2012).

B. DCTC method

DCTC method includes a spanning tree rooted at the sensor node that is close to the target and used to track it. Target position is estimated by the root sensor location. DCTC tree structure is called "protected tree" that includes the sensor nodes around the moving target. The tree is dynamically configured to add or prune the nodes while target moves (Zhang, 2004).
C. **OCO method**

OCO method (improved communication and organization) is a tree-based method used to track the target which has a self-routing and self-organizing capability with low and little computational overhead. There are three types of nodes in OCO (Mansh Tran et al., 2006): border nodes, forward nodes and redundant nodes. Different states of nodes in OCO are summarized in Table I.

<table>
<thead>
<tr>
<th>Table I</th>
<th>A SUMMARY OF THE VARIOUS STATES OF NODES IN OCO (Mansh Tran et al., 2006)</th>
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<tbody>
<tr>
<td></td>
<td>Boarder nodes</td>
</tr>
<tr>
<td>Sensor</td>
<td>Active</td>
</tr>
<tr>
<td>Radio</td>
<td>Receive</td>
</tr>
<tr>
<td>MCU board</td>
<td>Sleep; Weak up To Create Messages Only</td>
</tr>
</tbody>
</table>

Radio boards include all the nodes that are in Receive mode. Because the nodes need to relocate the data in OCO. Sensor boards include all the border nodes that are fully operational. Forward nodes are turned off and they are on when a message is received from a neighbor. Redundant nodes are used as support nodes. Sensor boards, Radio boards and MCU boards may be in one of two modes (Mansh Tran et al., 2006): Sleep Mode: In this mode, the energy loss is zero / full active Mode: In this mode, the power consumption depends on the related operations.
OCO method has four phases (step) (Mansh Tran et al., 2006):

Collection of locations: the base sensor node collects the location of all network nodes. 
Processing phase: This phase includes three steps. The base node has cleared the additional 
nodes, identified the border nodes, and performed the routing. 
Tracking Phase: it identifies all objects that enter out of range (ambient) of sensor network. 
Sensor nodes are usually clear on. When a border node identifies the object (using its original 
name), it periodically sends information about its location to the base sensor node. When it 
loses the object, it sends a clear message until sensor units turn on all its own adjacent nodes. If 
the adjacent node identifies an object, it continues sending the data to the base node. Just after it 
loses the object, all sensor units turn on their own neighbor nodes and the same situation 
continues. If activated neighbor nodes do not recognize an object, the sensor units will 
automatically turn off after a short interval. With this method, the objects are tracked until they 
are on the network.
Preservation Phase: It begins when a node is dead in the network (e.g., a node whose energy is 
finished). At this time, base node removes the dead node from the list, and then it organizes the 
network again with the commencement of same four-step process.

D. DAT method

DAT (deviation avoidance tree) has two phases (Ramya et al., 2012):
The first phase is designed to reduce the cost of updating and the second phase is to further 
reduce the search costs. Updating and searching may be done in several ways. Usually the update 
process begins when an object moves from one sensor to another sensor. One way to search is to 
search the entire network which this process is inefficient. Because when the network scale is 
large or search rate is high, energy consumption will increase. Another method is to put all the 
tracking information in a particular sensor (Sink). If so you do not have to search the entire 
network. This method is not also useful when objects are in movement and relocation frequently 
because the update should be performed regularly.

E. Z-DAT method

This method is similar to DAT. With the exception that it tests the links via a different 
arrangement. DAT and Z-DAT techniques are to reduce the cost of update. But sometimes they 
have difficult to reduce search costs (Ramya et al., 2012).

V. Clustering - based Tracking Methods

The clustering-based methods in target tracking divide the network into several clusters to 
support the coordinated data processing. A cluster consists of a cluster head (CH) and member 
sensor nodes. Formation of a cluster begins with the rise of interest. When the sensor with 
sufficient battery and calculation ability detects the interest signals, It is a volunteer to play the 
role of cluster head. Since more than one "strong" sensor may detect the signal, there may be a
few volunteers. To ensure that there is only one active cluster head around the target traced with high probability, a measured and decentralized Method should be used.

A. Static Clustering

In this way, the clusters form network arrangement statically. Properties of each cluster are static such as size, coverage area and number of members. Given the same simplicity, the statistic clustering faces to several problems. Its error threshold is not so high if a cluster head node is destroyed due to energy fades; all the subset sensors of this node are useless. The sensor nodes of different clusters cannot share information and cooperate with each other for a given process (Ramya et al., 2012).

B. Dynamic Clustering Method

Dynamic clustering algorithm in wireless sensor networks has applications for target tracking via sound waves. In this way Voronoi diagram is mapped to the cluster heads and the nearest cluster head to the target in each interval is one that puts a target with in its cell. The cluster head is selected as the active cluster-head. This active cluster head disseminates a small packet and the nodes respond that they have received the package. And they send information sensed from the target for this package. Active cluster head calculates the final position (current position) of target and sends to the central receiver (sink). Protocol for energy efficient target tracking is presented based on two algorithms Area-RARE (Reduced Area Reporting) and the RARE-Node (Reduction of Active node Redundancy) by dynamic clustering. RARE-Area reduces the number of nodes that participate in tracking by eliminating the presence of remote nodes in the tracking. RARE-Node reduces the redundant information by detecting overlapping sensors. Cluster is dynamically formed at the time of target tracking via prediction. Therefore the number of nodes involved in tracking decreases. Although this method has low energy consumption, but the missing target retrieval process is not well defined.

C. Method LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH (low energy and adaptive clustering hierarchy) is one of the most popular clustering algorithms in wireless sensor networks. This algorithm forms clusters based on the received signal strength. And it uses the cluster head nodes as a path to the main site. All data processing operations, such as composition and aggregation of data are done within the cluster. LEACH forms the clusters by using distributed algorithms, where the nodes decide independently (autonomous) and without any centralized control. Initially, a node decides to be a cluster head and spreads (transmits) its decision. Non- cluster head node determines its cluster by choosing a cluster head that reaches to it with the minimum communication energy. The role of load cluster head is periodical between cluster nodes in order to balance. Operations in LEACH are divided into two phases (Ramya et al., 2012): installation phase (Setup) and route maintenance phase (Steady). In set up phase, the clusters are formed and a cluster head is selected for each cluster. In Steady Phase, sensed data is sent to the central receiver (sink). Overall, this protocol has two major targets: one is to increase the lifetime of sensor networks by distributing energy consumption among all nodes in the network. And other reduces the energy consumption in network nodes performing the data aggregation and reduction of exchanged messages number.
VI. Tracking Method based on Prediction

Prediction-based methods, predict the next location of a moving target using a prediction mechanism. Such methods, after predicting the next location of a target, choose the number of nodes that are close to this location for tracking. And other nodes remain in sleep mode for energy saving. PES (Prediction based Energy Saving), DPT (Distributed Predicted Tracking) and DPR (Dual Prediction-based Reporting) are examples of algorithms based on prediction.

A. Method PES (Prediction-based Energy Saving)

Considering the fact that sometimes the motion of tracked objects is predictable, Energy saving programs are suggested based on a prediction called PES. To reduce the energy consumption for object tracking under acceptable conditions, this method, while makes inactive and creates sleep mode for other nodes, reduces the number of nodes participating in tracking activities. PES is composed of three parts (Ramya et al., 2012):
1. Prediction Model, it predicts the next motion of nodes participating in tracking activities.
2. Wake up mechanism, it is based on a number of initiatives in energy efficiency and calculated efficiency. It awakens the set of nodes when they must be active.
3. Recovery mechanism, it is used only when the tracking network loses the object.

B. Method DPT (Distributed Predicted Tracking)

DPT uses a method based on clustering for scalability and it uses a tracking mechanism based on prediction to provide a distributional and efficient solution in energy consumption. The algorithm does this argument how to select the sensor nodes which are located on the predicted path of a target motion in order to send "preparation "message. First, the cluster head node CHi predicts the next position of target.
Then the cluster head node CHi + 1 receives messages from cluster head node CHi that is in the predicted direction. And the cluster head node CHi finds three appropriate Sensor nodes based on data from sensor nodes belonged to its cluster which has two main conditions (Yang and Sikdar, 2003).
1. The nodes must have a minimum distance to the target.
2. The distance of nodes is less than r from the target.
Each sensor node has two radio radiuses called a normal radio radius (r) and radio radius (R).
After selecting the appropriate sensor nodes, the cluster head node sends messages to the selected nodes. If the cluster head node CHi + 1 cannot find enough nodes even with a distance less than R, then it requires help from its cluster head nodes. It has been proved that this protocol is resistant against all defects related to the node or a prediction that may cause loss of target temporary. And it is improved quickly and with very little extra energy in such situations.
C. Method DPR (Dual Prediction-based reporting)

Mechanism DPR (Dual Prediction-based Reporting) reduces the energy consumption in the radio parts by reducing the number of remote transmitters between main base (radix) and sensor nodes with acceptable overhead. In DPR, either main base and sensor nodes predict the future movements of moving objects according to their previous move equally. The sensor nodes can take decision concurrent to monitor the objects motion to determine whether or not the predictions are effective on the real condition of object motion. If the prediction is the same with supervised conditions. It is not necessary to send new data to the main database since it has correctly predicted the current movements of the object. Sensor nodes are responsible, however, for correcting the wrong predictions done in the main database. DPR is comprised of two main components (Xu et al., 2004): Location Model and Prediction Model. Choosing a location model determines that the motion of moving objects states should be granular. On the other hand, a prediction model estimates the next move of objects through the previous record of moving objects. Simulation results show that firstly, DPR reduces the power consumption for tracking in various states. Secondly, the energy is stored sustainable by DPR.

D. Method PBCA (Prediction-based Clustering Algorithm)

A prediction-based clustering tracking algorithm is proposed in this method. This algorithm does not run in the cluster head (CH) nodes, but it is run locally at the sensor nodes. The following definitions are used in this algorithm (Pravin and Vijeyakumar, 2012):

thr is a user-defined error threshold.

PL-is the next location of predicted target  And CL is the current location of target. Algorithm description:

Firstly the next target location is predicted by the active cluster head (CH) (calculated PL). If PL is running in the cluster, then it activates the cluster head. And three nodes near to PL are selected. Then one of them is selected as a Leader and PL message is sent to the Leader. And also Leader node ID is sent to other two nodes. Each node except the leader node has computed its distance to the target and sends it as a message to Leader. Leader node receives the messages from other two nodes and calculates its distance to the target. Leader node then calculates the
amount of CL using trilateration algorithm. If |CL-PL| < thr then a message of CL will be sent to the cluster head. If the above condition is not established, the nearest cluster head to PL is elected as an active cluster head (CH) with a message. If the active cluster head receives a message from Leader node, it sends CL and location of the message to Sink. Otherwise, it sends PL to Sink. It is observed that method PBCA uses two sensor nodes selected in each time period and both send to the third node (leader) their distance to target and location is done via this node. While in previous methods, each node sends to another cluster head its distance to target and the cluster head (CH) performs the track. This makes the method PBCA to reduce power consumption in the network compared to other methods. Because it reduces the transmission distance of location packages sent and therefore increases the network life time.

Trilateration algorithm uses the following equation to calculate the current target location (CL).

\[
(x_i - x_t)^2 + (y_i - y_t)^2 = d_i^2 \quad (i=1,2,3)
\] (1)

In the above equation \((x_i, y_i)\) is the coordinates of node \(i\), \((x_t, y_t)\) is the coordinate of target and \(d_i\) is the node distance \(i\) from target.

Figure 4 shows the difference in performance of location algorithm using the active cluster head (CH) node and Leader node (Deldar and Yaghmaee, 2011).

Figure. 4. (a) Location using the active cluster head (CH) node (b) location using leader node.
Comparing the number of disabled nodes and average energy consumption between three algorithms based on prediction (DRP, PES and PBCA) is shown in Figures 5 and 6 respectively.

![Figure 5](image1.png)

**Figure 5.** Comparing the number of disabled nodes in 3 clustering-based algorithms.

![Figure 6](image2.png)

**Figure 6.** Comparing the average energy consumption in 3 cluster-based algorithms.

**E. Method PET (Prediction-based energy-efficient target tracking protocol)**

This approach has deduced the path of target motion. It determines the amount of energy stored to track the target in the network with respect to the patterns obtained from a moving target. PET is produced with the cooperation of sensors and this cooperation allows the target to be identified with greater accuracy and speed. This method predicts the future position of the target using a
linear prediction. Because some sensors may have usable data, then skillful selection of sensors with the best data for cooperation can be very valuable in power consumption. PET firstly has determined the target location and then predicts the next target location truly using 2 dimension normal distribution (Ramya et al., 2012).

VII. Mobicast based Tracking Methods

It is a new communication model in a simultaneous multi-channel data transmission in which the transfer related to space and time (space-time) is called Mobicast. The distinguishing feature of this new form of simultaneous information transfer is that the delivery of data to all nodes occurs in a certain region of space and in a specific point of time. This defined area is a geographic area and is used as a transfer region here. The Receptors of messages are sent to multiple networks simultaneously. Transmission regions vary in different intervals. When they constantly monitor the moving object, the accuracy in prediction of transmission region is a key performance measure for designing the efficient routing protocols in energy consumption. The accuracy of prediction is used to determine the shape, size, and location of transmission region at the right time. The more prediction accuracy is, the more energy is saved.

A. Routing Protocol FAR (Face-Aware Routing)

A completely new Routing protocol Mobicast has been proposed called FAR for tracking function. Protocol FAR is a geometrical protocol that has reliable tracking results. It estimates the reliability and routing protocols simultaneously (Ramya et al., 2012). Protocol FAR should provide a list of spatial-temporal neighbor at regular intervals that will result in heavy communication overhead to achieve this reliability.

B. Routing Protocol Mobicast based on VE (Variant-Egg)

Mobicast VE-based routing protocol can determine the location and shape of messages transmission region in the sensor networks effectively and adaptively to keep awake the number of sensor nodes equally. With respect to both speed and direction, VE-Mobicast protocol can improve the accuracy of prediction in transmission region (Ramya et al., 2012). However, message delivery method is node-based in VE-Mobicast. This method which is a fully distributed method is not efficient enough and wastes energy too.

C. Routing Protocol Mobicast based on HVE (Hierarchical Variant-Egg)

HVE-Mobicast routing protocol is a routing protocol VE-Mobicast based on clustering. Transmission of nodes' message in a transmission region of routing protocol HVE-Mobicast is transmitted in two phases: Phase I cluster to cluster and phase II cluster to node. In the cluster to cluster phase, cluster heads and nodes are distributed awake. In the cluster to node phase, cluster head nodes awake all member nodes according to the estimated time of transmission region appearance. The main field in which routing protocol HVE-Mobicast cooperates is energy efficiency (Chen et al., 2009).
VIII. Conclusions

In recent years, wireless sensor networks have been the subject of speculation. The growing use of these networks has a significant impact on military and civilian areas particularly in remote and enemy-occupied areas. Efficient use of energy is one of the key challenges in designing the target tracking protocols in the wireless sensor networks given the limited energy resources of sensor nodes. The ultimate goal in designing the protocols is to increase the lifetime of this network using the sensors as soon as possible. LEACH algorithm has more efficiency than other tracking algorithms based on clustering either for energy consumption and for message transmission.

References


