An Efficient Process to Track the Objects in Wireless Sensor Networks using Dynamic Clustering Algorithm

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Abstract— Object tracking sensor network(OTSN) is one of the important application of wireless sensor networks. OTSN is for detecting moving objects, therefore need a dynamic clustering algorithm for efficient data aggregation and data routing in OTSN. This paper proposes an algorithm to avoid redundant data and also reduces energy consumption based on prediction result of moving objects. LEACH is used to elect the cluster head randomly and periodically to prevent energy consumption. It also introduces an algorithm for cluster formation to minimize the overlap area between two clusters which would cause redundant data and unnecessary data transmissions from the cluster head to base station. Thus this paper uses dynamic clustering algorithm to achieve more energy efficiency and better performance.

Key words: Wireless sensor network, data transmission, redundant data

I. Introduction

Wireless sensor networks (WSNs) have gained worldwide attention in recent years. WSN is used for certain task such as battle field surveillance, large-scale environment monitoring. Because of the characteristics of sensor that it is cheap and it is very difficult to replace their battery after deployed, sensors are very dependent on their own battery. Therefore, energy efficiency is the most critical issues in WSN.

Object tracking is one of the non-trivial applications of wireless sensor network. OTSN can be used for military area intrusion detection and wildlife animal monitoring. Because of the the characteristics of sensors, OTSN requires an algorithm that can increase energy efficiency as well.

In general, a sensor is composed of sensing module and a communication module. Sensing module is used when sensor detects an object or sense the state of objects, and communication module is used when a sensor communicates with another sensor or base station to send or receive data. In sensing module, the sensor nodes that can sense the target at a particular time are kept in active mode while the remaining nodes are to be retained in the inactive mode which will save energy until the target approaches them. In order to continuously monitor the object, a group of sensors must be turned in active mode just before the target reaches to them. This group of active sensors varies depending on the velocity of the moving object. In communication module, when the senor nodes are in active mode, it can transmit data or receive data and consumes energy. But in the inactive mode, it doesn't sense, transmit, or receive anything.

There are two research topics on OTSN in this paper. One is Prediction algorithm [1][2][3][4], and the other one is clustering [5][6][7]. In Prediction algorithms, a sensor can predict the future movement of moving object using control sensor's state (active mode, sleep mode), it can maximize energy efficiency. Usually, the protocols related to prediction focus on two factors below. One is monitoring method, and the other is reporting method.

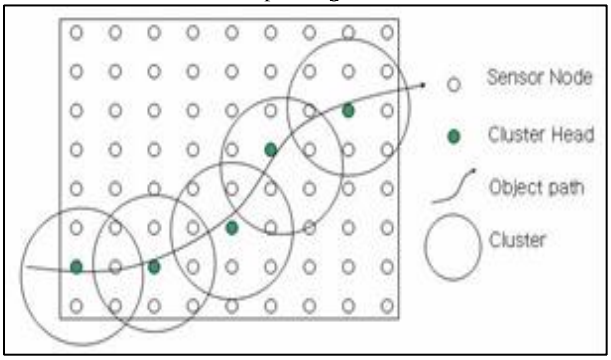


Fig. 1: Dynamic Clustering Mechanism for OTSN

As it shows in Fig. 1, another important topic in OTSN is dynamic clustering. The reason why we need clustering is usually to facilitate data aggregation. In general, the cluster head is responsible to forward the data from the cluster member nodes to the base station. But if the cluster head is activated for data forwarding to base station whenever it receives any data from the member nodes, the base station not only receives many duplicated data but also consumes unnecessary energy in communication.

LEACH is one of famous cluster-based routing protocols in WSN. In LEACH, cluster head is elected randomly and periodically. Therefore, energy consumption is distributed evenly. However, because cluster head is randomly elected, LEACH is not fit for moving object tracking scenario. So we need a dynamic clusteing algorithm for moving object tracking. Moreover, when the cluster formation mechanism is not carefully designed, the overlap area between clusters may be very large, and the sensor nodes in such overlap areas may produce much duplicate (or redundant) data that may cause unnecessary data transmissions. Thus an efficient dynamic clustering mechanism with the consideration of the object moving is desired for OTSN cluster formation.

Many researches have been done on the prediction algorithm of object moving and dynamic clustering mechanism in OTSN. But none of them tend to develop a mechanism that considers both of these two very important aspects in OTSN.

This paper proposes a dynamic clustering mechanism to minimize inter-cluster overlap. By this scheme, duplicated data communication can be reduced when a cluster head sends the aggregated data to the base station. Therefore, by implementing this scheme, the OTSN can be more energy efficient.

II. RELATED WORKS

Nowadays, the researchers are developing to important topics in OTSN. One is prediction bsed object tracking, and the other is clustering. In this section, a brief discussion on some related works in object tracking protocols in WSN is introduced.

Some prediction algorithm for predicting the object movement are developed in [1] [2] [3]. In Premon[1], As shown in Fig. 2. (a), a sensor node transfers its data to its cluster head. The cluster head uses the data from its member nodes to predict the object movement. When the object is moving out of a sensor node's sensing area, the sensor will send the object movement information to the cluster head for further prediction computation. And the cluster head will send the latest prediction data to the next sensor node that the object approaches. Thus in PREMON, sensors need to communication with cluster heads to exchange the prediction data which can be regarded as "long distance transmission". Generally, these long distance transmissions cause much energy consumption[14].

In [3], the prediction is made by a sensor node and the cluster head as well to reduce long distance transmissions （data transmission from sensor node to cluster head）. Prediction of the object moving is made based on a dual prediction mechanism. And when the object enters a sensor node's sensing area, the sensor node will transmit its latest prediction data to the cluster head and the next sensor node of the prediction as well. As it shows in Fig. 2. (b),With this localized mechanism, sensors don't need to communication with the cluster head every time for exchanging the prediction data. Thus this localized mechanism can effectively reduce the long distance transmission between sensor nodes and cluster heads. As a result, the energy consumption for the prediction data transmission can be saved conspicuously.

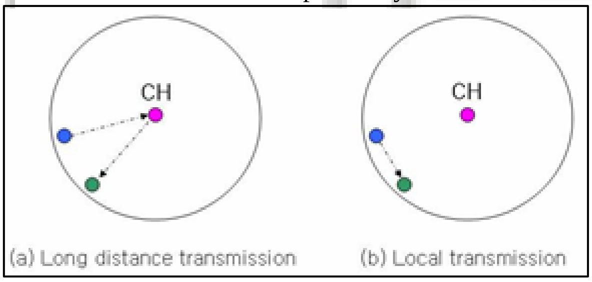


Fig. 2: (a) & (b): Long & Local Distance Transmission

But, Algorithm [3] does not consider the cluster formation. But in many cases clusters can be formed with overlap between clusters. In this situation, as it shows in Fig. 3, when a node have more than one cluster head then this node have to report to both of its cluster heads. So unnecessary transmissions and redundant (duplicate) data would be generated and cause a lot of unnecessary energy consumption

In LEACH [8], cluster head is elected randomly and periodically to prevent energy consumption in a specific node. It assumes that nodes always have data to send, it is difficult to adopt to OTSN. Because the object randomly moves in OTSN field, sensors don't know when they have data to send Thus we need a cluster head election algorithm for OTSN environment.

Researches about the target tracking with continuous monitoring mechanism can be divided into three categories: tree-based scheme, cluster-based scheme and prediction-based scheme. For tree-based scheme, in [15], a dynamic convey tree-based collaboration (DCTC) framework has been proposed that the convoy tree in DCTC includes sensor nodes around the detected target and it progressively adapts itself to add more nodes and prune some nodes as the target moves. For cluster-based scheme, in [16] a dynamic cluster-based algorithm is proposed and when a high capability sensors are triggered by certain signal events, the sensors will be activated and form a cluster around it by asking sensors in its vicinity to cooperate to track the target object.

In dynamic cluster-based algorithm, there are many research about cluster formation [5][6][7]. But they adopts predefined clustering algorithm. But these predefined clustering algorithms are not suitable for object tracking sensor network.

Therefore, we need a dynamic clustering algorithm that can avoid duplicate data and unnecessary data transmissions, thus reduce unnecessary energy consumption. In the following part we will introduce an algorithm to solve this problem.

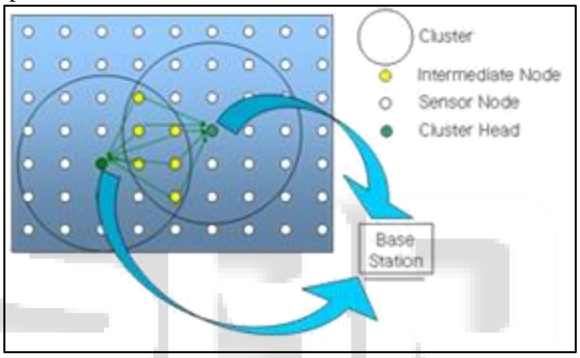
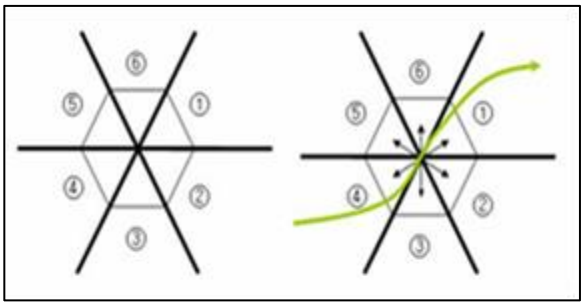


Fig. 3: Redundant data reported to Base Station caused by overlapped area

III. THE PROPOSED ALGORITHM

A. *Prediction Based Object Tracking:*

In this section, we describe about the dual prediction mechanism The basic idea for dual prediction is to have sensor nodes and their cluster heads both calculate the next states of tracked objects. The sensor nodes do not send an update of object movement to its cluster head unless it is different from the prediction. In addition, no prediction values need to be sent from cluster heads to sensor nodes. However, the saving of long distance transmissions between a sensor node and its cluster head comes with a small price, i.e., transfer of moving history from a current node to the destination node.



(a) Six divisions (b) Six directions

Fig. 4: Hexagon topology for sensor's sensing area

Generally, the hexagon topology is a good choice in WSN. Because in the hexagon topology, the sensor can minimize the overlap between its sensing area and others', and it can be deployed equally. According to the hexagon topology we can divide a sensor's sensing area into 6 triangles as below Fig. 4. (a). When a node makes a prediction, the node predicts not only the speed of moving object but also the direction of moving objects. Therefore, as Fig. 4. shows. (b), when a moving object is in one sensor's sensing area, the object will move through triangle 1 to triangle 6 and when the object leaves the sensing area it will leave from one triangle of the 6 triangles.

B. Cluster Head Election:

If the node which makes the prediction has a cluster head, the cluster formation is simple. This node just wakes up the next node according to its prediction data. But when the node which makes the prediction does not have a cluster head, firstly the next cluster's cluster head will be elected in the predicted direction of moving object, and then the new cluster will be formed by the elected cluster head. As the Fig. 5.shows, let's assume that the object enters node A's NO 4 triangle and will leave from the triangle 1. Then node A sends a wake up message to the next node B according to the prediction. Being waken up, B node then sends an ELECTION message to the nodes in the direction of node B's triangle 1 for cluster head election and starts a timer. When a sensor node receives the ELECTION message from node B, they will send back an ELECTION-REPLY message containing its sensor ID, its distance from node B and its current energy to node B. Here we define a tDIST which is a threshold value of the minimized cluster head election range which means all the candidate cluster head's distance to node B have to be longer than tDIST.

When the timer expires, the node B checks the messages it has already received, and selects the node with adequate energy and the distance which is longer than tDIST to be the cluster head. Thus using the cluster head candidate nodes as the input of the Algorithm. 1, the result of the algorithm will be elected as the next cluster head. Then the node B will report its tracking data to the selected cluster head.

Algorithm 1. Cluster head election algorithm

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Incoming Value: SID, SID_DIST, SID_ENERGY
Given Variables: tDIST
Local Variable: DIFF, MAX, GRADE
Procedure:
DIFF[ID] = SID_DIST - tDIST
if DIFF[ID] >= 0 then {
MAXID = The sensor ID with max energy
} else {
GRADE = (1-α) * DIFF[ID] + α* SID_ENERGY
MAXID = The sensor ID with max GRADE
}
end if
MAXID will be elected as the cluster head.
Send Prediction result to the CH
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In Algorithm. 1. ,αis a weight value between DIFF[ID] (distance to B node) and SID _ENERGY(remaining energy). As the equation presents, if α is too big, SID _ENERGY is more important for selecting the cluster head but maybe the selected node is not one of the nodes with the longest distance from the node B to reduce the cluster overlap. And if αis very small, DIFF[ID] is more important for cluster head selection then maybe the selected node's energy is not adequate for the responsibility of a cluster head. Thus, αvalue should be carefully selected.

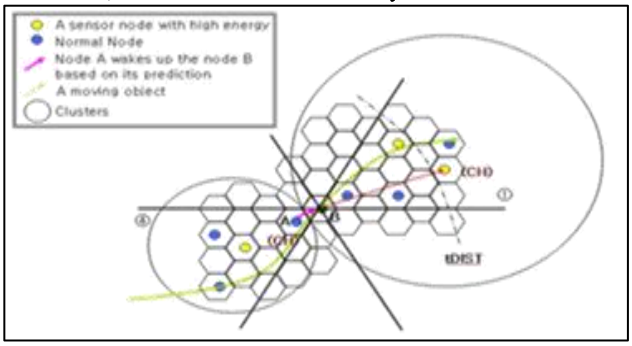

Fig. 5: Cluster head election

C. Cluster Formation Mechanism of Leach Algorithm:

1) Cluster Set Up Phase:

After each node has decided to which cluster it belongs, it must inform the cluster-head node that it will be a member of the cluster. Each node transmits this information back tothe cluster-head again using a CSMA MAC protocol. During this phase, all cluster-head nodes must keep their receivers on.

2) Schedule Creation:

The cluster-head node receives all the messages for nodes that would like to be included in the cluster. Based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule telling each node when it can transmit. This schedule is broadcast back to the nodes in the cluster.

3) Data Transmission:

Once the clusters are created and the TDMA schedule is fixed, data transmission can begin. Assuming nodes always have data to send, they send it during their allocated transmission time to the cluster head. This transmission uses a minimal amount of energy (chosen based on the received strength of the cluster-head advertisement.

The radio of each non-cluster-head node can be turned off until the node's allocated transmission time, thus minimizing energy dissipation in these nodes. The cluster-head node must keep its receiver on to receive all the data from the nodes in the cluster. When all the data has been received, the cluster head node performs signal processing functions to compress the data into a single signal. For example, if the data are audio or seismic signals, the cluster-head node can beam form the individual signals to generate a composite signal. This composite signal is sent to the base station. Since the base station is far away, this is a high-energy transmission. This is the steady-state operation of LEACH networks. After a certain time, which is determined a priori, the next round begins with each node determining if it should be a cluster-head for this round.

4) Multiple Clusters:

The preceding discussion describes how the individual clusters communicate among nodes in that cluster. However, radio is inherently a broadcast medium. As such, transmission in one cluster will affect (and hence degrade) communication in a nearby cluster. Thus, when a node decides to become a cluster-head, it chooses randomly from a list of spreading codes. It informs all the nodes in the cluster to transmit using this spreading code. The cluster-head then filters all received energy using the given spreading code. Thus neighboring clusters' radio signals will be filtered out and not corrupt the transmission of nodes in the cluster. Efficient channel assignment is a difficult problem, even when there is a central control center that can perform the necessary algorithms. Using CDMA codes, while not necessarily the most bandwidth efficient solution, does solves the problem of multiple-access in a distributed manner.

5) Hierarchical Clustering:

The version of LEACH described in this paper can be extended to form hierarchical clusters. In this scenario, the cluster-head nodes would communicate with "super-clusterhead" nodes and so on until the top layer of the hierarchy, at which point the data would be sent to the base station. For larger networks, this hierarchy could save a tremendous amount of energy. In future studies, we will explore the details of implementing this protocol without using any support from the base station, and determine, via simulation, exactly how much energy can be saved.

IV. CONCLUSIONS

In traditional dynamic clustering mechanisms, overlap area between two clusters may bring redundant data transmissions from nodes to base station. To solve this problem, based on previous researches on prediction-based mechanisms such as PREMON and DUAL and researches on dynamic clustering mechanisms, we proposed our Efficient Dynamic Clustering Algorithm for Object Tracking in Wireless Sensor Networks. In proposed mechanism, it proposes a new cluster head election algorithm and helps to minimize the overlap area between clusters, so as to reduce the energy consumption from reducing unnecessary transmission for duplicated data.

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