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Sleep-awake energy efficient distributed clustering algorithm for wireless sensor networks ☆

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ABSTRACT

Hierarchical clustering technique is an effectual topology control methodology in Wireless Sensor Networks (WSNs). This technique is used to increase the life time of the network by reducing the number of transmissions towards the base station. We propose and validate a new routing protocol termed as Sleep-awake Energy Efficient Distributed (SEED) clustering algorithm. We divide the network sensing field into three energy regions because in SEED cluster heads are communicating directly with the base station. The cluster heads of the high energy region are communicating with the base station through a longer distance and paying extra energy cost as compared to the cluster heads of the low energy region. Same application base sensor nodes form sub-clusters to decrease the number of transmissions towards the base station. In every round, one node from these sub-clusters nodes awake and transmit the data and the rest of them sleep to save available resources. We select six criteria to check the performance of our algorithm. The simulation results show that SEED achieves longer network life time and high throughput as compared to the existing clustering protocols.

1. Introduction

Wireless Sensor Networks (WSNs) can present the distinctive benefits and flexibility with respect to low-power and economical fast deployment for many applications [1]. A WSN can be homogeneous [2] or heterogeneous [3,4]. A homogeneous WSN consists of sensors with similar technical characteristics i.e., initial energy and data rate. Whereas, a heterogeneous WSN consists of sensor nodes having different initial energy and data rate. The nodes in WSNs are usually battery-operated sensor nodes with limited energy resources and replacing the batteries of these sensor nodes is not an option. However, we can use good energy management schemes to save energy of individual nodes as discussed in [5,6]. Designing energy efficient routing protocol is important for prolonging the life time of the network.

There are three types of routing protocols namely, direct communication [7], minimum transmission energy [8], and clustering protocols [9–11]. In direct communication, sensor nodes directly communicate with the base station. However, as the size of the network increases, more energy is required for communication, causing the sensor nodes to die very quickly. In case

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of minimum transmission energy, when the node senses data to transmit, it may find the shortest possible route consisting of several hops to the base station. Optimal routes help to save the energy of the network [12]. However, the nodes closer to the base station forward more packets as compared to the distant nodes. In this way, the power of the sensor nodes closer to the base station will be drained very quickly.

Many energy efficient schemes are defined in [13–17], among these schemes cluster based routing is found to be a more energy efficient and scalable way to organize sensor nodes. The whole sensing field is divided into small clusters. In every cluster, a cluster head (CH) is selected on the basis of different parameters, such as energy or distance from the base station. A cluster head is responsible for transmitting any gathered information sensed by the nodes in its cluster. The cluster head may aggregate and diffuse [11] the data before transmitting it to the base station. However, this additional responsibility results in a higher rate of energy drainage for the cluster heads. However, selecting the optimal number of cluster heads is a good way to increase the life time of WSNs [18]. Low Energy Adaptive Clustering Hierarchy (LEACH) is the most popular clustering mechanism [1]. LEACH addresses the problem of energy by probabilistically rotating the role of cluster head among all the nodes. Each node has equal probability to become a cluster head. In this way, low energy sensor nodes are selected as cluster heads and this may degrade the performance of LEACH. Stable Election Protocol [4] introduces a two-level heterogeneous network, which contains two types of nodes i.e., normal nodes and advance nodes. These nodes have different initial energy levels. Rotating epoch of SEP is directly interrelated with the initial energy of sensor nodes. However, SEP performs weakly in multi-level heterogeneous networks.

Our contribution: Following the thoughts of clustering which reduces the number of transmissions to prolong the life time of the network. We proposed a routing protocol to reduce redundant transmission towards the base station in application base heterogeneous WSN. Same application base nodes form sub-clusters and in these sub-clusters only one sensor node transmits data and the remaining sensor nodes remain in sleep mode to save energy. The rotating epoch and election probability is correlated with the remaining energy. Only high energy sensor nodes belonging to a region have greater probability to become cluster heads. In this work, the cluster head also avoids the same data coming from different nodes to move towards the base station. In this way, the redundant data is avoided which reduces the consumption of energy. All the nodes are not constantly monitoring the sensing field; only one awake node from a sub-cluster monitors the field in allocated time slots. The remainder of the nodes is in sleep mode to save the resources. The main contributions of the proposed model are summarized as

- We divide the network sensing field into three energy regions for even energy distribution.
- In SEED, the data transmission phase is a longer phase. So, one node can communicate with the base station twice in a round in the data transmission phase.
- We introduce sub-clustering in SEED to decrease redundant data transmission towards the base station.
- The propose model utilizes sleep-awake awareness to save the available power.

The remainder of the paper is organized as follows: We review the previous approaches for WSN clustering in Section 2. In Section 3, we discuss the heterogenous network nodes deployment strategy of SEED algorithm and we describe our proposed routing protocol with the concept of sub-clustering among the sensor nodes with the same applications to reduce the redundant data flow towards the base station. Simulation results for network stability, network throughput, packet drop rate, and cluster head selection are discussed in Section 4. Finally, the conclusion is drawn in Section 5.

2. Related work

In [19,20], the authors proposed threshold based energy efficient hierarchal routing protocols. Reactive routing is used in these protocols. In these protocols, a hard and soft threshold value of data is defined for non-cluster head nodes in a cluster. The lower value of the threshold is soft threshold and the upper is hard threshold. In a cluster, the cluster head defines and sends these threshold values to their member nodes. Due to defined value of thresholds the number of transmissions are reduced and energy is saved. However, the cluster head selection process is poor and inefficient and as a result most of the time sensor nodes remain idle and have no cluster heads for communication.

Static clustering is used in AZR-LEACH [21] for optimal number of cluster heads selection. The authors divided the sensing field into equal size clusters and four such clusters form a zone. The zones are used to enhance the communication efficiency of the network. They deployed the base station in the center of the network and clusters closer to the base station are termed as advance clusters. The advance cluster head is responsible to forward the data of approximately 48 nodes and at the same time sense its own field. However, these sensor nodes are equipped with the same energy as normal nodes. This may cause the rapid depletion of the battery of advance cluster head nodes, making the network unstable and decreasing the network life time.

Centralized Energy Efficient Clustering (CEEC) is discussed in [7]. In CEEC, the base station is the central entity which selects the cluster heads for each round on the basis of energy and distance from the base station. They defined a strategy for deploying nodes in the sensing field for the optimal number of cluster heads formation. They identified three types of nodes: normal, advance, and super nodes. Then they divided the sensing field into three regions on the basis of initial energy of the nodes. The cluster heads communicate with the base station through single hop communication. However, they assigned the same initial energies for all type of nodes. The cluster heads sending data from distant regions deplete their batteries soon which effects the life time and stability of the network.

Energy Efficient Sleep Awake Aware (EESAA)[2] is an intelligent routing protocol for WSNs which introduced a technique of pairing among nodes. Among these pairs only one member node awakes in each round to forward sensed data while the other member node remains in sleep mode to save the energy resources. EESAA works in rounds and each round contains 4 phases

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