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An energy efficient multi-level route-aware clustering algorithm for wireless sensor networks: A self-organized approach

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ABSTRACT

Energy maintenance is one of the crucial characteristics for wireless sensor networks. Clustering techniques in WSNs is wildly used to cope with sensor network deficiencies. Organizing nodes in such clusters and specifying a particular node in each cluster to undertake the task of intra-cluster and inter-cluster data communications leads to alleviate the number of transmissions and hence longer lifetime of the Network. Most of decentralized clustering protocols are performed without any acknowledgement of a route which data traverse to reach the base station. In this paper, a new distributed energy efficient multi-level route-aware clustering algorithm for WSNs called MLRC is proposed. To establish tree among sensor nodes, MLRC applies a route conscious manner in which nodes could gain desired information about possible routes to the destination. The proposed protocol eliminates extra generation of routing control packets by implementing cluster formation and routing tree construction, concurrently. Cluster heads are elected based on effective parameters. The algorithm could moderate energy consumption of relays close to the base station with assigning probability to adjacent cluster head and avoiding the insistence on the nearest cluster head selection. Experimental results illustrate that the protocol improves network longevity in comparison with other known protocols.

1. Introduction

A great progress in sensor development technologies has enabled the expansion of tiny battery-powered sensor nodes. Wireless sensor network (WSN) is a network of large numbers of tiny sensors nodes with energy-constrained, low processing power and limited wireless communication capabilities. Each node in WSN undertakes the tasks of collecting, processing, storing, and transferring environment information. These devices integrate sensors and actuators that operate in an unattended manner even in hostile environments [1,2].

WSNs become popular for a wide range of applications such as military and civil domains. They can be employed for civil surveillance, military, environmental monitoring, target tracking, disaster forecast and territory/premises protection [1]. They can facilitate many applications which require simply an aggregate value to be reported to the information sink. Data aggregation is an energy conservation technique which tries to reduce the volume of data communicated by collecting local data at intermediate nodes and forwarding only the result of an aggregation operation, such as min and max, towards the

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sink node. Sensors in different districts of the target area can collaborate to aggregate the gathered information. For instance, in habitat monitoring applications the sink may require the average of temperature; in military applications the existence or not of high levels of radiation may be the target information that is being sought [3,4].

Nodes in these networks, typically deployed in an ad-hoc manner, operate individually and consonant with each other to perform a common task. Accordingly, each sensor node monitors its neighboring area, extract information, and send the sensed data to remote sinks directly or via other sensor nodes in order to reconstruct the characteristics of the phenomenon being monitored [5, 6]. In these networks failure of a node leads to loss of coverage area and increasing delay in diagnosing the event. However, it hasn't much effect on overall values estimated, since nodes in a close region may provide similar values which are reduced with data fusion and quantum.

Organizing nodes in several clusters and specifying a particular node in each cluster to perform cluster head (CH) task, not only allows aggregation of data, but also limits data transmission primarily within and among the clusters [7]. Moreover, the coordination provided by the CH allows sensor nodes to sleep for extended period and aid to save more energy in each node. Thus, clustering improves network scalability and longevity by reducing both the traffic and the contention for the channel.

In a large-scale WSN, the inter-cluster traffic usually consumes more energy than intra-cluster traffic due to the long distance between CHs. So besides intra-cluster energy maintenance, the energy saving in inter-cluster data communication should also be considered [8]. A number of clustering algorithms are proposed with the aim of balancing load among sensor nodes. Some assume that a node can send its data directly to the base station (BS); however it wastes much energy due to the long data transmission distance. To solve these problems, some approaches let nodes to relay their data within multiple hops to the BS [9]. Hereupon, an energy efficient transmission tree is constructed among sensor nodes and the optimal path is determined for sensor's data to reach the BS.

In this paper we proposed an energy efficient multi-level route-aware clustering algorithm for wireless sensor networks in a fully distributed manner. It includes two major phases: setup phase and data transmission phase. In setup phase CHs are selected based on effective parameters. With introducing a new route aware method an optimal path from each relay to the BS is specified and routing tree is constructed among sensor nodes. The algorithm balances inter-cluster and intra-cluster energy consumption among CHs by considering the remaining energy and density of nodes when choosing the next hop. In cluster formation stage cluster members give a probability to each adjacent CH and prevent greedy selection of nodes closer to the BS. Residual energy, proximity degree, number of hops through the path to the BS and actual distance each data traverses to reach the BS are such parameters involved in selection of relay nodes. Besides, route specification and cluster formation stage are performed concurrently which leads to decreasing the number of control packets. In data transmission phase all sensed data transfer to the BS through the constructed routing tree.

The remainder of this paper is organized as follows. Section 2 expresses a brief survey of some related works. Section 3 describes the network and energy model in our algorithm. Section 4 presents the route-aware clustering algorithm in detail. Section 5 analyzes some properties of the proposed protocol. Section 6 evaluates the performance of the algorithm via simulations and analyzes the obtained results in detail. Eventually, Section 7 gives the concluding remarks.

2. Literature survey

There have been a lot of research ideas proposed for organizing nodes in clusters and direct data to the destination sink. Some of these protocols such as LEACH [10] utilizes power control to alter the amount of transmission power and communicates directly to the BS. LEACH is a self- organizing clustering protocol which assumes that each node has the same initial energy power in the network. The operation of LEACH is divided into rounds and each round is divided into two phases named: setup phase and steady-state phase. To minimize the overhead, steady-state phase is always considered longer than the setup phase. Sensor nodes are organized in local clusters and a particular node in each cluster takes the responsibility of CH and rest of the nodes act as ordinary nodes. LEACH includes randomized rotation of the CH and performs data fusion and aggregation in each CH to decrease the amount of data transmissions from the CHs to the BS. Set of clusters would be changed for different periods and the decision to become a CH depends on the amount of energy remained for each sensor.

PDC [11] is a prediction-based clustering approach that mainly contributes in data-aware clustering. It forms highly stable clusters of nodes sensing similar values with the use of both spatial and temporal correlations. Sink node utilizes only the local prediction models of cluster heads to forecast all readings in the network without direct communication. PDC is an energy efficient approach which provides a high precision of the approximate results with bounded error. Proposed prediction model presents high accuracy as well as low computation and communication costs.

In article [12] A Dynamic Data-aware Firefly-based Clustering (DDFC) protocol is proposed to handle spatial similarity between node readings. It defines architecture for dynamic and distributed data-aware clustering. The DDFC operation takes into account the biological principles of fireflies to ensure distributed synchronization of the clusters' similar readings aggregations. DDFC results demonstrate the capability of maintaining synchronized cluster readings aggregations, thereby enabling nodes to be dynamically clustered according to their readings.

LA-EEHSC [13] is a learning automata-based energy efficient heterogeneous selective clustering scheme for WSNs. Automaton is assumed to be located on each normal and advanced sensor node. Based upon the weighted election probability (WEP) of each group of nodes, CHs are selected among the group of sensor nodes by the automaton. Automaton at each sen-