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Load management scheme for energy holes reduction in wireless sensor networks ☆

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ABSTRACT

In a wireless sensor network where sensors are arranged into a flat topology, sensors near the sink consume much more energy than sensors at the boundary of the network. Sensors near the sink relay many packets than far away sensors to the sink. After these sensors expire, energy holes are created near the sink. Therefore, other sensors cannot reach to the sink and the network becomes disconnected. In this paper, we propose some strategies that can balance energy consumption of the deployed sensors and reduce energy holes from the network by balancing the communication load as equally as possible. We performed extensive experiments on the proposed algorithm using various network scenarios and compared it with other existing algorithms. The experimental results verify the effectiveness and feasibility of the proposed work in terms of network lifetime, energy consumption, and other important network parameters.

1. Introduction

Wireless sensor network (WSN) is a collection of low cost, low power, small sensing devices, where sensor nodes are deployed into a monitoring field without a preconfigured infrastructure [1]. After deployment, sensor nodes find neighbour nodes and organize themselves into a network [2,3]. The maximum amount of the energy of a sensor is consumed on two major tasks, viz sensing data from the monitoring environment and transmitting data to a sink or Base Station (BS) [4]. Energy consumption on sensing is dependent only on the sampling rate and does not depend on the network topology or location of the sensors. Therefore, energy consumption on sensing is constant. However, the data routing strategy is the most significant factor that determines the performance of the network [5–7]. In a homogeneous WSN, sensors near the sink consume much more energy compared to the sensors far away from the sink. Since, sensors near the sink relay many packets from sensors at the margin of the network [8], communication load of these sensors is much more compared to the far away sensors and they expire earlier than the far away sensor. After the expiry of these sensors, energy holes or communication gaps are created near the sink [9,10].

Hence, far away sensors cannot transmit data to the sink and then the network becomes disconnected, but still most of the nodes can survive for a long period of time [11–14]. Thus, load distribution among the deployed sensors is one of the most critical problems in the designing of WSNs. It has a profound impact on the network lifetime and performance of

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the network. Therefore, it is necessary to design and develop a load balancing scheme for WSNs to prolong the network lifetime and performance of the network.

Several cluster-based load management approaches have emerged in the literature review. Most of them have selected cluster head, depending on the remaining energy of the sensor nodes [2,8,15]. Cluster-based data routing strategy is more suitable for energy conservation compared to the direct data transmission. Most of the clustering approaches select cluster head dynamically in each round for better energy management among the sensor nodes. However, each round cluster head selection process imposes extra message overhead or traffic load on these approaches. An on-demand based cluster head selection strategy has selected cluster head depending on the network demand and reduces extra cluster formation overhead from the network. Thus, an on-demand based cluster head selection strategy is perfectly suitable for WSN load management scheme.

In this paper, we propose a new cluster-based load management scheme, referred to as load management scheme for energy holes reduction in wireless sensor networks (LMSEHR) that can balance the energy consumption of the deployed sensor nodes and minimize energy holes creation in the WSN by balancing communication load as equally as possible. For doing this, proposed scheme does not make any assumptions like node distribution, node capacities, and network size. It does not use any location awareness Global Positioning System (GPS) to locate the position of the deployed sensor node. In this paper, we only consider deployed nodes which are varied in their transmission power and are capable of computing their remaining energy. In our proposed scheme, all sensors are organized into distinct clusters and each non-cluster head node belongs to exactly one cluster as a cluster member node. To achieve better energy management, proposed scheme selects CHs on-demand basis. The CHs are selected from the special regional nodes that can reduce extra message overhead and time delay in cluster head selection process. Furthermore, CHs communication load are balanced by the associative cluster heads. The main contributions of this paper can be summarized as follows:

- We propose a new load management strategy for large scale sensor networks where communication load and residual energy of deployed sensors are used for CHs selection.
- We focus on the problem of minimizing energy holes within the network. Then, we mathematically derive an optimal solution based on the load balancing strategies.
- We propose special region based CHs selection mechanisms for energy and time saving.
- We also propose a load balancing data routing strategy for balance energy consumption.
- We carry out extensive simulations. The effectiveness and feasibility of the proposed algorithm are verified by comparing with other existing algorithms.

The rest of the paper is organized as follows. In Section 2, the related work which provides an exhaustive survey about the previous work is discussed. Section 3 states the problem of load-balancing and network model. Section 4 presents the problem formulation and the assumptions made in this paper. The proposed load management scheme is presented in Section 5. Section 6 gives simulation results and some discussions. Finally, Section 7 concludes this paper.

2. Related works

Minimizing load is a major objective in several multi-hop wireless networks. This requirement has become more important for WSNs where sensor nodes are powered by batteries. Numerous studies have been conducted to reduce the load of the sensor nodes and to extend lifetime of the network. Cluster-based data routing strategy is one of the most popular data gathering mechanisms that has been used to maximize WSN lifetime. It also helps to reduce the communication load and data redundancy from the large scale WSNs. Low energy adaptive clustering hierarchy (LEACH) [15] is a well-known dynamic clustering approach where CH load dynamically rotates amongst the non-CH nodes that balance energy dissipation between the non-CH nodes. It works in two phases: (a) setup phase, and (b) steady state phase. In the setup phase, the entire network is divided into different clusters. For cluster formation, each node selects a random number between 0 and 1. If the selected random number is less than the threshold value, the node is selected as a CH. After cluster formation, CHs allocate a time slot to each cluster member node or non-CH node, depending on Time Division Multiple Access (TDMA) approach. In steady state phase, each cluster member transmits sensing information to the CH according to the given time slot. CHs aggregate receiving data and it transmits to BS. The main disadvantages of the LEACH protocol can be summarized as follows.

- The LEACH protocol follows random cluster head selection strategy. Therefore, in this approach message overhead is very high.
- The LEACH protocol selects CHs based on some probability. If any node is detected of low residual energy, it may be selected as a CH for data gathering process. As a result, number of cluster head election process is increased throughout the network lifetime and it potentially degrades the functionality of the network.
- The LEACH protocol does not assure even distribution of the CHs within the network.
- In LEACH protocol, CHs directly transmit aggregated data to the BS by the single-hop communication, which is unrealistic for the large scale WSN. In medium scale WSN, direct data exchange mechanism increases communication load within the CHs and hence it creates high load difference between CHs and cluster member nodes.