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A Low Energy MCL-Based Clustering Routing Protocol for Wireless Sensor Networks

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ABSTRACT

Wireless sensor networks (WSNs) have attracted increasing attention during the two last decades. Indeed, their applications target a wide range of fields such as healthcare, industrial control, environmental monitoring, etc. The main challenge of WSNs is the limitation of resources requiring efficient management of energy consumption. Coverage is also considered as one of the critical indicators of the quality of service (QoS) of WSNs. Therefore, the design of routing protocols should focus on energy efficiency and network coverage. In this paper, the authors propose a novel energy-efficient clustering protocol that is more efficient than some prominent routing protocols and offers better coverage of the network than LEACH. The protocol combines the MCL algorithm for cluster formation and a new cluster head selection strategy based on location and residual energy of sensors. Simulation results demonstrate that the proposed protocol is better than other protocols in terms of energy management and extending the lifetime of the network, whereas, it achieves good coverage than LEACH.

KEYWORDS

Base Station (BS), Cluster Head (CH), Clustering Protocols, Clusters, Coverage, MCL (Markov Clustering Algorithm), Network Lifetime, Sensor Nodes (sensors), WSNs (Wireless Sensor Networks)

1. INTRODUCTION

A Wireless Sensor Network (WSN) (Vijayalakshmi and Muruganand, 2012; Selmic et al., 2016; Fahmy, 2016; Forster, 2016) is a network composed of a large set of cooperating sensors deployed on a monitoring field. Sensors have generally limited energy and randomly dispersed over the area of interest. Each sensor is able to capture data and transfer it to a base station through a flat or hierarchical architecture. The base station then transmits this data to a central computer in order to analyze it and make decisions. Quite recently, considerable attention has been paid to WSNs. Indeed, WSNs have been widely used in different application fields: military (Priyantha, 2002), industrial control (Levis et al., 2003), environmental monitoring (Stehlik, 2011), healthcare (Dishongh and McGrath, 2009;

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Julien-Vergonijanne et al., 2016), domestic monitoring and smart homes (Ilakkiyadeepaa et al., 2015; Cetinkaya and Akan, 2016; Gnanavel et al., 2016).

One of the major issues is the energy consumption of wireless sensor networks. The energy is mostly powered by batteries that are practically consumed during data transmission. For this reason, the design of efficient routing protocols is inevitable in order to increase batteries' lifetime and thus network longevity. In clustering routing protocols, sensors transmit collected data over short distances to cluster heads (CHs) rather than communicate directly to the base station. Therefore, the consumed energy in communication with cluster heads is less than that spent in the transmission with the base station. That is the main advantage of this type of routing protocol compared to others. Several studies (Liu, 2012; Gupta, 2013; Sirsikar and Wankhede, 2015; Xu et al., 2017) have appeared documenting clustering routing protocols. Coverage being a critical indicator of the Quality of Service (QoS), is also considered as one of the major problems in wireless sensor networks (Meguerdichian et al., 2001; Selmic et al., 2016). The aim of coverage is to determine how a set of sensor nodes can monitor appropriately an area of interest (Selmic et al., 2016). Diverse research works have been carried out to study the problem of network coverage: Tian and Georganas, 2002; Adlakha and Srivastava, 2003; Kar and Banerjee, 2003; Wang et al., 2003; Zhang and Hou, 2005.

Clustering protocols are focused on minimizing energy consumption and ensuring both scalability and network coverage (Akyildiz and Vuran, 2010). The first research works were LEACH (Heinzelman et al., 2000) and all its variants, PEGASIS (Lindsey et al., 2001; Lindsey and Raghavendra, 2002), TEEN (Manjeshwar and Agrawal, 2001), APTEEN (Manjeshwar and Agrawal, 2002) and HEED (Younis and Fahmy, 2004). The main difference between clustering protocols is the way that clusters are formed and CHs are selected.

In this paper, the authors propose a new clustering protocol MCL-BCRP (MCL-Based Clustering Routing Protocol) that:

- Offers an appreciable coverage of the sensing area by the set of cluster heads compared to LEACH.
- Extends the network lifetime by reducing the average dissipated energy and the number of dead nodes compared to some existing protocols.
- Offers the possibility to perform an offline configuration of the network according to the objectives of the application using the protocol (lifetime, coverage, and granularity of the clustering).

MCL-BCRP combines the MCL algorithm for cluster formation and a new cluster head selection strategy based on location and residual energy of sensors. The MCL algorithm (Markov Cluster algorithm) was discovered by Stijn van Dongen in order to simulate stochastic flows in graphs (Van Dongen, 2000). MCL has been applied in a number of different domains, mostly in bioinformatics. Moreover, it is a widely-used approach to extract meaningful information from biological networks (Enright et al., 2002; Shih and Parthasarathy, 2012; Ochieng et al.; 2016; Azad et al., 2018).

The paper is organized as follows:

- Section 2 is devoted to related works. A clustering protocols overview is explained. Next, a survey of prominent clustering routing protocols for WSNs is presented with a comparative study.
- Section 3 is dedicated to the theoretical background of the Markov Clustering Algorithm (MCL). The principle of MCL is detailed, and then the pseudo-code is given. Finally, the convergence of the algorithm is discussed.
- Section 4 presents the architecture and the working process of MCL-BCRP. The authors explain in detail: the network model, the protocol overview followed by its architecture, the construction of the network topology, and the data routing.
- Simulation results and benchmarks are discussed in Section 5. First, the authors explain the simulation setting. Next, they study the features and the granularity of the MCL clustering allowing offline configurations of the network topology. Next, the performances of the MCL-BCRP are