A Clustering Protocol for Maximum Coverage in Large-Scale Wireless Sensor Networks

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ABSTRACT

The optimum use of coverage in wireless sensor networks (WSNs) is very important. The hierarchical routing protocol LEACH (Low Energy Adaptive Clustering Hierarchy) is referred to as the basic algorithm of distributed clustering protocols. LEACH allows clusters formation. Each cluster has a leader called Cluster Head (CH). The selection of CHs is made with a probabilistic calculation. It is supposed that each non-CH node join a cluster and becomes a cluster member. Nevertheless, some CHs can be concentrated in a specific part of the network. Thus several sensor nodes cannot reach any CH. As a result, the remaining part of the controlled field will not be covered; some sensor nodes will be outside the network. To solve this problem, the authors propose O-LEACH (Orphan Low Energy Adaptive Clustering Hierarchy), a routing protocol that takes into account the orphan nodes. O-LEACH presents two scenarios, a gateway and sub cluster that allow the joining of orphan nodes.

Keywords: Clustering, Coverage, Gateway, LEACH, O-LEACH, Orphan Nodes, Routing, Sub-Cluster, WSNs

1. INTRODUCTION

A Wireless Sensor Network consists of great number of sensor nodes distributed autonomously, communicating with each other via short-range transmissions and to monitor environmental conditions such as fire detection, health care, temperature, vibration, pressure and motion at different locations.

LEACH (Heinzelman et al., 2000) is the basic hierarchical routing protocol (cluster-based approach). It is also one of the most popular cluster based routing algorithms for Wireless Sensor Networks (WSNs). It combines both the efficiency in energy consumption and the quality of access to the media, and it is based on the division into groups of sensor nodes, with a view
allowing the use of the concept of data aggregation for a better performance in terms of lifetime. Many features, such as network lifetime, energy consumption, and the number of orphan nodes, should be considered in the design of a routing protocol. LEACH uses a TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions. The rotation role of the CH has proved to be an important factor in the organization of the nodes including the context of distributed clustering protocols. This role is exhausting in terms of energy since a CH is active throughout its election. The CH compresses data coming from its members, and sends a packet to the aggregation node sink in order to reduce the amount of information that must be transmitted to it. This reduces the complexity of routing algorithms, simplifies the network management, optimizes the energy costs, and finally gives a more scalable network.

Cluster Heads (CH) are randomly chosen in a specific election algorithm based on a probability function that takes into account various criteria such as the available energy. The routing protocols are actually divided into two families: central data and hierarchical routing protocols. In a hierarchical topology, can be cited references protocols, HEED (Younis et al., 2004), PEGASIS (Lindsey et al., 2002), TEEN (Manjeshwar et al., 2001), and APTEEN (Manjeshwar et al., 2002).

Leach performs the single-hop inter-cluster, directly from CHs to the BS, routing method, which is not applicable to large-region networks (Akyildiz et al., 2002). It is not always a realistic assumption for single-hop inter-cluster routing with long communication range (Sukhdeep et al., 2015). Besides, long-range communications directly from CHs to the BS can breed too much energy consumption; despite the fact that CHs rotation is performed at each round to achieve load balancing, LEACH cannot ensure real load balancing in the case of sensor nodes with different amounts of initial energy, because CHs are elected in terms of probabilities without energy considerations (Al-Karaki et al., 2004). The idea of dynamic clustering brings extra overhead. For instance, CH changes and advertisements may diminish the gain in energy consumption (Liu, 2012).

LEACH is very favorable in terms of energy efficiency. However, controlling the number and the location of the clusters head (CHs) and also the size of the clusters about the node number leads to a balance in energy use of the CHs and increasing the lifetime of the network (Jian et al., 2013). Routing protocols in Wireless Sensor Networks can be classified as flat and hierarchically based on the network topology. In flat routing, all nodes are assigned equal roles and a similar functionality whereas in hierarchical routing, they exhibit different roles (Li et al., 2011; Selva et al., 2015). Energy efficiency of the sensor nodes and load balancing of the cluster heads (CHs) are the two most important processes that must be addressed in designing clustering algorithm for WSNs (Asgarali et al., 2015; Mehta et al., 2012).

Nevertheless, in a round, the nodes which are not CH may not join a cluster. In such a case, the data which must be collected from the node outside the network (orphan node) could have a great importance in some applications. Hence, these applications will be concrete ones and will satisfy our needs. Obviously, we need to collect data from all distributed nodes inside the network, hence allowing taking the suitable decisions.

Recent advances in the field of microelectronics and communications have brought the domain of Wireless Sensor Networks (WSNs) under the spotlight. WSNs can be formed by distributing inexpensive sensor devices on a large scale, typically, in a harsh environment (Aderohunmu et al., 2011). The large-scale deployment of controlled high Wireless Sensor Networks (WSNs) necessitates an efficient organization of the networks for high network connectivity and a low orphan node ratio.

Where sensor networks are randomly deployed, they are not uniformly distributed inside field. As a result, some places in the field don’t benefit from a good connectivity. Hence, the
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