Chapter 27
Fuzzy Logic-Based Cluster Heads Percentage Calculation for Improving the Performance of the LEACH Protocol

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ABSTRACT

In wireless sensor networks, cluster-based routing was proven to be the most energy-efficient strategy to deal with the scaling problem. In addition, selecting the proper number of clusters is a critical decision that can impose a significant impact on the energy consumption and the network lifetime. This paper presents FL-LEACH, a variant of the well-known LEACH clustering protocol, which attempts to relax the stringent strategy of determining the number of clusters used by LEACH via fuzzy logic decision-making scheme. This relates the number of clusters to a number of network characteristics such as the number of sensor nodes, the area of the sensing field, and the location of the base station. The performance of FL-LEACH was evaluated via simulation and was compared against LEACH using standard metrics such as network lifetime and remaining network energy. The results depicted that the proposed approach has the potential to substantially conserve the sensor node energy and extend lifetime of the network.

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INTRODUCTION

A Wireless Sensor Network (WSN) is a distributed system composed of wireless nodes which collaborate with each other in order to achieve a certain sensing task. It is expected that WSN applications will impose themselves strongly in our daily lives in the near future. These applications range from commercial and civil applications, such as environmental monitoring, to military applications such as surveillance and border monitoring (Akyildiz, Su, Sankarasubramaniam, & Cayirci, 2002; Chong & Kumar, 2003).

In some WSN applications, hundreds or even thousands of such sensor nodes are randomly deployed in a large area. This large number of sensor nodes results in a scalability problem. That is, how should these sensor nodes be organized in order to achieve their task efficiently? Since the main task of the sensor nodes in any WSN system is sensing and monitoring the surrounding area and then forwarding the sensed data to the base station (BS), these randomly-deployed sensor nodes should organize themselves in groups or clusters in order to overcome the scalability problem. It has become well-known that the limited power of the sensor node battery is the main constraint that WSNs suffer from. This constraint imposes itself as a major player in the design of any clustering algorithm.

Furthermore, it is well-known that most of the battery energy is consumed during the process of transmitting the sensed data to the BS (Raghunathan, Schurgers, Park, & Srivastava, 2002). For this reason, most of the proposed protocols in WSNs have targeted the clustering mechanisms as a solution for the scalability problem. Clustering in WSNs was proposed as an efficient solution to reduce the energy consumption over long distances as compared to the direct transmission (Abbasi & Younis, 2007).

One of the most familiar clustering protocols is the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol (Heinzelman, Chandrakasan, & Balakrishnan, 2000, 2002), in which the sensor nodes are self-organized into groups. In each group, one node acts as a cluster head (CH) which is responsible for delivering the data gathered by all nodes within the cluster to the BS. The number of CHs in the LEACH protocol determines the number of clusters in WSN. The method that determines which nodes should act as CHs is probabilistic-based and it uses a thresholding equation that depends on a desired percentage of CHs called the P value. In the original LEACH protocol, the P value is assumed to be constant irrespective of the network characteristics.

This paper presents FL-LEACH, a variant of LEACH that employs fuzzy logic as a decision making system (Zadeh, 1965) in order to relax the restriction on the P value and to make it variable based on the area of the sensing field, the number if sensor nodes, and the location of the BS. The rest of the paper is organized as follows. First, we introduce some background and related work. Next, the proposed fuzzy logic-based approach is presented, followed by the simulation results. Finally, the paper is concluded.

BACKGROUND AND RELATED WORK

In this section, we discuss the background that contributes in understanding the rest of the paper and review the related work. We begin with an overview of fuzzy logic. Then, we discuss the main principles of clustering approaches in WSNs. The last part of this section reviews LEACH protocol and the related work that was proposed to improve its functionality.