Chapter 18

Fuzzy Logic Based Clustering Algorithm for Wireless Sensor Networks

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ABSTRACT

WSNs have many applications in modern life. Thus, optimization of the network operation is required to maximize its lifetime. The energy is a major issue in order to increase the lifetime of WSNs. The clustering algorithm is one of the proposed algorithms to enhance the lifetime of WSNs. The operation of the clustering algorithm is divided into cluster heads (CHs) selection and cluster formation. However, most of the previous works have focused on CHs selection, and have not considered the cluster formation process, which is the important issue in clustering algorithm based routing schemes, and it can drastically affect the lifetime of WSNs. In this paper, a Fuzzy Logic based Clustering Algorithm for WSN (CAFL) has been proposed to improve the lifetime of WSNs. This approach uses fuzzy logic for CHs selection and clusters formation processes by using residual energy and closeness to the sink as fuzzy inputs in terms of CH selection, and residual energy of CH and closeness to CHs as fuzzy inputs in terms of clusters formation. Simulation results justify its efficiency.

1. INTRODUCTION

Recent advances in sensor devices and wireless technologies have enabled deployments of large-scale wireless sensor networks (WSNs) for a diversity of applications such as (Akyildiz et al., 2002, and Yick et al., 2008):

DOI: 10.4018/978-1-7998-2454-1.ch018
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- **Health applications:** Like smart wearable body for patient monitoring, doctor tracking, drug administration in hospitals, and so on;
- **Environmental applications:** These include water level monitoring, reliable forest fire detection, etc.;
- **Military applications:** For example, friendly forces surveillance, battlefield monitoring, nuclear attack defense systems, and much more;
- **Home applications:** Such as smart home devices for home automation, smart life, etc.

In such variety of applications, hundreds or thousands of sensors are deployed over the monitoring field, with sensors intelligently organized into a wireless network, in which each sensor periodically forwards its sensed information to the sink (base station) (Kulkarni et al., 2011, and Hua and Yum, 2008).

In large-scale WSNs, sensors collect data and forward it to a user over the wireless link. Moreover, the sensors are usually powered by limited battery capacity in expectation of surviving for a long lifespan. Thus, routing in WSNs becomes more challenging as compared to wireless ad hoc networks (Saleh et al., 2014). Keeping the fact in mind that the number of sensors is large in networks, the need of routing algorithms with the capability to convey sensed data along lengthy paths is becoming much more demanding. Regardless of the network size, and all the way through the network setup, some of the engaged sensors may not operate properly due to their energy exhaustion. However, this concern should not have an impact on the ongoing network configuration.

In the direct transmission, each sensor node communicates directly with sink or user. Thus, distant sensor nodes die at a faster rate as compared to nearer ones. In hop by hop transfer, each sensor node communicates with its nearest neighbor sensor node which in turn transfers to its neighbor, the process continues till information reached the sink. As a result, nearer sensor nodes drain more energy and die at a faster rate as compared to distant ones (Shepard, 1996). On the subject of energy efficiency in WSNs, the current research group is much more attracted towards routing algorithms, for example, routing protocols based on clustering algorithm in which the sensor nodes are organized into clusters (Heinzelman et al., 2000, and Heinzelman et al., 2002). In clustering algorithm, each sensor is responsible for transmitting the gathered data to the sink through its respective cluster head (CH). Some representative’s designs are clustering algorithm based hierarchical routing protocols (Heinzelman, et al. 2002, Smaragdakis et al., 2004, Manjeshwar and Agrawal, 2001, and Qing et al., 2006), which use probabilistic method to elect CHs and rotate the CHs periodically in order to balance energy dissipation in WSNs. However, irrespective of the network size, in some cases, inefficient CH can be selected and cluster sizes are unbalanced.

Because clustering algorithm based hierarchical routing protocols depend on only a probabilistic method in terms of CHs selection and use one parameter (strongest signal strength) in terms of clusters formation. Moreover, some CHs may be very near each other and can be installed in an edge of network field; furthermore, some non-CH nodes may receive multiple advertisement messages from neighboring CHs, they will pick only the one located at the smallest distance. These disadvantages could not extend the energy efficiency in WSNs. Appropriate CHs selection and appropriate clusters formation can considerably decrease energy consumption and extend the lifetime of the network (Yetgin et al., 2017). Therefore, CHs selection and clusters formation are ones of challenges in clustering algorithm based hierarchical routing protocols.

The new proposed approach, namely CAFL, aims to maximize the lifetime and throughput of WSNs. After sensor nodes’ distribution, each sensor node computes a chance value based on two fuzzy parameters which are residual energy and distance to the sink (closeness to sink) during CHs selection process. If