Chapter  13  
Clustering in Wireless  
Sensor Network:  
A Study on Three Well–Known  
Clustering Protocols  

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ABSTRACT  
The purpose of this chapter is the study of the clustering process in Wireless Sensor Networks (WSN), starting with clarifying why there are different clustering protocols for WSN by stating and briefly describing some of the variate features in their design; these features can represent questions the clustering protocol designer asks before the design, and their brief description can be considered probabilities for these questions’ answers to represent design options for the designer. The designer can choose the best answer to each design question or, in better words, the best design options that will make its protocol different from the others and make the resultant clustered network satisfies some requirements for improving the overall performance of the network. The chapter also mentions some of these requirements. The chapter then gives illustrative examples for these design variations and requirements by studying them on three well-known clustering protocols: Low-Energy Adaptive Clustering Hierarchy (LEACH), Energy-Efficient Clustering Scheme (EECS), and Hybrid, Energy-Efficient, Distributed clustering approach for ad-hoc sensor networks (HEED).  

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INTRODUCTION

Naturally, grouping sensor nodes into clusters has been widely adopted by the research community (Yang, Zhuang, & Li, 2011; Boregowda, Babu, Puttamadappa, & Mruthyunjaya, 2011; Hasnaoui, Hssane, Ezzat, & Benalla, 2010; Mohammad El-Basioni, Abd El-kader, Eissa, & Zahra, 2012; Abdel Hady, Abd El-kader, Eissa, Salem, & Fahmy, 2012; Abbasi, & Younis, 2007; Katiyar, Chand, & Soni, 2010) to satisfy scalability, achieve high energy efficiency, and prolong network lifetime in large-scale WSN (Akyildiz, 2010; Misra, Woungang, & Misra, 2009; Boukerche, 2009) environments. The corresponding hierarchical routing and data gathering protocols imply cluster-based organization of the sensor nodes in order that data fusion and aggregation are possible, thus leading to significant energy savings. In the hierarchical network structure each cluster has a leader, which is also called the Cluster Head (CH) and usually performs special tasks such as fusion, aggregation, cluster coordination, and transmission to the sink, and several sensor nodes as members.

The cluster formation process eventually leads to a two-level hierarchy where the CH nodes form the higher level and the cluster-member nodes form the lower level. The sensor nodes periodically transmit their data to the corresponding CH nodes. The CH nodes aggregate the data (thus decreasing the total number of relayed packets) and transmit it to the Base Station (BS) either directly or through the intermediate communication with other CH nodes. However, because the CH nodes send all the time data to higher distances than the common (member) nodes and do other additional functions as mentioned before, they naturally spend energy at higher rates (Zhang, Yang, & Chen, 2010). It is essential to rotate the role of CH among nodes especially in homogeneous networks so as not to burden a few nodes with more duties than others; this achieves load-balance and also fault-tolerance.

VARIATION IN THE DESIGN OF CLUSTERING PROTOCOLS

Clustering protocols can differ from each other in many features such as:

1. The criteria of selecting the nodes that will take the head role: The head selection criterion may be:
   a. Completely random, for example, node ID or a probability not based on any property of the node itself such as node’s residual energy.
   b. Random selection upon a probability based on nodes properties such as residual energy, i.e., as each node compares its CH selection probability against random number, the probability condition randomly may satisfied or not but with a larger chance for the node has the required property to be a CH.
   c. Non-probabilistic CH selection, rather the CH is selected upon its weight which defines its significance or its suitability to become a CH, this weight may depend on a certain metric such as node degree (number of its neighbors which are the nodes in a certain range around it) and residual energy, may depend on more than one metric, or may be a weighted function in more than one metric like:

   \[
   \text{Weight} = w_1 \times \text{metric}_1 + w_2 \times \text{metric}_2 + w_3 \times \text{metric}_3 \tag{1}
   \]

   The values of the weighting factors of the used metrics may be chosen according to application requirements.

2. The method by which a node takes the head role: The CH may appoint itself in the head role, it may be appointed in this role by a centralized authority, or it may nominate