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Full Length Article

Energy efficient heterogeneous DEEC protocol for enhancing lifetime in WSNs

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ABSTRACT

In this paper, we propose a 3-level heterogeneous network model for WSNs to enhance the network lifetime, which is characterized by a single parameter. Depending upon the value of the model parameter, it can describe 1-level, 2-level, and 3-level heterogeneity. Our heterogeneous network model also helps to select cluster heads and their respective cluster members by using weighted election probability and threshold function. We compute the network lifetime by implementing DEEC protocol for our network model. The DEEC implementation for the existing 1-level, 2-level, and 3-level heterogeneous network models are denoted as DEEC-1, DEEC-2, and DEEC-3, respectively, and for our proposed 3-level heterogeneous network model, the DEEC implementations are denoted as hetDEEC-1, hetDEEC-2, and hetDEEC-3, respectively. The network lifetime in DEEC-3 and hetDEEC-3 increases by 154.17% and 182.67%, respectively by increasing the total network energy 100% with respect to the original DEEC.
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1. Introduction

The wireless sensor networks (WSNs) contain hundreds or thousands of sensor nodes equipped with sensing, computing and communication abilities. Each node has the ability to sense the environment for an activity or object and can perform simple computations. A sensor node either communicates among its peers to collect the sensed data or sends (receives) the data to (from) a base station. A base station connects the sensor networks to another network. Designing protocols for sensor networks has to be energy aware in order to prolong the network lifetime, because the replacement of the embedded batteries in sensors is a very difficult process, once these have been installed. The WSNs should utilize their network energy in an efficient way so that they can monitor the environment for longer time [1]. A sensor node is basically made of four components namely: sensing unit, processing unit, transceiver unit, and power unit. It may also have additional application-dependent components such as a location finding system, power generator, and mobilizer. The sensing units are usually composed of two sub-units as sensors and analog-to-digital converters (ADCs). The analog signals produced by a sensor based on the observed phenomenon are converted into digital signals by the ADC, and then fed into the processing unit. The processing unit, which is generally associated with a small storage unit, manages the events that make the sensor node collaborate with other nodes to carry out the assigned sensing tasks. A transceiver unit connects a node to network. One of the most important components of a sensor node is power unit, which may be supported by power scavenging units. Most of the sensor network routing techniques and sensing tasks require the knowledge of location with high accuracy. Thus, it is common that a sensor node has a location finding system. A mobilizer may sometimes be needed to move sensor nodes when required to carry out the assigned tasks [2]. The nodes in wireless networks can be deployed deterministically or randomly. The deterministic deployments are more preferable in applications where the deployment area is physically accessible. The examples include the line in sand for target tracking, city sense for urban monitoring, soil monitoring, etc., where the sensor nodes are placed manually at the selected locations. On the other hand, random deployment of sensor nodes are used when the deployment area is physically inaccessible, e.g., bird observation on Great Duck Island, Mines, etc. In such environments, the sensor nodes are dropped from an aircraft [3–6].

The most important issue in WSNs is related to longevity of the network, which is directly or indirectly influenced by the network

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energy. The efficient utilization of the network energy may be done by organizing the sensors into groups, called clusters. Each cluster has a master node, which is also called the cluster head and several sensor nodes as members of it. The cluster head usually performs the fusion and aggregation. In order to have longer lifetime, the network should have good amount of energy. The network energy can be increased by increasing the number of sensors in the monitoring area. Increasing the number of sensor nodes does increase the network energy, but the cost is quite high because deploying an extra sensor incurs the cost of the sensor, which is ten times more than the cost of the batteries. Therefore, it is more appropriate and economical to increase the network lifetime by deploying some sensors with high battery. The sensor networks with such characteristics, i.e., sensor node with different energy levels are termed as heterogeneous wireless sensor networks [7]. In this paper, we propose a 3-level heterogeneous network model for WSNs to prolonging the network lifetime. Our heterogeneous network model also helps to select cluster heads and their respective cluster members by using weighted election probability and threshold function.

The rest of the paper is organized as follows. Section 2 discusses the literature review. Section 3 discusses the proposed 3-level heterogeneity network model and in Section 4, clustering process of heterogeneous distributed energy efficient clustering protocol for 3-level heterogeneity network model are discussed. In Section 5, experimental results are discussed and finally in Section 6, the paper is concluded.

2. Literature review

The WSNs have attracted several researchers because of their potential applications and related challenges. They have several applications like military applications, environmental applications, health applications, scientific exploration, area monitoring and structural health monitoring, etc. At the same time, they have numerous challenges like simplicity, coverage, connectivity, scalability, robustness, fault-tolerance, security, efficient use of energy, etc. One of the most important challenges is related to the enhancement of network lifetime so that it can observe the monitoring area for long time for the activities of objects. The network lifetime is essentially related to the efficient use of network energy. Accordingly, several approaches have been developed including various protocols. The very first protocol for increasing the lifetime in WSNs was discussed by Heinzelman et al. in 2000, which is known as low energy adaptive clustering hierarchy (LEACH) protocol [8]. It is one of the most accepted protocol based on clustering. In clustering, the sensors are divided into groups, each group is called as cluster. There is a master node in each cluster, called cluster head, that collects the data from its cluster members and sends that data directly or via some intermediate nodes to the base station. All sensors don't send the data directly to the base station rather they send their data through cluster heads that is why it is called hierarchical protocol.

In LEACH, the cluster heads may not be dispersed uniformly in the entire region as they are selected randomly. Another problem in LEACH is that the number of cluster head nodes is not fixed due to stochastic selection. These problems have been addressed in LEACH-C and fixed LEACH [9], by dispersing the cluster heads all over the network so that it can produce better performance. In LEACH-C, the base station (BS) organizes the nodes and controls the network. In each round of LEACH-C, a node needs to send its residual energy and location information to BS. Based on the received information, the BS can uniformly distribute the cluster heads throughout the topology and adjusts the size of each cluster. The BS also adjusts the probability of selecting the cluster heads according to the nodes' residual energy because the BS carries out energy intensive tasks like cluster formation and cluster head selection. In fixed-LEACH, the number of cluster heads is fixed. The sensor nodes choose their nearest node as cluster head where the number of supported nodes may be different for each cluster head. This leads to the uneven energy dissipation among the nodes. The LEACH has been modified by Lindsey and Raghavendra [10] and named as power efficient gathering in sensor information systems (PEGASIS) protocol. The PAGASIS protocol is nearly optimal in terms of energy cost for data gathering applications. The key idea in PEGASIS is to form a chain among the sensor nodes so that each node receives from and transmit to a closest neighbour node. The gathered data moves from node to node, gets fused, and, eventually, a designated node transmits it to the base station (BS). The nodes take turns in transmitting to the BS so that the average energy spent by each node per round is reduced. It, however, due to excessive delay, is not suitable for large networks. Manjeshwar et al. discuss the threshold sensitive energy efficient sensor network (TEEN) protocol [11] based on hierarchical clustering. In this protocol, a cluster head broadcasts two thresholds to the nodes, which are called as hard and soft thresholds for sensed attributes. The hard threshold is the minimum possible value of an attribute to trigger a sensor node to switch on its transmitter and transmit to the cluster head. Thus, the hard threshold allows the nodes to transmit only when the sensed attribute is in the range of interest; thus reducing the number of transmissions significantly. The soft threshold further reduces the number of transmissions if there is a little or no change in the value of the sensed attribute. The TEEN is however not good for applications where the periodic reports are generated because some users may not get any data at all if the thresholds are not reached. The TEEN protocol has been extended in [12] and the resultant protocol is known as adaptive threshold sensitive energy efficient sensor network (APTEEN) protocol. This protocol is meant for capturing periodic data collections and time-critical events. It allows users to set threshold values and a count time interval. The main drawbacks of the APTEEN protocol are overhead and complexity of forming the clusters. Younis et al. discuss hybrid energy efficient distributed (HEED) clustering protocol [13], an extension of the LEACH protocol, which uses two parameters for selecting the cluster heads. The primary parameter for cluster heads selection is the residual energy and the secondary parameter as degree of the node. The degree of a node and the number of nodes in its range, help in distributing the load among cluster heads for load balancing. It has low overhead in terms of processing cycles and message exchanged. This protocol does not assume any distribution of the nodes or location awareness.

For past few years, the WSNs have mainly focused on technologies based on the homogeneous WSNs in which all nodes have same system resources. Recently, the heterogeneous wireless sensor networks are becoming more and more popular. The researches [14,15] show that heterogeneous nodes can prolong the network lifetime and improve the network reliability without significantly increasing the cost. The heterogeneous nodes are more capable of providing data filtering, fusion and transport; but they are more expensive than the homogeneous nodes. A heterogeneous node may possess one or more types of heterogeneous resources, e.g., enhanced energy capacity or communication capability. Compared with the normal nodes, they may be configured with more powerful microprocessor or more memory or both. They may also communicate with the base station via high-bandwidth and long-distance network. The deployment of heterogeneous nodes increases the network energy and hence the network lifetime. There have been some works that discuss heterogeneous network models. Smaragdakis et al. discuss stable election protocol (SEP) [16], an extension of LEACH, that uses heterogeneity. It is the very first protocol, which talks about heterogeneity. In this protocol, a

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