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An adaptive clustering approach to dynamic load balancing and energy efficiency in wireless sensor networks

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ABSTRACT

Clustering is a well known approach to cope with large nodes density and efficiently conserving energy in Wireless Sensor Networks (WSN). Load balancing is an effective approach for optimizing resources like channel bandwidth, the main objective of this paper is to combine these two valuable approaches in order to significantly improve the main WSN service such as information routing. So, our proposal is a routing protocol in which load traffic is shared among cluster members in order to reduce the dropping probability due to queue overflow at some nodes. To this end, a novel hierarchical approach, called Hierarchical Energy-Balancing Multipath routing protocol for Wireless Sensor Networks (HEBM) is proposed. The HEBM approach aims to fulfill the following purposes: decreasing the overall network energy consumption, balancing the energy dissipation among the sensor nodes and as direct consequence: extending the lifetime of the network. In fact, the cluster-heads are optimally determined and suitably distributed over the area of interest allowing the member nodes reaching them with adequate energy dissipation and appropriate load balancing utilization. In addition, nodes radio are turned off for fixed time duration according to sleeping control rules optimizing so their energy consumption. The performance evaluation of the proposed protocol is carried out through the well-known NS2 simulator and the exhibited results are convincing. Like this, the residual energy of sensor nodes was measured every 20 s throughout the duration of simulation, in order to calculate the total number of alive nodes. Based on the simulation results, we concluded that our proposed HEBM protocol increases the profit of energy, and prolongs the network lifetime duration from 32% to 40% compared to DEEAC reference protocol and from 25% to 28% compared to FEMCHRP protocol. The authors also note that the proposed protocol is 41.7% better than DEEAC with respect to FND (Fist node die), and 25.5% better than FEMCHRP with respect to LND (last node die) while maintaining the average data transmission delay. We found also that HEBM achieved 66.5% and 40.6% more rounds than DEEAC and FEMCHRP respectively.

1. Introduction

Networks of Wireless Sensor devices are being deployed to collectively monitor and disseminate information about a variety of phenomena of interest. A wireless sensor device is a compact battery-operated device, capable of sensing physical sizes of its surroundings, and sending out the related information to a base station. Advances in integrated circuit design are continually shrinking the size, weight and cost of sensor devices while simultaneously improving their resolution and accuracy [1]. At the same time, modern wireless networking technologies enable the coordination and networking of a large number of such devices [2]. A Wireless Sensor Network (WSN) consists of a large number of sensor nodes working collaboratively to achieve a common mission. One or more sinks (base stations) are dedicated to collect data from all sensor nodes and forward them to the end user. These sinks constitute the interface through which the WSN interacts with the outside world. Although nodes are able to self-organize and collaborate together in order to establish and maintain the network [3] they are battery powered, limited in terms of

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processing, storage, and communication capabilities. Challenges in WSN arise in the implementation of several services, there are so many controllable and uncontrollable parameters [4] by which the implementation of wireless sensor network can be seriously affected such as energy conservation. As it is known, the valuable small size of a sensor node imposes a small battery with a limited available energy budget. When the wireless sensor network replaced the single macro sensors, it gained an advantage in the extended range of sensing, fault tolerance, improved accuracy and lower cost than its predecessors.

But as the number of nodes increases in the WSN, to increase the coverage range and accuracy, energy management becomes a major constraint since all these nodes are battery powered. And in that situation recharging or replacing of the battery is impossible [5]. In this paper, we propose an Energy Efficient Adaptive Clustering Protocol with data gathering using intra-inter cluster multi-hop communication. The aimed goal is to achieve better cluster size balance offering a network topology dissipating minimum energy. A node clustering is admitted as an efficient way to reduce energy consumption and extend the lifetime of the network. This is doing through data aggregation and fusion in order to reduce the number of transmitted messages to the Base Station (*BS*) [6]. So, nodes of the network are organized into clusters for processing and forwarding the information whereas lower energy nodes can be used for sensing target events. *HEBM* makes no assumptions on the size and the density of the network. The number of levels depends on the cluster range and the minimum energy path to the head. The proposed protocol reduces the number of dead nodes, the energy consumption, and extends the network lifetime. Recent applications of exergy analysis wsn have been simulated by the quest for more sustainable industrial systems. However, the benefits and drawbacks of exergy analysis in comparison to energy analysis are less prevalent in wsn literature. One of the biggest disadvantages of the previous work is that, sensor nodes are randomly divided among clusters which leads to lack of balance. Thus, some clusters have more nodes while some others have lesser. Also, certain cluster heads are located at the center of the cluster and some cluster heads may be in the edge of the cluster; this situation can cause an increase in energy consumption and may have great impact on the performance of the entire network. Due to any reason when the Cluster head dies, the cluster will become useless because the data gathered by the cluster nodes would never reach the Base Station. Also, the load balancing scheme for optimization of the consumed energy in previous work has not been used for service oriented WSNs. The service oriented WSNs should resolve the energy optimization issue by considering the constraints of cluster head distribution for coverage preservation in the network and the implementation of load balancing among the sensor nodes. Hence, in this paper the author's have proposed (HEBM) approach to reach the following objectives: reducing the overall network energy consumption (Extending the network lifetime duration) through balancing the energy consumption among sensor nodes and developing an efficient hierarchical clustering scheme in WSN. The implementing of the load balancing among sensor nodes leads to avoid energy hole and to obtain clusters quasi completely distributed. The clustering scheme we used is efficient in complexity of messages and time and the cluster-heads are well-distributed across the network. Like this, the proposed protocol HEBM selects a cluster head node not only by considering residual energy of the node greater than the average residual energy level of nodes in network, but in this work, a new Cluster-Head selection mechanism was proposed. This way identifies a cluster head which covers the entire field with minimum communication distance, using a combination of four metrics: residual energy, communication distance between the sensor nodes, communication distance between the sensor and the base station, and the number of neighbors. And we consider the problem of conserving energy by turning off the node's radio for periods of a fixed time length. The aim is to design sleep control laws that minimize the expected value of a cost function representing both energy consumption cost and holding costs for backlogged packets.

2. Related work

The growing interest of wireless sensor networks and the increasing advancements in microelectronics and wireless communication technologies constantly intensify efforts in the design and development of wireless sensor network: design of low-power signal processing architectures, low-power sensing interfaces, energy efficient wireless media access control, adaptive routing protocols, quality of service etc. Smaragdakis et al. [7] proposed (SEP) Stable Election Protocol which is an extension to the pioneer LEACH protocol. SEP is a heterogeneous aware protocol, based on weighted election probabilities of each node to become cluster head according to their respective energy. This approach aims to ensure a uniform use of the nodes energy in order to prevent prematurely dead nodes. In Linked Cluster Algorithm LCA [8], the nodes with the smallest *ID* become cluster head. All the other nodes which are 1-hop to the heads become children of the cluster-heads. In Refs. [9], the nodes with the highest degree among their 1-hop neighbors become cluster heads. The authors propose two load balancing heuristics for mobile ad hoc networks, where one is similar to LCA and the other is a degree-based algorithm. PEGASIS (Power-Efficient Gathering in Sensor Information Systems) [10], creates a near optimal nodes-chain in which each node communicates only with a close neighbor and takes turn transmitting to the base station, thus reducing the amount of energy spent per round. This is an improvement over LEACH. . The Weighted Clustering Algorithm (WCA) [11] elects cluster-heads based on the number of surrounding nodes, transmission power, and residual battery life duration and mobility rate of the node. WCA also restricts the number of nodes in a cluster so that the performance of the MAC protocol is not degraded. These weights are based on the application and the highest weight node among its one hop neighbor. All of the above algorithms generate 1-hop clusters and require synchronized clocks and have a complexity of O(n), where n is the number of sensor nodes. This makes them suitable only for networks with a small number of nodes (not scalable). Also, all the previous protocols require either knowledge of the network density or homogeneity of node dispersion in the network area. Hybrid Energy Efficient Distributed clustering (HEED) [12] does not make any assumptions about the network, such as, density and size. Every node runs HEED individually and at the end of the process, each node either becomes a cluster head or a child of a cluster head. Residual energy of a node is the first parameter in the election of a cluster head, and the proximity to its neighbors or node degree is the second. HEED generates a 1-level hierarchical clustering structure for intra-cluster communication. EAP (Energy Aware Routing Protocol) [13] clusters sensor nodes into groups and builds routing tree among cluster heads for energy saving communication. In addition, EAP introduces the idea of area coverage to reduce the number of working nodes within a cluster in order to prolong network lifetime. In Refs. [9], Sajjanhar et al. proposed a Distributive Energy Efficient Adaptive Clustering protocol. This protocol is adaptive in terms of data reporting rates and residual energy of each node within the network, which is having Spatio-temporal variations in data reporting rates across different regions. The proposed protocol selects a node to be a cluster head depending upon its hotness value and residual energy. In Refs. [14], authors proposed A cluster Based Energy Efficient Location Routing Protocol