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An energy efficient clustering scheme using multilevel routing for wireless sensor network☆

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ABSTRACT

The wireless sensor network (WSN) has attracted much research interest due to its many potential applications in different fields. In this work, we have tried to improve energy efficiency at the node level and to increase the network lifetime by proposing routing model called energy-efficient clustering (ENEFC) based on a hierarchical routing scheme. The proposed ENEFC provides three different hierarchical routing schemes: hierarchical routing using cluster identification (HRCI), hierarchical routing using multi-hop (HRMH) and hierarchical routing using multilevel (HRML). The HRML assigns a level to each cluster head during the publicizing of the base station over the entire network, and when the route collapses the scheme efficiently establishes a new level for the route between the base station and cluster heads. The experimental results and analyses for the three schemes show that HRML is more effective in terms of energy efficiency than the other two schemes.

1. Introduction

Wireless sensor networks (WSNs) are highly distributive in nature and are self-organized in functionality. A WSN incorporates numerous tiny sensor nodes in its network, thereby creating an environment that can sense and collect information about certain phenomena. This was not feasible previously under conventional network systems. The WSN is built to observe certain phenomena, and it carries out the process of collecting and forwarding this information to interested persons. For example, WSN may be installed in a construction environment where people are engaged in building massive skyscrapers. Architectural designs might sometimes create situations where a certain column of beams in a building may experience huge loads, and monitoring the level of stress the beams are actually experiencing is important in such circumstances.

Advancement in the fields of microprocessors, memory modules and microelectronic devices has led to WSNs becoming wafered and encapsulated together into tiny devices. These devices are programmed to carry out specific tasks. Thus, humans, technology and the world are integrated into a single autonomous domain. The versatility of WSNs in the environments in which they are employed has resulted in such networks gaining greater scope; they can be applied in any environment where human interaction is minimal or difficult. These areas include security surveillance, environmental applications, defense establishments, disaster and seismic applications, home applications, traffic monitoring, precision agriculture, medical diagnosis and healthcare. The wide applicability of the WSN is due to its simple node architecture. The simple architecture itself poses a serious constraint. One of the most serious limitations in WSNs is the energy source for

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the node's functionality, since charging or replacement of energy sources is virtually impossible. No matter how big or small the environment, the sensors are densely installed in such a way that the environment is monitored in detail. This dense deployment leads to some major obstacles, such as collisions in sent data, overhearing of transmissions and possibility of superfluous transmissions. These obstacles further increase the need for providing improved energy usage in WSNs, an issue that is still a major design challenge. The main objective of this research is to investigate energy-efficient schemes for cluster-based WSNs. The key aspects addressed in this research are minimizing the total energy consumed in the network, minimizing the number of data transmissions, maximizing the number of active nodes over a certain period of time and balancing the energy dissipation among the sensor nodes in the network. This research employs approaches such as clustering, multi-hop routing and multilevel routing. Clustering dramatically reduces communication overhead, thereby minimizing energy consumption and interference between sensor nodes. Analysis of the results for three hierarchical routing methods shows that multilevel hierarchical routing is much more effective in terms of energy efficiency in wireless sensor networks, as compared with other methods.

The remainder of the paper is organized as follows. Section 2 covers review literature. In Section 3, background on hierarchical routing using multiple hops for the representation of network topology is provided. In Section 4, hierarchical routing using multiple levels, including a clustering algorithm and a reliable routing algorithm among cluster nodes, is presented. Results are illustrated in Section 5. Finally, Section 6 concludes the paper.

2. Related work

2.1. Hierarchical routing

One of the major design constraints in any type of network is scalability, and WSNs are no exception. In a single-tier WSN architecture, if the nodes constituting the WSN are too dense, then the node that acts as the gateway is overloaded. This results in poor latency and improper event tracking. A WSN design that adopts single-tier architecture with a large set of sensors that cover a wide area cannot be scaled. There are some routing approaches that utilize network clusters, thereby making the WSN system scalable without affecting its service. If scalability is the only constraint, then it can be addressed by adopting a suitable type of framework, but since energy consumption is an important issue that is beyond the control of any framework, it is vital to consider energy consumption issue also. Among all the available routing strategies, hierarchical routing protocols are regarded as the most energy efficient [1,2]. These are achieved by providing a self-organizing feature among the nodes in the establishment of a large-scale network. Via self-organization, the protocol enables certain nodes to perform high-energy transmissions and the remaining nodes to perform normal tasks. A power-aware algorithm is employed to identify the high-energy transmission nodes that forward the transmitted data from normal nodes to the base station. Based on the topology of the WSN network, the hierarchical routing protocols can be categorized into cluster-based protocols and chain-based protocols [3,4].

High consumption of energy during data collection and distribution process is reduced using a clustering method; hierarchical routing capitalizes upon this advantage by dividing the nodes into clusters. The method usually selects the node with the most energy as the cluster head, which gathers together the data transmitted by lower-energy nodes in the cluster [5]. By employing multi-hop communication among the sensor nodes in a cluster, the data transmissions to the sink node are reduced, and thus the hierarchical routing protocol efficiently manages energy consumption. The schemes that incorporate hierarchical routing strategies mainly differ in the selection of routes and in the node behavior within inter- and intra-cluster domains. A review of previous work aiming at reducing energy consumption in WSN and increasing the network lifetime is provided. In this paper, the clustering algorithms developed for WSNs are discussed briefly, and cluster-based routing protocols and intra-network data aggregation are explained. The most interesting research issue regarding cluster-based protocols is the problem of how to form the clusters so that energy consumption and other contemporary communication metrics such as latency are optimized. The processes of data aggregation and fusion among clusters also provide an interesting problem to explore. In this research, clusters are formed using an appropriate cluster head selection process.

2.2. Hierarchical routing using clusters

The hierarchical routing protocols based upon clustering group the nodes into clusters, and for each cluster, the protocol chooses one node to act as cluster head [6]. The role of cluster head is to act as gateway between the base station and the nodes in the cluster as shown in Fig. 1.

In chain-based hierarchical routing protocols, the nodes are connected in the form of a chain structure and the sink node or the chain head is identified based on the energy level that each node possesses [7]. In a chain-based topology, the chain leader holds the responsibility of transmitting the data to and fro between the base station and the chain nodes [8]. Furthermore, performance enhancements such as data fusion are incorporated into both models by setting up threshold values and design principles to handle snoozing and inactive pairing among the nodes in both protocol types [9].

2.3. Hierarchical routing using cluster identification

Usually, in cluster-based routing schemes, the operations are broken up into rounds with each round having its own phases. For every round of operation, the protocol uses a routing table that helps in cluster head selection/replacement. At

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