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EDHRP: Energy efficient event driven hybrid routing protocol for densely deployed wireless sensor networks

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ABSTRACT

Efficient management of energy resources is a challenging research area in Wireless Sensor Networks (WSNs). Recent studies have revealed that clustering is an efficient topology control approach for organizing a network into a connected hierarchy which balances the traffic load of the sensor nodes and improves the overall scalability and the lifetime of WSNs. Inspired by the advantages of clustering techniques, we have three main contributions in this paper. First, we propose an energy efficient cluster formation algorithm called Active Node Cluster Formation (ANCF). The core aim to propose ANCF algorithm is to distribute heavy data traffic and high energy consumption load evenly in the network by offering unequal size of clusters in the network. The developed scheme appoints each cluster head (CH) near to the sink and sensing event while the remaining set of the cluster heads (CHs) are appointed in the middle of each cluster to achieve the highest level of energy efficiency in dense deployment. Second, we propose a lightweight sensing mechanism called Active Node Sensing Algorithm (ANSA). The key aim to propose the ANSA algorithm is to avoid high sensing overlapping data redundancy by appointing a set of active nodes in each cluster with satisfy coverage near to the event. Third, we propose an Active Node Routing Algorithm (ANRA) to address complex inter and intra cluster routing issues in highly dense deployment based on the node dominating values. Extensive experimental studies conducted through network simulator NCTUNs 6.0 reveal that our proposed scheme outperforms existing routing techniques in terms of energy efficiency, end-to-end delay and data redundancy, congestion management and setup robustness.

1. Introduction

The main objective of the WSN is to witness and report the events of the physical world. Over the last couple of years WSNs have witnessed increased popularity in several scientific and industrial application domains to explore events. In many cases, sensor nodes rely on their limited powered battery and computational resources, and after deployment are usually left unattended in sensing regions to make individual decisions to perform sensing and routing tasks which extremely makes it very challenging or impossible to recharge or replace their batteries (Garcia et al., 2010). Such limitations demand the data traffic to be evenly distributed among the sensor nodes. Otherwise, heavily loaded sensor nodes may bring many challenges including large end-to-end delay, congestion, memory overflow, and data reliability issues. Due to harsh working environments, reliable data forwarding with the least amount of energy expenses is assumed to be one of the most critical challenges in WSN applications (Karim et al., 2013).

In recent years, many researchers have reported that clustering is an efficient method for organizing a network into a connected hierarchy, load balancing, and prolonging the lifetime of WSN (Sendra Compte et al., 2011; Hu et al., 2015; Singh and Lobiyal, 2012). Clustering is a method in which sensor nodes are organized into groups around central sensor nodes usually called CHs with the responsibilities of up-keeping state and inter cluster connectivity for data processing. After processing the received information from its member's nodes, each CH is responsible for sending data to BS via single or multiple deployed sinks (Gungor, 2007). Clustering dramatically reduces the energy consumption of each sensor node in a WSN with the expense of increasing communication and data traffic load on CHs. However, in energy-constrained wireless sensor networks, a cluster head consumes more energy due to additional workload of receiving the sensed

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data, data aggregation and transmission of aggregated data to the base station (BS) (Agarwal and Kishor, 2014). Moreover, an inappropriate formation of clusters may lead some cluster heads overloaded with higher number of sensor nodes. This overload can make quicker death of the CHs and partitions the network, and thus, degrade the overall performance of the Wireless Sensor Network. The hot spots and bottleneck problems arise because of this unbalanced load among CHs when using the multihop forwarding model for the inter cluster communication (Faheem et al., 2013).

To overcome this situation, the idea of unequal size clustering plays a critical role to balance the energy consumption and workload of CHs. Furthermore, in WSNs, sensor node scheduling and network clustering are two efficient techniques for maximizing network coverage lifetime by reducing node energy consumption. When incorporating these two techniques, the challenges include how to choose the utmost energy efficient cluster size and how to appoint CHs and active sensor nodes (Shah et al., 2011). Furthermore, conservation of energy and fault tolerance are two major issues in the deployment of WSNs. Design of clustering and routing algorithms for a large scale WSN should incorporate both these issues for the long run operation of the network. Therefore, it is necessary to explore clustering characteristics in dense and large network deployments taking into consideration major performance issues, such as efficient data gathering, effective data traffic load handling, quick and low-overhad setup and maintenance, shortest reliable communication paths, minimum end-to-end delay and robust adaptation to node failure etc. (Mo et al., 2011; Wang et al., 2011).

In summary, prolonging network lifetime with reliable data communication must be considered as a critical issue in WSNs. In WSNs, the routing protocol and algorithms are crucial to manage these limited sensor nodes resource efficiently and provide reliable communication to explore real world events (Gungor et al., 2008). Therefore, designing an energy capable routing protocol has become one of the important challenging issues to extend the lifetime of sensor nodes, maximizing network coverage, and improving robustness against node failures (Afsar et al., 2015). Inspired by the above advantages of clustering approach, the main goal of this paper is to develop an energy efficient routing scheme, which provides reliable communication by taking into account above mentioned routing challenges, and extend the lifetime of WSNs.

The rest of the paper is organized as follows. Section 2 presents an overview of the existing routing approaches implemented in WSNs. In Section 3, the details of the proposed routing scheme are explained. Section 4 presents network and simulation settings. Section 5 presents performance analysis. Finally, the paper is concluded in Section 6.

2. Literature survey

To balance the data traffic and energy consumption workload of each sensor nodes evenly with improved overall scalability and network lifetime has become one of the most critical issues in WSNs. In recent years, in order to prolong the network lifetime of sensor network many researchers proposed a number of energy efficient routing protocols for WSNs. The authors in Liu et al. (2012b) propose an innovative distributed energy efficient clustering with improved coverage algorithm to solve high communication energy consumption and the impact of node failures on coverage with different densities clustering environment. The proposed scheme does not require any time synchronization and knowledge of a node's geographic location information and performs superior to prolong the network lifetime and improve network coverage effectively with the lack of quality of fault-tolerant management and grouping resilience.

The work in Bhattacharjee and Bandyopadhyay (2013) proposes an energy efficient routing scheme that considers the remaining energy of the node as well as energy efficiency to relay data packets toward the sink. The proposed scheme performs superior to prolong the network lifetime by balancing the data traffic between the nodes with the expense of latency and scalability issues in dense deployment. Furthermore, it faces high data redundancy issues when deployed in dense network and performs poorly in setup robustness.

In Lin et al. (2012) the authors propose an energy efficient ant colony algorithm for data aggregation and delivery. In the proposed scheme to compute the probabilities for dynamically selecting the next hop each node estimates the remaining energy and the amount of pheromones of neighbor nodes. The proposed scheme performs well to prolong the network lifetime, computation complexity and success ratio of one hop transmission. However, in the aspects of robustness, fault tolerance and scalability its performance is debatable.

The research in Azharuddin et al. (2014) proposes a distributed clustering and routing algorithms jointly called as DFCR. The proposed scheme equipped with energy efficient and fault tolerant capabilities uses a distributed run time recovery of the sensor nodes due to sudden failure of the cluster heads with satisfy coverage. The performance of the scheme is observed better to prolong the network lifetime. However, in the dense deployment scheme faces partial and transient failure of the sensor nodes.

In Liu et al. (2012a) to minimum high energy consumption cost entire network is divided into several clusters of unequal size where each sensor node maintains a gradient value which helps to find the next hop to convey data packets toward the sink. The proposed scheme called gradient based energy balancing unequal clustering routing approach performs well to prolong the network lifetime. However, in dense deployment it ignores fading and multi-path effects which cause a high data packet collision in the work.

The study in Kuila and Jana (2014a) provides a novel clustering algorithm equipped with a vector encoding and local improvement mechanisms to prolong the lifetime of the network by preventing faster death of the highly loaded cluster heads. The proposed scheme performs better to prolong the network lifetime in sparse areas. However, in dense deployment it shows poor in efficient cluster management and faces setup robustness issues.

Gong et al. (2013) propose one-hop and k-hop distributed clustering algorithms that account both residual energy of a node and the link qualities in its neighborhood to convey robust information. The proposed scheme shows its behavior superior to improve the data reception ratio and reduce the total energy consumption by providing better network scalability. However, excessive end-to-end (E2E) delay and congestion management are the challenging issues of the offered scheme.

Kuila and Jana (2014b) study the Linear and a Non-linear Programming for energy efficient routing and clustering issues in WSNs. The developed routing algorithm follows an efficient particle encoding scheme equipped with multi-objective fitness functions while the clustering algorithm considers energy conservation of the nodes through load balancing. The performance of the proposed algorithms is observed remarkable to prolong network life, number of inactive sensor nodes and the total data packets transmission with the expense of excessive network implementation complexity and synchronization issues in dense deployment.

Liu et al. (2013) propose an innovative balance energy efficient and real time reliable communication routing protocol to achieve joint performances of real-time, energy efficiency and reliability in