

Duty Cycle Scheduling and Routing in Path-Connected-Cluster Wireless Sensor Network

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Abstract—Wireless sensor networks (WSNs) have become popular due to their application in various fields such as home health care, military surveillance, and environmental science. For long-term and low-cost monitoring applications, Wireless Sensor Networks (WSNs) are commonly used. The key issue involved in wireless sensor networks is the energy efficiency of sensor nodes. Because nodes in WSN are powered by small irreplaceable and non rechargeable batteries. Existing research efforts show that clustering is an efficient method to prolong the lifetime of WSN network. We observe that many WSN applications to achieve fault-tolerance use redundant nodes. However, in the multi-hop communication redundancy is not required due to the low communication traffic load. In this paper, we present a new scheduling method Duty-cycle Backbone Scheduling (DCBS). Our proposed technique, DCBS, employs heterogeneous scheduling. In DCBS to preserve network connectivity, backbone nodes work with duty-cycling and non-backbone nodes turn off radios to save energy. Our simulation studies verify the effectiveness and efficiency of the proposed DCBS technique, and shows that our proposed technique is superior to the existing techniques.

Keywords—Communication system routing, wireless sensor networks, duty cycle scheduling, routing, and pathconnected clusters

I. INTRODUCTION

Wireless sensor networks (WSNs) have become popular due to their applications in various fields such as home health care, military surveillance, and environmental science. For long-term and low-cost monitoring applications, Wireless Sensor Networks (WSNs) are commonly used. The key issue involved in wireless sensor networks is minimize the energy consumption to perform node addressing and routing. A class of existing research efforts is dedicated to WSNs to tackle various issues in WSN such as routing [9] and power management [10].

In WSN it is important to address addressing and routing challenges. In a dense WSN network a pernode addressing scheme will be expensive due to the large address space. In

addition, per-node addresses are required to be allocated and managed according to the change in the network topology. Therefore, address allocation is a challenging task in the dense WSN network which is often underestimated [10]. On the other hand, addressing play an important role in the routing. Routing involves discovery of paths from source nodes to destination nodes based on their network addresses. End-to-end path discovery incurs high communication overheads. Therefore, it is crucial to design an efficient and effective WSNs protocol for addressing and routing. Energy consumption of sensor nodes is a major concern in WSNs and active field of research. To increase the usage of WSN in daily life. Energy saving techniques play an important role and are critical to the success of WSNs. A lot of research work has been dedicated to study duty-cycling techniques for power saving [2], [4]. However, existing duty cycling approaches do not consider the redundancy in WSNs, so all the sensors' cycles are identical.

A. Our Observations

Existing research efforts and solutions lack to provide an efficient and effective addressing and routing protocol for WSNs. In WSNs, we can form a backbone to maintain the connectivity in multi-hop communication without sacrificing the reliability. The overall energy consumption of the network can be reduced by using a single backbone. However, it has no effects on the network lifetime. Hence, to extend the network lifetime, it is necessary to rotate backbones.

B. Our Solution

In this paper, we further extend the path-connectedcluster (PCC) using Duty-cycle Backbone Scheduling (DCBS) technique, where a cluster of sensor nodes is used to deploy in the regions that require intensive sensing. Clusters are physically separated and connected by long paths for occasional communications. Our proposed technique, DCBS, employs heterogeneous scheduling.

In DCBS to preserve network connectivity, backbone nodes work with duty-cycling and non-backbone nodes turn-off radios to save energy. The primary goal of our research is to propose a light addressing and routing protocol for WSNs.

Our approach is based on the principle of Chia-Hung's [10] address assignment. However, our proposed technique leads to a compact address usage as compared to the original Chia-Hung's design. Moreover, using our addressing, low communication overheads is incurred by routing. Given a WSN, we present a scheme to automatically separate paths from clusters in a distributed manner. Then we propose a Chia-Hung's like address assignment scheme for a WSN.

C. Our Contributions

We proposed a light addressing and routing protocol for a path-connected-cluster (PCC) wireless sensor network (WSN). To summarize, this paper makes the following contributions:

We propose a new scheduling method called Duty-cycle Backbone Scheduling (DCBS). It uses a light addressing and routing scheme for PCC-WSN. Our proposed system uses a heterogeneous approach in cluster formation, so it increases the lifetime of sensor nodes. Our extensive simulation results show the performance of DCBS. The rest of this paper is organized as follows: Section II describes the background and related work. Section III presents the design of our solution and mathematical model. Section IV is simulation results, and we conclude the paper in Section V.

II. BACKGROUND AND RELATED WORK

A Wireless Sensor Network is comprised of sensor nodes which have limited capability of sensing, computing, and communication. Nodes in the sensor network typically contain one or more sensors, a radio transmitter/receiver, a small microcontroller to perform limited computations and a battery as an energy source. Extensive research efforts have been taken in order to minimize the energy consumption by designing energy efficient protocols at different layers. In [10], the authors presented a technique for disaster prevention and environmental monitoring for distributed sensor networks. Some sensor network applications require real-time communication with minimum routing delay.

To achieve this, many research efforts proposed realtime routing protocols such as RPAR [3], SPEED [8], and MM-SPEED [6]. These works proposed systems with minimal delay in routing. To control the topology of wireless sensor network existing mechanisms either control transmission power or impose a hierarchy on the network. Hierarchical approaches use clustering to change the logical structure of the network. In [5], the authors propose the clustering protocol that aims at the formation of stable cluster in WSN, where node locations are mostly fixed. Ali et. al., [1], proposed a node address naming method that assigns locally unique addresses and reduces the address size. The focus of his work is on clustering routing approaches. In [7], proposed a routing algorithm for multi-sink sensor networks using a reliability based path selection approach. In [10], the authors proposed the Priority-based Coverage-aware Congestion Control (PCC) algorithm which is fair, distributed, and priority-distinct. It provides higher priority to packets with the event information in which the sink is more interested. It also gives a fair chance to all sensors to send packets to the sink, irrespective of their locations in the network.

A. Summary Existing research efforts show that the duty-cycle scheduling in wireless sensor networks has a great importance in PCC-WSN for design a light-weight routing and addressing scheme, which reduces energy consumptions of nodes and prolongs the lifetime of the network.

III. DESIGN SECTION

In this section, we discuss algorithm and mathematical model of our proposed protocol, Duty-cycle Backbone Scheduling (DCBS). Algorithm 1 describes our proposed DCBS algorithm for effective routing in WSN. Every backbone node has hoptosink value set as 1. Only the sink's hoptosink value is set to 0 (zero). Sink sends its hoptosink value to neighboring backbone nodes. Every receiving node compares its own hoptosink value with the received value. If the received value is less than the current value then 1 (one) will be added to the received value and that value becomes the new current hoptosink value. The neighboring nodes will send their new hoptosink value to their neighbors until all nodes in the network find their distance to the Sink. In this way routing table is built for WSN network. Once routing table is built in by nodes in the network, they can send sensed information to the sink node. Our approach finds a disjoint set of backbone paths from sensor node to the Sink.

A. Addressing Assignment and Routing

Our proposed technique uses a two-level addressing scheme to reduce the address space. We used level-1 addressing for each cluster, which is formed of nodes with sensed data. In level-2 addressing, we assign each individual node in the cluster an n bit address. Similar, to two levels of addressing, we also design a two-level routing approach. In level-1 routing, packets are routed from a node to cluster head (also called as super node), and level-2 routing involves the routing of packets within supernodes or supernode to the sink.

Algorithm 1: Duty-cycle Backbone Scheduling Algorithm for effective routing in WSN

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1: Input: Collection of nodes  $V$ ,  $u, v \in V$ ,  $\text{hop-to-sink}(u) \Rightarrow$  hoptosink value of node  $u$ ,  $s_n \Leftarrow$  supernode of the cluster.
2: Output: Routing table formation in each node and end-to-end path between node ( $u$ ) and sink ( $S$ )
 $\forall u \in V$ , hoptosink value  $\Leftarrow \infty$ 
Sink's ( $S$ ) hoptosink value  $\Leftarrow 0$ 
3: Initialize all hoptosink value of all nodes
4:  $S$  sends hoptosink value to its neighbors. Propagation of value from sink to its neighbors.
for all  $\forall v \in V \cap v \in \text{neighbor of } S$  do  $v \Leftarrow S$ -hoptosink-val
end for
5: neighbors update their hoptosink value
for all  $\forall u \in V$  do
    if ( $S$ -hoptosink-val <  $u$ -hoptosink-val)
 $u$ -hoptosink-val =  $S$ -hoptosink-val + 1 end for
nodes with sensed data come together and form cluster
 $\forall s_n \in V$  form a cluster

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6: Data delivery to sink (S)

$v \Rightarrow sn$. node (v) sends data to supernode (sn) in the

cluster $sn \Rightarrow S$.

supernode (sn) in the cluster sends data to Sink

B. Dynamic Controls to Change in Topology of WSN

In this section, we discuss how our proposed protocol deals with the changes in WSN topology due to insertion of new nodes, removal of nodes, or dead nodes. To address these issues, we follow the specification in IEEE 802.15.4. A leaving node disassociates with its parent by issuing a NLME - LEAVE request. The network addresses assigned to it and its children will be released. Using an aging process, a dead node can be detected by its parent and the addresses assigned to the dead node and its children will be released. When a new node inserted into the network, it issues a NLME - JOIN request.

Then a neighboring router which receives the request and still has routing capacities may accept it. Note that this can be conducted within a supernode.

C. Mathematical Model

Let N be the total number of nodes in wireless sensor network, which is a path-connected cluster (PCC). Let $B = \{B_1, B_2, B_3, \dots, B_m\}$ be the total m number of backbone nodes in the PCC used for connecting the cluster with each other.

The number of duty cycle round C can be calculated as:

$$C = V \times E / n \times \epsilon$$

where, V is number of nodes in the backbone, E is initial energy of the node, n indicates number of nodes in one set, and ϵ is energy consumption per node in each round.

Our aim to find disjoint set of backbone paths $\{P_1, P_2, P_s\}$ that meets following criteria:

- 1) every sensor node in the PCC cluster has a route to any other node in the PCC,
- 2) every cluster in PCC has at least one active backbone path.

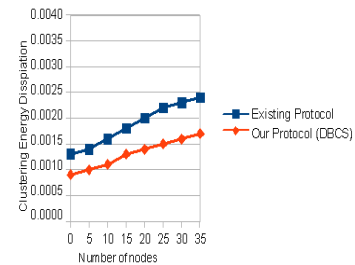
IV. EVALUATION

A. Simulation Setup

We simulate the proposed system using custom simulator running on the Ubuntu 12.04 operating system. We run our algorithm on several random networks created by randomly distributing nodes. The aim of this test was to evaluate situation-specific performance in networks. We developed a custom simulator software in JAVA to run simulations.

B. Energy Dissipation in Clustering

In this section, our algorithm (DCBS) will be compared to other protocols. The algorithms will be compared based on energy dissipation in clustering. The network lifetime can be prolonged by minimizing the energy dissipation in clusters. In addition, reducing the energy dissipation also increases the efficiency of clustering. Figure 1 shows our initial stage results of the number of nodes and energy dissipation in clusters. The results of impact of the number of nodes on the network lifetime was not available at the time of writing this paper.



V. CONCLUSION

We propose an energy efficient addressing and routing protocol, Duty-Cycle Backbone Scheduling (DCBS), for path-connected-cluster (PCC) wireless sensor network (WSN). Existing research efforts show that clustering is an efficient method to prolong the lifetime of WSN network.

We used a clustering approach in DCBS. The proposed DCBS protocol employs heterogeneous scheduling. In DCBS to preserve network connectivity, backbone nodes work with duty-cycling and non-backbone nodes turn off radios to save energy. Our simulation studies verify the effectiveness and efficiency of the proposed DCBS technique, and show that our proposed technique is superior to the existing techniques.

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