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An Enhancement Approach for Reducing the Energy Consumption in Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Networks (WSN) consist of low power devices that are distributed in geographically isolated areas. Sensors are arranged in clusters. Each cluster defines a vital node which is known as a cluster head (CH). Each CH collects the sensed data from its sensor nodes to be transmitted to a base station (BS). Sensors have deployed with batteries that cannot be replaced. The energy consumption is an important concern for WSN. We propose an enhancement approach to reduce the energy consumption and extend the network lifetime. It has been accomplished by augmenting the energy balancing in clusters among all sensor nodes to minimize the energy dissipation during network communications. The improved method is based on a cluster head selection method. In addition, an enhanced schedule of the TDMA has been implemented. Finally, the development approach indicates the progress in terms of network lifetime, Number of cluster head, energy consumption and number of packets transferred to BS compared to LEACH and other related protocols. Mathematical analysis and MATLAB 2015a simulation results show the effectiveness of the proposed approach. The energy consumption of WSN has been reduced up to about 60% and prolong the network life cycle by 73% than LEACH.

1. Introduction

Wireless Sensor Networks (WSNs) consist of hundreds or thousands of tiny devices that are capable of communicating with each other with limited power. These wireless sensors are deployed in a real-world environment to sense various environmental effects. Sensor nodes have limited power, so the collected data from target environment is sent directly to the base station (BS). BS is a node that interested in receiving data from a set of sensor nodes. It analyzes and reduces the similarities between their data, that is used for decision-making. In addition, BS is not only able to use these data locally, but it also is able to send these data to other networks which are located in a remote area. However, this would cause a high communication overhead, which cannot be tolerated by sensor nodes. In WSN, the processes of gathering data from whole sensors and reported them to BS are known as data aggregation (Sinha, 2013; Othman, 2015).

The technology of WSNs is extended to be used in a lot of various applications. These applications may include military applications, survival monitoring, traffic control, intelligent buildings and object tracking (Zhou, 2008; Amara et al., 2013; Estrin et al., 1999; Salim, 2014; Sheng et al., 2013; Jose et al., 2013).

However, WSN suffers from extensive constraints such as limited memory, little computational ability, not rechargeable and limited battery, security and set up a global addressing for all sensor nodes. Energy-efficiency is a ticklish problem of sensor nodes that have supposed to run without care for a long time. In addition, energy consumption depends on the application requirements. Furthermore, it is sometimes deployed in a hostile environment where a person cannot be replaced or recharge batteries of sensor nodes.

So, Batteries play the main role in WSN, it's the indicator of the lifetime. In Wireless network, most of the energy is consumed in the process of data transmission. Thus, the energy efficiency routing protocols are needed. Many kinds of literature take this consideration to design WSN of more energy-efficient. Multiple Types of research are introduced for saving energy. These Researches start from physical layer of passing through routing protocols, based on how to enhance data acquisition techniques (Batra, 2016). On

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the other hand, clustering based protocols (Ye et al., 2005) have attracted a lot of researchers. It's composed of two phases: the setup phase and steady state phase. In the setup phase, WSN is split into clusters (groups of nodes). In each cluster, there is a node that acts as a cluster head (CH). In steady state phase members in the cluster (Non-Cluster Head nodes) sense and transmit their data to CH systematically. Each sensor node in the cluster has its own time to send sensed data to his CH. The sending process has performed according to TDMA (Time Division Multiple Access) schedules. This schedule has established by each CH and sends it to all members in cluster see Fig. 1.

The cluster head is responsible for reducing redundant data and apply aggregation techniques that minimizing the data size and forward it to the BS.

LEACH (Low Energy Adaptive Clustering Hierarchy) protocol is a leading protocol that is used for micro-sensors network applications (Heinzelman, 2002). It integrates both concepts of energy-efficient cluster based routing and media access together. The idea behind LEACH is to save energy of sensors as possible to improve the lifetime of the network. In the setup phase, the nodes represent the cluster heads have chosen randomly after deploying all sensor nodes. The choice of Cluster Heads has performed at the beginning of each round. Every sensor node selects a random number between 0 and 1. If this random number is less than the threshold T(n) that node is chosen as a CH for the curren round. The T(n) is given in the next Eq. (1):

$$T(n) = \begin{cases} \frac{p}{1-p\times[rmod(1/p)]} & if\ n \in G \\ 0 & elsewhere \end{cases} \quad (1)$$

where:

p: is the percentage of choosing cluster heads.
R: is the current round.
G: is the set of sensor nodes that have not been cluster heads in $1/p$ rounds.

Even though LEACH protocol preserves energy in sensor nodes, and minimizes the size of the routing table. It still has some limitations (Shurman et al., 2014) such as:

- The residual energy in the nodes is not taking into account when the randomized choice of the CH is performed.
- When the size of the network increases, the CH's that are located far away from the BS consume more of their energy rapidly. The LEACH protocol is designed to work well if the deployment environment is small.
- TDMA (Time division multiple access) schedule has some restrictions: Each cluster head has its own time to send data in the designated slot in spite of there is no recent data.
- Some clusters may contain more sensor nodes than other clusters which affected on the frequency of sending data to the BS. Nodes in a smaller cluster will drain energy faster than nodes that belong to a bigger cluster.
- Sensor nodes generate a random number between 0 and 1. If a node number less than the threshold, it will become the cluster head. So, there are no restrictions produced of cluster heads. The energy efficiency of sensor node is affected by the number of using as a cluster head.
- LEACH protocol assumes that all sensor nodes have enough energy to communicate with the sink. So, more energy consumed if sensor nodes are far away from the sink.
- Also, LEACH assumed that all nodes in the network are homogeneous, which is not factual in most of the applications. Hence, it needs more improvements to handle heterogeneous nodes.
- LEACH doesn't preserve data privacy among sensor nodes and need more security.

The rest of the paper is organized as follows. Section 2 shows a brief description of the related work performed on the LEACH protocol. Section 3 presents network model and assumptions. In addition, the proposed approach is discussed in Section 4. Simulation results and analysis are discussed in Section 5. Finally, the conclusion and future work are introduced in Section 6.

2. Related work

In general, LEACH is used as a guideline to cluster-based routing protocols. It introduces a randomize technique to designate cluster heads that will die as their energies are consumed. The designated technique is based on some nodes that practically have a low residual energy to be used as cluster heads. Multiple researchers are introduced to achieve the energy balanced inside the wireless sensor networks. In (Long et al., 2011); authors introduced an assistant cluster head approach. They establish a dynamic method to accomplish the ability to create an assistant cluster head or not. The assistant cluster head is based on the metrics of the geographical location of nodes to be a cluster head, the number of members in each cluster, and the remaining energy of each node. This technique extends the lifetime of a wireless sensor network by reducing the energy consumption of member nodes in a cluster. But, the implemented technique requires complex operations that causes more delays.

In (Arumugam, 2015) the authors proposed an energy routing protocol depends on the effective ensemble data and optimal cluster head selection. This protocol prolongs the lifetime of the network. But, it still suffers from the delay caused by multifaceted operations. It always chooses the sensor node that has higher residual energy without consideration to any other factors such as the location of the sensor node that may be located far away from BS.

In (Junping et al., 2008), the authors proposed an algorithm based on the random timer to construct the cluster without the need to any global information. This algorithm suffers from big gap energy consumption between cluster heads and their sensor nodes. Other researchers are presented to the number of cluster heads and the node's residual energy issues.

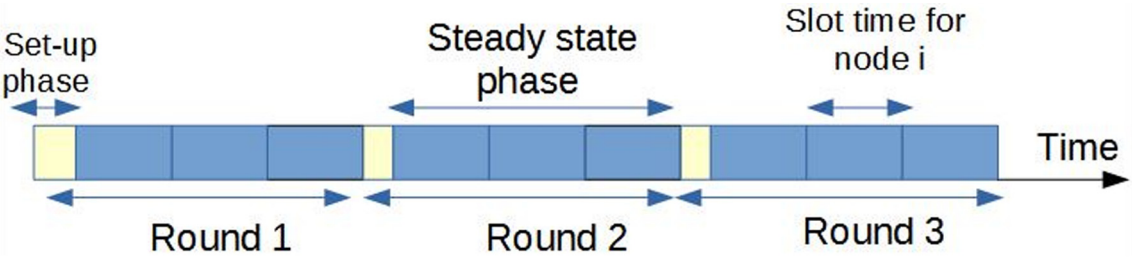

Fig. 1. Time Division Multiple Access schedule for LEACH operation.

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