Extending Lifetime of the Selected Sensor Nodes in Wireless Sensor Networks

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ABSTRACT

In Wireless Sensor Networks (WSN), sensors collect sensory data and transmits them to a central location. In most of the use scenarios, sensors are manufactured as disposable. Therefore, sensor nodes have very limited capabilities such as battery power. Once their batter is depleted the sensor nodes become unusable. One of the most energy consuming activities is radio transmission. In this paper, we propose a method for reducing radio transmission activities and, hence, reducing power consumption at the selected sensors. In simulation experiments, the extended lifetime of these sensors are observed.

Keywords **–** Wireless Sensor Networks, routing protocol, energy efficient, computer networks

1. INTRODUCTION

Wireless Sensor Networks (WSN) consist of sensor nodes. In general, sensor nodes have three main units: sensory, computation and communication [1]. For all these units, energy is provided by a battery which, most of the time, cannot be chargeable [2]. Thus, when the battery depletes, the sensor node is called to be "dead".

The collected data should be transferred to a central unit for further processing in a WSN [3]. There are several different approaches to realize data transfer from sensors to the central unit mostly called Base Station (BS). One of the methods used for this purpose is to clustering sensors into groups as in LEACH protocol [4]. Each group elects a Cluster Head (CH). CH is responsible for collecting the data from the grouped sensors and transmits them to the BS. As the BS station is further away from the sensors, transmitting data to it, would consume much more energy compared to the energy consumed in a group-wise communication. Therefore, CH would deplete its battery faster than the other group members. To prevent CH being dead soon, the role of being a CH is rotated among the all the sensors.

These kinds of energy-aware approaches have a common goal: to distribute the energy consumption on all the sensors almost equally such that the first node to die would be postponed as much as possible [2, 7, 9, and 10]. However, in some real applications, there can be some requirements that some selected sensor nodes should live longer than the others. For example in a field monitoring application, some parts of the monitored field are more important than the other parts such that the sensors monitoring these important parts should live longer.

In this paper, we propose an improvement over the existed well-known communication protocol such that the selected sensor node can function differently from the rest in order to extend their life span as much as possible. The suggested improvements are applied in a simulation environment and tested for various network parameters. The first results indicate the success of the proposed method over the existed protocol.

2. RELATED WORK

In WSN, sensor nodes can communicate with the sink node by employing different approaches [8]. In general, routing protocols manage how the collected data at the sensors can be forwarded to the base (sink) station. There has been an extensive research on this topic (interested readers can refer to one of the comprehensive surveys in [6, 7, 8]). One of the most famous routing algorithms is LEACH [4]. There are many proposals for improving and developing LEACH [11]. However, for comparison studies, the original LEACH routing algorithm has been used as a benchmark tests.

In general, LEACH aims to distribute the energy load to each cluster heads of dynamically created clusters [4]. Cluster heads (CH) are elected among the cluster nodes according to a priori optimal probability. After forming clusters and determining cluster heads, CHs aggregate data from their cluster members before forwarding them to the sink. As transmitting all aggregated data to the far-located sink requires much more energy compared to the one used in an in-cluster communication, LEACH proposes to rotate the cluster-head role uniformly among all nodes. In other words, the sensor node elected as a CH fulfills all the requirements of being a cluster head for a specific time period called a round. After each round, clusters are re-formed and cluster heads of these recently created clusters are re-elected. In election process, the probability of selection a node as a cluster head directly depends on whether this node has been recently selected as a cluster head or not. Since, during the network life time, nodes are almost elected the same number of times as a cluster head, each node tends to expend the same energy over time. This property of the LEACH algorithm extends the life time of the network by delaying the first to be dead.

As shortly discussed above, LEACH aims to decrease each sensor node's battery power level uniformly. Thus, the protocol does not differentiate between the nodes. In this paper, we assume that, in some real life situations, the system manager would like to extend life time of specific sensor nodes. For example, in a monitoring application, there could be thousands of sensors dispersed over a large field of interest. However, some part of the field could be critical important to be monitored as long as possible. Thus, system manager can select the sensors deployed on this regions and prioritize them to be functioned longer. In the proposed protocol, we enable the system manager to choose these sensor nodes. We modify the LEACH protocol such that some sensor nodes can be selected and their battery life times can be extended.

3. LEACH+: THE PROPOSED PROTOCOL

The proposed communication protocol is a modified version of the LEACH protocol, so we name it as LEACH+. In LEACH+, the selection and rotation of cluster head is modified considerable with respect to the original protocol as follows.

We assume that sensor nodes are labeled as regular nodes (RN) and critical nodes (CN) by the system manager. The proposed LEACH+ protocol applies the cluster head (CH) selection and rotation rules only to RNs. CNs are not selected as a CH as long as there is a RN which can be a CH. If all the RNs deplete their batteries, than, CN can become a CH for the other CN.

The aim of the modification is explicit: to save the battery power of CNs by dis-allowing them to become a CH. This modification clearly creates an advantage for the CNs. However, it could be disadvantage for the rest of the nodes. This argument is partially true. However, if we assume that the percentage of CN to RN is relatively low, then the increased workload on RNs would be ignorable. To observe the effect of LEACH+, we developed a simulation as explained in the next section.

3. SIMULATION EXPERIMENTS AND RESULTS

Below, we first introduce the Wireless Sensor Network Model and then provide the results of simulation experiments.

3.1 Wireless Sensor Network Model

In this work, the Wireless Sensor Network (WSN) model is designed as proposed in [4] and [5]. We assume that all nodes run either LEACH or LEACH+ for performance comparison. The LEACH+ code is developed in MATLAB tool modifying the LEACH code provided by [5]. We assume the same energy model as used in [5].

As seen in Table 1, we assume that each sensor node has an initial battery power equals to 0.5 Joules. Receiver consumes fixed amount of energy with respect to received bits. However, transmitting consumes different amount of energy depending on the distance of the target sensor node. In a short range communication, energy consumption is increased by the square of the distance whereas, in a long distance communication, it is increased by the forth power of the distance.

The size of the message that nodes send to their CH as well as the size of the (aggregate) message that a cluster head sends to the sink is assumed to be 4000 bits. Thus, energy consumed by data aggregation is computed according the size of corresponded messages. For more details about the energy model please see the reference [5].

Table 1. *Energy consumption model [5].*

Activity	Energy Consumption
Initial Battery Power	0.5 J
Receiving	50 nJ/bit
Transmitting (Transmitter Electronics + Amplifier for short range)	50 nJ/bit +10 pJ/bit/m^2
Transmitting (Transmitter Electronics + Amplifier for long range)	50 nJ/bit + 0.0013 pJ/bit/m^4
Data Aggregation	5 nJ/bit/message

For the experiments, we use the hyper parameters at Table 2.

Table 2. *Simulation hyper parameters and their values.*

Parameter	Value
Number of Nodes	500
Percentage of Selected Nodes	1%
Number of Simulation Runs	10

3.2 Results

In Figure 1 and 2, the number of sensor nodes depleting their batteries is given for each round when the original LEACH protocol and the proposed method LEACH+ are used, respectively. As seen in Figure 1, the first of the selected sensor nodes dies at 200^{th} round when the LEACH method is implemented. However, in Figure 2, where the proposed method, LEACH+, is applied, the first of the selected sensor nodes dies at about 400^{th} round.

Furthermore, we also observe the time when the last of the selected sensors dies. The last selected node dies at 300^{th} round and 480^{th} round for LEACH and LEACH+ respectively. These results indicate that, as desired, the proposed method can extend the lifetime of selected nodes. As seen in Figures 1 and 2, the proposed method delays the first node die and delays the last of the

selected node die. Thus, selected nodes can function longer, about 180 rounds. Thus, we can argue that the proposed method extend the lifetime of the selected nodes significantly.

One important question is how much the proposed method has a side effect on the regular nodes. Since selected nodes behave selfishly by not becoming a cluster head, we expect that there should be a negative effect on other nodes lifetime. The second result from the Figure 1 and 2 can be drawn is that the side effect is relatively limited.

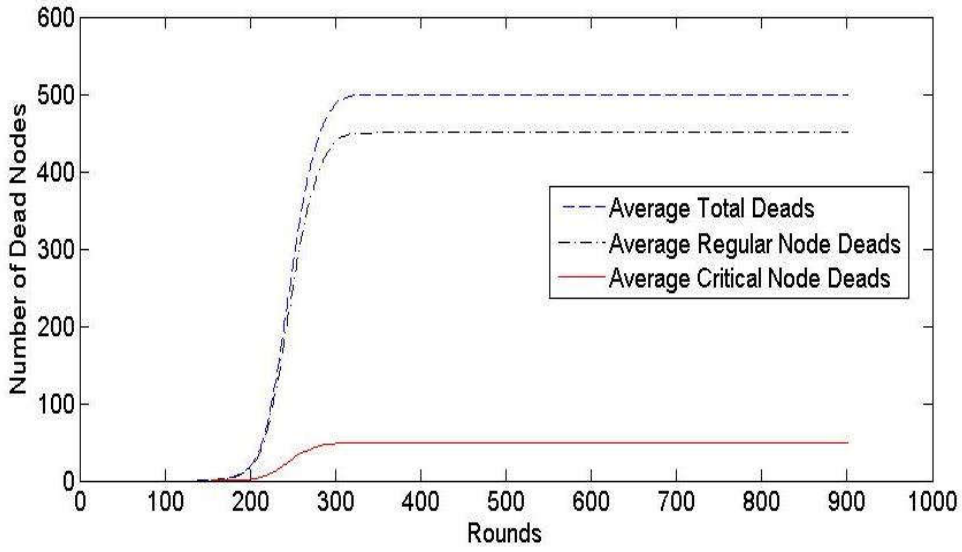

Figure 1. *Number of sensors depleted their batteries during simulation rounds when LEACH protocol is implemented.*

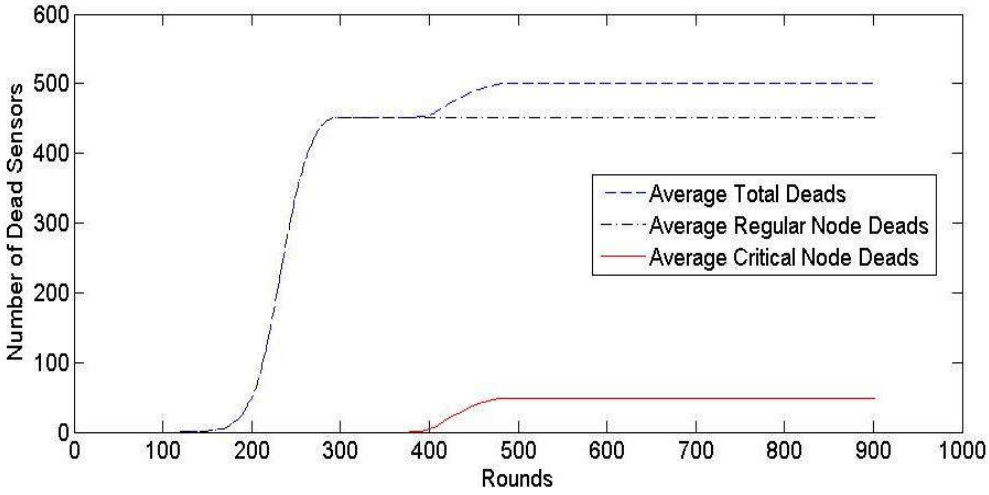

Figure 2. *Number of sensors depleted their batteries during simulation rounds when LEACH+ is applied.*

As seen in Figure 1, the first of the regular sensor nodes dies at 180th round when the LEACH method is implemented. However, in Figure 2, where the proposed method, LEACH+, is applied, the first of the regular sensor nodes dies at about the same time, 180th round. Thus, the proposed LEACH+ protocol does not cause an early-dead of regular sensor nodes.

Furthermore, we also observe the time when the last of the regular sensors dies. The last regular node dies at about 290th round and 270th round for LEACH and LEACH+ respectively. These results indicate that, the proposed protocol does not shorten the lifetime of regular nodes considerably for the selected simulation parameters. We should note that we keep the percentage of selected nodes as 1%. That is, the number of the selected nodes is very low and their burden

created by not being selected as a CH has very low impact on lifetimes of regular nodes. As a result of all these observations, we can conclude that the proposed protocol can extend the lifetime of the selected nodes effectively without degrading the service time of the regular nodes considerably.

4. CONCLUSIONS

In this work, we first define a new problem for efficiently collecting data from the sensor nodes. We assume that there can be some sensor nodes which should function longer. Thus, WSN manager can identify some of sensor nodes and would like to extend their life. We develop such a communication protocol in which we can identify some nodes and extend their lifetimes. For this reason we modified a well-known communication protocol, namely LEACH.

In the experiments, we observe that the proposed communication protocol, called LEACH+, can extend the life times of the selected nodes without degrading the life times of the regular nodes.

As a future work, we would like to extend the proposed method for different communication protocols and develop more sophisticated simulation models and experiments.

6. REFERENCES

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