A Novel Threshold-Based Transmission Control Scheme for Wireless Sensor Networks

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***Abstract*—Wireless Sensor Networks (WSNs) have become more important over the past few years, among others due to their ability to deliver information in difficult and dangerous situations. Developments in microelectronics have achieved a reduction in costs and size related to the manufacturing of a node. Based on these facts, there is the need of energy efficient routing schemes so that the lifetime of a network increases. In this paper, we introduce and analyze a modification of the threshold sensitive energy-efficient sensor network protocol (TEEN) in order to increase the lifetime of a WSN. Simulation results have shown that our event driven modification can increase a network's lifetime dramatically.**

Keywords: *Cluster based routing, energy efficiency, syncronized clusters, network lifetime, wireless sensor networks*

I. Introduction

Wireless Sensor Networks (WSNs) can be used for gathering context information of an environment in order to serve several applications. In most cases, replacing a sensors' battery is not economically advantageous. Therefore, WSNs need to act in an energy efficient manner to maximize their lifetime. Energy-efficient protocols have been developed for data centric networks, offering the possibility to aggregate data from adjacent nodes if they have the same or similar data [1]. Kulik et al. [2] designed an energy efficient protocol for wireless sensor networks. Heinzelmann et al. [3] introduced a low-energy adaptive clustering hierarchical routing protocol (LEACH). Ajina et al. [4] present a modification of dynamic source routing, so that the amount of route request messages gets reduced. Sazak et al. [5] developed an energy-efficient MAC protocol for cluster-based WSNs.

This paper is structured as follows: Section II presents a brief overview about related work done in this field of research. In Section III, we present our extension of TEEN, called **E**vent **D**riven-TEEN (ED-TEEN). In Section IV, we analyze ED-TEEN and compare its performance with TEEN.

II. An extension for TEEN

A. Characteristics of TEEN

TEEN [6] is a cluster-based, reactive routing protocol that works with two threshold values. These values regulate whether a node becomes active or not. A hard threshold is defining a threshold value for the measured attribute. Nodes only turn their transceivers on if their measured value is beyond that defined threshold. A soft threshold determines the necessary difference between two measurements for a transceiver becoming active. Every time new cluster heads get selected, the threshold values can change. An advantage of the protocol is the reduced amount of deliveries. As a disadvantage, one can consider situations where an irrelevant, however frequent variation of the measured values leads to numerous threshold changes. Increasing the soft threshold value would solve that issue but one would risk not recognizing from a node for a while and possibly miss a sensor using up all its energy. Therefore, we introduce our extension for TEEN in order to avoid that problem.

B. Extension for TEEN

One can hypothesize the measured attribute follows a continuous process. Therefore, differences in successional elements are most likely small. Accordingly, we introduce three states for our extension for TEEN:

- If a node transmits its exact value p times, the node will send a short message including a flag defining the tendency of the measured attribute instead of the exact value.
- If a node has to send a data packet for k times, it will turn its transceiver off for m rounds.
- If a node notices a dramatic change in the measured attribute, it will send a data packet directly to the base station.

Implementing those three states, we presume a heavy reduction in the power consumption in a WSN. Our research is based on the IRIS node by Crossbow where the temperature and barometer sensor deliver a 16bit value. Therefore, submitting a single flag with the size of one bit will reduce the time a transceiver has to be turned on. Hence, this will reduce the power consumption of a node. According to the assumption that changes in temperature are continuous, changes will be rather small. Thus, if a transceiver did not have to become active for a certain time, its measured attribute will not change significantly. This will give a node the opportunity to stay idle for a certain amount of rounds. Since the WSN is using a TDMA scheme within its clusters, nodes are synchronized to each other and know by their allocated slots when they have to have their data ready if new attributes are available. In case of an (unlikely) significant change in a measured value, a node is able to deliver its new data directly to the base station. In order to be able to use these new states, we had to restructure the existing TEEN protocol. Instead of picking new cluster heads every round, we are going to determine new cluster heads every n ($n \geq m$) rounds. If the network started the setup phase earlier, some nodes would not be able to finish their idle period

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and we would notice losses in the performance of our new approach. If k and p are chosen too large, a network will loose its accuracy and there would be a risk to loose important information about certain states the network is in. Having k and p too small, there will not be a significant advantage to TEEN. Thus, one can derive optimal values for k and p depending on the desired application for a WSN.

III. System Modeling and Simulation Results

Since we are interested in a network's lifetime, simulations will provide results faster than experiments with the nodes. Figure 1 shows a general model of a node's energy consumption. With our approach, we try to minimize the amount of time a node has to keep its transceiver turned on.

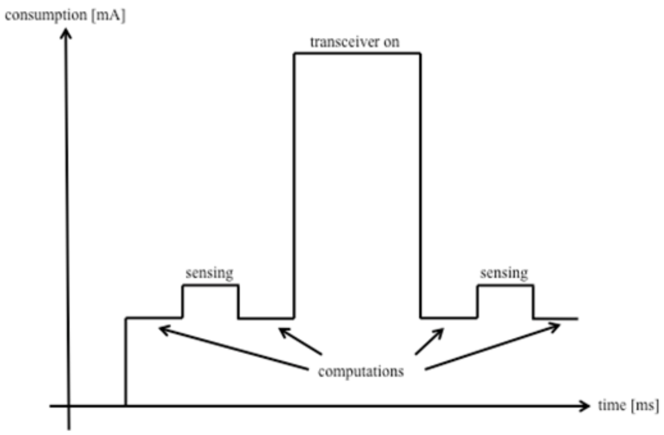

Figure 1: Model of energy consumption

The transceiver of the IRIS node consumes between 10 to 17 mA for a data transmission, depending on the transmission power. The bit rate of the transceiver is 250 kbps. Since the temperature sensor produces a 16bit value for the measured temperature and air pressure, the transceiver would be turned on for a while. In contrast to the active antenna, the idle transceiver consumes 0.1 μA.

For our simulations, we used the network simulator 2, version 2.34. The optimal amount of cluster heads within a WSN of 100 nodes is between three and five [2]. We chose five as the desired amount of cluster heads. Also, we set the deployment area to 100x100 meter. The simulation compares TEEN with ED-TEEN where we allow nodes to sleep for one period if they did not have to become active the last four periods. Furthermore, nodes will only send a flag with the attributes tendency after p=3 consecutive periods of changes.

Figure 2 presents the performance evaluation between TEEN and ED-TEEN using the parameters described before. Network lifetime increases intensely. One can consider that increasing k and p is going to impact the reliability of a network if the values are chosen too high. Since ED-TEEN encourages nodes to stay idle instead of being active or reduces the size of a packet to send, it is possible that some nodes have to execute more operations than others in the network. Thus, the slope of ED-TEEN is less steep than the one of TEEN.

IV. Conclusions and Future Work

With TEEN, a reactive cluster based routing scheme was developed. In our extension, we changed a message into a small notification for a cluster head determining whether the measured value increased or decreased. As long as there is no drastic change, a cluster head can disregard a sensor's attribute. Drastic changes in measurements will be accounted for by an immediate data transmission.

It has been shown that in certain scenarios, like monitoring a room's temperature or fire detection, ED-TEEN is more efficient than TEEN. One has to consider that ED-TEEN will have no advantages in situation of a constant significant change in the attribute. In that case, ED-TEEN has a similar behavior as TEEN.

Future work includes a detailed energy model for a WSNs behavior, e.g. the consumption of a node during a transmission or reception of data packets. Also, the energy consumption of executing computations and sensing processes on a sensor will be studied.

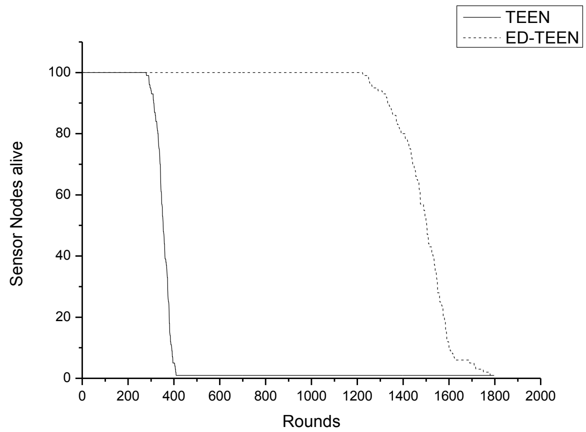

Figure 2: Comparison of network lifetime

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