TFD-assisted Threshold–sensitive Stable Election Protocol for WSNs

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***Abstract*—Energy efficiency is important in the case of devices which has strictly limited energy resources, such as battery powered sensors. Cluster wireless sensor networks enable the sensors within the cluster to select the most appropriate node at a given moment for long-distance transmission (Cluster Head) and use it to communicate with the base station. This paper proposes the use of the Traffic Flow Description option for the IP protocol to improve the selection of Cluster Heads. The simulation results showed that the benefits of using TFD-assisted selection of Cluster Heads outweigh the costs of having to transmit additional signaling information using the TFD option.**

***Index Terms*—TFD, WSN, sensors, Cluster Head, energy efficiency, TSEP**

I. Introduction

Energy efficiency is a key feature of battery powered sensors, which have strictly limited energy resources. In the case of wireless sensor networks (WSN), limited energy resources necessitate the use of dedicated transmission technologies, such as clustered WSNs, which are considered as one of the most useful approaches to improving the energy efficiency of WSN networks [1].

Clustered WSNs include clusters of sensors managed by cluster head (CH) nodes that collect data from their clusters, aggregate them and send them to a Base Station (BS). CH nodes are selected for specific time slots, then a new round of selection is carried out. The decision algorithms for the selection of CHs use information about the amount of energy that a given node has. Higher energy nodes have a better chance of being selected.

The aim of this paper is to propose the use of the Traffic Flow Description (TFD) option [2] of the Internet Protocol (IP) to improve CH management in clustered WSN. In the proposed solution, the selection of CH nodes uses, in addition to information about the amount of energy, the knowledge about the amount of data that will be sent in the near future.

II. Related Work

The TFD option was introduced by the author as an Internet Engineering Task Force (IETF) working document [2]. The option enables the description of the amount of incoming traffic in a given time horizon, and this information is transmitted through the network along the path between end nodes. Although the description of the traffic provided by the TFD option can be used to allocate any resources, so far the authors' efforts have focused on allocating network resources (bandwidth, buffer occupancy) for high definition video transmission [3], [4].

The transmission in the WSN can be made directly from the sensor to the base station (which requires a lot of energy and is sometimes impossible) or indirectly by means of clustering. Using clustering, the sensors send data via their CH node, which allows them to reduce energy consumption compared to direct transmission. Clustering protocols often found in the literature are: Low Energy Adaptive Clustering Hierarchy (LEACH) [5], Centralized Low-Energy Adaptive Clustering Hierarchy (LEACH-C) [5], Stable Election Protocol (SEP) [6], Threshold sensitive Stable Election Protocol (TSEP) [7], and Energy Efficient Sleep Awake Aware (EESAA) [8].

III. The Concept of the TFD-Assisted Selection

In the CH selection process, information on the amount of data that each sensor will send in the near future is estimated during each round. This information is sent in the TFD option attached to the IP packets that convey TSEP packets. Next, the probability of selecting a given node is determined on the basis of the amount of energy this node has and the amount of data that will be sent from the cluster. If the amount of data to be transmitted exceeds the capabilities of a given node, it is excluded from the decision-making process. In this way, some nodes on the verge of power loss can retain their energy longer without taking part in some rounds. This also increases the operational reliability of the entire system, because the node selected as CH, thanks to this check, should remain active until the end of a given round. This prevents pathological situations in which a given CH stops working before it finishes sending a packet, which results in less reliable transmission and energy expenditure for retransmission of this packet.

The use of the TFD also influences cluster set-up. Clusters can be created not only on the basis of the nearest neighbourhood, but also on the basis of the amount of data to be transferred by a given cluster. If it is possible to classify a given node into two different clusters, the one with the smaller

This work was supported by the Polish Ministry of Science and Higher Education with the subvention funds of the Faculty of Computer Science, Electronics and Telecommunications of AGH University.

amount of data to be transferred will be selected. In this way, the load is distributed over different clusters and thus different CHs, which allows more efficient use of the energy of all nodes, and to modify the clusters in individual rounds, as well.

The proposed solution has been implemented in the MATLAB environment (version R2021a). For implementation, the publicly available code [9] was used, in which a WSN network was defined and the TSEP was implemented. Implementation of the proposed solution included the addition of TFD signaling and modification of TSEP's algorithms for CH selection, cluster formation to take into account TFD signaling, and a simple prediction of the amount of data based on properties of built-in traffic generator.

The proposed solution was tested with the use of MATLAB software. The simulation tests were carried out for a WSN consisting of 100 nodes operating in the area of 100 m × 100 m. The simulation parameters in the MATLAB environment were set in accordance with Table I. The set packet size was the default for the [9], [10] codes. During the tests, the code [9] with the above-mentioned changes was used. For comparison, the publicly available EESAA protocol code implemented in the MATLAB environment was also used [10]. It works in the same WSN network as code [9].

TABLE I
SIMULATION PARAMETERS

Simulation Parameter	Value
Initial Energy	0.5 J
Transmitter Energy	50nJ/bit
Receiver Energy	50nJ/bit
Amplifiier Energy	100 pJ/bit/m^2

IV. PRELIMINARY RESULTS

As seen in Fig. 1, the TFD-assistance improved the efficiency of the selection performed by the TSEP protocol mechanisms. Contrary to the EESAA protocol, which paid a narrow range of a larger number of alive nodes (from round 3286 to round 3953) with a faster start of the process of deterioration of the WSN and a subsequent high graph descent rate, the advantage of the TFD-assisted selection over the analogous selection without TFD was maintained in the entire tested range. The use of the TFD option allowed to extend the time to the first dead node, thanks to which the entire set of nodes remained alive longer.

Transferring the 8 bytes of the TFD option also consumes energy. The energy losses associated with TFD signaling are less than the savings generated by the TFD-assisted selection. Due to the positive energy balance, the total lifetime of the network when the TFD-assisted TSEP selection was used (5690 rounds) turned out to be longer than when using both the classic TSEP selection (5275 rounds) and the EESAA selection (4360 rounds).

V. CONCLUSIONS

In this paper we propose to determine the amount of data that they will send by each sensor in near future and

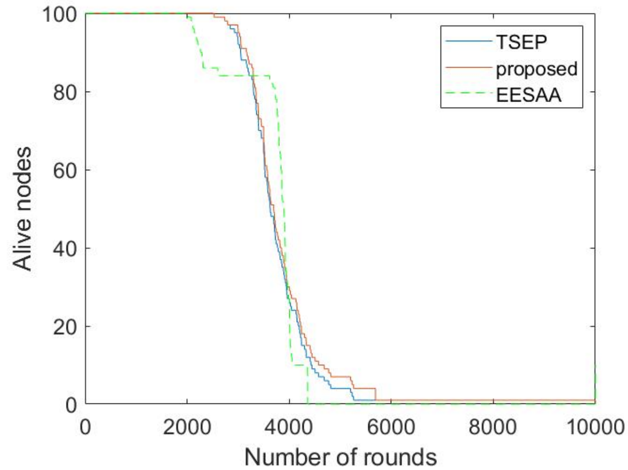

Fig. 1. Number of alive nodes as a function of a number of rounds.

to use it for WSN management purposes. This knowledge is transmitted using the TFD option of the IP traffic. Our solution does not alter but extends existing WSN management mechanisms, used in WSN routing protocols.

The results of simulations of the TFD-assisted TSEP protocol show that the proposed improvements of selection allow nodes to better estimate their future energy consumption. As a result, the TFD-assisted TSEP increases the total service life of the wireless sensor network when compared with the TSEP without our improvements.

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