Cooperative Wireless Sensor Networks for Green Internet of Things

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ABSTRACT

Green internet of things are investigated by studying energy-efficiency in wireless sensor networks. A cooperative multi-hop data transmission approach is presented and analyzed. Significant energy savings are achieved with the proposed approach compared to the non cooperative scenario, in addition to better delay results.

Categories and Subject Descriptors

J.2 [**Computer Applications**]: Physical Sciences and Engineering

General Terms

Theory, Algorithms, Performance

Keywords

Internet of things, green communications, sensor networks, energy minimization, multihop

1. INTRODUCTION

The Internet of Things (IoT) is expected include billions of connected devices communicating in a machine-to-machine (M2M) fashion [2]. Wireless sensor networks (WSNs) will constitute an integral part of the IoT paradigm, spanning different application areas including environment, smart grid, vehicular communication, and agriculture [4]. The main limitation in WSNs operating autonomously is the power consumption of sensors [2], hence the need for energy-efficient techniques to reduce the consumed power, thus contributing to the green IoT concept.

In this paper, a method for energy efficient multihop communications in WSNs is presented. In the proposed approach, sensor nodes (SNs) form cooperative groups or clusters. Within each cluster, SNs communicate with each other over multihop short range (SR) links, and the SN at the last hop communicates with the base station (BS) by relaying the aggregated multihop data over a long range (LR) wireless link.

The paper is organized as follows. The multihop approach is described in Section 2. The simulation results are presented in Section 3. Finally, conclusions are drawn in Section 4.

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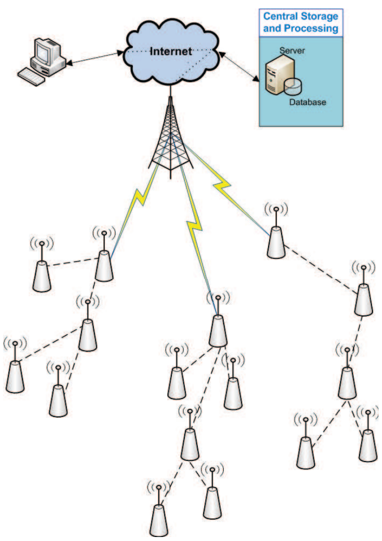

Figure 1: System model with multihop communications.

2. PROPOSED MULTIHOP APPROACH

SNs form cooperating clusters for the purpose of energy minimization during cooperative data transmission. Within each cooperating cluster, the data is delivered from the SNs in that cluster to the BS using multihop communications. Fig. 1 shows the scenario considered.

Each SN transmits its measured data to a single destination, which could be either the BS or another SN. The BS and SNs are denoted as "nodes", with node $k = 0$ corresponding to the BS and nodes $k = 1, ..., K$ corresponding the SNs. As shown in Fig. 1, these nodes appear to form a direct acyclic graph (DAG) starting from the node $k = 0$. If node j receives the data of node k on hop h, a parameter α_{kj}^{h} is set to one, marking the existence of an edge in the graph between k and j. Otherwise, α_{kj}^{h} is set to zero.

The proposed multihop approach is summarized as follows: Starting with the SNs having worst channel conditions on the LR (and hence worst achievable rates and highest energy consumption), we find for each SN k the parent p_k to which it can send the data with the minimum energy consumption. When the turn comes to SN p_k, a parent p_{p_k} is found to which p_k can send the data with the minimum energy consumption, thus leading to an additional hop if $p_{p_k} \neq 0$. The details of this approach along with detailed formulations and results can be found in [5].

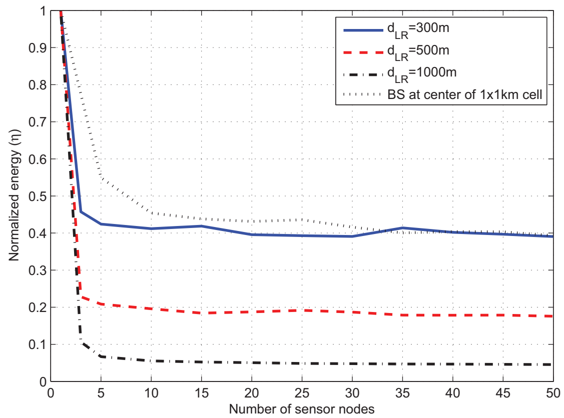

Figure 2: Normalized energy consumption vs. the number of SNs for different values of d_{LR}.

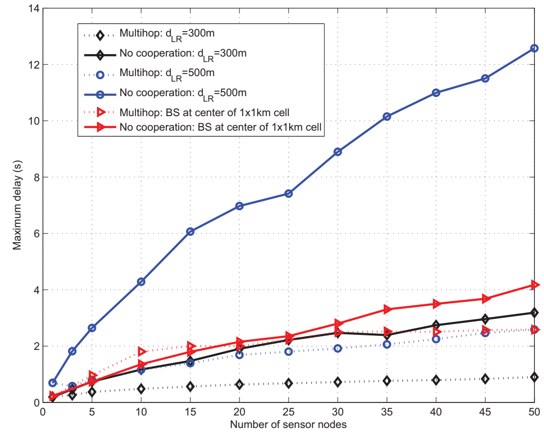

Figure 3: Total delay to send the measurements of all SNs to the BS vs. the number of SNs for different values of d_{LR}.

3. RESULTS AND DISCUSSION

In this section, simulation results are presented and analyzed. Channel parameters are obtained from [1], whereas energy consumption parameters are taken as in [3].

We investigate a scenario corresponding to multihop data transmission in a WSN. We consider that each sensor sends its measurement data in a file of size $S_T = 1$ Mbits, to be routed to the BS in an energy efficient manner. Two main SN deployment scenarios are investigated: In the first deployment scenario, SNs are assumed to be uniformly distributed in a rectangular area of size 200m × 200m, whose origin is at a distance d_{LR} m from the BS. In the second scenario, the SNs are assumed to be uniformly distributed throughout the whole cell, with the BS placed at the center of a 1 × 1km cell.

The energy savings achieved by using the proposed multihop method, compared to the non-cooperative scenario, are displayed in Fig. 2, which shows the results for normalized energy (ratio of the energy with cooperation to the energy consumed in the non-collaborative case). Significant energy savings are achieved, especially when d_{LR} increases, where the gains reach an order of magnitude for $d_{\mathrm{LR}} = 1$ km. Fig. 2 shows that the gains are reduced as the distance to the BS decreases. This is due to a reduction in the energy needed on the LR without cooperation and not to an increase in energy consumption with the proposed approach, since the LR distance was reduced. This leads to an increase in the energy ratio.

Fig. 3 shows the maximum delay, i.e., the delay incurred by the last SN to send its data to the BS, thus corresponding to the total delay needed to transmit the measurements of all SNs in the network. It can be seen that the delay increases with the distance to the BS, since a longer distance leads to lower achievable rates on the LR, which leads to an increase in data transmission time. Fig. 3 shows that the proposed cooperative multihop method significantly outperforms the non cooperative case by leading to shorter maximum delay due to benefiting from high SR rates during SN collaboration, and thus constitutes a suitable approach leading to both energy and delay efficiency in WSNs. Consequently, the proposed approach leads to energy savings and enhanced quality-of-service (QoS).

4. CONCLUSIONS

Energy efficiency via cooperative data transmission in wireless sensor networks was studied. An efficient multihop communication method was presented. Significant energy savings were achieved with the proposed approach compared to the non cooperative scenario, in addition to better delay results.

5. ACKNOWLEDGMENTS

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