Context-Aware Broadcast in Duty-Cycled Wireless Sensor Networks

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ABSTRACT

As the energy efficiency remains a key issue in wireless sensor networks, duty-cycled mechanisms acquired much interest due to their ability to reduce energy consumption by allowing sensor nodes to switch to the sleeping state whenever possible. The challenging task is to authorize a sensor node to adopt a duty-cycle mode without inflicting any negative impact on the performance of the network. A context-aware paradigm allows sensors to adapt their functional behavior according to the context in order to enhance network performances. In this context, the authors propose an enhanced version the Efficient Context-Aware Multi-hop Broadcasting (E-ECAB) protocol, which combines the advantages of context awareness by considering a multi criteria and duty-cycle technique in order to optimize resources usage and satisfy the application requirements. Simulation results show that E-ECAB achieves a significant improvement in term of throughput and end-to-end delay without sacrificing energy efficiency.

KEYWORDS


1. INTRODUCTION

Recently, the emerging field of wireless sensor networks (WSN) has attracted a great research interest. Due to their ease of deployment, WSNs applications cover a wide spectrum of fields, such as military, healthcare, habitat, and environment monitoring. The contextual and technical requirements may differ significantly considering the diversity and heterogeneity of various target domains. Nowadays, WSNs are commonly used for long-term and low-cost monitoring applications, where the network remains idle until activated by sensor nodes reacting to the occurrence of a certain event. Besides, many of these applications are mainly deployed to monitor the occurrence of rare events, such as forest fire or habitat monitoring. Since sensor devices are usually powered by battery, major efforts focused on reducing the energy consumption. As the radio communications are considered the main source of energy dissipation, duty-cycle mechanisms (Anastasi et al., 2009, Alfayez et al.,2015) have been widely deployed in WSNs due to their efficiency in reducing the energy waste related to idle listening and useless overhearing. As such, sensor nodes are active only for a short (ON) period of time between two dormant (OFF) long periods. Once the radio is turned off, the node becomes unable to send or receive a new packet.
Putting sensors into a sleep mode can significantly prolong the network lifetime. Nevertheless, the temporary unavailability of nodes can result in losing connectivity which may affect the communication performances related mainly to latency and throughput. In fact, we must take into account waiting times in intermediate nodes since a sender node must wait the wake-up of neighbors to be able to deliver the pending packet. Consequently, this working pattern brings challenges to the network design, mainly for a fundamental service like network flooding. Performing such operation under a duty-cycle mode constitutes a difficult task in an asynchronous environment, where involved nodes wake up independently of each other and follow different activity schedules. Besides, resource limitations of sensors and links unreliability, in combination with various performance demands of different applications, impose many challenges in designing efficient communication protocols for duty-cycled WSNs. To this end, a context-awareness paradigm (Perera et al., 2014) offers the possibility to automatically adapt the protocol behavior according to the changing context. Context-aware systems are able to adapt their operations to the current context without explicit user intervention, increasing consequently usability and effectiveness by taking environmental context into account. The sensor node context (Ghrab et al., 2016) concerns any information characterizing the situation of the sensor and providing knowledge about other entities within the environment. Considered itself as a context-aware device, its particular contextual parameters, such as the current battery status, location, radio information and its capabilities, help to understand more about the sensor and its surrounding and can be used for improving the execution performance, and adapting to the application behavior.

Through the enhanced version of ECAB, the authors highlight how the combination of a duty-cycle mechanism and a context-aware paradigm can improve system performances and maintain desired characteristics for supporting certain application requirements such as throughput and end-to-end delay. ECAB (Ghrab et al., 2015) is an efficient context-aware multi-hop broadcasting protocol performed over an adaptive asynchronous duty-cycled network. The basic idea of ECAB is to modify the behavior of nodes and adjust their duty-cycling schedules in a distributed manner by exploiting efficiently acquired awareness, specially related to neighborhood activity and traffic load to enhance the broadcast operation without penalizing the network performances. The key novelty of this work lies in exploiting multi relevant contextual information to adapt node behavior and adjust scheduling for communications in duty-cycle WSNs. Combining several context values may generate a more powerful understanding of the current situation. While energy level and traffic load are the most frequently used contextual attributes, other attributes like communication history and medium conditions may also be relevant and useful. Through the E-ECAB, the authors explore further kinds of context information and investigate the potential performance gains.

The rest of this paper is organized as follow. In Section 2, the authors discuss related work. The details of our approach are introduced in Section 3. In section 4, E-ECAB with similar state-of-the-art previous approaches are evaluated in terms of energy efficiency, data delivery performance, and overhead needed to maintain the protocol mechanism. Finally, section 5 summarizes our important results, and discusses some future work.

2. RELATED WORK

Many duty-cycled protocols are proposed in literature, mainly classified into synchronous and asynchronous approaches. Synchronous approaches reserve a portion of the active state to synchronize all nodes to a global active/sleep schedule to allow neighboring nodes to communicate during the common active periods. In S-MAC (Ye et al., 2002), neighboring nodes form virtual clusters to auto-synchronize on sleep schedules. Thus, each member communicates with its neighbors in the cluster
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