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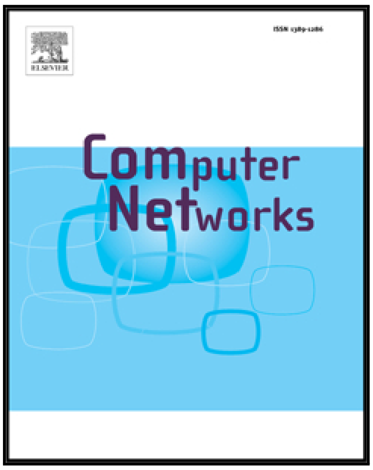

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Adaptive Learning-Enforced Broadcast Policy for Solar Energy Harvesting Wireless Sensor Networks

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Abstract

The problem of message broadcast from the base station (BS) to sensor nodes (SNs) in solar energy harvesting enabled wireless sensor networks is considered in this paper. The aim is to ensure fast and reliable broadcast without disturbing upstream communications (from SNs to BS), while taking into account constraints related to the energy harvesting (EH) environment. A new policy is proposed where from the one hand, the BS first selects the broadcast time-slots adaptively with the SNs schedules (to meet active periods that are constrained by EH conditions), and from the other hand, SNs adapt their schedules to enable optimal selection of the broadcast time-slots that minimizes the number of broadcasts per message and the latency. Compared to the existing solutions, this enables fast broadcast and eliminates the need of adding message overhead to the broadcast message. For this purpose, an analytical energy model, a hidden Markov model(HMM), Baum-Welch learning algorithm, and a heuristic algorithm of the minimum covering set problem (MCS) are proposed and combined in a unique solution. The proposed solution is analyzed and compared with a state-of-the-art approach. The results confirm that the former has the advantage of performing the broadcast operation more reliably and in lower delay.

Keywords: Wireless Sensor Networks, Energy Harvesting, Green Communication, Broadcast, HMM

1. Introduction

The interconnection of heterogeneous wireless networks will enable large scale deployment in the near future and provide unique applications and services, such as health care, smart buildings and grids, environment monitoring, smart cities, smart object tracking, etc. One of the challenges that prevent large scale deployment is energy limitation. Most existing network protocols assume the use of portable and limited batteries, while many applications are expected to be deployed in unintended, sometimes hostile environments, which makes batteries replacing unfeasible. Environment energy harvesting emerges as the appropriate alternative for battery replacement. The ambient energy harvesting ability of wireless devices is expected to enable self-sustaining systems. However, satisfying communication requirements while tuning activities to the available energy and energy profiles is a nontrivial problem. Existing protocols and architectures should be revisited and rebuilt upon an energy model that reflects the real world constraints for harvesting [19, 20, 10]. To our knowledge, this paper is the first that considers broadcast under slotted EHWSN and proposes ADAPCAST(Adaptive Learning-Enforced Broadcast Policy for Solar Energy Harvesting Wireless Sensor Networks), a policy that minimizes the number of time-slots allocated to the broadcast while considering the EH constraints. The main contributions of ADAPCAST is the use of a new energy model suitable for solar EH environment and of a Hidden Markov Model (HMM)[28] that faithfully reflects the nodes behavior activities under this environment. The proposed policy considers local broadcast (one-hope) and targets the selection of the optimal time-slots within the frame for broadcasting the message from the BS to SNs (on the downstream links) while avoiding interfering with the upstream communications to the best effort. In particular, the policy attempts to match the broadcast time-slot with all active periods of SNs (to the best effort), i.e., to ensure SNs are ready for reception. The policy also allows nodes to adapt their activity in a way that optimizes the broadcast time-slot selection. Contrary to the proposed solution in [20] that uses the concept of erasure coding and relays on adding packets to increase reliability, the solution proposed herein minimizes the number of time-slots dedicated to the broadcast operation without augmenting the packet payload with overhead. This has a positive impact on the minimization of the number of transmissions required for broadcast at the BS, and it allows SNs to preserve their energy and to allocate up-link communication time-slots. A Hidden Markov Model (HMM)[28], Baum-Welch learning algorithm [12], and an heuristic algorithm of the minimum covering set(MCS)[30] are applied for this purpose. Rather than using Bernoulli distribution (used in [20]), the

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