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On packet transmission scheduling for min-max delay and energy consumption in wireless mesh sensor networks

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Abstract

Optimization of channel utilization in wireless networks is typically based on transmission parallelization under signal-to-interference and noise constraint assuming minimum frame-length scheduling. In application scenarios like sensor networks this approach may not be suitable since it does not explicitly consider end-to-end packet delay nor energy consumption. In the paper we propose a mixed-integer programming formulation for scheduling optimization in wireless sensor networks characterized by periodic data gathering where minimization of the maximum packet delay and sensor node energy consumption are the main objectives. The model, which assumes cooperation in packet forwarding and interference cancellation, is compared to traditional single path forwarding.

Keywords: wireless scheduling, cooperative forwarding, interference cancellation, delay minimization, energy efficiency, integer programming

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1 Introduction

In wireless mesh networks efficient utilization of the radio channel is achieved through parallel transmissions satisfying the signal to interference and noise ratio (SINR) requirement at the receivers. In the common case of *single path forwarding*, the level of cooperation between the nodes is limited when packets are transmitted along their (multi-hop) path. Cooperation of nodes can be achieved by taking advantage of the broadcast nature of radio transmissions, as a packet sent from a node can be received by other nodes. These nodes can then perform *cooperative forwarding* by sending the packet simultaneously to other nodes making the useful signal at a receiving node the sum of the signals transmitting the packet in question. Cooperation can be further extended using *cooperative interference cancellation*. When a receiving node is aware of the scheduled packets to be transmitted by each node in each time slot, it can cancel the interference caused by transmissions of the packets the node has already received [6]. These two mechanisms make meeting the SINR requirement easier, allowing for larger transmission ranges and more parallel transmissions.

The problem of parallel transmission scheduling for single path forwarding has been widely studied [1,5]. Most of the work has been focused on minimum frame-length scheduling that assures the least number of time-slots per frame required for link transmissions by traffic demands [2,9,8]. In multi-hop wireless networks the number of packets to be transmitted per link depends on routing which therefore should also be optimized as to increase network efficiency [3]. For the delay maximization with single path forwarding this paper extends the ideas of [7]. The model for cooperative forwarding with interference cancellation formulated in (2) is original, with some influence of [4].

Minimum frame-length scheduling, however, is not well suited for the investigations of this paper. Our scheduling problem is related to sensor networks that periodically deliver information to the gateways so that all packets for a given session must be sent within the cycle duration. Our basic objective is to schedule the packet transmissions so that the time when the last packet reaches one of the gateways is minimized. At the same time we combine delay minimization with that of minimization of the maximum energy consumed over all the sensor nodes. In the paper we compare the cooperative transmission with interference cancellation scheme with the single path forwarding scheme, using appropriate mixed-integer programming (MIP) formulations. The numerical results show the gains from the former scheme, and illustrate the trade-off between min-max delay and min-max energy consumption.

The centralized scheduling schemes assumed in this paper can be applied in those wireless sensor networks where traffic is almost periodic according to data gathering rounds and a global synchronization is assumed. A global transmission schedule can be centrally computed and then notified to the