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Enabling Green Wireless Sensor Networks: Energy Efficient T-MAC Using Markov Chain Based Optimization

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Abstract: Due to the rapidly growing sensor-enabled connected world around us, with the continuously decreasing size of sensors from smaller to tiny, energy efficiency in wireless sensor networks has drawn ample consideration in both academia as well as in industries' R&D. The literature of energy efficiency in wireless sensor networks (WSNs) is focused on the three layers of wireless communication, namely the physical, Medium Access Control (MAC) and network layers. Physical layer-centric energy efficiency techniques have limited capabilities due to hardware designs and size considerations. Network layer-centric energy efficiency approaches have been constrained, in view of network dynamics and available network infrastructures. However, energy efficiency at the MAC layer requires a traffic cooperative transmission control. In this context, this paper presents a one-dimensional discrete-time Markov chain analytical model of the Timeout Medium Access Control (T-MAC) protocol. Specifically, an analytical model is derived for T-MAC focusing on an analysis of service delay, throughput, energy consumption and power efficiency under unsaturated traffic conditions. The service delay model calculates the average service delay using the adaptive sleep wakeup schedules. The component models include a queuing theory-based throughput analysis model, a cycle probability-based analytical model for computing the probabilities of a successful transmission, collision, and the idle state of a sensor, as well as an energy consumption model for the sensor's life cycle. A fair performance assessment of the proposed T-MAC analytical model attests to the energy efficiency of the model when compared to that of state-of-the-art techniques, in terms of better power saving, a higher throughput and a lower energy consumption under various traffic loads.

Keywords: wireless sensor networks; S-MAC; T-MAC; discrete-time Markov chain; energy optimization

1. Introduction

Wireless sensor networks (WSNs) have numerous real-life applications in various fields, such as precision agriculture [1], patient healthcare [2], target tracking, homeland security, environmental monitoring, surveillance [3], vehicular traffic management [4,5], and electric vehicle charging recommendation [6,7]. WSNs' role is significant in the emergence of the Internet of Things (IoT) [8,9]. Sensor nodes are deployed in WSNs in large amounts in a geographical area. There are

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