Chapter 5

Adaptive IEEE 802.15.4 MAC Protocol for Wireless Sensor Networks

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ABSTRACT

The energy efficiency is a main challenging issue for employing wireless sensor networks (WSNs) in extreme environments where the media access progress consumes the main part of network energy. The IEEE 802.15.4 is adopted in low complexity, ultra-low power and low data rate wireless sensor applications where the energy consumption of nodes should be managed carefully in harsh and inaccessible environments. The beacon-enabled mode of the IEEE 802.15.4 provides a power management scheme. When the network traffic is variable, this mode does not work as well and the coordinator is not capable for estimating the network traffic and adjusting proper duty cycle dynamically. In this chapter an approach for estimating network traffic in star topology is proposed to overcome this issue where the coordinator could estimate the network traffic and dynamically adjusts duty cycle proportion to the variation of network traffic. The simulation results demonstrate the superiority of proposed approach for improving the energy consumption, throughput and delay in comparison with the IEEE 802.15.4 under different traffic conditions.

INTRODUCTION

As wireless sensor networks is deployed in harsh and inaccessible environments for collecting data and monitoring applications, connecting the sensor nodes in simple and efficient manner is an important and challenging issue (Jung, et al., 2009). The IEEE 802.15.4 standard for low-rate wireless personal area networks (LR-WPANs) has been introduced to achieve these requirements (IEEE Standard 802.15.4, Part 15.4, 2006). In many applications using this standard, devices will be battery powered (IEEE Standard 802.15.4, Part 15.4, 2006). Therefore to extend the network
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lifetime, energy consumption for devices should be managed carefully. Beacon-enabled mode of IEEE 802.15.4 provides a power management mechanism based on duty-cycle. The MAC sub-layer of this mode provides various duty cycles by setting two system parameters, beacon order (BO) and superframe order (SO) (Chung, et al., July 2006; Sheu, et al., 2005). The nodes communicate with coordinator to send their packets in active period while during inactive period they enter in low power state to save energy. The standard IEEE 802.15.4 allocates further portion of active period in beacon-enabled mode to the contention access period (CAP) and if the contention free period length be zero, the CAP will be completed at the end of the active portion of the superframe. So the CAP has very important role in the standard performance.

Generally, contention based protocols like S-MAC (Ye, et al., 2004), B-MAC (Polastre, et al., 2004) and T-MAC (Dam, et al., 2003) have advantages such as scalability, flexibility and self-organization but in other hand they have disadvantages such as idle listening and collision which increase the devices consumption energy (Gilani, et al., 2011).

The throughput and energy consumption are major performance metrics for 802.15 (Park, et al., 2005). In case that the CAP length is longer than the time interval which is required for network traffic, the devices will spend more time in idle mode which increases the energy consumption. In the other side, if CAP length is shorter than the time interval required for network traffic, lots of packets will be lost because of collision and as a result the network throughput will be reduced.

The devices number or packet generation varies with the time in some networks. Also, in some networks, traffic is not predictable. In such conditions to optimize nodes energy consumption and achieve high throughput, the CAP length must be selected proportional to the network traffic. Therefore the coordinator should be able to estimate network traffic, so that the network traffic varies, it can dynamically adjust CAP length proportional to the traffic network variation.

In this study, in order to enhance coordinator capability of estimating the network traffic, the devices inform the coordinator about the number of packets inside its queue along with sending their packets. The coordinator also evaluates network traffic using devices queue state and channel idle time intervals at the end of active period of each superframe then selects CAP length for the next superframe based on network throughput.

RELATED WORKS

In order to evaluate the CAP, according to significance of CAP in this standard, recent literatures provide a lot of analytical models (Huang, et al., 2009; Ashrafuzzaman & Kwak, et al 2011; Ramachandran, et al., 2007; Tao, et al., 2006). The most studies conducted on CAP concentrate on slotted Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) algorithm, So that many accurate models have been provided which can evaluate the CSMA/CA algorithm (Pollin, et al., 2008; He, et al., 2008). Chung et al. (Chung, et al., July 2006) presented a new model for the slotted CSMA/CA, and evaluated its throughput limit.

Some other works concentrated on energy consumption and throughput. In order to minimize the energy consumption, a new model to determine the optimal BO and SO values has been provided regarding to the number of successful packet transitions and maximum delay constrain (Shu, et al., 2006). Suh et al. (Shu, et al., 2008) presented a new model in which the nodes that can’t send their packet in active period can send packets in time intervals of inactive period called sentinel duration. Xiao et al. (Xiao, et al., 2010), proposed a new analytical model for IEEE 802.15.4 MAC with sleep mechanism to compute the energy consumption and throughput in single-hop networks in real-time applications. It has been shown that using of one CCA mechanism
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