

Chapter 7

Energy-Efficient Backoff Algorithms for Wireless Sensor Networks

S. Mehta

Inha University, Korea

K.S. Kwak

Inha University, Korea

ABSTRACT

A prime goal of wireless sensor networks (WSNs) is to minimize energy consumption than high channel efficiency and low channel access delay. Existing MAC protocols for WSNs reduce energy consumptions by introducing variation in an active/sleep mechanism, but they cannot save energy during the execution of backoff algorithm. In this chapter, we study and compare the different backoff algorithms for wireless sensor networks. We also use the concept of a geometrically increasing probability distribution for contention process. This allows us to introduce improved backoff (IB) algorithm for energy efficient MAC protocol in WSNs, where binary exponential backoff (BEB) based algorithm is widely used. With the help of numerical results we show that the IB gives edge over BEB in throughput, channel access delay, and energy efficiency under varying traffic conditions.

INTRODUCTION

Communication in wireless sensor networks is divided into several layers. Medium Access Control (MAC) is one of those layers, which enables the successful operation of the network. MAC

protocol tries to avoid collisions by not allowing two interfering nodes to transmit at the same time. The main design goal of a typical MAC protocols is to provide high throughput and QoS. On the other hand, wireless sensor MAC protocol gives higher priority to minimize energy consumption than QoS requirements. Energy gets wasted in traditional MAC layer protocols due to idle listening,

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collision, protocol overhead, and over-hearing (I.F Akayildiz et.al, 2002; W. Heidemann et. al., 2002). There are some MAC protocols that have been especially developed for wireless sensor networks. However, we discussed a very few MAC protocols here just to present some examples of Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) based MAC protocols for WSNs. Typical examples include S-MAC, T-MAC, and H-MAC (W. Heidemann et. al., 2002; T.V.Dam et.al., 2003, S.Mehta et.al., 2009). In large amount of literature authors proposed new MAC protocols for WSNs but in this chapter our approach is to concentrate on backoff algorithm than a complete MAC protocol. In this chapter we introduce an energy efficient backoff algorithm, which is easy to integrate with existing energy efficient MAC protocols for WSNs.

Before going into more details about the backoff algorithms, it is useful for readers to take a glimpse at some important sensor networks MAC protocols.

S-MAC is proposed to improve energy efficiency in wireless sensor networks. It divides the time into large frames. Every frame has two parts: an active part (on time) and a sleeping part. A node turns off its radio during the sleep time to preserve the energy. During the active time, a node can communicate with its neighbors and transmits the queued packets during the sleeping time. Hence, S-MAC saves the unnecessary waste of energy on idle listening. Periodic sleep may result in high latency (for multihop sensor networks) and low throughput problems (Heidemann et. al., 2002). Timeout-MAC protocol is proposed to enhance the performance of S-MAC under variable traffic conditions. It defines the minimum time out timer TA. T-MAC works similar to S-MAC with one difference of time out timer. In T-MAC, active time ends when no activation has occurred for a time out timer TA. Time-out timer may result in early sleeping and low throughput problems (T.V.Dam et. al., 2003). Data gathering MAC falls into duty cycle based MAC protocols category. The main

aim of D-MAC is to achieve low latency as well as energy-efficiency. D-MAC is an improved slotted aloha protocol where slots are assigned to the sets of nodes based on data gathering tree (Parent-child topology). In D-MAC, low latency is achieved by assigning subsequent slots to the nodes that are successive in the data transmission path. However, D-MAC works well only for tree based structure and may cause a collision problem (G. Lu et. al., 2004). Pattern-MAC is a 'time slotted' protocol. It adaptively determines the sleep-wake up schedules for a node based on its own traffic and the traffic patterns of its neighbors. In P-MAC, a node gets information about the activity in its neighborhood before hand through patterns. Based on these patterns, a node can put itself into a long sleep for several time frames when there is no traffic in the network. If there is any activity in the neighborhood, a node will know this through the patterns and will wake-up when required. Hence, P-MAC saves more energy compared to S-MAC without compromising on the throughput. But it is worthwhile to mention about complexity, collision, and overhead problems in P-MAC (T. Zheng et. al, 2005). In (S.Mehta et.al., 2009) authors proposed a hybrid MAC to achieve the energy efficiency along with good QoS. H-MAC is based on IEEE 802.11's PSM mode and slotted aloha. In H-MAC, time is divided into large frames, every frame has two parts: an active part (on time) and a sleeping part. Active part is further divided into N slots and can dynamically assign to nodes. However, H-MAC protocol requires a good synchronization method to work efficiently. In most of the sensor networks MAC protocols, to maximize the battery lifetime, implement the variation of active/sleep mechanism. With this mechanism most of the MAC protocols trades networks QoS for energy savings while H-MAC protocol reduces the comparable amount of energy consumption along with maintaining good network QoS such as latency, throughput, and channel utilization. However, most of the sensor networks MACs' backoff algorithm is similar to

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