Chapter 66
A Game Theoretical Approach to Design:
A MAC Protocol for Wireless Sensor Networks

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ABSTRACT

Game Theory provides a mathematical tool for the analysis of interactions between the agents with conflicting interests, hence it is a suitable tool to model some problems in communication systems, especially, to wireless sensor networks (WSNs) where the prime goal is to minimize energy consumption than high throughput and low delay. Another important aspect of WSNs are their ad-hoc topology. In such ad-hoc and distributed environment, selfish nodes can easily obtain the unfair share of the bandwidth by not following the medium access control (MAC) protocol. This selfish behavior, at the expense of well behaved nodes, can degrade the performance of overall network. In this chapter, the authors use the concepts of game theory to design an energy efficient MAC protocol for WSNs. This allows them to introduce persistent/non-persistent sift protocol for energy efficient MAC protocol and to counteract the selfish behavior of nodes in WSNs. Finally, the research results show that game theoretical approach with the persistent/non-persistent sift algorithm can improve the overall performance as well as achieve all the goals simultaneously for MAC protocol in WSNs.

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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 protocol 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, collision, protocol overhead, and over-hearing (Heidemann et al., 2002; Dam et al., 2003). There are some MAC protocols that have been especially developed for wireless sensor networks. Typical examples include S-MAC, T-MAC, and H-MAC (Heidemann et al., 2002; Dam et al., 2003; Mehta et al., 2009). To maximize the battery lifetime, sensor networks MAC protocols implement the variation of active/sleep mechanism. S-MAC and T-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. However, their backoff algorithm is based on the IEEE 802.11 Distributed Coordinated Function (DCF), which is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) Mechanism. The energy consumption using CSMA/CA is high when nodes are in backoff procedure and in idle mode. Moreover, a node that successfully transmits resets it contention window (CW) to a small, fixed minimum value of CW. Therefore, the node has to rediscover the correct CW, wasting channel capacity and increase the access delay as well. So during the CSMA/CA mechanism, backoff window size and the number of active nodes are the major factors to have impact on the network performance and over all energy efficiency of MAC protocol. Hence, it is necessary to estimate the number of nodes in network to optimize the CSMA/CA operation. Furthermore, optimizing CSMA/CA operation is more challenging task for self-organizing and distributed networks as there are no central nodes to assign channel access in sensor nodes.

Furthermore, MAC protocol (or any other protocol) is designed under the assumption that all participating nodes are well behaved. While well-behaved nodes strictly obey the protocol operation, the misbehaving nodes may deviate from the standard or protocol rules to either cause unfairness problems or disrupt the network services. This misbehavior may be hard to differentiate from some normal cases. For example, when a node selects a smaller contention window, it is hard to distinguish whether this is due to an intentional choice or a random selection. In such distributed environment as sensor networks where coordination or punishment mechanisms could be expensive or in some cases even impossible to implement, so it is critical to evaluate the network performance under selfish behavior of nodes.

Recently lots of researchers have started using game theory as a tool to analyze the wireless networks. Their game theoretic approaches were proposed to the wide area of wireless communication right from the security issues to power control, etc., (Mehta et al., 2009; Agah et al., 2004; Kannan et al., 2004; Sengupta et al., 2005; Zhang et al., 2006). In sensor networks each node has a direct influence on its neighboring nodes while accessing the channel. So, these interactions between nodes and aforementioned observations lead us to use the concepts of game theory that could improve the energy efficiency as well as the delay performance of MAC protocol. As we mentioned earlier energy efficiency of MAC protocol in WSN is very sensitive to number of nodes competing for the access channel. It will be very difficult for a MAC protocol to accurately estimate the different parameters like collision probability, transmission probability, etc., by detecting channel. Because dynamics of WSN keep on changing due to various reasons like mobility