

# Chapter 34

## Practical Experiences and Design Considerations on Medium Access Control Protocols for Wireless Sensor Networks

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### ABSTRACT

*In this chapter, the practical and experimental aspects of medium access control protocol design for wireless sensor networks are discussed. We outline the basic design principles of medium access control procedures and the general development trends from the perspective of real world implementations. We take into account especially energy consumption and latency requirements. We share our experiences gained in practical research and pre-commercial projects, wherein we have been tackling issues such as traffic awareness, coexistence of different protocols, spectrum agility for wireless sensor networks and porting of MAC-layers to different platforms. The contemporary focuses on medium access control design such as cross-layer approaches, multi-radio based protocols and radio wake-up based medium access solutions are also covered in this chapter.*

### INTRODUCTION

Medium Access Control (MAC) protocols and Link Layer Control protocols are responsible for reliable and efficient transfer of information

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across physical links. MAC protocols in wireless sensor networks control radio activities and coordinate nodes to access the shared communication medium. Since wireless medium is inherently broadcast in nature, the MAC-layer is a very important part of wireless systems. If the nodes do not coordinate while transmitting, data from

different nodes transmitted at the same time will be superimposed and consequently the packet transmission may be lost due to collisions.

MAC protocols are designed based on different network characteristics and application requirements. Wireless Sensor Networks (WSNs) have a broad range of applications. These include the military domain, such as battlefield surveillance (Alshrabi *et al.*, 2008), environmental and habitat monitoring (Szewczyk *et al.*, 2004), healthcare applications (Kim *et al.*, 2007), home automation (Mozer, 2004), traffic control (Chen *et al.*, 2005), etc. In most of the application scenarios, sensor nodes are battery powered and deployed at remote locations or in massive scale. This makes battery service or replacement difficult. Sensor networks are expected to be in operation for years to make a WSN solution economically viable. The classical performance metrics for network services include throughput, latency, fairness, delivery rate, etc. However, due to the limited energy supply to sensor nodes and the requirement for long lifetime, reducing power consumption in WSNs has become one of the primary objectives for designers (Demirkol *et al.*, 2006).

Sources of energy consumption in sensor nodes include radio communication, computation and sensing activities. The energy consumption of sensing activities is independent of the communication protocol stack and thus out of scope for this chapter. Radio communication bears a much heavier energy consumption than computation. MAC protocols, which directly control radio activities, play an important role in determining the power consumption in data communication for sensor networks. Therefore, WSN MAC protocol designs are focused more towards energy conservation than towards classical performance metrics. Although WSN applications still impose different requirements on latency, throughput and reliability, energy consumption remains as the most important optimization goal. This makes the design of MAC protocols for WSNs unique and challenging. One of the challenges is that power

consumption is often difficult to be estimated theoretically since it depends on implementation specific knowledge.

Vast literature exists on fundamentals of MAC protocols, especially on their theoretical underpinnings. In this chapter, we focus on some of the practical issues of sensor network MACs that are of high interest to engineers and researchers wishing to implement and deploy MAC solutions on a real hardware platform in real-world applications. Thus, we bias our discussion towards providing specific lessons learned from implementation projects in order to bridge the gap between theory and practice. Furthermore, we extend our discussion to include comments on the implementation complexity, memory usage, fault tolerance and the availability of compatible hardware for realizing the design. This chapter begins with the background information on the trends of MAC protocol development and their analysis from a practical perspective. We have implemented a number of MAC solutions based on various suggested methods in order to meet the power consumption limits in different projects. A detailed discussion on the practical aspects of design, implementation, performance evaluation and the integration of these MAC protocols is presented in this chapter. These designs consider traffic awareness in MAC protocols, multi-radio platforms and wake-up radio based solutions. Empirical studies on the coexistence of a sensor network with other networks, and spectrum agility aspects are also highlighted. The cross-layer design aspects are covered with two experimental designs and portable MAC architectures are introduced afterwards. Finally, we conclude the chapter.

## **MEDIUM ACCESS CONTROL TRENDS AND SOLUTIONS**

A number of WSN MAC protocols have been developed with different design goals and techniques for various application scenarios. These protocols are fundamentally different from the ones de-

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