Chapter 2
Low Power Design Techniques for Wireless Sensor Networks

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ABSTRACT
WSNs can be applied in several areas for the monitoring and control of variables. In the design process of a WSN, one of the most important design objectives is to minimize the energy required for sensing, signal processing and communication tasks to extend the lifetime of the network. This chapter discusses a broad variety of schemes used to reduce power consumption in WSNs. The design of sensors nodes involves several core aspects, such as supported sensors, the communication interface, applications, the control system and peripherals. Strategies to preserve the energy used by each of these components are discussed. A specific scheme using digital signal processing to reduce power consumption by decreasing the number of transmissions is proposed. The chapter also considers protocol architectures, focusing on link layer, network layer, and cross-layer approaches. Finally, a comparative analysis among the main techniques is presented.

INTRODUCTION
Wireless Sensor Networks (WSNs) are defined as networks that are composed by a number of spatially distributed sensor nodes equipped with radio transceivers. Each sensor node is designed to cooperatively monitor physical variables (Culler, 2004). The node itself is relatively simple, but the real power of this technology emerges from the ability of a node to perform a task in a cooperative manner with others, thanks to communication protocols. In this manner, one of the most striking aspects of this technology lies in the reliable flow
of information through the nodes. The applications of this technology are very wide due to the large number of different sensors that can be used in a network. Some relevant examples include environmental monitoring, using temperature humidity or illumination sensors (Tors et al., 2004); healthcare applications, using Electrocardiogram/electroencephalogram (ECG/EEG) sensors (Culler 2004; Tors et al., 2004; Lo, 2005); and home automation, using activity sensors (Heidemann, 2003).

One of the main goals of WSNs is to populate areas with large numbers of nodes, probably hundreds or even thousands, in order to track a set of variables. To achieve this goal, however, the power consumption of the nodes has to be minimized to extend the lifetime of the network. This issue has become a very relevant research challenge in the field of WSNs, since it determines the performance and cost of the entire system.

The design process of both the nodes and the network includes the following design features: they must operate with very limited power resources, require little maintenance, and have a small size (Paradiso, 2005). Other requirements which should be satisfied by WSNs include ease of deployment and low cost. The set of functions performed by WSNs together with these requirements involves a high computational complexity, which translates into a high power consumption of the devices, which limits autonomy.

The problem of power consumption has been approached by researchers from different angles that can be classified into the following categories:

- Hardware and signal acquisition
- Protocol architecture

The first approach directly deals with optimizing the embedded system (hardware) and the algorithms used for signal sensing and processing at each node. Some proposed strategies proposed to reduce power consumption by modifying the nodes include developing processing units with low power modes, distributing tasks among the different nodes and implementing different network topologies (Hill, 2003; Taieb, 2007; Imad, 2005). Some studies have presented strategies to reduce power consumption in WSNs using a signal processing theory. Alippi et al. (2007) use Kalman filters to determine the sampling frequency of sensors based on the availability of the communication channel. This estimation is performed through a handshaking protocol between the node and the server, which determines whether the frequency and its new value should be changed. Römer and Santini (2006) propose a strategy to reduce transmission by network nodes based on the Least Mean Square algorithm, in which the sink assumes the estimated values of the nodes.

The second approach aims at analyzing and proposing a modification to the network protocol architecture. This can be done either by implementing a new MAC protocol (Heidemann, 2003; Shakshuki & Malik, 2007; Polastre, Hill & Culler, 2004), a new routing protocol, (Heinzelman et al., 2000; Slama et al., 2007; Shibli et al., 2007), or by using a cross-layered approach in which the topology of the network is also considered (Jurdak et al., 2007; Wang et al., 2005). The cross-layer approach has been shown to exhibit the best performance in terms of power consumption.

The goal of this chapter is to present the state-of-the-art of the schemes used to reduce power consumption in WSNs. This chapter reviews, analyzes, and compares different strategies proposed in the literature using the above mentioned approaches. It focuses on a specific scheme proposed by the authors using digital signal processing to reduce power consumption by decreasing the number of transmissions (Gaviria et al., 2009). This chapter will also present the most important research and development challenges to reduce power consumption in WSNs.

This chapter is organized as follows: The first section describes the principles of WSNs and the main challenges associated with their design. This is followed by a discussion on low power techniques, with an analysis of the hardware