Chapter 3
Hierarchical Wireless Networks of Body Sensor Networks for Healthcare Applications

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ABSTRACT

Conventional wired body sensor networks have been used in hospitals over the last decade; however, the tethered operation restricts the mobility of the patients. In the scenario considered in this chapter, the signals collected from the patients' bodies are wirelessly transmitted to a base station, and then delivered to a remote diagnosis centre through a communication infrastructure, enabling full mobility of the patient in the coverage area of the wireless network. Healthcare applications require the network to satisfy demanding requirements in terms of quality of service (QoS) and, at the same time, minimize the energy consumption of the sensor nodes. The traffic generated by data-intensive healthcare applications may lead to frequent collisions between sensor nodes and the consequent loss of data, if conventional MAC protocols for wireless sensor networks are used. Therefore, this chapter presents LPRT and CCMAC, two MAC protocols that intend to satisfy the QoS requirements of these applications, but differ in the wireless topology used. Experimental results for an implementation of the LPRT using an IEEE 802.15.4 compliant wireless sensor platform are presented, as well as simulation results comparing the performance of direct communication (between wireless body sensor nodes and the base station) with two other approaches relying on a cluster-based topology (similar to the one proposed by the authors of LEACH), which demonstrate the benefits of using a cluster-based topology on wireless healthcare applications.

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Table 1. Bio-signals electrical characteristics

Vital signal (Hz)	Freq. range (Hz)	Sampling rate (Hz)	Resolution (bit)
ECG (per lead)	0.01…60-125	120-250	12
Temperature	0…0.1-1	0.2-2	12
Oximetry	0 … 30	60	12
Blood pressure (BP)	0 … 60	120	12
Respiratory rate	0.1 … 10	20	12
Heart rate (HR)	0.4 … 5	10	12

1. INTRODUCTION

A body sensor network (BSN) consists of a group of sensors attached to a patient in order to acquire physiological data. Conventional wired BSNs have been used in hospitals over the last decades; however, these systems do not allow the patient to move around freely. Recent advances in wireless technologies are changing this scenario by enabling mobile and continuous monitoring of patients, even during their daily life activities. In such healthcare systems, the information sensed at the patient´s body is wirelessly transmitted to a base station, located no more than a few tens of meters away, and then delivered to a remote diagnosis centre through a communication infrastructure. These systems may require the monitoring of several bio-signals, such as electrocardiogram (ECG), heart rate, blood pressure, respiratory rate, pulse oximetry and temperature. Table 1 presents the electrical characteristics of the bio-signals commonly used in emergency medical care (Arnon et al., 2003; Paksuniemi et al., 2005).

Although extensive measurement of biomedical information is currently available in many hospitals, the diagnostic and monitoring procedure is normally limited in time and it is not adequate to capture the patients' physiological states. In this scenario, transient abnormalities cannot always be detected. For example, many cardiac diseases are associated with episodic abnormalities such as transient surges in blood pressure, arrhythmias or episodes of myocardial ischemia (Lo and Yang, 2005). These abnormalities are important but since their timing is impossible to predict, much time and effort is wasted when capturing an abnormality episode with controlled monitoring. Therefore, vital and even life threatening disorders can go undetected due to their random behavior. These episodes, if properly detected, have the potential to replace life saving but expensive therapies. Recent advances in microelectronics, wireless communications and sensors technology foresee a rapid expansion of wireless sensor networks development over the next years with corresponding reduction in size and cost. This will facilitate continuous wireless monitoring, initially of at-risk patients but eventually including an increasing proportion of the population.

Despite of the evident benefits that can result from the adoption of wireless systems, there are still many concerns that limit their widespread application and challenge researchers to devise potential solutions. In healthcare applications, the network needs to satisfy demanding requirements in terms of quality of service (QoS), such as sustainable throughput, bounded delay and reliable packet delivery. At the same time, it is necessary to minimize the energy consumption of the battery powered sensor nodes, in order to increase their lifetime. A difficulty arises from the fact that some sensors must be sampled quite often, generating a great amount of data and, consequently, requiring the network to operate under high loads. For example, an ECG can require sampling rates of up to 250 Hz per lead with a resolution of 12 bits