Chapter 5
Using Cross-Layer Techniques for ECG Transmissions in Body Area Sensor Networks

Tao Ma
University of Nebraska – Lincoln, USA

Hamid Sharif
University of Nebraska – Lincoln, USA

Michael Hempel
University of Nebraska – Lincoln, USA

Fahimeh Rezaei
University of Nebraska – Lincoln, USA

Dongming Peng
University of Nebraska – Lincoln, USA

Pradhumna L Shrestha
University of Nebraska – Lincoln, USA

Hsiao-Hwa Chen
National Cheng Kung University, Taiwan

ABSTRACT

Body Area Sensor Networks (BASN) with miniature sensors providing wireless communications capabilities have become a promising tool for monitoring and logging vital parameters of patients suffering from chronic diseases such as diabetes, asthma, and heart diseases. Particularly, as the technical development in BASN, a low-cost, high-quality, convenient Electrocardiographic (ECG) diagnosis system becomes a future major tool for healthcare systems. However, numerous important research issues remain to be addressed in BASN for ECG transmissions. Among these, communication energy efficiency and security are the most concerning issues. In this chapter, the authors introduce, survey, and analyze effective cross-layer strategies for wireless ECG transmissions in BASN. The key idea of these cross-layer communication techniques is to take advantage of both source data properties and communication strategies for the optimization of the system energy efficiency while providing secure wireless ECG transmissions. The goal of improving communication energy efficiency is achieved by matching the source coding of ECG signals with the channel coding strategy. In addition one can leverage biometric ECG properties to implement an energy-efficient cross-layer security strategy. As an example the authors showcase two security methods in this chapter—selective encryption and self-authentication. Thanks to the dependency property of the compressed ECG data, a selective encryption algorithm needs only to be applied on a

DOI: 10.4018/978-1-4666-0960-0.ch005

very small portion of the transmitted data, and at the same time it provides a level of security equivalent to traditional full-scale encryption using block or stream ciphers without the burden of the associated energy and computational expense. In the example authentication scheme, sensors for the same body can authenticate each other by common traits such as inter-pulse intervals. The authors analyzed the proposed cross-layer techniques for ECG transmissions and validated the achieved energy efficiency improvements by both simulation and experimental results.

INTRODUCTION

Recent advances in wireless Body Area Sensor Networks (BASN) make feasible a wireless and mobile diagnosis system for delivering medical and healthcare services. In such systems, wearable or implantable medical sensors, around or inside the human body, form a wirelessly interconnected network. This system is then used to collect an individual's medical information ubiquitously and to perform critical and complicated tasks collaboratively. Communications among sensor nodes must be energy-efficient, and reliably protected against errors from wirelessly transmitted packets, as well as malicious or fraudulent actions.

Particularly, with the technical development in BASN, a low-cost, high-quality, convenient Electrocardiographic (ECG) diagnosis system becomes a future major tool for healthcare systems. In this chapter, an energy-efficient and secure scheme for ECG transmissions in BASN is proposed. Differently from previous research in the literature, in this technique, the diverse properties of compressed ECG data are extensively explored and exploited at the application layer before data transmission. The transmission schemes crossing the link and MAC layers are then adapted to diverse ECG data properties in a way that both data security and quality as well as communication energy efficiency are ensured. Our study's results have demonstrated a considerable degree of performance improvement in transmission quality, security and energy consumption.

In this chapter, we address the primary concern for energy efficiency in ECG transmissions for BASN utilizing cross-layer techniques. Because BASNs are constrained by resource limitations such as battery power, computing and processing power, communication link vulnerability and bandwidth availability, there is a strong need for employing cross-layer techniques to tackle diverse issues to achieve a low-cost, reliable and secure wireless collection and monitoring system for BASN applications.

To showcase the advantages of cross-layer designs we leverage our approach to implement a novel approach to secure transmissions for ECG-based BASN; using source authentication and data encryption. Based on this approach, we will investigate and summarize the common cross-layer methodologies being used in ECG systems using wireless BASNs.

BACKGROUND

Heart disease, stroke, cancer, chronic respiratory diseases, and diabetes are the major causes of mortality in the world, representing 60% of all deaths. Since chronic diseases often have asymptomatic or intermittent properties, long-term continuous health monitoring is essential in detecting and treating such diseases. For example, long-term monitoring of ECG data helps detecting these diseases at an early stage and improves the chance of successful treatments. For preventing strokes, real time ECG information monitoring is essential for heart rate control and prompt re-treatment. Long-term monitoring requires the transmission of a large amount of data in a reliable, convenient, energy-efficient and secure manner. Thus, it generates a huge challenge for today's technology.