OrbitECG: Mobile Phone-Based Ambulatory Wearable ECG Monitoring

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1. INTRODUCTION

Chronic diseases have become a prominent problem in public health, especially in the developed world, due to lifestyle changes, longevity, and environmental factors. For example, heart disease is the number one cause of death in the US, and 11% of adults suffer from it. Existing health care systems are oriented toward acute diseases rather than chronic ones. Care of chronic illness requires continual interaction between patients and medical personnel for an extended period of time. However, the average hospital stay associated with heart disease lasts less than five days. Even when the patient is affluent enough to afford follow-up visits, they can only provide accurate data on a limited snapshot of time. This limits the health professional's ability to accurately judge heart conditions during the different activities inherent in normal daily life.

Ambulatory ECG monitoring can revolutionize healthcare for heart disease patients by providing the health professional with real-time access to the patients' health information in real-life conditions, instead of a limited snapshot in the doctor's office or hospital. Portable ECG recording systems already exist in various forms, but they are primarily used as a stopgap measure for a short period, usually a day to a week. The user either returns the device, or manually transfers the recorded data, which is far from real-time. Furthermore, medical personnel cannot tweak the ECG monitoring system parameters on the fly.

We have developed a three-tier solution for real-time ambulatory ECG monitoring to address its challenges regarding energy efficiency and security, while remaining scalable, cost-effective, and configurable (Figure 1). It consists of 1) a low-power wearable Bluetooth ECG sensor, 2) a mobile phone with cellular and Wi-Fi connectivity as a personal server, and 3) an Internet health server for data storage and access control. Our sensors are based on the energy-efficient Rice Orbit Platform[1]. We employ Context-for-Wireless[2] to address the energy challenge of wireless data transfer. We provide secure multi-layer access control for the data stored on our server. While we have developed an ECG monitoring system, our work is general and can be applied to other health monitoring systems as well. Furthermore, our personal server supports multiple health sensors simultaneously.

We next present details of our wearable ECG monitoring system, and our proposed demo.

2. THREE-TIER ECG MONITORING

We have developed a three tier ECG monitoring system, as follows. The first tier is the body-worn wireless ECG sensor. We have developed a low-power bio-amplifier to interface between commercially available electrode leads and an Orbit Sensor [1]. The bio-amplifier amplifies and filters the

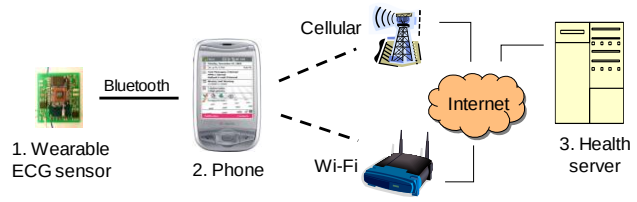

Figure 1. The three-tier ECG monitoring system

ECG signal from the electrodes. We have programmed an Orbit Sensor to sample the amplified signal. The Orbit Sensor buffers the ECG data and transfers it over Bluetooth to the user's mobile phone. The Orbit Platform enables a simple yet effective technique to minimize Bluetooth energy usage, which we use: After every data transfer, we schedule the time of the next connection and turn off the Bluetooth module until the next scheduled connection.

The second tier is a mobile phone as the personal server. It controls and commands the ECG sensor, receives the ECG data from it, and transfers the data over SSL to our internet server. We have employed a high performance phone with Wi-Fi and cellular (EDGE) data connectivity. Wireless data transfer in general, and cellular data transfer in particular, is known to be extremely power hungry [2]. To address the energy challenge of data transfer between the phone and the Internet server, and achieve maximum energy efficiency, we employ Context-for-Wireless to determine whether to use cellular or attempt a Wi-Fi connection for each data transfer.

The third tier is the Internet health server. Security and data management are the key challenges. Our server can, through its secure web interface, graphically display the received ECG data and allow the healthcare professional to alter ECG monitoring parameters such as time interval between recordings. The server supports multiple levels of access control for patient data. Each patient can assign other users to different levels of access. For example, the patient may choose to provide full access to their doctor and read only access to their family members.

3. DEMONSTRATION

In the demo, we will display our ECG monitoring system in action. Conference delegates will be able to see the wireless ECG sensor and the personal server (phone). They can also, through a standard web browser on a laptop PC, access the ECG data and change the monitoring parameters. At a minimum, our demo will require Wi-Fi or cellular connectivity for the phone, and Wi-Fi or Ethernet connectivity along with an electricity outlet for the laptop.

4. REFERENCES

[1] Rice Orbit Platform, Rice Efficient Computing Group http://www.ruf.rice.edu/~mobile/orbit.

[2] Rahmati, A. and Zhong, L. Context-for-Wireless: Context-Sensitive Energy-Efficient Wireless Data Transfer. *Proc. 5th Int. Conf. Mobile Systems, Applications and Services (MobiSys)* (2007).