An Android-Based Body Area Network Gateway for Mobile Health Applications

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ABSTRACT
This paper presents a Body Area Network (BAN) gateway to Android mobile phones for mobile health applications. The proposed approach is based on a Secure Digital Input Output (SDIO) interface, which allows for long-term monitoring since the mobile phone hardware can be extended in order to operate with ultra low-power radios. The software architecture implemented on the mobile phone enables different features; data can be displayed, further processed or sent to a remote server exploiting the WLAN or 3G networks. Moreover, the system allows to configure thresholds on the measured parameters and to automatically send alerts such as SMS messages and emails based on these values. The system is illustrated for the case of ambulatory ECG monitoring.

Categories and Subject Descriptors
J.3 [**Computer Applications**]: Life and medical sciences

General Terms
Performance, Design, Experimentation

Keywords
mHealth, SDIO, Android, Body Area Networks.

1. INTRODUCTION
An increasingly aging population, combined with decreasing hospitals capacities and rising costs of health care suggests that maintaining the current level of hospital care is becoming an increasing challenge. The adoption of mHealth technology (the use of mobile devices for delivering health services) is expected to improve the efficiency of healthcare service delivery, and therefore reduce healthcare costs. Body Area Networks (BANs) [1], appear as an essential component of mHealth. BANs are miniaturized sensor networks, consisting of lightweight, ultra low-power and wireless nodes, able to provide long term monitoring of physical and vital parameters. Adopting BANs as monitoring systems would allow home monitoring of the patients, who are no longer compelled to stay in hospitals. Using a mobile phone as a gateway for BANs can provide to the user all the advantages already brought to him by commercial ad-hoc monitoring systems along with support for a variety of technical functions, integrated seamlessly with our everyday life. They offer high computing power, personalization, high connectivity, and require very little training in the technology, since users can use their own mobile phone to benefit from mobile health services. In this demo, we present a mobile health monitoring system that uses (i) the Human++ BAN sensor nodes to retrieve bio-signals from the body, (ii) an Android mobile phone to collect, store, process, and send the data. The paper describes a SDIO interface to Android-based phones for low-power BAN radios, representing an energy-efficient alternative to Bluetooth.

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2. RELATED WORK
Several mobile devices have been proposed for continuous monitoring. Some of them act as standalone systems, offering a limited subset of functionalities compared to a BAN composed of several bio-sensors. Our focus is on the development of a low-power and low-cost BAN interface to mobile phones.

Since mobile phones are equipped with BT (Bluetooth) radios many of such interfaces adopt Bluetooth as the communication protocol [2]. However, BT power consumption is too high for long term monitoring, often leading to a very limited usage of the BAN sensors. In its current version, the Human++ BAN platform adopts the nRF24L01+ radio (by Nordic). The power consumption of the Nordic radio is significantly lower compared to BT modules on the market (12 against 40 mA in reception mode). With this demo we show how we can achieve good results in terms of both power consumption and data throughput implementing the SDIO protocol without an SDIO controller, adopting only an SPI interface and some additional logic components to interface a low-power radio to the smartphone. Being Android a system that is not only open, but also available on handsets produced by many different manufacturers, we decided to develop our system on the Android Dev Phone by Google. To the best of our knowledge, we are the first group to develop a low-power interface to BANs using a standard SDIO interface on Android mobile phones, enabling long-term monitoring and the integration of all the features available on Google's operating system.

3. SYSTEM ARCHITECTURE

3.1 Body Area Network
The Human++ BAN platform adopts sensor nodes that can detect different kind of bio-signals (ECG, EMG, EEG, etc.). The sensor nodes communicate with a central receiver, the base station, in a star network using a static TDMA protocol.

3.2 Low-power gateway to smart phone
The base station is composed of three main components (see Fig. 1). A microcontroller (MSP430 series), a radio (nRF24L01+ 2.4 Ghz, by Nordic) and a synchronization logic block (see Fig. 2).

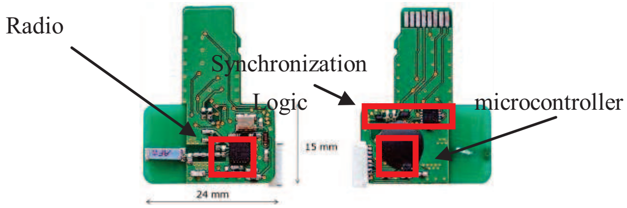

Figure 1. PCB of the micro-SDIO base station

The SDIO protocol [4] offers the possibility to use the SD interface for I/O instead of memory. A solution found in literature [3] to exploit this interface is to use an SDIO controller, capable of handling the SDIO communication with the mobile phone and presenting itself as a simple serial interface to the microcontroller. This solution leads to a limited data throughput, as well as to higher power consumptions (higher clock frequency and additional controller).

For these reasons we developed a novel approach. By means of a few extra components we can use the SPI interface, present in all low-power and low-cost microcontrollers, and communicate with the smartphone by means of the SD protocol. The whole protocol is then implemented in firmware on the MSP430. Emulating the SD protocol over the SPI interface enables the smartphone to communicate with ultra-low power radios, increasing the autonomy of the BAN (e.g. compared to Bluetooth based body area networks).

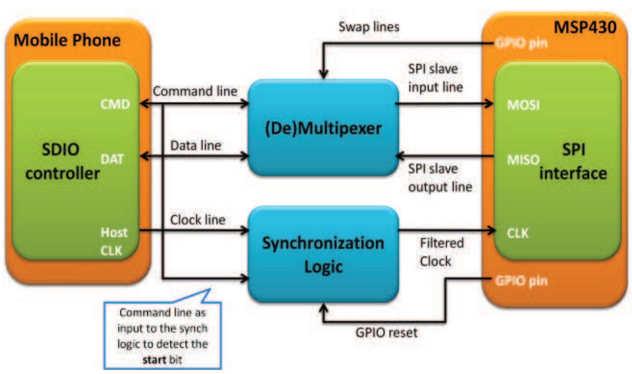

Figure 2. Block diagram of the synchronization logic

3.3 Performance characterization

The performances of the SDIO base station are evaluated based on two parameters: power consumption and data throughput. The SDIO base station needs to be active (in receiving mode) for a longer time compared to the sensor nodes, since it receives the data from all the sensor nodes that belong to the network. Once the data has been received, the base station will take care of the transmission to the mobile phone, and the radio can be turned off. The power consumption is about 8 mA (including MSP430, static TDMA Medium Access Control layer, SDIO protocol), while the data throughput of the interface is approximately 100 kbps.

4. DEMO – ECG MONITORING

Considering that cardiovascular disease is the primary cause of death in both developed and developing countries, we selected the case of ECG monitoring as a case-study for our connected health platform demonstration. The ECG is monitored using an ultra-low-power wireless ECG necklace developed by imec, which consists in a simple case of body area network. The application features an optimized implementation of a CWT based algorithm [5] in order to determine the heart rate of the user. The algorithm achieved a Se=99.65% of and +P= 99.79% on the MIT-BIH database. The application provides the user with the possibility to configure different thresholds (e.g. minimum or maximum heart rate values). Based on these thresholds it is possible to trigger alerts, such as emails or SMS messages to one or more people (medical staff, relatives) who need to be informed about the changes in the ECG activity.

Additionally, the application allows the user to visualize and send a daily summary of the heart activity, reporting the minimum, maximum and average heart rate (see Fig. 3). Finally, data can be sent through Wi-Fi to a remote server, in order to collect or further process it.

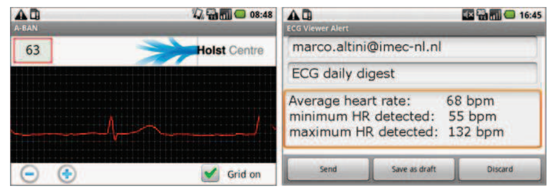

Figure 3. Android application

Fig. 4 shows a user wearing a sensor node, and displaying the ECG signal, as well as the heart rate, on the Android phone.

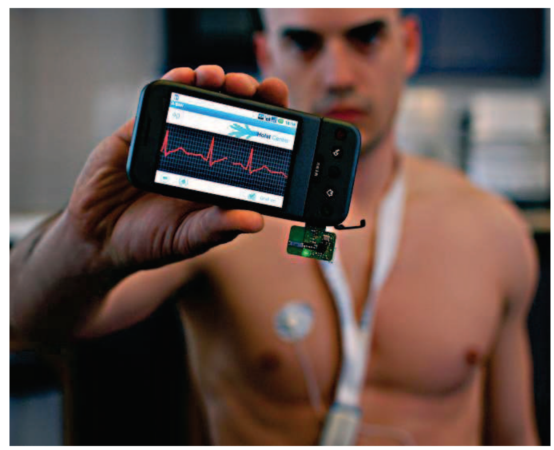

Figure 4. ECG monitoring

5. REFERENCES

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