Off-the-Shelf Platform for remote monitoring of vital signs

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ABSTRACT

This document shows work-in-progress in the implementation of a platform for remote monitoring of health care data using ready to use devices. The goal is to provide an easy-to-use application to gather specific control parameters directly related to type 2 Diabetes Mellitus. The idea of remote monitoring for e-health is not new but there exist open questions about the radio technology to use in these applications. Some standards are often associated with these kinds of applications, standards such as: IEEE 802.15.4 and ANT+. We try to explore the benefits of using out of the box technology to reduce development and deployment time of applications sending gathered data over the Internet. The utilization of Smartphones as concentrator node is also discussed, as it make possible to use sensors already embedded in the device as well as other multipurpose and ready to use sensors using ANT+ technology.

Keywords**:** e-health, telemedicine applications, type 2 Diabetes Mellitus, type 2 DM, Remote Monitoring, Android, ANT+.

RESUMEN

Este documento presenta el trabajo en proceso en la implementación de una plataforma de monitoreo remoto de datos de salud de las personas utilizando dispositivos listos para usar. El objetivo es proveer una aplicación fácil de utilizar para recuperar parámetros de control específicos directamente relacionados con la Diabetes Mellitus de tipo 2. Si bien la idea de monitoreo remoto en el contexto de salud no es nueva, persisten preguntas sobre la tecnología de radio a utilizar en estas aplicaciones. Los estándares frecuentemente relacionados con este problema son: IEEE 802.15.4 y ANT+. Se explotan los beneficios de usar tecnología ya disponible de fábrica para reducir los tiempos de desarrollo y despliegue de aplicaciones que envían datos a Internet. El teléfono inteligente o Smartphone es un nodo concentrador, ya que permite utilizar sensores integrados en el dispositivo, así como otros sensores multipropósito que utilizan la tecnología ANT+.

Palabras clave: e-salud, telemedicina, Diabetes Mellitus tipo 2, monitoreo remoto, Android, ANT+.

1. INTRODUCTION

Guide ALAD 2006 for diagnostic control and treatment of type 2 Diabetes Mellitus (DM) (Pan American Health Organization 2008), states reference values of blood pressure for per-sons with DM. Therewith, the guide present the protocol of clinical monitoring and laboratory, suggesting three frequencies in the following of persons with DM. Frequencies are: initial, every three to four months, and yearly. However, frequency could change accordingly to each person’s requirements. Weight and Body mass index (BMI), waist circumference, and blood pressure (BP) are among the most frequently requested parameters.

We envisage a basic telemonitoring application for obtaining body measures using mobile phones and other mobile technology. This platform uses telecommunication and information technologies to gather and communicate measures to the Internet. The goal is to provide a tool helping persons with type 2 DM to obtain a, shared with the doctor, log of sampled parameters with a higher temporal granularity. It is important to raise awareness of this condition as the number of elderly persons around the world (Robert-Bobée, 2007) grows.

Usually it is possible to separate four common stages in these kinds of applications: sensing/measuring, transmitting, storing/processing, and presenting. Every stage involves re-search to make applications more: affordable, reliable, imperceptible, and compatible.

It is possible to classify applications as ones using or not Smartphones. Another classification is possible by the transmission technology used (e.g. IEEE 802.15.4, or IEEE 802.15.3, or ANT+). There have been many initiatives to propose a de Facto standard. However, when not enough hardware is available some applications use standards off-the-shelf, making it adequate for research environments but not for quick deployment. It is possible to find very specialized solutions, like SHIMMER (Burns *et al.*, 2010), with hardware ready to deploy in patients with low energy consumption. Nevertheless, this solution is not compatible with Smartphones or with Internet transmission of data.

This paper tries to help address the question: What is the right platform/technology for remote monitoring of health care data?, targeting people having a Smartphone and willing to send collected data throughout the Internet.

2. RELATED WORKS

Related works can be classified by the stage they are focused on. Stages of Remote presentation and Storing and processing are mostly covered by the Information Technology (IT). Here we need new methods to detect and anticipate anomalies based on periodical data (Lagido *et al*., 2014).

There are stages where research attempts to integrate knowledge of physiology and electronics. The research area responsible for development of new sensors is very dynamic. New sensors allows developing new methods to gather physiological information on the body (Motoi *et al*., 2009; McCombie *et al*., 2005; Bulling *et al*., 2008). For example, Blood Pressure (BP) can be used as predictor of disease (Tamura *et al*., 2009) and it is an important parameter to follow. Oshima *et al*. (2009) shows a prototype for pressure detection in shoes and recollection of data from accelerometers for activity estimation. However, data are never sent to the Internet, and the device collecting data is a computer instead of a Smartphone.

The Transmission stage can further be classified in local or remote. Existent techniques can be used for remote data transmission. For example, Lateiff (Abdul Latiff *et al*., 2013) entirely let a well-known service, such as DropBox1, take care about the synchronization of files. This implies fewer features to be programmed into the software, reusing functionality. The local transmission stage employs knowledge of Wireless Sensors Networks (WSN) in this kind of applications because of the small size of devices and low power consumption. Low power is always attractive because less interaction is needed from users. Projects using IEEE 802.15.4 low power consumption protocol include (Fernández-López, 2011; Oshima *et al*., 2009; Burns *et al*., 2010).

Table 1 shows some projects ordered by year. The third column presents physiological parameters recollected by sensors. Some projects are conceived to work only with a Personal Computer (PC), including or not remote visualization. Protocols used for local transmission include Bluetooth, IEEE 802.15.4, and ANT+.

2.1. Problems integrating sensors and phones

Battaflino *et al.* (2011) uses SD and SIM hardware to operate with 802.15.4 on Windows Mobile phones using “Campus++”. Although they present architecture, they are not very specific about the hardware part more than a PDA with SDIO/ZSD and cell phones using ZSIM. However, it is not clear which cell phone is used in their project. Furthermore, in the conclusions they state moving from Windows Mobile to the Android Operating System (OS).

Another implementation using SD adapters is presented by Nengqiang (He *et al.*, 2011). Figure 1 present a prototype using a Nokia 5800XM running Symbian OS 9.4. The picture proves interoperability for the local transmission stage, but it is difficult to imagine a health care application without a more ergonomic device.

Park & Heidemann (2011) state that phones has low support for using 802.15.4 and it is considered a barrier. Moreover, the number of Smartphones already having an IEEE 802.15.4 transceiver from factory is inexistent despite that IEEE 802.15.4 is preferred for its low energy consumption (Lee *et al*., 2007). A typical current consumption, according to the technology, when the radio is transmitting is presented in Table 2. Most of the radio technology used in this kind of applications has low power consumption. Wi-Fi consumes more current than other standards.

However, the author only uses Wi-Fi and BT because these radio interfaces are already available on cell phones using Android such as HTC Hero, HTC Touch, Samsung Galaxy S, and HTC EVO. The authors also state that cell phones can help to integrate most of the communication technologies in a single device. Nowadays cell phones include many radio interfaces such as Wi-FI, NFC, BT, ANT+ among others. For this reason, it is necessary to not only survey Smartphones network interfaces but also the communication technology used in sensors.

Figure 1. Prototype using uSD taken from He *et al*. (2011).

Most of the work is in experimental phase, requiring the development of their own circuits and software.

2.2. Off-the-shelf products

There exists some proposition to use off-the-shelf devices to have a faster deployment of the application. Beutel *et al*. (2004) adopt this approach using Bluetooth devices in the year 2004. Among the advantages of this approach are: the low cost of the devices and the integration of antennas in different devices, such as cell phones. Belchior *et al*. (2013) follows a similar approach, but using ANT+. The local transmission is provided by an Android based ANT+ capable Smartphone and native support of the communication protocol in scales and blood pressure devices. Lagido *et al*. (2014) shows a similar study design using a scale and a blood pressure device too. Local transmissions use the ANT+ protocol to send physiological parameters to an ANT+ able device. Then data is processed in the Smartphone and if a special event is detected an alert is sent to a remote server.

3. STUDY DESIGN

As presented in Section 2, many fully functional devices working with the ANT+ standard exist. On the other hand, IEEE 802.15.4 devices usually involve a prototyping phase (see Fig. 1). Some parameters to survey in persons with type 2 DM are listed in Section 1. Those physiological values can be obtained directly from some devices. This study uses three ANT+ capable devices to obtain a straightforward communication layer toward a concentrator node with multiple radio interfaces, such as a Smartphone. In turn, Smartphone report information to a remote server for further analysis.

Figure 2 shows a schematic view of the system. Most of the work consists in changing the code of a Smartphone application to: detect, pair, and extract data from the following devices:

- A scale “Tanita BC-1000 plus”. The scale allows collecting data about: weight, body fat percentage, total body water percent, muscle mass, physique rating, BMR/DCI, metabolic age, bone mass, and visceral fat.
- A “Garmin” Premium heart rate monitor.
- An automatic upper arm blood pressure meter “SmartLAB profi+”.

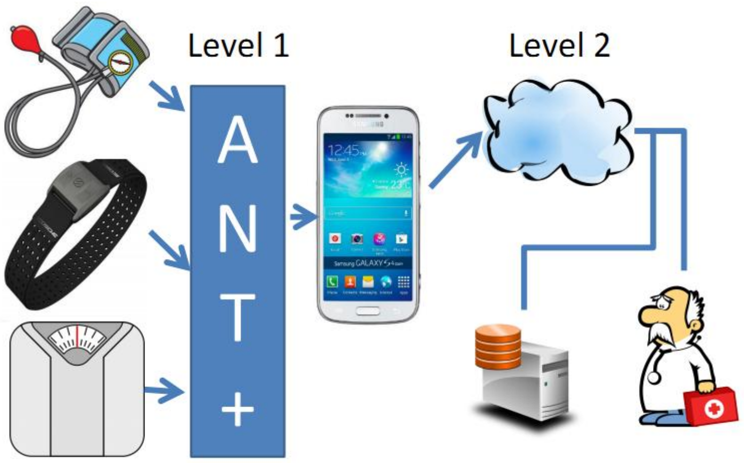

Figure 2. Automatic Blood pressure reader, sports heart rate monitor, and radio wireless body composition platform are used in this study. Level 1 communications use ANT+ and level 2 various technologies to reach a remote server on the Internet.

An available integrating node with different radio interfaces is the A Smartphone Sony Xperia Z3 using Android and ANT+. An application was built for collecting from sensors and for remote reporting to a web server. At the web server side data is received via Java Servlets and stored in a database server for generating reports.

To simplify the problem of compatibility a mechanism called profiles exist. A new device producer willing to make a product compatible with other ANT+ products must implement correctly the profile specific to the device capabilities. Profiles determine the format and the periodicity of data, making it easier to interact with other devices.

Devices must install “ANT Radio Service” and “ANT+ Plugins Service” before use of modified code. The “ANT+ Plugin Sampler” is the starting point for developing Android based applications. Its source code is freely available and allows integration with existing code. In this study, the application was modified to send gathered data over the Web. The time required to modify the code was not very long. Nevertheless, some additional time is needed to improve the software quality. The prototype was ready in less than two weeks, and difficulty is considered to be easy.

4. RESULTS

For the blood pressure monitor, it is possible to read all historical measurements, including key values such as: time stamp, Systolic and Diastolic pressure. Additionally, heart rate is also measured. Time required for communication must be respected. There is no communication while the device is sampling the sensors. After the measurement, the communication module is activated and makes a search for “pairs” to send the information collected.

Using the heart rate monitor there is a field called time stamp, which does not provide the human heart rate obtained with a traditional blood pressure sensor. In this case, another time stamp must be sent to the server to be able to relate calculated values with a specific and usable time stamp. This sensor detects heartbeats events and calculates time between them to estimate the number of beats per minute.

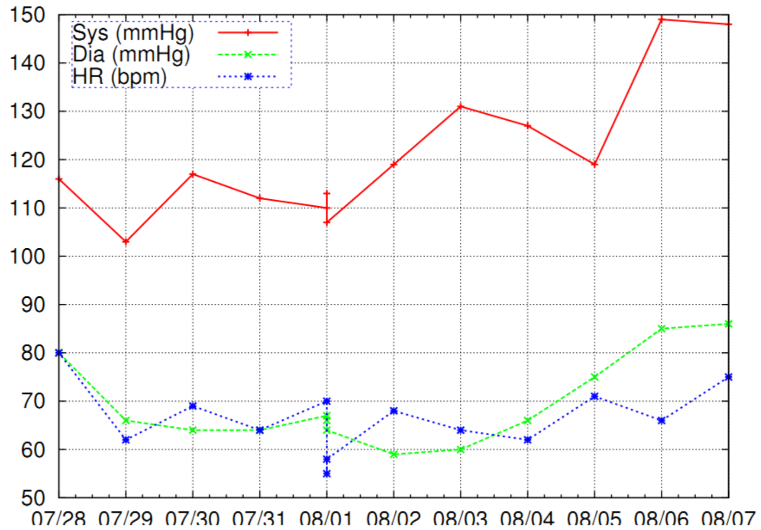

Figure 3. Graph of collected data: heart rate, systolic and diastolic pressure; received at the server for one person.

The weight scale is supposed to report specific features such as: hydration percentage, body fat percentage, muscle mass, bone mass, active metabolic rate, basal metabolic rate, and weight. Those values give more data about fat and bone mass evolution over time, giving some flags about modifications in diet and sport activities. However, there still exist some problems reporting those values except for the weight value. More work is required to solve this problem, possibly debugging the exchange of data frames between the Smartphone and the scale.

Once in the Smartphone, data are seamlessly transmitted to a remote database on the Internet. Figure 3 shows an example of graph generated with data received at the server.

5. CONCLUSIONS

Technology nowadays allows us to generate remote monitoring health care applications in less time than before. We show a real implementation of an application used to store additional periodic information about parameters to watch in the context of type 2 DM.

ANT+ profiles allow an organized generation of new sensors achieving compatibility between a range of devices that meet these profiles. The new generated sensors and profiles can be easily integrated into already existing applications, making it easier to add functionality on-the-go.

Future works will be related to implementing already known methods to predict special conditions based on gathered data in the Smartphone. On the server side, we can look forward to new methods to analyze big amounts of historical data to relate future states of illness with specific detection in the time-series. This is work-in-progress and more work have to be made to tune up the platform. However, a small group of persons already use our services and help us find ways to improve.

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