A Biosensor and Data Presentation Solution for Body Sensor Networks

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Abstract — **A Body Sensor Network can sense health parameters directly on the patient's body, allowing 24/7 monitoring in an unobtrusive way. Several tiny sensors collect and route data to a special sink node. A new intra-vaginal biosensor was developed to study the relation between temperature variations and women health conditions, such as ovulation period, among others. We present a biosensor prototype and some initial results on real scenarios with a woman. One of the main issues in a body sensor network is the transformation of the sensor raw data into meaningful medical data for medical staff. Several approaches exist, from mobile device-based approaches to more powerful hardware such as a personal computer. This paper presents our current work in body sensor networks, namely a prototype for intra-vaginal temperature monitoring with initial results, and a mobile tool for data presentation of a three-tier body sensor network. The gathered results demonstrate the feasibility of the approach, contributing to the widespread application of body sensor networks.**

I. INTRODUCTION

Wireless sensor networks began in military applications, driven by the need to sense data on hostile environments with cost-effective solutions. Such networks are composed of small smart sensing nodes with a processing unit and memory, a wireless transceiver, and a limited power supply.

One of the civil applications of sensor networks is in medical care, providing healthcare monitoring services. From the nature of the in-body sensing capabilities where the sensors are placed in contact or very near the person's body, the designation evolved to body sensor networks [1].

Smart sensors scattered around a person's body can sense medical parameters such as body temperature, perform Electro Cardio Grams (ECG), Electro Mio Grams (EMG), calculate heartbeat rate, in an efficient and unobtrusive way [2].

Figure 1 presents a typical body sensor network scenario [3]. A sink node is responsible for capturing raw sensor data from every sensor placed on the human body. Sink data can then be sent for latter processing and analysis.

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Although offline analysis of health data is essential, the online analysis is also needed. Moreover, a real-time biosensor data presentation for the patient and medical staff is more than desirable. Such scenario demands on-site transformation of raw sensor data to some meaningful form of data presentation that can easily be interpreted by the patient and the medical staff.

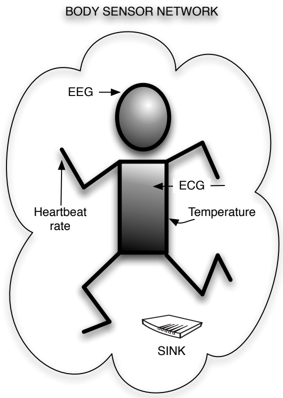

Fig. 1. An example of a body sensor network.

Some solutions rely on a personal computer [3], while others rely entirely on a mobile phone as a sink node [4]. Some even rely on dedicated portable hardware such as a wristwatch [5]. The mobile tool uses the convenience of a generic mobile phone with Bluetooth and Java technology; with a body sensor network where the sink is responsible for data capture and communication coordination among smart sensor nodes [6].

Medical research has been striving to find relationships between intra-vaginal temperature and certain female health conditions, such as ovulation period. A study presents some conclusions on the correlation between covert attention and basal temperature changes during the menstrual cycle phase on 22 adult females proves the importance of basal (intra-vaginal) temperature [7].

To measure the temperature a digital thermometer was given to each female to measure oral temperature each morning. Such process greatly disturbs the women, which need to take the measurement themselves, in opposite to a biosensor-based solution.

Another proof of the importance of internal body temperature comes from a study using a radio pill developed for astronaut use, to access internal body temperature on athletes and take measures to cool them down, avoiding excessive fatigue [8].

This paper presents recent work on body sensor network, namely a prototype of an innovative intra-vaginal biosensor, and a mobile tool for data presentation on a Java and Bluetooth-enabled phone.

The paper is organized as follows. Section II introduces the intra-vaginal biosensor with a software tool for data logging and initial measurements. On Section III a mobile tool for data presentation is briefly described and finally, on Section IV draws some conclusions and notes on future work.

II. A BIOSENSOR FOR INTRA-VAGINAL TEMPERATURE MONITORING

This section presents a prototype for intra-vaginal biosensor construction, with hardware details, a software tool, and some initial results. Due to the innovation of the proposed task, we find very encouraging the results obtained with this first prototype.

A. Challenges

The main challenge is the construction of a totally new biosensor for intra-vaginal temperature (a. k. a. basal temperature) monitoring. To the best of the authors' knowledge and medical team involved there is no biosensor that can sense intra-vaginal temperature, not even studies.

The information provided by this sensor can be used to detect fertile cycle from temperature variation due to the association with ovulation, but can also be used to study temperature effects of some administrated medicines. The medical team also points its use for the detection of preterm labor and the discovery of new contraceptive methods.

The biosensor must take into account the sensitivity of the body area, critical for the comfort of the user on a daily basis. Such comfort is related to the biosensor size, materials and produced heat.

B. Biosensor architecture

A first prototype has already been developed, based on a MA100 temperature sensor (thermistor) from General Electric (GE) [9] and an ALFATxp [10] development board. The development board features Java programming with integrated SD card reader/writer for permanent storage. Figure 2 shows the MA100 thermistor, which is able to measure temperatures in the range of 0ºC to 50ºC, and converts temperature values into electric resistance.

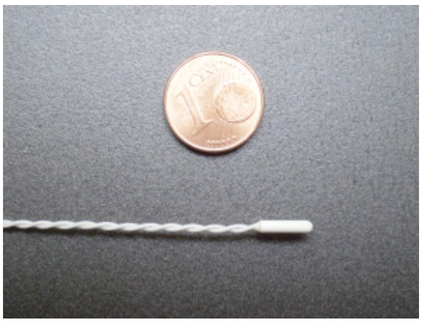

Fig. 2. A detail on the MA100 thermistor from GE.

Figure 3 presents the developed prototype. The MA100 thermistor connects to the analog input of ALFATxp that translates an up to 3V signal with a 10 bits resolution, and connects to the personal computer through a USB connection.

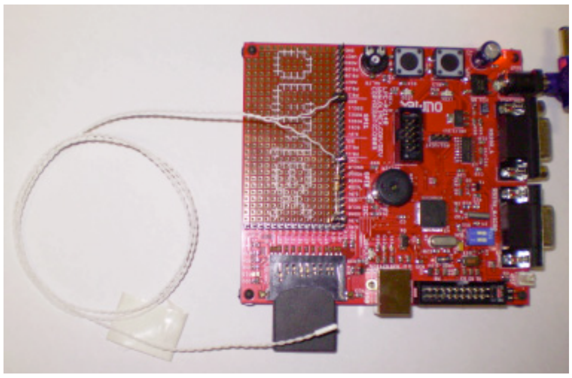

Fig. 3. Biosensor for intra-vaginal temperature monitoring prototype.

The ALFATxp board connects to the personal computer in operation mode through a RS-232 serial connection. The USB connector allows personal computer access to the SD card content, like a flash drive (pen drive). Figure 4 shows computer connections needed to operate ALFATxp board. A preliminary study was performed with ambient temperature to asset the feasibility of the temperature monitoring solution before real testing on the field.

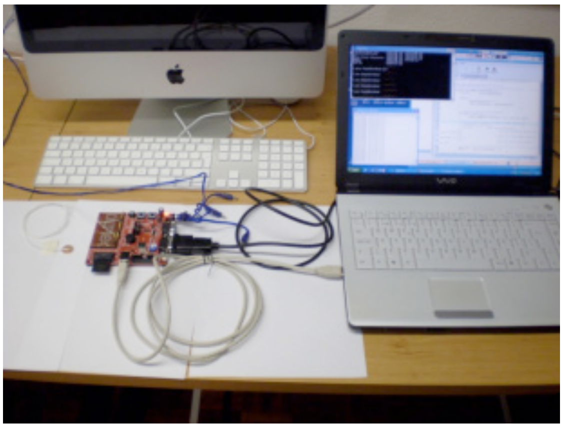

Fig. 4. One of the development phases of the project where ALFATxp is connected to a PC using USB and serial bus.

C. Software and Initial results

A Java-based software tool to collect and present the readings on a personal computer was also developed, as shown in Figure 5. The values are collected into a comma-separated values file on the personal computer, that can be imported for an available application, such as Microsoft® Excel®, for further processing if needed.

The application has a simple interface that controls the sampling frequency, shows the read sensor values, allows basic control over sampling operation (start/stop) and presents the total samples gathered.

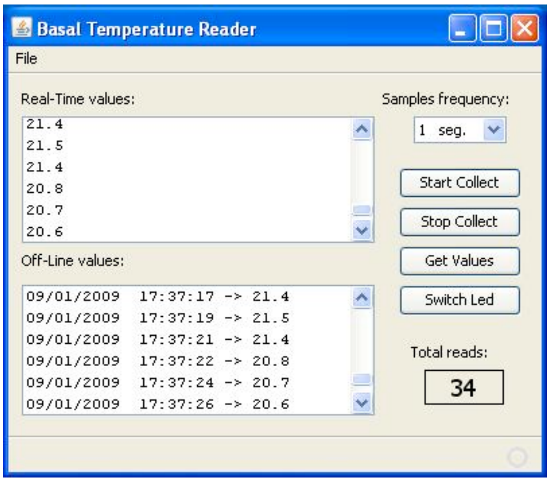

Fig. 5. Temperature monitoring application screenshot.

With the built prototype and the software tool, the medical team managed to achieve some preliminary results to asset the biosensor working condition. We ran a single test on one lady, and the results got us very encouraged to proceed. After biosensor placement we start collecting data, which is presented in graphical form in Figure 6.

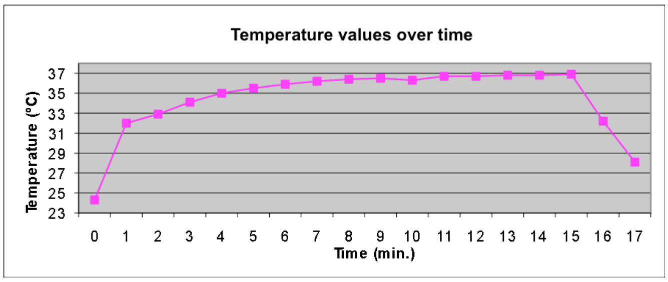

Fig. 6. Graphical representation of the measured temperature signal on a given woman.

The graph shows three different phases of observation: (a) the first phase up to the 8-minute, (b) the second phase from 8 to around 15-minute, and finally (c) from 15 to 17. The first phase corresponds to the sensor response to the difference between ambient and intra-vaginal temperature. The second phase is the real intra-vaginal temperature, while the last phase corresponds to the removal of the biosensor.

III. Mobile Solution for Data Presentation

This section presents a mobile tool for body sensor network data processing and presentation, using a Java and Bluetooth enabled phone. System architecture, the mobile tool with some screenshots and tests and validation are presented here.

A. System architecture

The mobile device connects to the body sensor network sink's device through wireless communication (Bluetooth). The sink manages the network responsibilities at the biosensor level, so a failure on the mobile device (for instance the absence of it) does not yield a failure on the body sensor network. Such approach clearly shields the more critical part of the system, the body sensor network from the presentation layer.

Figure 7 presents the system architecture. The mobile device can communicate with any body sensor network, provided it has the required authentication credentials. The number of biosensors that can me monitored is sink-dependant; with currently up to 8 channels, although only one channel is displayed on the screen at a given time.

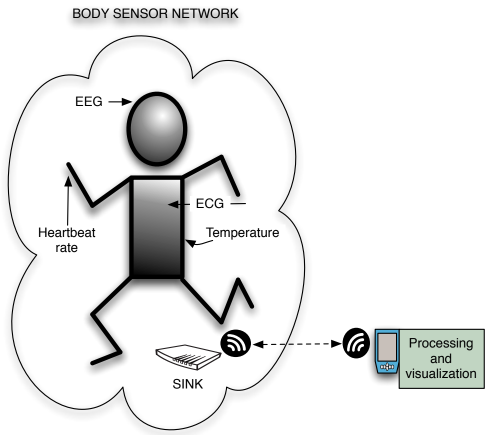

Fig. 7. System architecture for mobile tool development.

A mobile application development has different software engineering guidelines when compared to a personal computer application. The screen orientation, size, resolution and aspect ratio is radically different, the input methods are much more limited (only a D-Pad instead of a mouse), among other constraints.

A special attention was given to resolution independence of the application GUI, with calculations to achieve the optimum readability based on screen resolution. Also the number of key presses was kept to a minimum, with shortcuts for the most used functions.

B. Mobile tool

The mobile tool was entirely developed in J2ME with Connected Limited Device Configuration (CLDC) version 1.1 and Mobile Information Device Profile (MIDP) version 2.0. Besides the communication API developed for authenticated Bluetooth connection with the sink, the mobile tool captures, processes and presents data on the screen of the mobile device.

Two main information screens are defined in this mobile tool: a graphical screen with an oscilloscope-like presentation of a given channel, and a graphical screen with the actual sensor value.

Figure 8 presents the two main screens of the application. On the left a shadowed area graphically represents signal value, and a line across the screen represents the threshold. On top several information is displayed about the signal itself, the programmed threshold value, among other values.

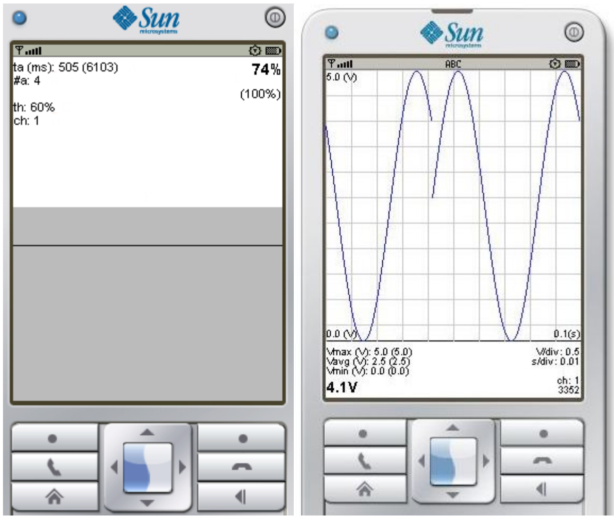

Fig. 8. The two main screens of the mobile application: instant value (left) and oscilloscope-like (right).

On the right side of Figure 8 an oscilloscope-type representation of the signal is displayed, with signal evolution over time. The maximum, minimum and average signal values, actual signal value, and graphical scale information is also given on the bottom part of this screen.

The tool also creates a logging file on the mobile device, using comma-separated values, which can be imported into a personal computer (for instance using Bluetooth technology also) for further analysis.

C. Deployment and validation

The mobile tool can be deployed onto every mobile device in Bluetooth range through the use of a dedicated installer on a Windows® computer. This removes the burden of individual installations on every device.

The mobile tool was validated through the use of on-field tests on several mobile phones from the World leader manufacturer, namely Symbian series 40 and S60 enabled phones such as Nokia® N80, N95, 6280 and 5200. Even in the least hardware-featured device, Nokia 5200 the application worked without flaws for a complete 24-hour cycle, even in the presence of cellular communication.

Since such behavior is more operating system-related than the application itself, we also stressed the application with communication failures, namely with Bluetooth disconnection simulating loss of power on the sink device.

IV. CONCLUSIONS AND FURTHER WORK

We presented some of the latter research results obtained while working with body sensor networks. Such work is very promising with proven results both on the development of a new biosensor until now inexistent and the development of associated software tools. We clearly believe in our first results, however more results must be captured to validate the prototype. The medical team is also very enthusiastic and looking forward to try this new sensor to study more than the ovulation period.

The mobile tool makes body sensor network solutions more reachable for non-technical persons, with appellative presentation of results, in two different forms.

As for future work we are developing another prototype of the intra-vaginal biosensor, namely with miniaturization in mind, and using wireless communication. In terms of presentation tools, we are refining the existing solution for data presentation based on mobile devices.

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