eHealth platform prototype for real-time biosensor data transfer

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***Abstract*— The current state of the biosensors market offers a big spectra of technologies and prices. The professional biosensors used in professional facilities are still expensive. Our idea is to create a more accessible platform using less expensive biosensors. The main point is to offer the same functionalities of the professional platforms for better price – performance ratio. The proposed platform considers easily accessible biosensors which are used to monitor and process bio signals in real time and store the results in the cloud for further examination and processing.**

***Keywords*—biosensors; ehealth; platform; cloud**

I. Introduction

In today's market we are faced with variety of biosensors. Their features vary in bio-impedance, communication protocol, power supply, price etc. The choice of appropriate biosensor is based on the context of the intended system and.

Our goal in platform usage is to monitor vital data signs and determine severity of patient state using triage protocol decision tree. One variation of the protocol is shown in Fig. 1. Based on the given decision tree the following parameters are important to determine the seriousness of the state: pulse rate, respiratory rate, SpO2 and blood pressure. Some of the recent researches also include the temperature parameter in the triage decision [1]. The idea is to determine severity of injuries in scenarios where medical aid is not always available or needs help by civilians or first aid medics. The scenarios include, but not limited to, mass disasters where communication can be limited. For that reason the communication protocols can vary.

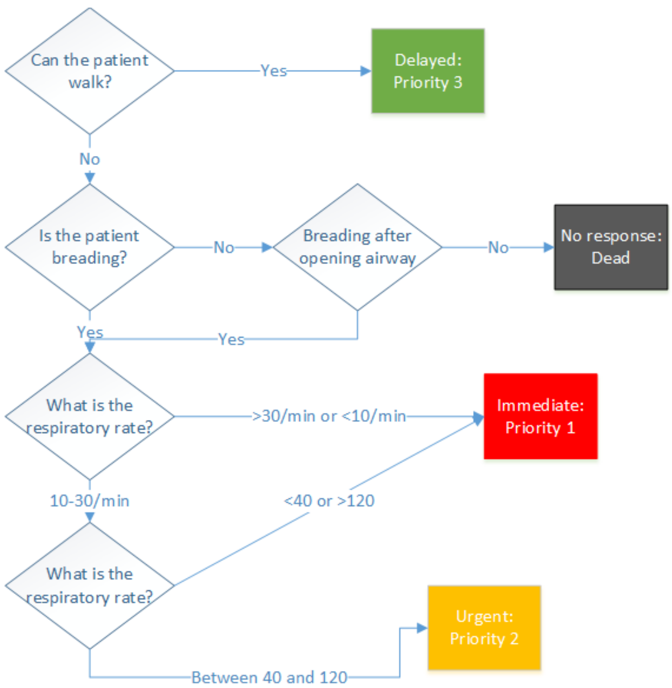

Fig. 1. Variation of triage decision tree

One of our goal was to determine the size of data needed to be transferred and to define the physical and logical constraints of the system. We have created controlled environment for initial testing.

The paper is organized as follows: in the next section we describe and compare available biosensors on the market, as well as published eHealth platforms. In Section III we described the used hardware components. Section IV gives overview of the platform. In section V we give the initial results and discuss them. Conclusive remarks are provided in Section VI.

II. Related Work

A. Biosensors

We have made a survey on biosensors available at the market. The results of the survey are shown in Table I.

TABLE I. OVERVIEW OF BIOSENSORS

Sensor	Communication	Bio-impedance	Power & Battery
Jawbone UP [2]	Bluetooth 4.0 BLE	Heart Rate, Respiration, Galvanic Skin Response (GSR), Skin Temperature	Battery life: Up to 7 days Charge time: ~60
Vitality [3]	N/A	ECG, Heart Rate and Heart Rate Variability, Blood Oxygen, Respiration, Core Body Temperature, Blood Pressure	N/A
Sensium Vitals [4]	Custom comm. hardware	Heart Rate, Respiration, Temperature	Battery life: Up to 5 days
HealthPatch MD [5]	Bluetooth 4.0 BLE	Single-Lead ECG, Heart Rate, Heart Rate Variability, Respiratory Rate, Skin Temperature, Body Posture, Fall Detection	Battery life: Greater than 2 days
QardioCore [6]	Bluetooth 4.0 BLE	ECG, Heart Rate, Heart Rate Variability, Respiratory Rate, Body Temperature, Galvanic Skin Response (GSR)	Battery life: Up to 2 days
PCARD [7]	Bluetooth 4.0	ECG, Skin Temperature	Battery life: Up to 3 days

B. eHealth Platforms

Numerous eHealth platform has been described in the literature. The initial platforms were more focused on quick interaction and alerting medical personnel [8] and introduction of distributed platforms in this area [9]. As the biosensors became more available on the market the researches started to target inclusion of eHealth platforms in personal homes [10, 11, 12].

With the availability of cloud platforms and their increased availability and popularity, the eHealth platforms started to use the benefits of the cloud. The researches include evaluation and in demonstration the usefulness of a cloud-based integrated health care system [13], development of intelligent management system based on cloud computing [14], increase of Quality of Service (QoS) using scalability in cloud [15] and development and integration of time critical eHealth services with DACAR platform [16].

III. Hardware Description

In this sections we will describe the hardware elements we use.

A. Cooking Hacks - e-Health Sensor Platform v2.0

The e-Health Sensor Shield V2.0 [17] created by Cooking Hacks allows Arduino and Raspberry Pi to interact with the shield and be used for biometric and medical applications where body monitoring is needed by using different sensors. It allows monitoring in real time the state of a patient and/or getting sensitive data in order to be subsequently analyzed for medical diagnosis. Biometric information gathered can be wirelessly sent using any of the 6 connectivity options available: Wi-Fi, 3G, GPRS, Bluetooth, 802.15.4 and ZigBee depending on the application.

1) Pulse and Oxygen in Blood Sensor (SPO2)

This sensor is used for noninvasive method of indicating the arterial oxygen saturation of functional hemoglobin. Oxygen saturation is defined as the measurement of the amount of oxygen dissolved in blood, based on the detection of oxygenated Hemoglobin (HbO2) and Deoxyhemoglobin (Hb). Two different light wavelengths are used to measure the actual difference: Deoxygenated hemoglobin (Hb) has a higher absorption at 660 nm and oxygenated hemoglobin (HbO2) has a higher absorption at 940 nm. Then a photo-detector perceives the non-absorbed light from the LEDs to calculate the arterial oxygen saturation. Fig. 2 depicts the usage of the sensor.

2) Electrocardiogram Sensor (ECG or EKG)

The Electrocardiogram Sensor (ECG or EKG) in this set is a single-lead ECG which uses 3 ECG electrodes. These basic leads acquire enough information for rhythm-monitoring, but are insufficient for determination of ST elevation (since there is no lead that gives information about the anterior wall). Fig. 3 depicts the usage of the ECG sensor.

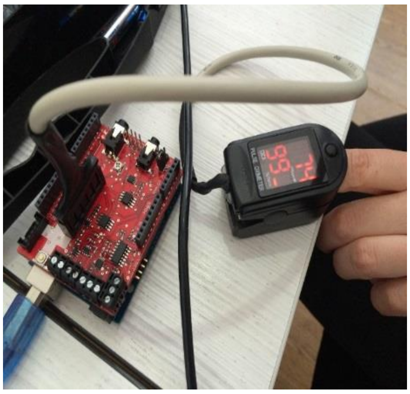

Fig. 2. Pulse/SpO2 sensor

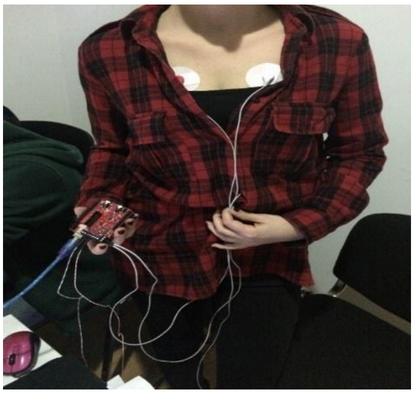

Fig. 3. ECG sensor

3) Airflow (breathing) or nasal / mouth airflow sensor

The Airflow (breathing) or nasal / mouth airflow sensor represents a single channel thermocouple sensor with a set of two prongs which are placed in the nostrils. The stay-put prongs (adjusted using flexible thread which fits behind the ears) position the sensor in the airflow path. Fig. 4 shows the usage of the airflow sensor.

Fig. 4. Airflow sensor

4) Body Temperature sensor

Body Temperature sensor is actually used by measuring a voltage and relating that to what the operating temperature of the sensor must be. The precision of the sensor can be improved by a calibration process. Calibration is a process of measuring voltage and resistance real values. In case of this sensor, the configuration file (library) contains default values for voltage (RefTension) and resistance (Rc, Ra, Rb). By measuring this values with multimeter and modify the library, greater accuracy can be obtained.

5) Patient position sensor (accelerometer)

The Patient position sensor (accelerometer) is used for monitoring of different patient positions (standing/sitting, supine, prone, left and right). This accelerometer is packed with embedded functions with flexible user programmable options, configurable to two interrupt pins. The accelerometer has user selectable full scales of ±2g/±4g/±8g with high pass filtered data as well as non-filtered data available real-time.

6) The Galvanic Skin Response Sensor (GSR - Sweating)

Skin conductance is a method of measuring the electrical conductance of the skin (which varies with its moisture level). Skin conductance is used as an indication of psychological or physiological arousal. The Galvanic Skin Response Sensor (GSR - Sweating) measures the electrical conductance between 2 points. It represents a type of ohmmeter. This sensor's precision can be also improved by calibration using a multimeter (since it is based on measuring a voltage).

7) Glucometer Sensor

Glucometer Sensor is used for determination of the approximate concentration of glucose in the blood by using blood sample. It uses disposable test strips that the meter reads and uses to calculate the blood glucose level in mg/dl or mmol/l.

8) Muscle/electromyography sensor (EMG)

Muscle/electromyography sensor (EMG) measures the electrical activity of skeletal muscles. It detects electrical potential generated by muscle cells when these cells are electrically or neurologically activated. This sensor uses three leads (MID, END and GND). It is designed by Advancer Technologies.

B. Arduino Uno

Arduino Uno microcontroller board is based on the ATmega328 (datasheet). The Uno board is the first in a series of USB Arduino boards, and it is used as reference model for the Arduino platform. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. This microcontroller specifications are given in Table II.

The Uno can be programmed with the Arduino Software (IDE). The ATmega328 comes preprogrammed with a bootloader. It communicates using the original STK500 protocol. The bootloader can be bypassed and the microcontroller can be programed through ICSP (In-Circuit Serial Programming) header using Arduino ISP or similar.

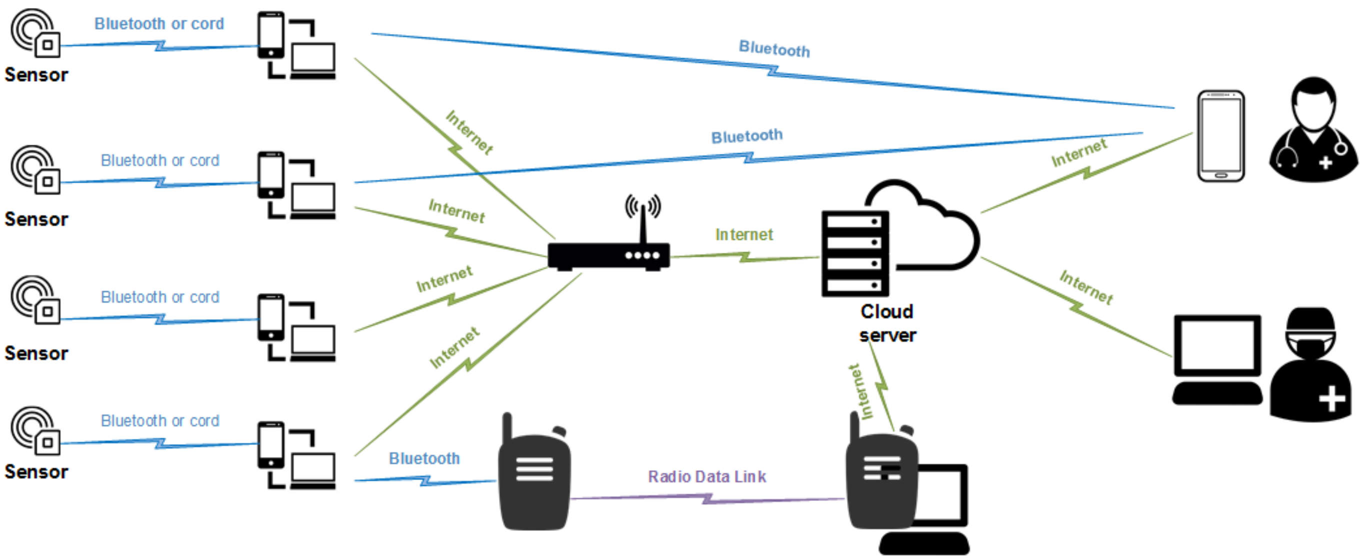

Fig. 5. eHealth platform concept

TABLE II. ARDUINO UNO SPECIFICATIONS

Characteristic	Value
Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

IV. PLATFORM DESCRIPTION

The general concept of the platform consists of several elements: biosensors, local devices for communication with the sensors, connectivity of these devices to the cloud server and real-time monitoring of the available data by medical personnel. In general case, where Internet is available, the data is transmitted to the cloud and then distributed to the available doctors. In cases where Internet is not available the bio-data are transferred directly to the available medical personnel on site using Bluetooth technology. In cases of available HF radios with data link, these radios can also be used for data transfer. Fig. 5 depicts the general concept of the platform.

The solution can be adapted three different general scenarios, shown in Table III. The usage of devices and communication protocols is depicted in Fig. 6.

TABLE III. COMMUNIATION USAGE IN DIFFERENT SCENARIOS

Scenarios	Communication
Scenario 1: Internet available	**From biosensors to local devices**: Bluetooth or serial connection **From local devices to cloud**: Internet **From cloud to medics**: Internet
Scenario 2: No Internet available	**From biosensors to local devices**: Bluetooth or serial connection **From local devices to medics**: Bluetooth
Scenario 3: HF radios with data link available	**From biosensors to local devices**: Bluetooth or serial connection **From local devices to cloud**: HF radio data link **From cloud to medics**: Internet or HD radio link

Every type of communication impose some limits in transfer. While the Bluetooth connection has certain limitations, the HF data link has lowest data rate. The standard HF radios work with low bandwidth, use simplex mode and can be used as broadcast medium. Applications that use HF radios for communication should be able to perform data compression, group data (for minimizing the turnaround time) and avoid repeat transmissions, except when data is lost. The bandwidth of the radios vary between 256Kb/s (older models) up to 1 Mb/s. Due to the limitations in the link, the amount of data transfer is limited in scenario 3.

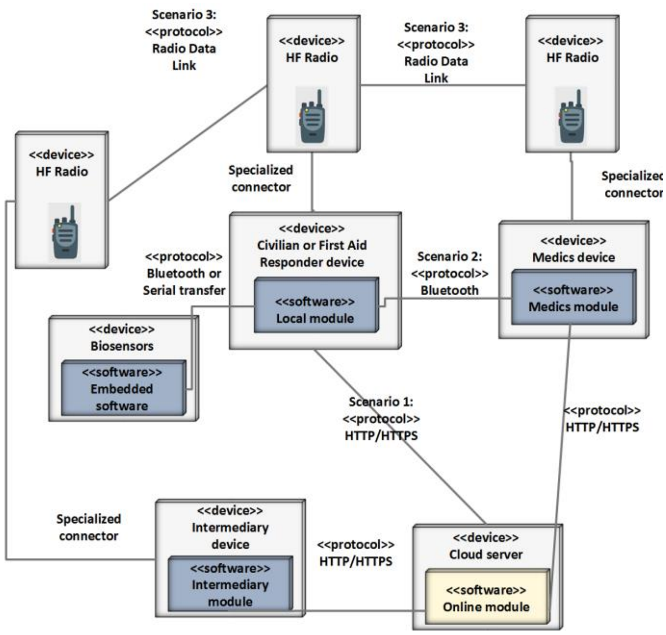

Fig. 6. Communication between elements in all scenarios

V. Results & Discussion

We set out initial platform using the Tonido cloud system [18], which represent a platform for private cloud. It offers access to files from a web browser, smartphone, tablet or DLNA enabled devices.

Our goal was to test the size of data that will be generated. We started by generating data using the SPO2 sensor with delay of 500ms (2Hz) between reads and the average result we obtained was data growth 2KB/minute. We also tested the same sensor with delay of 1ms (1000Hz) between reads and the data growth was on average 130KB/minute. We have also tested the size of data for generated by airflow sensor with delay of 1ms (1000Hz) between reads and we obtained average data growth of 40KB/minute.

We established that wearing the standard airflow sensor in many situations won't be practical, but this data can be extracted from raw data of ECG sensor. Fig. 7 shows the difference between raw and filtered ECG signal. We have also tested the size of data generated by ECG sensor and we obtained the following results:

- Readings with delay of 8ms (125Hz) between reads give average data growth of 30KB/minute
- Readings with delay of 5ms (200Hz) between reads give average data growth of 50KB/minute
- Readings with delay of 2ms (500Hz) between reads give average data growth of 110KB/minute
- Readings with delay of 1ms (1000Hz) between reads give average data growth of 180KB/minute

According to the results the total size of data using for vital signals (per person) has data growth of 40 KB/minute when using a sampling rate of 125 HZ and 310 KB/minute when using a sampling rate of 1000 HZ. According to the trauma surgeons a sample rate of 125 is adequate to use for triage decisions. Given the lowest connection available in the scenarios (usage of HF radios with only 256Kb/s data link) data from biosensors can be simultaneously transferred for more than 40 persons.

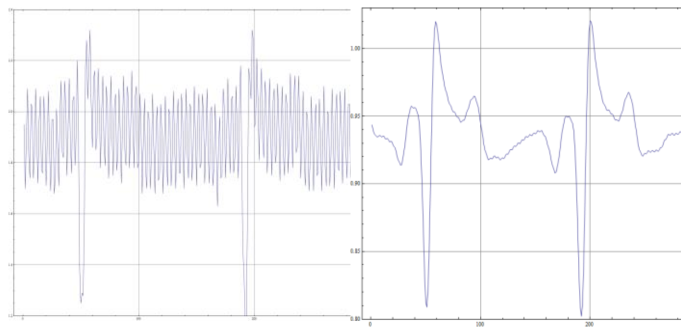

Fig. 7. ECG (raw signal – left, filtered signal – right) measurement

VI. Conclusion

The platform can be used for monitoring bio signals in home surrounding, as well as in situations where professional equipment is not available or there are no enough units available.

Given different scenarios the platform can support real-time data transfer for more than 40 persons in worst case scenario and much more in other scenarios. This means that the platform can be used for real-time monitoring and can significantly aid the process of prioritization in case of multiple injuries. One possible application is during the Medical Response to Major Incidents (MRMI).

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