A Platform with Combined Environmental and Physiological Wireless Data Acquisition for AAL Applications

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Abstract Ambient Assisted Living is based on a set of technologies with the aim to provide an enhanced support to people's daily life. One important field deals with the offer of new solutions for healthcare. Those solutions intend to improve the population quality of life and reduce costs associated with healthcare. Before that happens, new platforms, hardware and software, must be available in order to acquire and store the required signals, to process and extract information from those signals, and to detect a set of features required to fire alarms and/or electronic assistance. This paper presents a platform (hardware and software) that was designed to acquire data from a subject, or from a device, and send it to a remote hub. It was designed taking into account its size, power autonomy, and quality of service, and is able to perform the required monitoring tasks, at least, for one day.

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1 Introduction

Ambient Assisted Living (AAL) is an emergent technology that envisions offering new solutions for healthcare. Those solutions will improve the population quality of life and will reduce costs associated with healthcare [1]. However, before that happens, new platforms, hardware and software, must be available in order to acquire and store the required signals, to process and extract information from those signals, and to detect a set of features required to fire alarms and/or electronic assistance.

Once the relevant data is available an AAL system, will allow to remotely monitor one subject and to monitor his health and activity. Based on that, and on a set of information associated to that subject, it is possible to offer different levels of services. One will be self-remainders that are pre-set by the subject; the other will be reminders by some familiar or caregiver; and finally, an health service based on clinical data may also be offered, if good enough health engines are available to extract the "health condition".

Despite the availability of several platforms for signal acquisition [2], a few technological issues must be solved before they can be used. The platforms must offer quality of service, must be wearable, and must operate for a comfortable period of time. The quality of service is required; otherwise no company will be able to offer a highly critical service. If we hire a service for health monitoring and it fails, everybody involved must be aware of how safe is that system. Also, nobody will be willing to wear some device that reveals that it is being monitored, and it is also difficult to wear a device that needs to be recharged too often. At least, is must be able to operate for one day. In this way, the system may be replaced when the person goes to the bed, or when it gets up.

This paper presents a platform (hardware and software) that was designed to acquire data from a subject, or from an environment monitoring device, and send it to a remote hub. It was designed to provide quality of service, to be small enough so it can be worn, and that it can operate, at least, for one day.

2 Software

The software developed, fig. 1 shows a snapshot, is responsible to collect all the data from the sensors, both biometric data (monitor health and activity) and data from home automation. This last set of sensors is used to determine activity with the use of some simple activity related models. This simple activity models related to the presence in a room on a weekly base, water flow in pipes on weekly and diary base, daily and weekly schedules of opening and closing of some room doors.

Fig. 1. Software snapshot.

The visual aspect of the software front end is divided in three main blocks. One block acts as a pill dispenser with the possibility to send text messages through SMS (short message service) and/or MMS (multimedia message service) with previous recoded familiar voices to advice for prescriptions. A day (timeline) progress bar with emergency status (colors from green to red) linked to the continuous health monitoring system. A sensor panel showing the data of the several sensors: ECG, temperature, humidity, water flux, weight, door opening/closing, and arterial pressure with voice messages when getting high or very low arterial pressure readings.

Platform for Data Acquisition

The software described in the previous section operates based on the acquired data from different sensors. Fig. 2 shows the main blocks of the acquisition hardware. It is presented as used on a person, but it is equally valid for data acquisition form home automation.

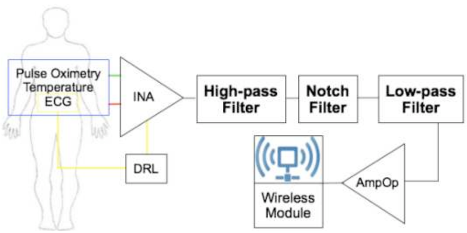

Fig. 2. Data acquisition system.

Since a few of those sensors must be mobile and must be placed on persons, they must be designed to have special features. They must be wireless, offer quality of service, low power, wearable, and operate at least one day on batteries. This led to the use of a modified version of a Zigbee based platform.

2.1 Wireless Communications

The BSN is composed of wireless modules build around the ZigBit [3], an IEEE 802.15.4/ZigBee-compliant module operating in the 2.4 GHz frequency band. The IEEE 802.15.4 standard specifies the physical layer and the MAC sublayer [4]. Normally this protocol operates with the unslotted CSMA-CA, a contention-based MAC protocol that is vulnerable to collisions. Computer simulation results have shown that unslotted IEEE 802.15.4 is not adequate for several sensors to transmit ECG signals directly to a BS with full efficiency [5]. It has been proofed analytically that an unslotted 802.15.4 single-hop WSN containing 10 motes sampling the ECG signals at 250 Hz with a resolution of 16 bits present a packet delivery ratio less than 90%, independently of the packet size [6]. Consequently, IEEE 802.15.4 is unable to meet the strict application requirements demanded by healthcare systems.

In order to find an alternative to IEEE 802.15.4, a new MAC protocol, named iLPRT [7], has been developed. iLPRT is a simple MAC protocol based on time division multiple access (TDMA) technique, which can provide bounds on per-hop latency, transmission determinism and medium access fairness. It uses short size beacons, autonomous transmissions, and multiple retransmissions techniques to improve the packet delivery and energy efficiency, and subsequently the QoS of the WSN. In iLPRT, the available bandwidth is used dynamically, and packets are sent in contiguous short time-slots. The highly-grained superframe starts with the transmission of a beacon packet by the BS, followed successively by the Contention Access Period (CAP), the Retransmission Period (RP), and the Normal Transmission Period (NTP). The CAP may be used for sending MAC commands and responses. The NTP is used for motes to transmit new data. Lost data are retransmitted in the RP. Data packets transmitted to the BS during the NTP are acknowledged by the ACK bitmap present in the beacon of the next superframe. The BS uses also the beacon packet to inform the WSN about some reconfiguration need, e.g., to require a different sampling rate of a patient´s physiological signal. The implementation of this important feature using a CSMA-based MAC protocol becomes the WSN very inefficient energetically as the motes cannot enter in sleeping mode, otherwise the data from the BS may not be listened.

As iLPRT presents interesting characteristics for providing QoS to e-health systems, we have implemented it into the ZigBit motes, replacing the native unslotted IEEE 802.15.4, and was used in this platform. In order to guarantee a maximum ECG delivery delay of 500 ms, cf. IEEE 1073, a beacon is transmitted every 250 ms. This value was chosen to assure that retransmitted packets are delivered timely to the BS. All samples collected during this time are transmitted together in a packet to the BS. Since the ECG signal is acquired at 250 samples/s, each data packet contains in average 50 samples, i.e. 500 bits of sampling data.

A header of 3-bytes size is added to the samples payload, as shown in Fig. 11. The first byte is the identification field, which contains two subfields: the sensor signal identification (3 bits) and the BSN identification (5 bits). Therefore, up to 8 distinct signals captured in a maximum of 32 patients are identified unequivocally. The next two bytes contain two reserved bits and the sequence number field. Two bits are reserved for internal operation of the application. The sequence number field (14 bits) contains the sequence number of the latest sample contained in the payload, i.e., the last sample in the packet payload to be transmitted to the BS. This sample-oriented approach was chosen to identify all undelivered samples. As the packet payload may be variable, a packet-oriented sequence number is not convenient for this aim. Null padding bits are included for the payload size to become a multiple of byte length. In every field, the most significant bit is the first bit to be transmitted into the wireless channel.

BITS: 0–2	3–7	8–9	10–23	24–33	34–43			
SENSOR ID	BSN ID	RESER- VED	SEQ. NR. OF SAMPLE N	SAMPLE 1	SAMPLE 2	...	SAMPLE N	PADDING

Fig. 3. Packet payload description.

2.2 Data Acquisition

For data acquisition, a small and power efficient module was designed. Moreover, since the set of signals that may be relevant for this system are highly heterogeneous, the module was designed in a way that can be configured for the different applications. The most demanding signal we have in this scenario is the electrocardiogram. It is the measurement of the electrical activity of the heart muscle and may range from about 0.5 mV to a maximum of 10 mV. It has a spectral range of 0.05-150 Hz for diagnostic ECG and 0.5-40 Hz for monitoring ECG [8, 9].

The requirements of the front end of an ECG sensor circuit include the capability to sense low amplitude signals in the range of 0.05–10 mV, an High Common Mode Rejection Ratio (CMRR), high input impedance, low input leakage current, flat response of 0.5–40 Hz, low weight, low power (<1 mA) and signal amplification to a range specified by the ADC.

The first stage of amplification is one of the most important components of the system. This amplifier presents excellent characteristics on the acquisition of biopotencials, such as high input impedance, high differential gain e high common mode rejection range [10]. The integrated circuit (IC) used was the INA333 from *Texas Instruments*. The ECG is often contaminated with undesired spectral components. In order to attenuate them, the circuit must include a high-pass filter, notch filter and a low-pass filter. All the implemented filters are active filters, so Operational Amplifiers were used. The IC's chosen to build the filters were the OPA2369 from *Texas Instruments*. The OPA2369 were chosen mainly because of their low power quiescent current (0,7 μA/channel), low offset voltage (250 μV) and its specification to portable medical instruments. The high-pass filter must attenuate the frequencies from zero to the cut-off frequency, thus it blocks the undesired DC components. The proposed filter is a second order Sallen-key high-pass filter with a Butterworth response. The filter's main characteristics are its quality factor (Q) of 0.707, its gain A_u = 1, its pole frequency f_p = 0.45Hz, its cut-off frequency f_c = 0,45Hz and a slope of -40 dB/decade [11]. The ECG is frequently contaminated with 50/60 Hz power-line interference, or electrostatic charge. The strategie to attenuate this kind of interference involved a notch filter or band stop filter with a centre frequency of 50 Hz. The implemented notch filter is a second order Sallen-Key, with a gain of 1.5, a Q of 1, a fc of 50Hz and a slope of -40 dB/decade. The low-filter is used to attenuate frequencies beyond the desired to the ECG measurement. These frequencies can come from sources such as radio frequency and communication equipment. A second order low-pass Sallen-key filter with Butterworth response was implemented. The filter has unitary gain, a Q of 0.707 and a cut-off frequency of 40 Hz. The filtered signals have to be amplified so that the ADC from the Zigbit module can measure it. The gain of this amplification stage is about 60, so the total gain of the system is 300. Finally, a DRL circuit was also implemented to measure the ECG. This circuit is used to amplify, invert and feedback the common-mode signal to the body, preventing the operation amplifiers from going into saturation [10].

The described system and its frequency response are showed in fig. 4 and fig. 5.

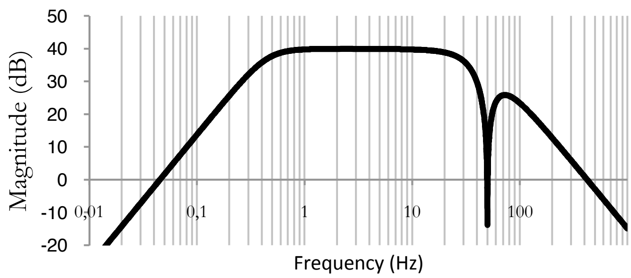

Fig. 4 Decibel plot of the normalized gain versus frequency plot.

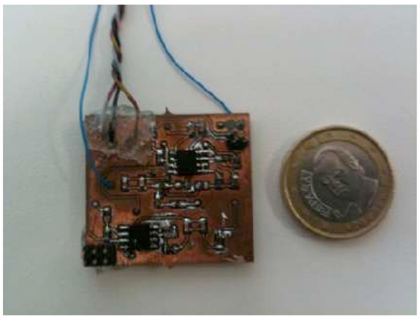

Fig. 5 Photograph of developed PCB layout.

The device shown on fig. 5 has low power consumption (90μA), and a small size (33x30 mm^2).

Conclusions

The developed platform was designed to acquire signals from a different range of sensors, and to transmit them to a base station where those signals were registered and processed to help a subject in their daily life. The module is very low power, allowing it operation for one day and the wireless data was delivered with quality of service, making it suitable for AAL applications under controlled environments.

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