A Near Field Communication-Based Platform for Mobile Ambient Assisted Living Applications

Alessandro Leone, Gabriele Rescio and Pietro Siciliano

Abstract This paper presents an open platform for continuous monitoring of clinical signs through a smart and non-invasive wearable device. In order to accomplish a communication in proximity, the Near Field Communication wireless technology is used, providing a fast link between the device and the host, avoiding the pairing (as typically occurs for Bluetooth protocol) and limiting the power consumption. The Arduino ecosystem has been used for prototyping since it allows an easy and open integration of ad-hoc functionalities. The first release of the platform has been customized for human body temperature measurement, although other kind of clinical signs could be handled with a low-level effort.

1 Introduction

In recent years the healthcare costs for aged population are rising, so that new welfare models have been defined in order to permit homecare monitoring through ICT infrastructures. The health status monitoring of aged people becomes a priority in order to improve the wellbeing and the autonomy level. The interest of research and market is not limited to dangerous events detection (as falls)

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but also on the physical condition evaluation [1]. Wearable devices might contribute to improve the quality of life of elderly, promoting healthy behavior and health awareness. Wearable systems for health monitoring may include several kinds of miniaturized/implantable sensors. Normally, they are able to measure relevant clinical parameters as heart-rate, blood pressure, body temperature, etc., providing an useful tool in self-care activities supporting healthcare specialists with elaborated and customized information. In order to guarantee a wide diffusion of wearable devices for clinical monitoring, an easy-to-use, comfortable, robust and maintenance-free technology is required [2]. Moreover, an important constraint about the usage of them is the lifetime of battery that should allow a long-term monitoring to reduce the intervention of the end-users or caregivers. Several wearable commercial devices for healthcare applications are often limited in terms of usability and feasibility due to the high power consumption (and then limited battery lifetime), especially when wireless modules are activated for data transmission. A more recent technology for radio transmission is the Near Field Communication (NFC) that assures a very short-range link (up to 10 cm) through inductive coupling. According to the TouchMe paradigm [3], NFC is easy-to-use and low-power, presenting a short latency compared to the Bluetooth protocol. Several consumer mobile devices integrate NFC, so they can be used as gateway in homecare medical services, by transmitting clinical parameters/measurements from the point-of-care to remote servers [1, 3–6]. A NFC-based architecture for Ambient Assisted Living (AAL) scenarios is described in the following. The first prototype realized integrates a biomedical chip thermistor for body temperature measurements. It allows a continuous monitoring of the thermal balance, even in presence of critical diseases, during medical treatment or everyday life. Moreover, an open source Arduino ecosystem is used [7], allowing the integration of different kind of sensors for clinical signs monitoring with low-level effort during tuning and adjusting activities.

2 Near Field Communication Technology in Healthcare

The market NFC devices is growing more and more in both active and passive form. It has been estimated that the amount of smartphones adopting NFC will increase to more than 800 million by 2015 [8]. NFC technology is a short-range half-duplex wireless communication protocol, which enables an easy, fast and secure communication between two devices in proximity. The communication occurs with 13.56 MHz operating frequency [9] providing a high-level safety than other well-known wireless technologies as Bluetooth. Since NFC reaches a maximum transfer speeds of 424 kbps, the power consumption is lower than the other aforementioned wireless protocol. However, the time to establish a connection through NFC is lower than 0.1 s., whereas Bluetooth normally takes up to 6 s. For pairing (see Table 1 for technical details about NFC and Bluetooth).

Table 1 Comparison between NFC and Bluetooth technologies

Features	NFC	Bluetooth
Network standard	ISO 13157 etc.	IEEE802.15.1
Network type	Point to point	WPAN
Range (m)	<0.2 m	10–100 m
Frequency	13.56 MHz	2.4–2.5 GHz
Set-up time	<0.1 s	6 s
Bit rate	<424 kbit/s	<2.1 Mbit/s
Power consumption	<1 mA	>15 mA

In healthcare domain, the need for a secure communication is very important. NFC enables a connection only if two devices are close, so that the data exchange is less prone to hacking by a third. Moreover several encryption techniques and security system has been developed and other new security schemes are important topics of research [10]. Furthermore, the data size generated by medical devices is usually within the capability of NFC to transmit without any undue delay. The wearable/implanted devices or long-term monitoring medical devices should have highly energy efficient and save as much power as possible. NFC protocol is well suited for such applications, as the reader can activate the RFID tag only when necessary and can also transfer power wirelessly. NFC is also more intuitive and easily understandable than other wireless technologies for elderly patients. Since NFC, in its passive form, acts just like any other RFID tag, it can be used to keep tabs on pill boxes, blisters and other drug dispensing solutions.

3 Hardware Architecture for Clinical Signs Measurement

Arduino is an open-source electronics prototyping platform, based on easy-to-use hardware and software. Arduino has developed many boards Atmel AVR-based processor since their compact size, useful peripherals and low-power sleep modes. The main features of the Arduino boards are reported in Table 2.

Table 2 Key features of Arduino boards

Supported microcontrollers	CPU speed (MHz)	Analog input	Digital I/O	EEPROM (KB)	Serial output
ATMega328 ATMega1280 ATMega2560 ATMega32U4 SAM3X	8 16	Up to 12	Up to 54	Up to 4	SPI I2C UART

A USB slave connector is used both to program the board and to provide power (otherwise a separate regulator can be used). Arduino software is implemented by using a simple Integrated Development Environment (IDE): the system accepts simplified and compiled C/C++ codes in a standard GNU tool-chain, and a simple boot-loader to automatically upload code to the processor. In this work, the first release of the platform has been customized for body temperature measurement. The Arduino NANO board (43 mm × 18 mm) [11] has been considered for the integration of a commercial thermometer since the expected workload is compatible with the integrated microcontroller (8-bit Atmel Atmega328p). The main features of the board are reported in Table 3.

For the final prototyping, the Arduino board has been replaced with a full custom designed board, by integrating the same microcontroller and the circuit blocks shown in Fig. 1. The dimensions of the overall system are lower (and then compatible with the mobile application), an accurate power management of each electronic module has been made and a full compatibility with Arduino open-source software platform has been guaranteed.

The proposed platform integrates (a) the MA300GG103A NTC thermistor [12] for human body temperature measurement, (b) an interface circuit for the

Table 3 Main features of Arduino NANO board

	Microcontroller	Atmega328p
	Voltage input (V)	7–12
	Digital I/O	14
	Analog input	8
	Output current	40 mA
	FLASH	32 kB
	SRAM	2 kB
	EEPROM	1 kB
	Operation frequency	16 MHz
	Serial output	SPI, I2C, UART

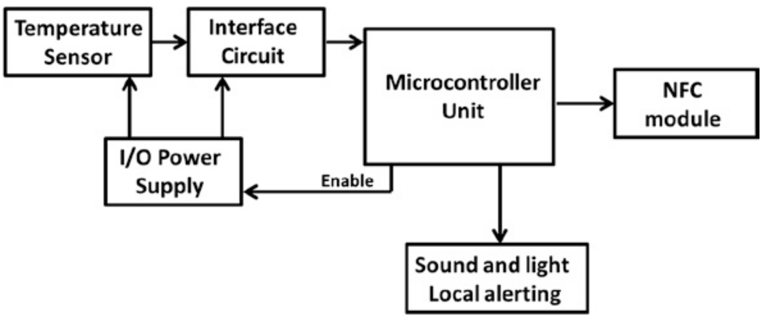

Fig. 1 Block diagram of the platform for temperature measurement

temperature sensor, (c) the SonyFelica NFC Dynamic Tag [13] module for NFC wireless communication (up to 10 cm range, up to 212 kbps speed communication) and (d) a speaker and a low power led for the local alerting. The microcontroller receives and processes data coming from the temperature sensor. The platform also provides one I2C input and five analog inputs to add other micro-sensors and textile sensors for the measurement of biometric parameters. The temperature sensing part has a low-power consumption with a resolution of 0.1 °C in the range of 35–43 °C.

The Atmega328p microcontroller is connected to NFC module through the SPI link. The NFC Dynamic Tag can emulate an NFC Forum Type 3 Tag if the data from the host microcontroller (in response to any commands sent by the reader/writer) follows the specifications of the NFC Forum [14]. Moreover, the NFC Dynamic Tag includes a function able to detect the magnetic field generated by the reader/writer allowing appropriate information to the host Microcontroller Unit (MCU). In this way the biometric parameters can be read by the user in "on demand" mode, approaching the smartphone to the device. The temperature sensor conditioning circuit has been designed according to a well-known Wheatstone bridge-based interface circuit (Fig. 2).

The platform can be set to work up to 16 MIPS and frequency up to 16 MHz. A good trade-off between MIPS and power consumption for the acquisition, real-time computing and data transmission has been found for 4 MHz operating frequency. In this configuration, the maximum total current consumption of the system is lower than 20 mA and MIPS is 4. The system is supplied by two micro-power Low-DropOut (LDO) CMOS voltage regulator with a low temperature dependence. When it is set to shutdown mode (via a logic disable signal), the power consumption of LDO and related circuits are reduced to almost zero watt (only few nA of current consumption). As shown in Table 4, the power consumption is dominated by the local alerting circuit, but it is activated (in intermittent mode) only when a critical situation is detected (a simple threshold approach). Through an intelligent and proper management of every electronic components, a long battery life is provided.

The final discrete prototype circuit is shown in Fig. 3.

The developed platform is suitable to be integrated in a wearable device. In Fig. 4b it is shown a first prototype of a customized package (as a watchstrap),

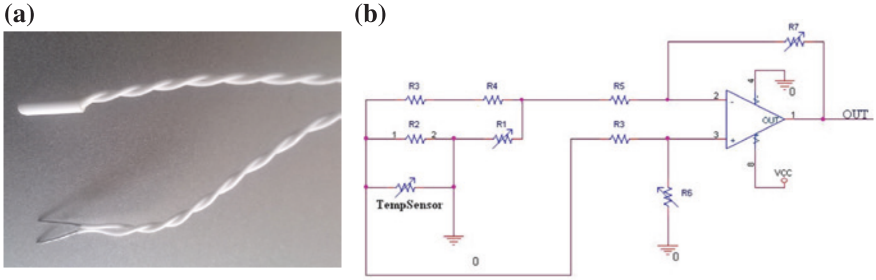

Fig. 2 NTC temperature sensor (**a**) and read-out interface circuit (**b**) for temperature acquisition by NTC thermistor

Table 4 Current consumption of each logical part of the platform

Block unit	Current consumption	
	Active mode (mA)	Sleep down (mA)
Temperature sensor	0.15	<0.001
Interface circuit	0.60	<0.010
Microcontroller unit	2.80	<0.010
Sound and light local alerting	12.00	<0.001
NFC transmission	0.80	<0.001
Power supply	0.05	<0.001
Total	16.40	<0.030

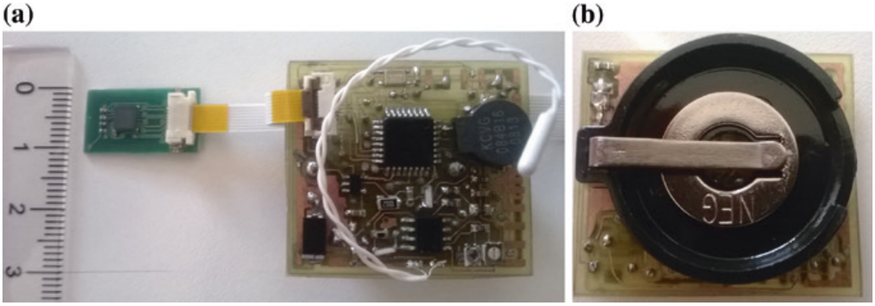

Fig. 3 *Bottom* (**a**) and *top* (**b**) layers of the final platform

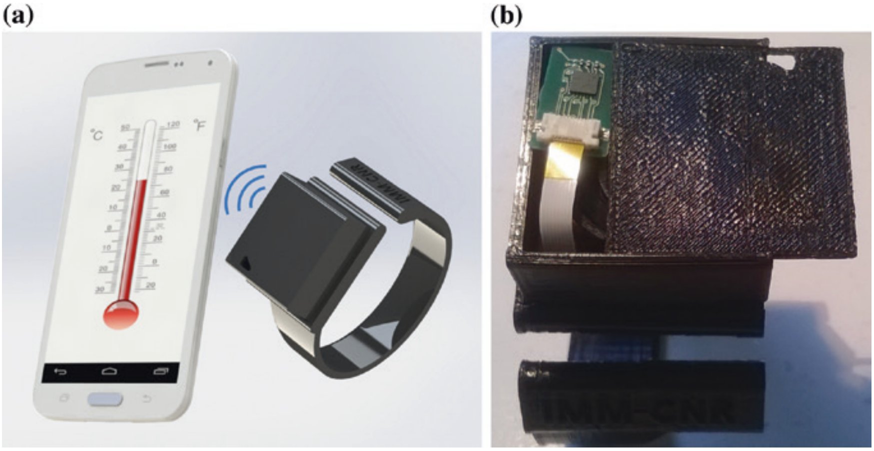

Fig. 4 Application example (**a**) and picture of the first package (**b**) integrating the platform

made in Polylactic Acid (PLA) by a BQ Witbox 3D printer [15]. The layout of prototype presented can be optimized and the dimension reduced. An example of application that can be developed for NFC-equipped smartphone is reported in Fig. 4a. Approaching the smartphone to the wearable device, the values of body temperature can be read instantly and automatically by the users. Furthermore the temperature data can be sent to a caregiver for home healthcare services (HCS), by using the smartphone as gateway.

4 Open-Based Firmware for Temperature Monitoring

The firmware for Atmega328p has been developed by using the Arduino IDE and the related open source libraries. The first step of the code considers the initialization of the peripheral I/O ports and the NFC parameters set up. Afterwards, the device is ready to measure the human body temperature and to send the data by NFC. In order to guarantee stability of the measurement, and according to the functional principle of the commercial temperature measurement devices, the time required to calculate the temperature is about 30 s. The system is able to record on the on-board EEPROM up to 500 body temperature values, allowing to evaluate the trend of body temperature along the days. During the temperature measurement phase, the maximum current consumption is about 4 mA (temperature sensor, interface circuit, microcontroller unit and power supply are activated). Moreover, by considering the NFC hardware module, the total current consumption is less than 5 mA. In Fig. 5 the duration of battery at varying of the daily measurements cycles is shown. By analyzing Fig. 5, it is apparent that it is possible to calculate and transmit the temperature measurements 100 times a day for 2 months. The local sound and light alerting is activated (in intermittent mode) only when a critical situation is detected (a simple threshold-based approach). To manage the NFC SonyFelica tag the free libraries for Arduino has been considered.

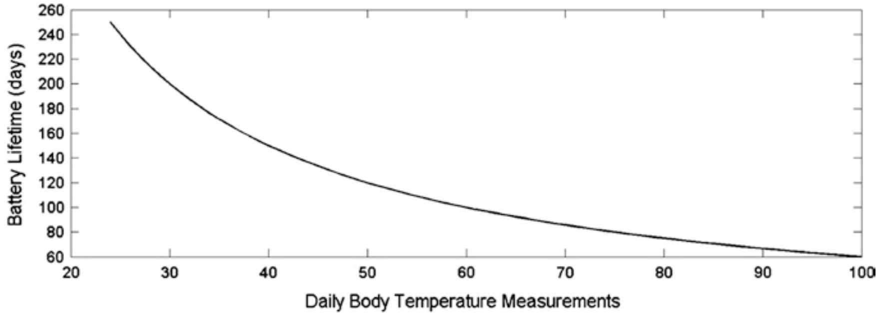

Fig. 5 Battery lifetime versus daily body temperature measurements

5 Conclusion

An open and low-power platform based on Arduino ecosystem for mobile clinical signs monitoring has been developed. To reduce the power consumption and to obtain a user-friendly system, the NFC technology has been chosen as wireless protocol in proximity. The first prototype of the platform integrates a NTC thermometer for temperature acquisition. The dimensions and weight of the 3D printed package are compatible with the considered application scenario, though the dimension of the device can be further optimized. The architecture is based on Arduino libraries permitting an easy integration of other customized functionalities. Through the free SonyFelica SDK for healthcare, cost-effective applications for smartphones or mobile devices can be realized in order to read and handle data coming from the presented platform.

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References

1. Scherr, D., Zweiker, R., Kollmann, A., Kastner, P., Schreier, G., Fruhwald, F.M.: Mobile phone-based surveillance of cardiac patients at home. J. Telemed. Telecare **12**(5), 255–261 (2006)
2. Filho, R., et al.: An evaluation method of research on wearable wireless body area network in healthcare. Int. J. Comput. Sci. Inf. Technol. **5**(1), 65–78 (2013)
3. López-de-Ipiña, D., Vazquez, J.I., Jamardo, I.: Touch computing: simplifying human to environment interaction through NFC technology. In: Proceedings of 1as Jornadas Científicas sobre RFID, pp. 30–40 (2007)
4. Kollmann, A., Kastner, P., Schreier, G.: Utilizing mobile phones as patient terminal in managing chronic diseases. In: Hakim LA. (ed.) Web Mobile-Based Application for Healthcare Management. Idea Idea Group Inc., pp. 227–257 (2007)
5. Morak, J., et al.: Near field communication technology as the key for data acquisition in clinical research. In: IEEE First International Workshop on Near Field Communication, pp. 15–19 (2009)
6. Strommer, E., Kaartinen, J., Parkka, J., Ylisaukko-oja, A., Korhonen, I.: Application of near field communication for health monitoring in daily life. In: 28th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. EMBS '06, pp. 3246, 3249 (2006)
7. http://www.arduino.cc/
8. Frost & Sullivan's Digital Identification Research and Consulting Practice.: Retrieved 15 March 2013 from http://www.frost.com/prod/servlet/svcg.pag/AEST
9. Coskun, V., Ok, K., Ozdenizci, B.: Near Field Communication (NFC): From Theory to Practice. Wiley, London (2012)
10. Hasoo, E., Hoonjung, L., Junggab, S., Sangjin, K., Heekuck, O.: Conditional privacy preserving security protocol for NFC applications. In: IEEE International Conference on Consumer Electronics (ICCE), pp. 380, 381 (2012)
11. http://www.atmel.com/products/microcontrollers/avr/
12. http://www.ge-mcs.com
13. http://www.sony.net/Products/felica/business/products/RC-S801_802.html
14. http://nfc-forum.org/
15. http://www.bqreaders.com/it/prodotti/witbox.html