Low Cost Wireless System for Monitoring Ambient Parameters in Clinical Environment

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***Abstract* — The paper proposes a flexible and low-cost architecture for monitoring ambient parameters (temperature and oxygen concentration) in a hospital environment. The system conveys wireless the data from the supervised clinical wards to the hospital emergency room by the means of transceivers operating in ISM band and some Arduino boards. Following their transmission, the data is processed and displayed by a program created in LabVIEW(*Abstract*)**

Keywords — low-cost wireless system, hospital environmental parameters monitoring, Arduino Uno, Arduino Mega, LabVIEW.

I. INTRODUCTION

Wireless monitoring in hospitals by implementing Ir, Bt or RF technologies is a topic often addressed in the engineers work and published in the scientific literature [1], [2]; but most of the studies referred to the collection and wireless transmission of vital signs (indeed, a matter of great interest and importance) and less in the transfer of parameters characterizing the clinical environment.

Often, providing and monitoring specific environmental parameters in a medical room (temperature, humidity or oxygen concentration) represents - for patients with certain diseases - a problem almost as important as the medical act itself [3] [4]; therefore, approaching this topic in medical engineering research requires a special attention [4], [5].

When the measurements aim an intensive care unit, surgery room or an incubator for newborns, monitoring temperature and oxygen concentration level become a critical issue; this is the reason why the cost, implementation, maintenance and the systems reliability are essential criteria when choosing a viable solution [3].

At the same time, the fact that wireless communication systems may interfere with medical equipment located in hospitals, must be also considered. There are studies highlighting that important parameters used in assisted mechanical ventilation (expiratory volume, inspiratory pressure, expiratory pressure, mean pressure and tidal volume) suffer significant changes when a wireless communication disturbing source is at walking distance of the sensitive medical equipment. [6]

According to this idea, the paper proposes a low cost and flexible system, designed for hospital spaces, capable to provide a suitable environment and support optimal management of energy expenditure. For the system to be applied in surgery and neonatology, it has also the possibility to monitor oxygen concentration, not only the temperature and air humidity.

II. MATERIALS AND METHODS

The realized application proposes monitoring two environmental parameters (temperature and oxygen concentration) in two different hospital rooms and the data transfer to the physicians emergency room, according to the block diagram presented in figure 1:

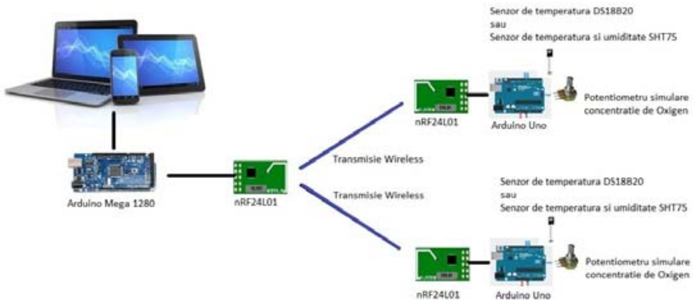

Fig. 1. Block diagram of the wireless transfer application of measured ambient parameters

According to figure 1, the required hardware in order to implement the communication and the data flow circulation between the medical wards and the physicians emergency room consisted in two *Arduino Uno* boards in the same configuration (for wireless transmission of measured parameter values), one *Arduino Mega 1280* board (for receiving the previously sent values), two *nRF24L01* small size wireless transceivers (able to transmit in the 2.4 GHz ISM band) and two temperature sensors (*DS18B20*); the oxygen concentration in each medical wards was simulated by varying a resistance, by the mean of a potentiometer located on the *Arduino Uno* boards.

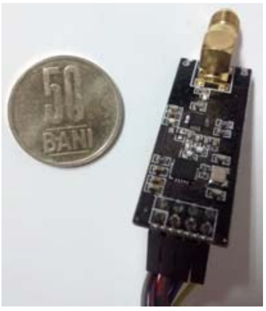

Fig. 2. The wireless transceiver *nRF24L01*, used to transfer the monitored parameters(the near placed coin highlights its extremely low size)

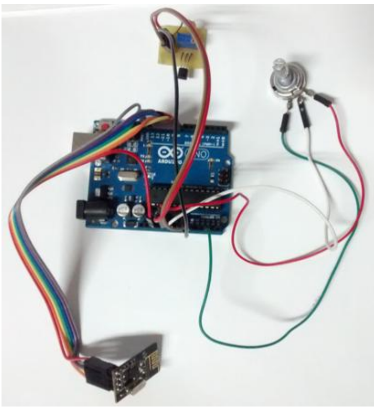

Fig. 3. The *Arduino Uno* board, together with the sensors and the wireless transceiver

Fig. 4. The *Arduino Mega* board, together with the data reception system

Functionally, the raw data coming from the two sensors (temperature and oxygen concentration) is delivered, via the *Arduino Uno* board processor, to the wireless transfer module. Once submitted, all data are received by a wireless module and then delivered to the *Arduino Mega* board.

In terms of software, in order to implement the communication with the sensors and to transmit the acquired information, the application relies on appropriate code lines of the *Arduino* development environment IDE 1.0.5. [7], [8] and on specific modules used libraries; also, for creating the graphical user interface and processing the measured signals, the *LabVIEW* program was used [9].

The *nRF24L01* RF module communicates with the development board by using the SPI protocol, and the sensors transmit the biomedical information on the analog pins of the board [10]. The proper operation of the module in each medical ward is provided by a power supply of 5 – 12 V.

A unique ID is assigned to each medical ward, in order to properly select the information received by the *Arduino Mega 1280* board (which, in turn, has a unique ID).

III. Results

The realized prototype, used to transfer the ambient parameters (temperature and oxygen concentration) from the medical wards to the physicians emergency room (ER), is presented in figure 5:

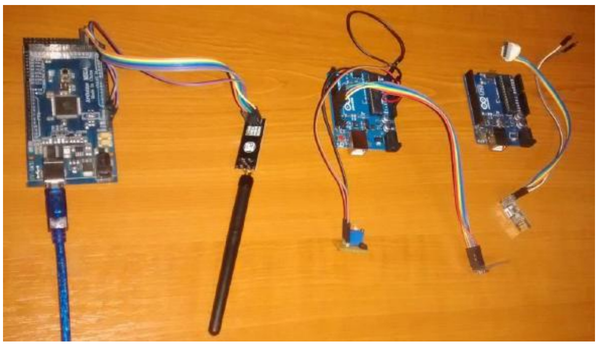

Fig. 5. The realized prototype

Prototype testing was performed in the Biomedical Engineering Laboratory (Faculty of Electrical Engineering, TUC-N), where the data were transmitted (wireless) between two adjacent rooms.

After initializing the parameters that will be transmitted, the data received from sensors are delivered to the *Arduino Mega 1280* board pins.

Unlike the boards used in the medical wards, the ER board must be connected to a PC / tablet or any other device, that can receive information transmitted on the serial port and has the ability to run *LabVIEW* Run Time Engine.

The information transmitted on the serial port are in string format, where the first character represents the ID of the medical ward, delimited by a tab (/t); then, it follows the time elapsed from application startup (from the starting moment of the measurements), and the successive two values represent the readings from the two sensors (temperature and oxygen concentration).

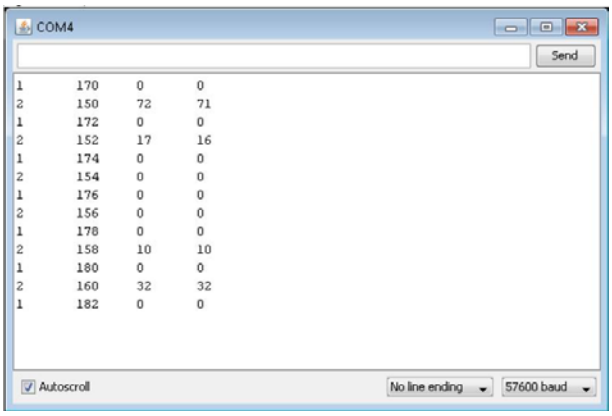

Fig. 6. Medical wards IDs, time elapsed, the measured data

The data transfer from the computer's serial port to the *LabVIEW* program is made by means of *„VISA Serial"* sub-VI, the device detected by the computer being selected by using the *„Source Name"* terminal (also, in this stage of the application, the communication between *LabVIEW* and the serial port is initialized at a transfer rate of 57600 Bits/s).

The data read from the serial port are delivered to *LabVIEW („String"* terminal of *„Match Pattern"* block), which is configured such that strings whose first element is „1" will be available at the *„After Substring"* terminal (so, the data transmitted by the medical ward „1" will be read).

If data transmission is successful, then the serial port will print the message „Sending OK"; if this operation fails, the serial port will print the message „Sending failed". If at two consecutive runs of the program, the data string from a medical ward is empty (it contains no elements) (two consecutive times, the specified medical ward transmitted no information, iterations quantified by incrementing the „failed_counter" counter), the reset function is called. Simultaneously, the frame of the medical ward on the graphical user interface (including the frame for the indicators) will turn red, signaling the absence/end of the transmission, or a potential problem (linked to the sensor or to the transmission) (see figure 7).

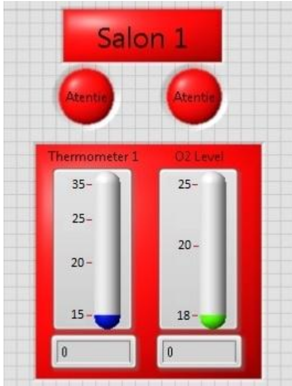

Fig. 7. Alarm coming from medical ward „1" (lack of transmission)

The value read by the temperature sensor and transferred to the computer is delivered to the input of a comparator, where the lower and upper limits are set. Any deviation from the accepted range of values (previously set) will result in sending a control signal that will trigger a visual alarm (the user from the ER is warned by lighting a LED). The monitored temperature is analog represented on a graph on the virtual instrument interface, but also on a thermometer type indicator.

For the sensor detecting the oxygen concentration, the steps for implementing the algorithm are identical to those described for monitoring the temperature.

The application's graphical interface, developed in *LabVIEW*, is presented in figure 8:

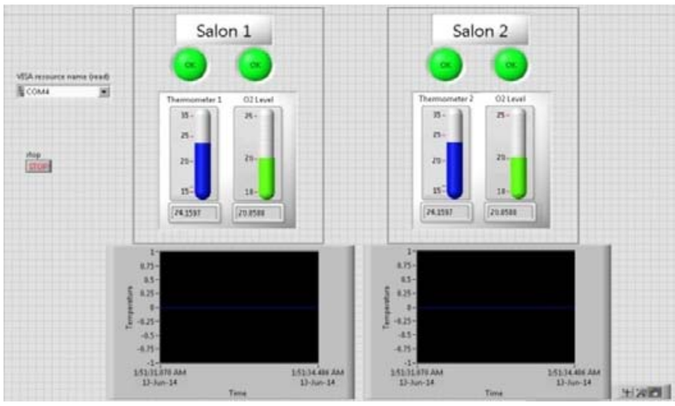

Fig. 8. Graphical user interface for monitoring ambient parameters (temperature, oxygen concentration) in the two medical wards

IV. CONCLUSIONS

This paper presents a flexible and low-cost monitoring system, for clinical ambient parameters (temperature, humidity, oxygen concentration), which was realized by conjugating hardware structures (an *Arduino Mega1280* development board, based on *ATMEGA1280* microcontroller and two *Arduino Uno* boards, based on *ATMEGA328* microcontroller) and Software elements (code lines related to the IDE 1.0.5. Arduino development environment and *LabVIEW* programming). Also, the proposed system allows monitoring the specified ambient parameters, without requiring the installation of communication cables.

The main advantages offered by the proposed solution are specific to the virtual instrumentation and to the measurement instruments with programmable interface: simplicity and instrument-user interfacing flexibility, easy reconfiguration of analyzing system, the communication possibility (via the Internet) with a database, for storing the information. In addition, the low cost (about 70 Euros) and easy maintenance recommend this system as a viable solution, that can be successfully implemented in any hospital environment.

Since the device has been tested only in the Biomedical Engineering Laboratory (Faculty of Electrical Engineering, TUC-N), in a following stage it will be tested in clinical environment. Also, monitoring the oxygen concentration is to be implemented by using a dedicated analog sensor.

REFERENCES

[1] M. Munteanu, C. Rusu, D. Rafiroiu, G. Chindriş, R. A. Munteanu, R. Moga, ”A hierarchical implementation of medical data transmission”, 2008 IEEE International Conference on Automation, Quality and Testing, Robotics AQTR 2008, Cluj-Napoca, Romania, 2008, p. 77-80

[2] John W. Webster (Editor), Medical Instrumentation: Application and Design, 3rd ed., John Wiley&Sons, 1998

[3] D. Moga, G. Lazea, M. Munteanu, R. A., Munteanu, R. Fati, ”A low cost distributed architecture for humidity and temperature monitoring in healthcare facilities”, IFMBE Proceedings, vol. I, p. 652-653, EMBEC Viena, Austria, 2002

[4] D. Moga, M. Munteanu, R. Munteanu Jr., ”Integrated Environment for Calibrating Humidity Sensors” Acta Electrotehnica, vol. 44, nr. 2, p.138-140, 2003

[5] R. Munteanu, M. Roman, M. S. Munteanu, C. Oltean, “Virtual Medical Instrument”, Proceedings of the seventh International Conference on Optimization of Electrical and Electronic Equipment OPTIM 2000, p. 891-895, mai 11-12, Braşov, România, 2000

[6] C. Luca, C. Corciovă, D. Andriţoi, R. Ciorap, ”Study on the influence of wireless communication technology on sensitive medical equipment”, IEEE International Workshop on Medical Measurements and Applications Proceedings (MeMeA), 7th -9th May 2015, Torino, Italy – in press

[7] M. Margolis - Arduino Cookbook, Second Edition

[8] http://arduino-info.wikispaces.com/Nrf24L01-2.4GHz-HowTo

[9] C. L. Clark, LabVIEW Digital Signal Processing and Digital Communications, 2005

[10] https://github.com/maniacbug/RF24Network