26th International Electrotechnical and Computer Science Conference ERK 2017 (IEEE), Portoroz, 2017.

Using ZigBee Based Wireless Sensor Networks for Wireless Monitoring of Base Life Functions

Edin Mujčić[1], Una Drakulić[2]

Faculty of Technical Engineering University of Bihac UNBI
E-mail: edin.mujcic@gmail.com, una.94@hotmail.com

Abstract. *Monitoring the health of the patient is one of the basic task that deal health services. This process can be automated in large extent. The benefits of that are: release resource of health services for those patients with bigger needs, make easier care and supervision of patients, data of current condition of the patient are available in real-time. Also, the data collected using modern technology for monitoring the health of patients can be memorized, what allows tracking the health of patients for a longer period of time. One of these technologies is the wireless ZigBee technology that is increasingly being used for monitoring the health of patients in different environments: houses, hospitals and nursing homes. That allows patient mobility within certain limits and doctors access to all information that can be measured using a small portable sensor at any time. To improve the characteristics of ZigBee based wireless sensor networks are added microcontrollers. They perform intelligent processing of data before or after sending data over ZigBee based wireless sensor networks.*

1 Introduction

Health Maintenance Systems for wireless monitoring of base life functions were conceived in early 1990's. The first patent in this area was registered in U.S.A by Alyfuku Kiyoshi, Hiruta Yoshiki [1]. These systems were primarily focused on wireless monitoring base life functions in home use. Today these systems find wider use from health institutions to nursing homes. These systems will become increasingly used in homes, because average age of population every day is increasing [2].

In this paper is described the use of wireless ZigBee technology for Health Maintnance Systems for wireless monitoring of base life functions. ZigBee-style self-organizing ad-hoc digital radio networks were conceived in the 1990s. The IEEE 802.15.4-2003 ZigBee specification was ratified on December 2004. ZigBee Alliance announced availability of Specification 1.0 on June 13, 2005, known as the ZigBee 2004 Specification [3].

ZigBee based wireless sensor network is using XBee modules at nodes. XBee is tiny RF module that has been developed and specifically designed to provide simple and cost-effective performance of wireless ZigBee technology [4]. It requires minimal energy to operate and provides reliable data transmission between devices [5]-[8]. Family Xbee modules is composed from 18 different modules with different characteristics [9].

To improve the characteristics of ZigBee based wireless sensor networks are added microcontrollers. Microcontrollers are added before sending data over ZigBee based wireless network. For this purpose Arduino boards with Atmel microcontrollers are used.

Arduino is an open-source platform designed for easy programming microcontrollers [10-14]. Arduino board is composed of an Atmel AVR microcontroller with additional components that are necessary for its proper operation. Also, Arduino board provides sets of digital and analog input/output pins that can be interfaced to various expansion boards ('shields') and other circuits [15].

In this paper XBee modules are used for serial communication between individual nodes while microcontrollers are used for collecting, processing and preparing data for serial communication. As sensors are used sensors of base life functions: heart rate sensor and human body temperature sensor. For processing and displaying of collected information using ZigBee based wireless sensor network, the programming language Processing is used. The reason for that is because Processing has a high-speed data processing.

2 ZigBee based wireless sensor network

ZigBee based wireless sensor network consists of XBee modules located on geographically different locations in the range of interaction of XBee modules. XBee modules must be configured to be able to communicate with each other.

XBee modules are developed and specially designed for simple and cost-effective wireless transfer of data. RF XBee family consists of 18 different XBee modules that have different characteristics (different operating frequencies, different power consumption, range ...) [7]. The best known and most commonly used XBee modules are XBee 802.15.4 (often known as XBee Series 1) and XBee Series 2.

In Figure 1 is shown appearance of XBee Series 1 module with pinouts and XBee PRO Series 2 module.

Figure 1. XBee Series 1 module and XBee PRO Series 2 modules

XBee/XBee PRO modules have 20 pins (see Figure 1). For work of XBee module four basic pin connections are enough: power supply Vcc (3.3 V), ground GND, Data input DIN and Data output DOUT. Other pins are used as input/output pins for the analog and/or digital data or as control pins (sleep, status, reset, etc.).

2.1 Designing ZigBee based wireless sensor network

Wireless sensor network consists of geographically distributed nodes that can communicate with each other. If nodes are the XBee modules then it gets ZigBee based wireless sensor network. According to its characteristics ZigBee based wireless sensor network belong to the PAN networks. Each ZigBee based wireless sensor network is defined with unique PAN ID. XBee 802.15.4 protocol defines two different types of nodes: ZigBee coordinator and ZigBee end devices, while ZigBee protocol defines three different types of nodes: ZigBee coordinator, ZigBee routers and ZigBee end devices.

ZigBee coordinator is responsible for channel selection, PAN ID and the establishment of a network. As coordinator in charge of setting up networks and devices accessing the network, it must assist in routing data and must be always connected to the power supply. The ZigBee router sends and receives RF data packets in the network, and performs routing data packets. ZigBee end device must join PAN network same as the router. Its purpose is to send and receive RF data packets. XBee end devices are designed to save energy.

In next chapter of this paper is described designed ZigBee based wireless sensor network using XBee Series 1 modules and ATMega2560 microcontrollers. The XBee modules are used for wireless communication and microcontrollers are used for collecting and processing data from the sensor.

3 Designing system for wireless monitoring of base life functions

ZigBee based wireless sensor network is created using XBee module Series 1. To measure base life functions are used heart rate sensor and human body temperature sensor. The functional block diagram of this system is shown in Figure 2.

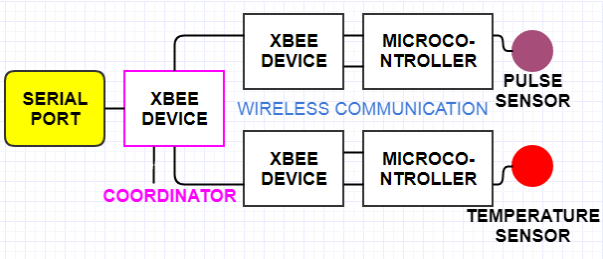

Figure 2. Functional block diagram of designed system

In Figure 2 can be seen that two XBee modules are mobile (ZigBee end devices) and third is static (ZigBee coordinator). ZigBee coordinator is connected over serial port on computer that is displaying received information using programming language Processing.

In Figure 2 also can be seen that along mobile ZigBee end devices are located ATMega2560 microcontrollers. They are used to convert analog data obtained from the sensor to digital data, their processing and sending to ZigBee end devices. Using wireless communication, data from ZigBee end devices are sent to ZigBee coordinator. ZigBee coordinator forwards received data over serial communication to computer. Computer is used for collecting, processing and graphic displaying received data over ZigBee based wireless sensor network. To create ZigBee based wireless sensor network is necessary to configure all XBee modules so they can communicate with each other. For configuration XBee modules programming tool X-CTU is used. Appearance X-CTU software is shown in Figure 3.

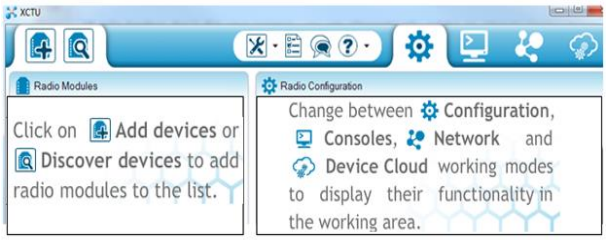

Figure 3. Appearance of XCTU software

In Table 1 are listed basic settings for XBee modules in order to ZigBee based wireless sensor network work properly. In order to XBee modules can communicate, PAN identifiers must be same. ZigBee coordinator in this case receives data of two ZigBee end devices. Besides basic configuration it is necessary to set a large number of parameters for proper and safe operation of ZigBee based wireless sensor network. After programming XBee modules and creating ZigBee based wireless sensor network, need to program ATMega2560 microcontrollers.

Table 1. Configuration of XBee modules to communicate with each other

	Xbee 1	Xbee 2	Xbee 3
PAN ID	3010 (or any number in the range of 0-FFFF)	3010 (or any number in the range of 0-FFFF)	3010 (or any number in the range of 0-FFFF)
CH	C	C	C
MY Address	1	2	2
DH	0	0	0
DL	2	1	1

In this project are used Arduino boards with ATMega2560 microcontroller which can program with Arduino software (IDE). In Arduino board with ATMega 2560 microcontroller is built bootloader that enable upload new code to the ATMega2560 microcontroller without use of external hardware programmer. It communicates using the original STK500 protocol. Also, one can bypass the bootloader and program the ATMega 2560 microcontroller through the ICSP header using Arduino ISP.

On the Arduino boards are connected heart rate sensor and human body temperature sensor as well as the SD card module. For converting analog to digital signals is used 10-bit A/D converter, for serial communication is used serial communication with a baud rate of 57600 bps. The SD card module is used to store data from sensors. In this way, is ensured that all data from the sensors are memorized. Also, it allows mobile nodes some time may be and out of range of ZigBee based wireless sensor network.

The heart rate sensor (see Figure 4.a)) that we use is essentially a photoplethysmograph, which is a well-known medical device used for non-invasive heart rate monitoring. Pulse Sensor Amped responds to relative changes in light intensity. If amount of light incident on the sensor remains constant, signal value will remain at (or close to) 512 (midpoint of ADC range). If there is lighter signal goes up and opposite. Light from green LED that is reflected back to sensor changes during each pulse.

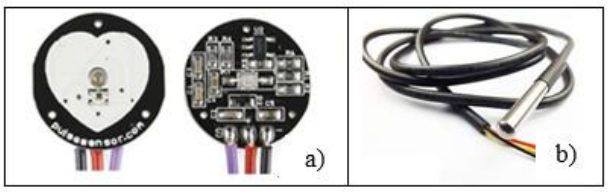

Figure 4. Sensors: a) Heart rate sensor, b) DS18B20 digital temperature sensor [17]

To measure human body temperature is used DS18B20 sensor temperature (see Figure 4.b)).

After configuring XBee modules and programming ATMega2560 microcontrollers it is necessary to merge them, connect sensors on input pins of Arduino board with ATMega2560 microcontrollers and power supply.

The heart rate sensor can be placed on different parts of human body. In our case we use finger as signal source. Very important is to properly put the finger on pulse sensor because of it depends the accuracy of the measured signal.

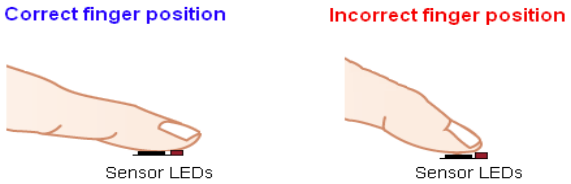

Figure 5. Correct and incorrect position of finger on pulse sensor

For processing of data on computer is used programming language Processing. The reason for use this programming language is because it is very fast for processing received data over serial port.

After connecting all of above mentioned components and their programming we get finished system for wireless monitoring of base life functions and its appearance is shown in Figure 6.

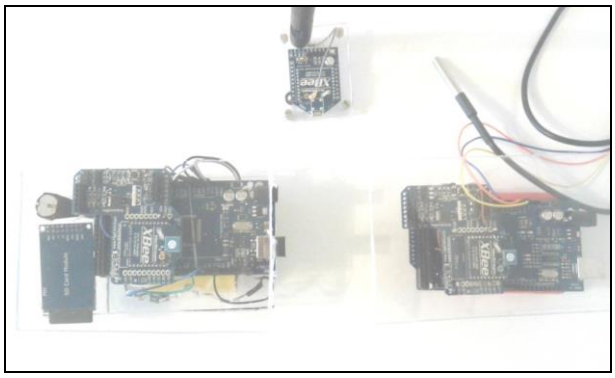

Figure 6. The appearance of finished system for wireless monitoring of base life functions

4 Experimental results

In this chapter of paper are presented experimental data obtained using projected system for wireless monitoring of base life functions. Mobile nodes (ZigBee end devices with associated ATMega2560 microcontrollers and sensors), when is performing the experiment, are located on geographically different locations. These locations must be within range ZigBee based wireless sensor network. The third node (ZigBee coordinator) is static node and is connected to the computer using a serial port. After starting the ZigBee based wireless sensors, the computer continuously receiving data from remote mobile nodes (ZigBee end devices).

In Figure 7 is shown snippet of received signal from heart rate sensor.

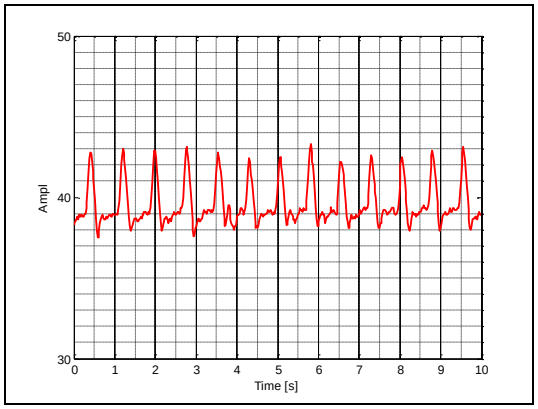

Figure 7. Heart rate pulse signal obtained using ZigBee based wireless sensor network

In Figure 8 is shown snippet of received signal from human body temperature sensor.

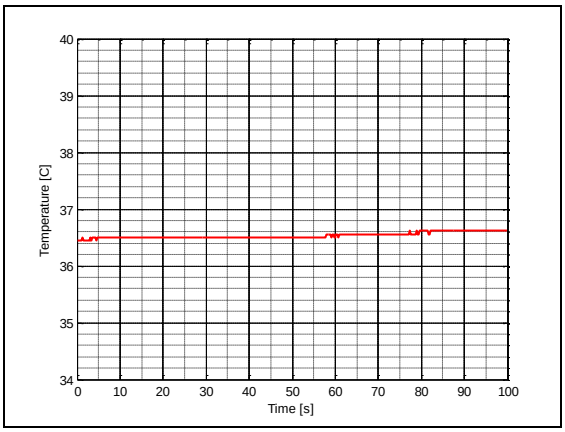

Figure 8. Human body temperature signal obtained using ZigBee based wireless sensor network

On the basis of the experiments can be concluded that ZigBee based wireless networks can be used to transfer information received from sensor of base life functions.

5 Conclusion

ZigBee based wireless sensor network have great advantages over other wireless networks regard to low power consumption, small size, weight and high data security. Disadvantage is limited flow of data through ZigBee based wireless sensor network. On basis of the experiments can be concluded that ZigBee based wireless sensor network can be used for collecting and processing data obtained from sensor of base life functions. The designed system for wireless monitoring of base life functions can be easily upgrading with a larger number of nodes and a larger number of sensors. Due to various influences (out of domain networks, the impact of barriers, etc.) can cause loss of part of the data. That problem is solved by inserting the SD memory card. Data from the sensors, after processing them, are memorized on SD memory card. In this way, mobile nodes may be some time and out of range of ZigBee based wireless sensor network. Also, due to very large possibilities of microcontroller, it is very easy to install alarms if measured parameters exceed allowed values.

Reference

[1] M. Chan, D. Esteve, et al. "A review of smart homes – Present state and future challenges" *Computer methods and programs in biomedicine*, Elsevier, vol. 1/91, pp. 55-81 (2008)

[2] M. Cerny, M. Penhaker, "Wireless Body Sensor Network in Health Maintenance Systems", Electronics and Electrical Engineering, No.9 (115), pp. 113-116 (2011)

[3] ZigBee [Online]. Available: https://en.wikipedia.org/wiki/ZigBee

[4] XBee/XBee PRO RF Modules [Online]. Available: http://ftp1.digi.com/support/documentation/90000982_S.pdf

[5] XBee/XBee PRO RF Modules [Online]. Available: http://ftp1.digi.com/support/documentation/90000982_S.pdf

[6] K. Sohraby, D. Minoli, T. Zanati, *Wireless sensor networks*, Wiley, 2007.

[7] XBee/XBee PRO RF Modules [Online]. Available: https://www.sparkfun.com/datasheets/Wireless/Zigbee/XBee-Datasheet.pdf

[8] P.V. Mane-Deshmukh, B.P. Ladgaonkar, S. C. Pathan, S. S. Shaikh, "Microcontroller PIC18f4550 Based Wireless Sensor Node to Monitor Industrial Environmental Parameters", *International Journal of Advanced Research in Computer Science and Software Engineering*, Vol. 3, Issue 10, pp. 943-950, Oct. 2013.

[9] XBee [Online]. Available: https://en.wikipedia.org/wiki/XBee

[10] R.Faludi, *Building wireless sensor networks*, O'reilly Media California, 2011

[11] V. Georgitzikis, O. Akribopoulos, and I. Chatzigiannakis, "Controlling Physical Objects via the Internet using the Arduino Platform over 802 .15. 4 Networks, "IEEE Latin America Transactions, vol. 10, no. 3, pp. 1686–1689 (2012).

[12] M. Jutila, H. Rivas, P. Karhula, and S. Pantsar-Syväniemi, "Implementation of a wearable sensor vest for the safety and well-being of children,"*ProcediaComput. Sci.*, vol. 32, pp. 888– 893 (2014)

[13] S. Abraham and X. Li, "A Cost-Effective Wireless Sensor Network System for Indoor Air Quality Monitoring Applications" *in Procedia - ProcediaComput.* Sci., vol. 34, pp. 165–171 (2014)

[14] B. Akhmetov and M. Aitimov, "Data Collection and Analysis Using the Mobile Application for Environmental Monitoring" *in ProcediaComput. Sci*., vol. 56, no. Harms, pp. 532–537 (2015)

[15] ZigBee Wireless Technology Architecture and Applications [Online]. Available: https://www.elprocus.com/what-is-zigbee-technology-architecture-and-its-applications/

[16] Wiring the ds18b20 1-wire temperature sensor [Online]. Available: http://www.14core.com/wiring-the-ds18b20-1-wire-temperature-sensor/