Environmental Engineering and Management Journal December 2016, Vol.15, No. 12, 2595-2604
http://omicron.ch.tuiasi.ro/EEMJ/

"Gheorghe Asachi" Technical University of Iasi, Romania

HEALTH CARE SYSTEM FOR MONITORING OLDER ADULTS IN A "GREEN" ENVIRONMENT USING ORGANIC PHOTOVOLTAIC DEVICES

Iuliana Chiuchisan[1], Oana Geman[2*], Marius Prelipceanu[1], Hariton-Nicolae Costin[3,4]

[1]Computers, Electronics and Automation Department, Stefan cel Mare University, Suceava, 13 Universitatii Street, Suceava, 720229, Romania
[2]Department of Health and Human Development, Stefan cel Mare University, Suceava
[3]Grigore T. Popa University of Medicine and Pharmacy, Faculty of Medical Bioengineering, Iasi, Romania
[4]Institute of Computer Science of Romanian Academy, Iasi Branch, Romania

Abstract

In this paper, we propose to present real solutions for close self-monitoring of older adults, given the permanent assistance and rapid intervention needed in emergency medical situations. The recent medical devices integrate existing or in development technologies that are easy to use, affordable, accessible and sustainable solutions that address a range of needs because the ultimate goal is the ensuring of a "living actively and independently at home" environment for older adults. We propose to contribute to the improvement of ICT-based and E-Health Internet of Things solutions that can solve the growing demand for health care systems with limited environmental resources using the energy autonomy of the medical technologies based on high efficiency organic solar cells. We systematically studied the relationship between the device performance and the preparation parameters, including the film thickness, drying time, annealing temperature of the active layers. The goal of these proposed health care devices is to provide "green" and ICT-based solutions which integrate recent technologies that will support older patients in their homes.

Key words: e-Health, environmental resources, health care systems, Internet of Things (IoT), monitoring of the elderly adults, organic photovoltaic cells

Received: August, 2015; Revised final: December, 2016; Accepted: December, 2016

1. Introduction

It is estimated that demographic aging and health degradation of the population will increasingly put pressure on society and on healthcare systems, so "it will require changes and innovations with a clear market orientation that support older adults to live independently in their homes, with choice and control over decisions, equipment, and assistance" (European Commission - Active ageing, 2015). Other factors, such as increasing urbanization and migration, will lead to increasing numbers of older adults living alone and will make the current approaches of the professional health care and health service delivery unsustainable.

According to European Commission, "it is forecasted that in 2060 the number of people over 65 years will grow to 29.5% of the total population. During the same time, the working age population in the EU is expected to decline by 14.2%. Pensions, health care, and long-term care systems risk becoming unsustainable, with a shrinking labor force no longer able to provide for the needs of the growing number of older people" (European Commission - Active ageing, 2015). Most of older adults prefer to remain in the home of their choice as long as possible. The older adults are at high risk

* Author to whom all correspondence should be addressed: e-mail: geman@eed.usv.ro; Phone: +40754212277

because they suffer from diseases that affect the ability to live independently and take care of themselves. Many older adults may have a special medical situation due to memory loss or neurological diseases, such as Parkinson or Alzheimer disease, or may have a stroke or heart attack at any time.

Health care self-monitoring of older adults uses various medical devices placed directly on patients that alert the medical assistant or the specialist if the person is unconscious or ill (Turcu et al., 2012). Health care systems are now offering a wider range of new services driven by the development of biomedical sensors and the availability of high mobile bandwidth (James, 2014). This revolution makes the idea of in-home health monitoring practical and provides the opportunity for assessment in "real-world" environments producing more ecologically valid data (Tmar-Ben Hamida et al., 2015).

Conforming to Tmar-Ben Hamida et al. (2015), in the field of insomnia diagnosis, for example, it is now possible to offer patients wearable sleep monitoring systems which can be used for the comfort in their homes over long periods of time. The recorded data collected from body sensors can be sent to a remote clinical back-end system for analysis and assessment (Fig. 1) (Tmar-Ben Hamida, 2015).

Using advanced sensors and energy autonomy powered by high efficiency organic photovoltaic cells in order to self-monitor the physiological and health condition, that communicate from a body area network (BAN) to the Internet for remote analysis, could help to provide a health care system and applications that offer an independent environment in-home health monitoring.

Our paper presents a complex health care system to monitor the health condition of older adults, in developing and testing, using ICT-based solutions and Internet of Things (IoT) technologies. To develop a health care sustainable model for older patients we considered the following criteria (Costin et al., 2009; Rotariu et al., 2010; Vermesan and Friess, 2013):

– IoT-based solutions and Green Environment can solve the growing demand for limited resources;

– IoT-based solutions and Green Environment can grow and facilitate the supply of formal and informal health care services for older adults;

– IoT-based solutions and Green Environment can reduce health care demand through prevention and self-management;

– IoT-based solutions and Green Environment can support the transition to better health care at home and in the community.

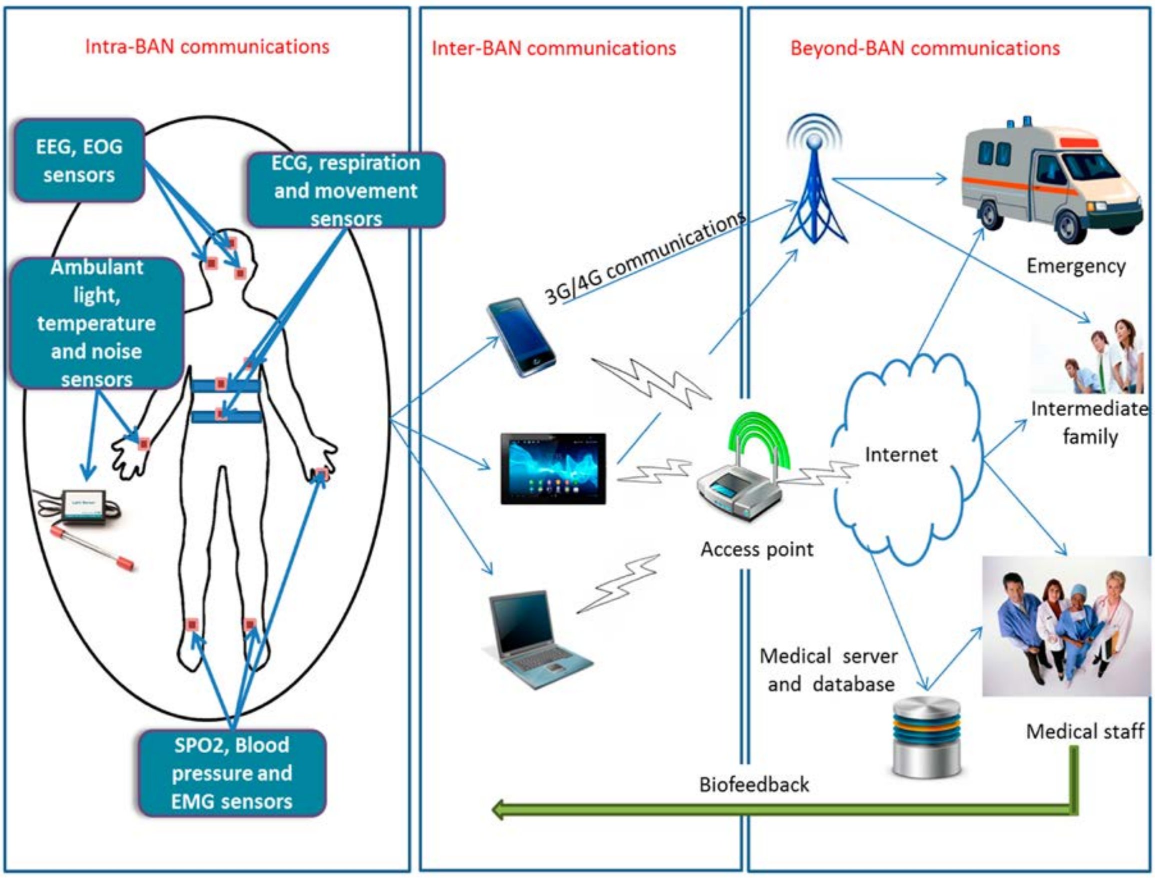

Fig. 1. The general architecture of Wireless Body Area Networks (WBANs) and the communication from WBAN to the Internet for remote analysis (Tmar-Ben Hamida et al., 2015)

2. Previous works

In our previous research (Chiuchisan et al., 2014a), a health care system for monitoring of patients at risk in the smart environment was presented (Fig. 2), using an ICT-based solution and IoT technologies. "The system alerts in real time the physician /medical assistants about the changing of vital parameters or the movement of the patients and also about important changes in environmental parameters, in order to take preventive measures. The patients have different types of sensors attached to their body which are connected to the monitor by wires, which displays specific signals and can generate alarms, which can signal to the medical staff if a body function needs attention" (Chiuchisan et al., 2014b).

In order to create a smart environment in the Intensive Care Unit (ICU) through monitoring the patients at risk we used: the intensive care unit bedside monitors used in hospital units to monitor and record multiple physiological parameters of patients; the Microsoft XBOX Kinect's sensors used to monitor the movement of the patients in order to eliminate situations in which the patient has removed from the sensing devices wires or to eliminate the false alarms; the sensor board for monitoring of environmental parameters such as temperature, humidity, atmospheric pressure and different types of gases (Chiuchisan et al., 2014c).

In another article (Geman et al., 2014a) it was presented a health care system for Neurological Disorders Screening and Rehabilitation. The system manages data acquired from the patients with Parkinson's disease in order to support physicians in diagnosis, treatment and monitoring the patients and also to facilitate the interaction at distance between physicians and patients. A component of this system was the Wiimote™ remote controller that has an infrared (IR) image sensor that can track up to five objects simultaneously, Bluetooth connectivity, and three-axis accelerometer that have been used to acquire the tremor signal from patients with Parkinson's disease (Geman, 2013; Geman and Costin, 2013a, 2013b).

Other proposed system (Geman et al., 2014b) combines data about the patient's medical history, anthropometrical measurements acquired using the Kinect™ sensor for measuring abdominal circumference, biochemical data or other medical examinations, in order to describe an algorithm capable to elaborate and generate a personalized diet (daily nutritional requirements and disease status) adapted to one type of cancer.

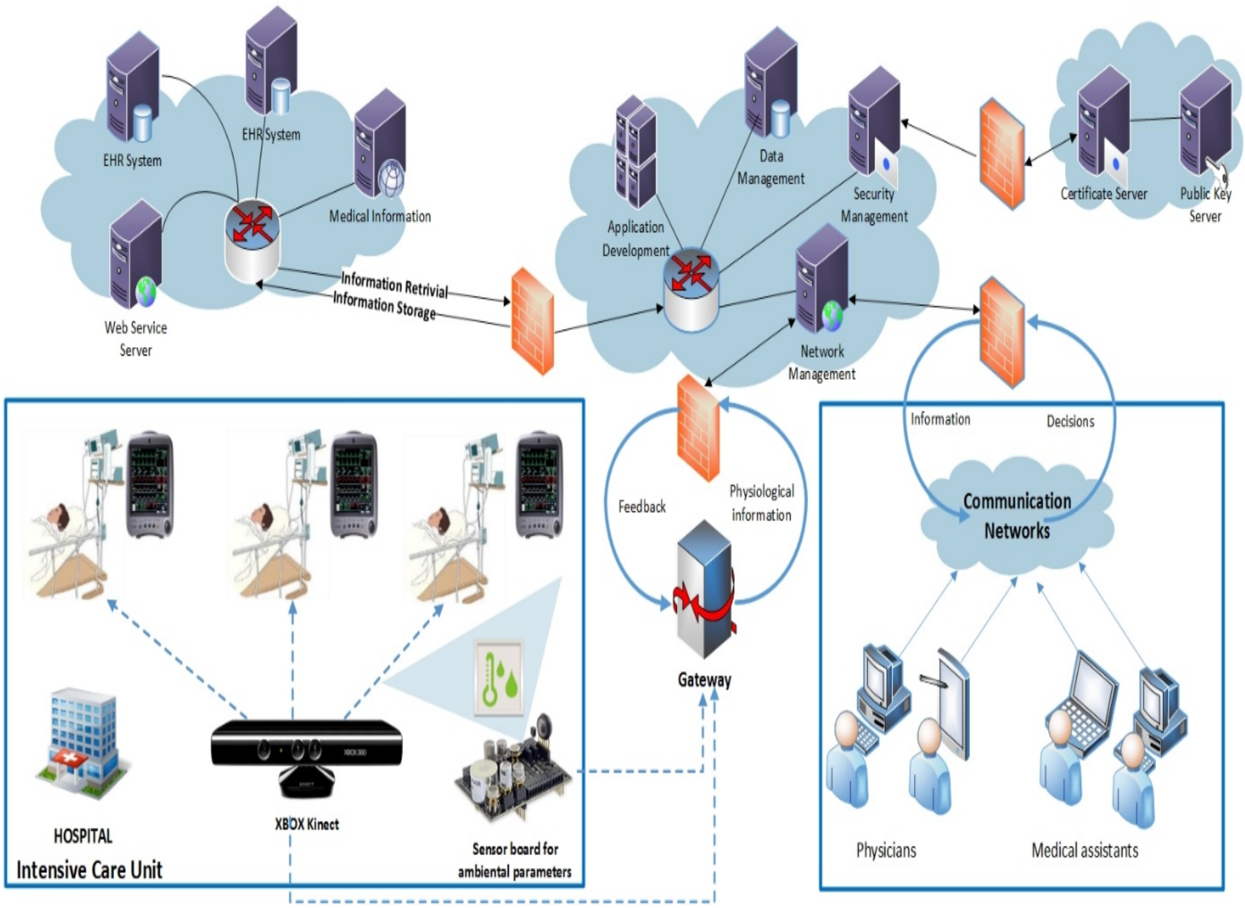

Fig. 2. The health care system architecture for monitoring the patients at risk in a smart environment (Chiuchisan et al., 2014a)

3. Health care application for monitoring the older adults

"Using the rapidly improving wireless communication technologies and advanced sensors available today, many companies are proposing solutions for health care applications. To design these systems, several semiconductor technologies are required. For example, *Freescale Semiconductor* has a broad range of technologies for body area network (BAN) measurements and communications in health care and other applications. They have developed a packaging concept to integrate these technologies into a compact form factor, using pressure sensors, gyroscopes and accelerometers" (Freescale Semiconductor Inc., 2015a).

With the appropriate advanced sensors and wireless technology, we can provide the solutions that will support older adults in order to live independently and actively in their homes (Fig. 3). For the health care system presented in this paper, we used the development kit provided by *Freescale Semiconductor Inc.* for the development of applications in the field of medical monitoring (TWR Development Kit-K53). The operating system delivers performance for real-time applications and includes boot, multi-threading or thread-based execution priorities. TWR-SER module provides functions for the communication and interconnectivity with other modules distributed in the local network or on the Internet. The serial card offers communication such as Ethernet, RS232, RS485, CAN and USB, ZigBee modules and features wireless connectivity with other systems (Freescale Semiconductor Inc., 2015b).

The health care system presented in this paper was built on this platform and its purpose is to monitor the older adults in their homes using medical sensors, and then health records were viewed on a computer or transmitted over the Internet to a server using the Ethernet interface. The proposed system monitors the heart rate, levels of oxygenation of the blood, and blood pressure, carried out during the day or while sleeping or when making an effort (e.g. boarding stairs). This system monitors the patient's temperature and generates a warning/alarm in case of high fever or when it detects a fall using the incorporated accelerometer. The family of microcontrollers, KINETIS K50 (with the core ARM Cortex M-4), is used for biomedical data acquisition and data were uploaded and used to remotely monitor older adults in their homes.

The Tower TWR-K53 system with the assembled modules and the TWR-K53N512 Microcontroller is presented in Fig. 4 (Freescale Semiconductor Inc., 2015c, 2015d). The K53 Tower system is equipped with medical connector that is used to connect and attach different dedicated module that can be used to develop the medical applications such as: Blood pressure monitors, Pulse Oximetry, Heart rate monitors, Blood Glucose Meter (glucometer), Continuous Positive Airway Pressure (CPAP) Machine (obstructive sleep apnea - OSA), Inhalers (Pulmonary Drug Delivery), Body Composition Meter, Sleep Monitor, Portable Electrocardiograph (EKG), Multi-Parameter Patient Monitor (a device that measures blood pressure, temperature, oxygen saturation and heart electrical activity), Digital Stethoscope, Infusion Pumps, Wearables devices (Freescale Semiconductor Inc., 2015a).

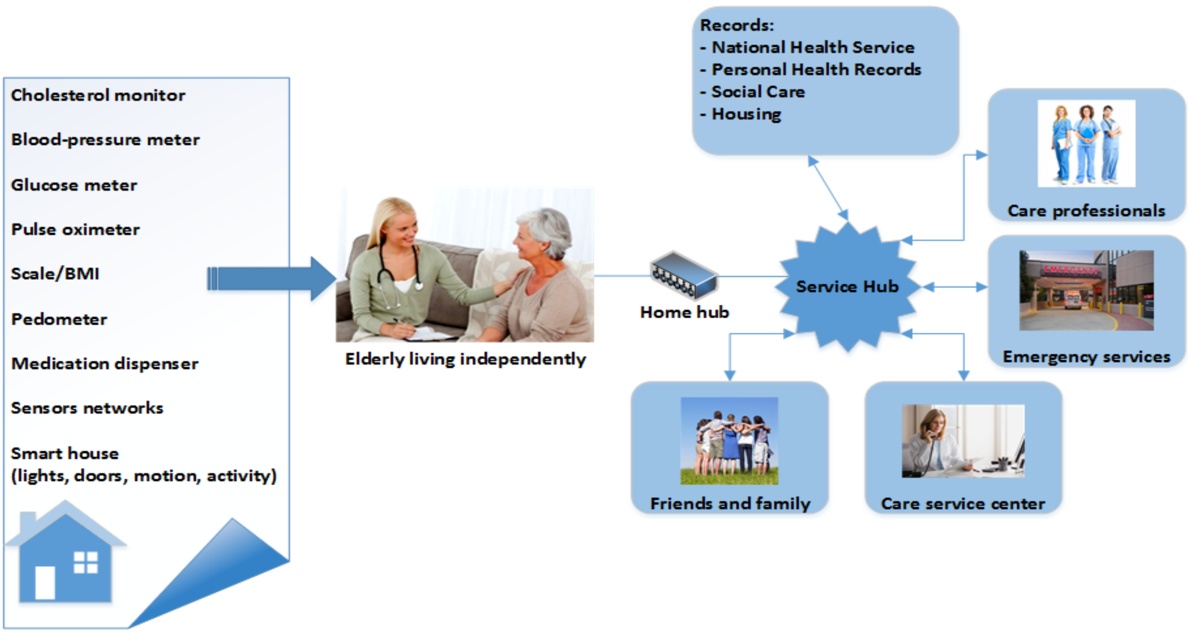

Fig. 3. Sensors, wireless technology, and applications that can be provided to older adults in order to ensure an independently living

Fig. 4. The Tower TWR-K53 system with the assembled modules (Freescale Semiconductor Inc., 2015a)

The connection with the remote servers was achieved through Ethernet protocols or ZigBee, and the USB interface was used to debug operations and to connect with a PC (Fig. 5) (NXP Healthcare, 2016). The wireless ZigBee modules were used when the medical device had to be mobile in a specific area of coverage.

The data collected by sensors are transmitted through Bluetooth technology to a gateway (usually a home computer or an intelligent mobile phone as the mobile gateway), for providing real-time monitoring (Rodas et al., 2015; Thomas et al., 2013; Wang, 2015; Zhang et al., 2016).

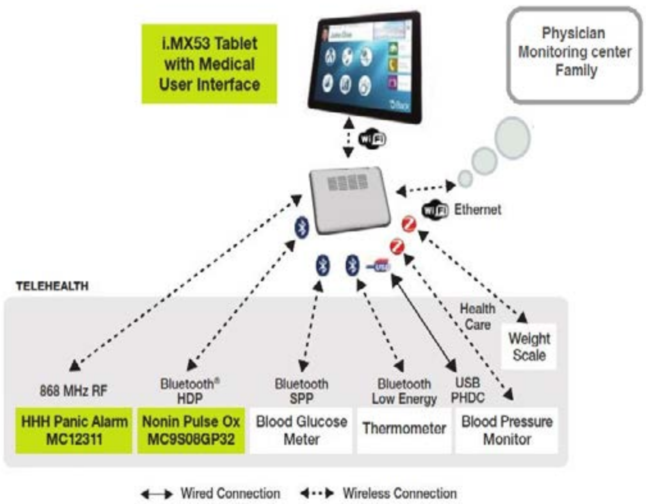

Fig. 5. Home health hub platform from NXP Semiconductors (NXP Healthcare, 2016)

Our system is a non-intrusiveness system because the patient can communicate through a friendly user interface, using a user and a password. This interface provides access in real-time to data acquisition and live sessions capabilities. Users are not required to have sophisticated computer skills in order to use services provided by the health care system. The patient has access to his personal data and medical history and can communicate with his physician using text messages or through Skype. The User Interface was designed using HyperText Markup Language (HTML), Hypertext Preprocessor (PHP) and C languages (Chiuchisan et al., 2014b).

3.1. Experimental

We have set an example for the case of 82 years female patient, with moderate Alzheimer disease, but also with severe heart problems. She must be constantly monitored, due to risk factors. Using Holter monitor and pulse oximeter the patient was monitored for 24 hours, acquiring the blood pressure, SYS – systolic (maximum value for pressure), and DIA – diastolic (minimum value for pressure) and pulse. At night the patient was also monitored in order to detect if she has sleep apnoea. The health care system proposed in this paper allows the acquisition of signals in real-time, and also the processing and transmission of an alarm to the physician or the family or to the emergency center (e.g. in the case of heart attack) (Fig. 6).

The physician can check in real time if the patient has taken medication for lowering the blood pressure and if it makes the effect and for how long. The results for patient’s monitoring in the evening, at night and in the morning are illustrated in Fig. 7.

The activities associated with the 48 hours of monitoring were: from 5 a.m. until 8.30 a.m. the patient ate and did some simple activities (listening to music, TV watching); from 8.31a.m. until 4.15 p.m. patient ate and stayed with a member of the family; from 4.16 p.m. until 8 p.m. the patient forgot to take her medication and tension has increased (see Fig. 7 **-** *event 1* – the result is that the member of the family was warned about the lack of medication); from 8 p.m. until 11.30 p.m. the patient watched TV; from 11.31 p.m. until 04.59 a.m. the patient slept (see Fig. 7 **-** *event 2* – that occurred as a result of sleep apnoea and the result was that an alarm has been sent to the family and the physician). Our system and approach are intended for general elderly, with cardiologic, movement or different problems of internal organs. Those persons with degenerative or psychic disorders (Alzheimer's disease, Parkinson, etc.) must be treated in specific manners, with special procedures.

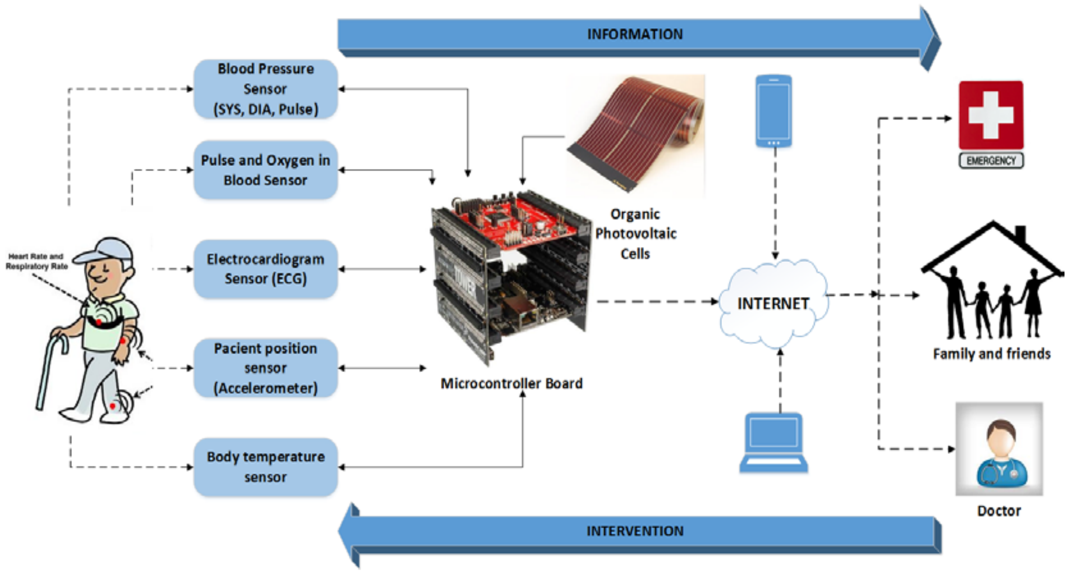

Fig. 6. The Health Care System Architecture

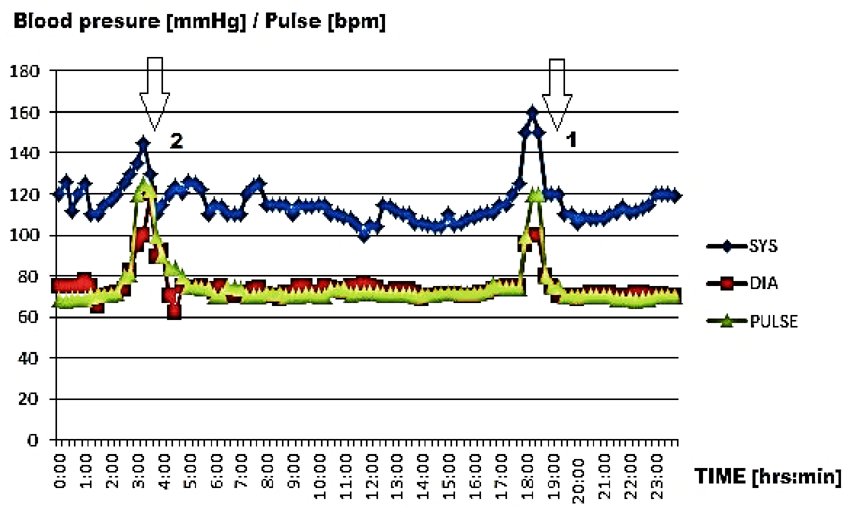

Fig. 7. Holter monitoring for the old female patient: Blood pressure: SYS – systolic (maximum value for pressure) and DIA – diastolic (minimum value for pressure) measured in millimeters of mercury; PULSE measured in beats per minute (bpm)

In order to monitor this patient constantly, we needed a large autonomy for our health care system and following we propose a new source of renewable energy using organic solar cells and we analyze the performance of devices that depends on many parameters, such as the film thickness, drying treatment time, and annealing temperature.

In recent years, new donor and acceptor materials or additive materials have been applied to improve the photoelectric conversion property of photoactive layer by enhancing the capture ability of the donor/acceptor hetero-junctions and optimizing the energy level alignment of the interface.

4. Renewable energy sources

As an alternate to the conventional renewable energy sources, organic photovoltaics have become a promising technology due to its potential of low cost, light weight, flexibility and large-area manufacturing (Kaltenbrunner et al., 2012). It is very important to control the film thickness and processing conditions of the active layer, where photons were absorbed to generate exciting, in order to achieve high short-circuit current and power conversion efficiencies (PCE) (Dennler et al., 2009). The Poly (3-hexylthiophene) (P3HT) (Susanna et al., 2011) is the one of the most commonly used donor materials due to its higher hole transporting ability (10^{-4}- 10^{-2} $cm^2 \cdot V^{-1} \cdot s^{-1}$) and lower band gap. Meanwhile, 6-phenyl-C61-butyric acid methyl ester (PCBM) (Tang et al., 2010) acts as a promising acceptor for organic solar cells of heterojunction structure with its excellent electron mobility and high stability.

During the preparation process of organic solar cells, the performance of devices depends on many parameters, such as the film thickness, drying treatment time, and annealing temperature.

Optimization of the thickness can balance the optical absorption and series resistance of the active layer (Kristian, 2007; Sylvester-Hvid et al., 2007). Besides, the P3HT: PCBM morphology strongly depends on its thickness since the D/A (P3HT/PCBM) interface can be well organized and attains the best aggregation state in a film with optimized thickness.

The device with the optimal morphology can reach a very high efficiency even it absorbs only a little part of the available photons (Liu, 2009; Prelipceanu et al., 2007a; Tang et al., 2010). In addition, thermal annealing can improve the microstructure of the active layer and increases the crystallinity of P3HT as well as the size of the PCBM-rich domain, which results in more efficient electron transport across the interface (Tang et al., 2010; Prelipceanu et al., 2007b, 2007c). In our study, we systematically studied the effect of thickness, drying and annealing condition of the active layer on the device's performance to achieve high efficiency solar cell based on P3HT: PCBM blend.

4.1. Experimental of the organic photovoltaics cells

The structure of the devices in this study is ITO - an indium tin oxide/PEDOT: PSS - Poly(3,4-ethylenedioxythiophene):Poly(styrenesulfonate) for (3500 revolutions per minutes rpm)/P3HT - poly(3-hexylthiophene: PCBM - phenyl-C61-butyric acid methyl ester (1:1, 17 mg/mL)/LiF (0.8 nanometers (nm))/Al (120 nm). The commercial ITO-coated glass with a sheet resistance of around 10 Ω/m was used as the anode. ITO glass substrates were successively rinsed with detergent, de-ionized water, acetone, and isopropyl alcohol. Each rinsing step was carried out in an ultrasonic bath for 10 min. The cleaned and dried substrates were treated with oxygen plasma for 3 min. PEDOT: PSS was spin-coated at 3500 rpm for 60 s. The PEDOT: PSS films were slowly dried in covered Petri dishes at 120 ^{0}C on the hot plate for 30 min. The treated ITO substrates were transferred into a glove box filled with nitrogen. The active layers of different thickness were spin-coated from a 1, 2-dichlorobenzene (DCB) solution consisting of 15 mg/mL P3HT and 15 mg/mL PCBM at 650 (about 100 nm) or 800 rpm (about 85 nm) respectively for 60 s. After drying at room temperature, the substrates covered with P3HT: PCBM films were annealed at 120 ºC and 150 ºC for 20 min, respectively.

The devices were completed by the thermal deposition of a 0.8 nm thick LiF layer and subsequently a 120 nm thick Al layer through a shadow mask under the high vacuum less than 3.75×10^{-6} Torr (5×10^{-4} Pa). The active area of each device was defined as 0.10 cm^2 by the overlap of ITO and Al electrodes. The devices were encapsulated by the following procedure: epoxy glue was spin-coated on top of the devices and cured under UV lamp for 5 min before taken out for the electrical testing in air. The photovoltaic performance was measured with a computer-programmed *Keithley 2400* source meter. The devices were illuminated by a solar simulator, which simulated the 100 $mWcm^{-2}$ sunlight. P3HT: PCBM of film thickness was measured by surface profiler (Dektak). The morphology of P3HT: PCBM blend films were characterized by AFM microscopy (AFM). However, good results were obtained even if the incident lighting was weaker, like that found in indoor conditions. Of course, in the indoor environment, the autonomy of the monitoring modules will be consequently reduced.

4.2. Results and discussion

Fig. 8 indicates the current density-voltage (I-V) curves of devices under different processing conditions.

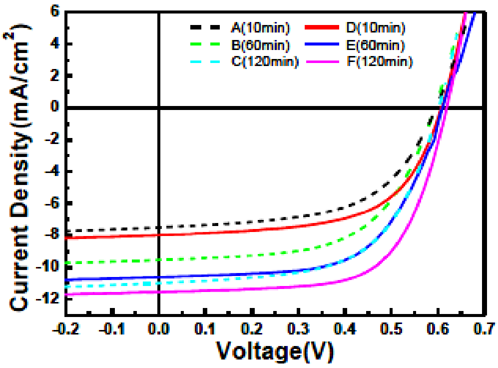

Fig. 8. I–V characteristics of devices based on an active layer thickness annealing

The corresponding photovoltaic performance of these devices was summarized in Table 1. It can be seen from Fig. 8 and Table 1 that the efficiency of all devices was proportional to the drying time regardless of the variation of annealing temperature and film thickness of the active layer thickness.

Table 1. Performance summaries of polymer solar cells with P3HT: PCBM films with different fabrication parameters: thickness, annealing temperature, drying time, the open-circuit Voltage (Voc), the values of short circuit current density (Jsc), the fill factor (FF), maximum power conversion efficiency (PCE), resistances (Rs , Rsh)

Thicknes (nm)	*Annealing temperature (ºC)*	*Drying time (min.)*	*Devices*	*Voc (mV)*	*Jsc (mA/cm²)*	*FF (%)*	*PCE (%)*	*Rs (kΩcm²)*	*Rsh (kΩcm²)*
650	120	10	A	592.17	7.49	57.01	2.53	12.9	0.63
		60	B	592.18	9.53	58.49	3.30	10.6	1.03
		120	C	592.17	11.00	60.09	3.91	9.4	1.42
650	150	10	D	604.43	7.98	60.26	2.91	9.1	0.74
		60	E	604.43	10.61	61.06	3.92	8.5	1.34
		120	F	616.60	11.55	65.03	4.63	7.1	1.79

Drying treatment benefits the formation of ordered structure in the P3HT: PCBM blend system through self-organization effect, which leads to stronger inter-chain π–π interaction and promotes inter-chain carrier hopping. As a result, the mobility is increased and charge transport is more balanced. Hence, drying treatment can facilitate the collections of both the electron and hole from the two electrodes and give rise to higher PCE (power conversion efficiency). In Fig. 9 are illustrated the Atomic Force Microscopynm (AFM) images of P3HT: PCBM blend film with different film thickness and roughness analyses. Therefore it can be concluded that sufficient time for the drying process played an important role in the increase of the photo-generated current density. The influence of the drying treatment on the performance of the device was observed to be more effective in devices with thinner film than those with the thicker one. This should be attributed to the well-ordered structure due to the formation of self-organized in the P3HT: PCBM blend system. And this trend was stronger at 120ºC annealing temperature with 800 rpm film thickness comparison with at 120ºC annealing temperature with 650 nm film thickness.

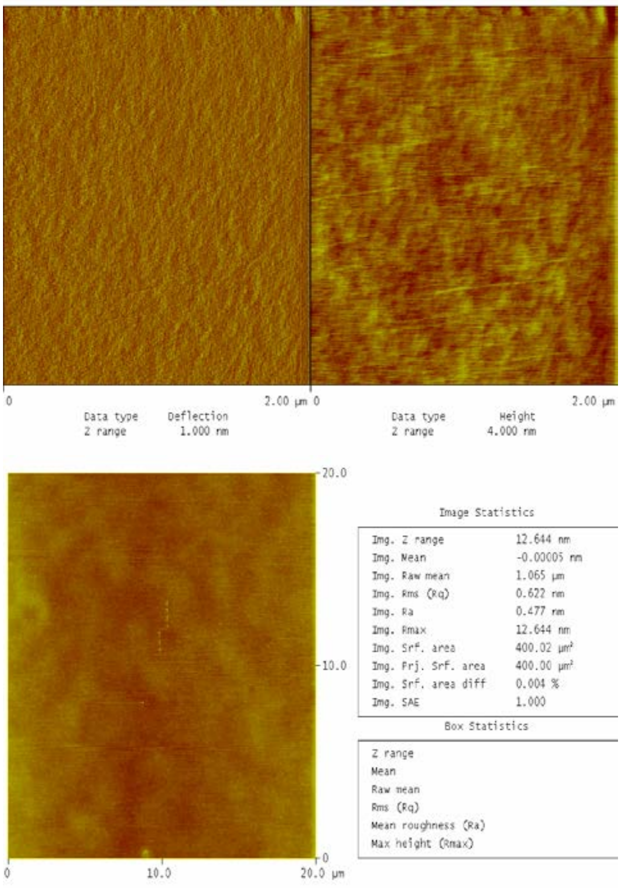

Fig. 9. AFM images of P3HT

It was also found that the thicker film needs longer drying time and higher annealing temperature to achieve the higher efficiency. Both FF and Jsc of all devices were observed to increase with the annealing temperature for the same active layer thickness and the same drying time. The efficiency of the device F (4.63%) annealed at 150ºC was up to 1.18 higher than that (3.91%) of Device C annealed at 120ºC without any change in other treatment condition.

The result is probably ascribed to the increase in exciting dissociation. Thermal annealing at a higher temperature would lead to the rough surface of the active layer, which in turn reduces the free volume and improves the interface with the electrode. The size of PCBM domain increased as the phase separation was developed during the annealing treatment. We also have conducted experimental studies for five types of solar cell test structures with different thicknesses of active layers based on: 1) P3HT (about 100 nm) PCBM (about 85 nm), 2) P3HT (about 100 nm) PCBM (about 100 nm) 3) P3HT (about 100 nm) PCBM (about 110 nm), 4) P3HT (about 100 nm) PCBM (about 120 nm) and 5) P3HT (about 120 nm) PCBM (about 120 nm), and results are similarly, with respect to the range of measured current. In Fig.10 are presented two current humps on I-V dependence, and we see two respective extremes $\alpha max_1 = 16$ and $\alpha max_2 = 8$ on α-V dependence. Here we have a limit α=2, and, due to classification, it corresponds to the monomolecular mechanism of recombination. Under the illumination (2000 lx), in the case of a high enough photosensitivity, we have α=1.5 and bimolecular mechanism of recombination.

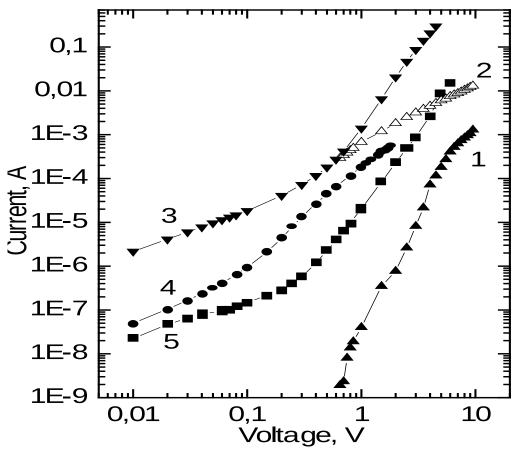

Fig.10. I-V characteristics of solar cell test structures: 1) P3HT (about 100 nm) PCBM (about 85 nm), 2) P3HT (about 100 nm) PCBM (about 100 nm) 3) P3HT (about 100 nm) PCBM (about 110 nm), 4) P3HT (about 100 nm) PCBM (about 120 nm) and 5) P3HT (about 120 nm) PCBM (about 120 nm)

The test structures were fabricated by means of five different thicknesses of the active layers. Fig. 11 shows a typical efficiency decay pattern for a standard architecture with an organic hole-transporting layer as the anode and an ITO cathode. One typically observes a burn-in period characterized by an exponential loss in efficiency whose magnitude and duration can vary by polymer system, followed by a linear decay period that sometimes ends abruptly when the packaging fails. Device lifetime is typically measured in the linear decay period once burn-in has ended. Lifetime is defined as the point at which the efficiency from the beginning of the linear decay period has fallen to 70% of this initial value. Since testing and environmental conditions, as well as sample preparation can vary greatly between laboratories, it is important for any lifetime study to use a sufficiently large sample size and to compare any new system against a well-studied system under identical aging conditions. In the current experiment solar cells were prepared with average initial device efficiencies of 5.6 ± 0.10% and 3 ± 0.05%. All devices were protected by using encapsulation architecture. The maximum lifetime measured was about 3000 hours in air under sun intensity.

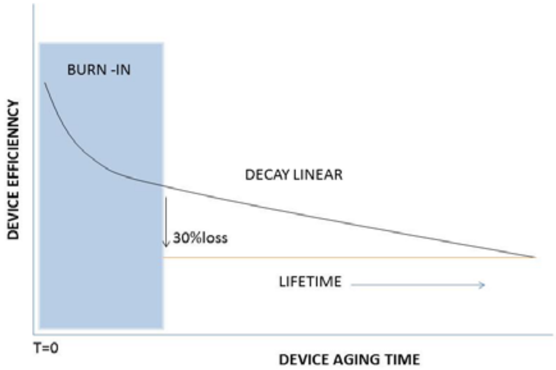

Fig. 11. Typical efficiency decay pattern for standard experimental solar cells architecture

The Voc and FF of the devices remained remarkably stable for more than 2500 h after a burn-in period of about 200 h. The decay was then dominated by a slow decline in Jsc over the duration of the experiment. The encapsulated devices showed a drop in efficiency of 8.72% per 800 h of continuous exposure to air under sun intensity. The OPC (organic photovoltaic cells) can be combined in series and parallel wiring to get for sensors the needed voltages (3 V, usually) and related powers (tens of mW/sensor). Tests were performed for individual sensors using the OPC power supply and the results are encouraging.

4. Conclusions

The aim of this paper is to provide low-cost solution using organic photovoltaic cells combined with the health monitor system based on TWR Development Kit-K53 platform that will support older patients in their homes.

In this paper, we present a health care system that acquires the blood pressure signal, temperature, pulse and accelerometer signals, and includes pulse oximeter module and electronic sphygmomanometer. The system allows the Holter automatic measurements and uploads data to a database. In order to reduce in size, conserve the battery, save the electric resource and make the system more portable, low cost and also friendly with the environment, we propose an innovative solution: to use organic solar cells (organic photovoltaic cells) as electric power source for medical sensors.

In conclusion, we propose new organic photovoltaic cells to be used in medical applications and we have systematically investigated the dependence of the device efficiency on preparation conditions. The efficiency of the device is highly dependent on drying time regardless of film thickness and annealing temperature. Drying process was proved to effectively affect the self-organization of P3HT: PCBM aggregation. In addition, optimized annealing temperature helped to improve the ability of photon absorption of the photoactive molecules. The maximum power conversion efficiency (PCE) of 4.63% was achieved by the comprehensive consideration of the film thickness, annealing temperature and time.

The results of AFM measurements further confirmed that the electrical properties indeed highly correlate to the morphology of the photoactive films. These photovoltaic cells make smaller some medical devices and give them energy autonomy. The proposed system is small and has energetic autonomy, without other conventional energy sources, providing patient safety. Through this proposed system and the new organic photovoltaic cells, we intend to reduce the costs of health care services and to ensure a "green" environment for older adults in order to live actively and independently in their homes.

Acknowledgements

This paper was supported by the project "Sustainable performance in doctoral and post-doctoral research PERFORMS - Contract no. POSDRU/159/1.5/S/138963", project co-funded from European Social Fund through Sectorial Operational Program Human Resources 2007-2013.

References

Chiuchisan I., Costin H.N., Geman O., (2014a), *Adopting the Internet of Things Technologies in Health Care Systems*, Proc. of The 2014 International Conference and Exposition on Electrical and Power Engineering, Iasi, Romania, 532-535.

Chiuchisan I., Geman O., Chiuchisan Iulian, Iuresi A.C., Graur A., (2014b), *NeuroParkinScreen – a Health Care System for Neurological Disorders Screening and Rehabilitation*, Proc. of The 2014 International Conference and Exposition on Electrical and Power Engineering, Iasi, Romania, 536-540.

Chiuchisan I., Geman O., (2014c), An approach of a decision support and home monitoring system for patients with neurological disorders using internet of things concepts, *WSEAS Transactions on Systems, Issue: Multi-models for Complex Technological Systems*, **13**, 460-469.

Costin H.N., Rotariu C., Alexa I., Constantinescu G., Cehan V., Dionisie B., Andruseac G., Felea V., Crauciuc E., Scutariu M., (2009), *TELEMON – A Complex System for Real Time Medical Telemonitoring*, Proc. of The World Congress on

Medical Physics and Biomedical Engineering, Munich, Germany, 92-95.

Dennler G., Scharber M.C., Brabec C.J., (2009), Polymer‐Fullerene bulk‐heterojunction solar cells, *Advanced Materials*, **21**, 1323-1338.

European Commission - Active ageing, (2015), On line at: http://ec.europa.eu/social/main.jsp?catId=1062.

Freescale Semiconductor Inc., (2015a), Freescale Solutions for Electrocardiograph and Heart Rate Monitor Applications, Document No: AN4323, Application Note Rev. 1, 04/2013, On line at: http://www.nxp.com/assets/documents/data/en/application-notes/AN4323.pdf.

Freescale Semiconductor Inc., (2015b), Code Warrior Development Studio for Microcontrollers V10.x, Getting started guide, On line at: http://cache.freescale.com/files/soft_dev_tools/doc/user_guide/CW_MCU_10.1_UM.pdf?fpsp=1http://cache.freescale.com/files/soft_dev_tools/doc/user_guide/CW_MCU_10.1_UM.pdf?fpsp=1.

Freescale Semiconductor Inc., (2015c), TWR-K53N512 Quick Start Demo Lab Guide. Lab guide, Rev. 2, On line at: http://docplayer.net/25594198-Twr-k53n512-quick-start-demo-lab-guide.html.

Freescale Semiconductor Inc., (2015d), TWR-K53N512 Tower Module. User`s manual, Rev. 1.0, On line at: http://www.nxp.com/assets/documents/data/en/user-guides/TWR_K53N512_UM.pdf.

Freescale Semiconductor Inc., (2015e), Freescale MQX RTOS 3.7.0 TWR-K53N512 Patch, Rel. notes, Rev. 1.0, On line at: http://www.nxp.com/assets/documents/data/en/supporting-information/MQXTWRK24F120MRN.pdf.

Geman O., (2013), Screening and rehabilitation system for patients with Parkinson's disease, *Advances in Biomedicine and Health Science Series*, 45-50.

Geman O., Costin H.N., (2013a), Parkinson's disease prediction based on multistate Markov models, *International Journal of Computers Communications & Control*, **8**, 525-537.

Geman O., Costin H.N., (2013b), Tremor and gait screening and rehabilitation system for patients with neurodegenerative disorders, *Bulletin of the Polytechnic Institute of Iasi, Automatic Control and Computer Science Section*, **LIX (LXIII)**, 43-56.

Geman O., Sanei S., Chiuchisan I., Prochazka A., Vysata O., (2014a), *Towards an Inclusive Parkinson's Screening System*, Proc. of the 18th International Conference on System Theory, Control and Computing, Sinaia, Romania, 470-475.

Geman O., Chiuchisan I., Iuresi A.C., Chiuchisan I., Dimian M., Bosancu A., Buliga D., Covasa M., (2014b), *Intelligent System for a Personalized Diet of Obese Patients with Cancer*, Proc. of The 2014 International Conference and Exposition on Electrical and Power Engineering, Iasi, Romania, 528-531.

James R., (2014), The Internet of Things: A Study in Hype, Reality, Disruption, and Growth, U.S. Research, Technology & Communications, *Industry Report*, 154-175.

Kaltenbrunner M., White M.S., Głowacki E.D., (2012), Ultrathin and lightweight organic solar cells with high flexibility, *Nature Communications*, **3**, 770-776.

Liu Y., Liu M., (2009), *Nanostructured Electrodes Prepared by Combustion CVD for Solid Oxide Fuel Cells, Lithium-Ion Batteries, and Gas Sensors*, In: *Nanomaterials for Energy Storage Applications*, Hari Singh Nalwa (Eds.), American Scientific Publishers, Los Angeles, 130-155.

NXP Healthcare, (2016), Medical Applications User Guide, On line at: http://www.nxp.com/assets/documents/data/en/user-guides/MDAPPUSGDRM118.pdf.

Prelipceanu M., Prelipceanu O.S., Tudose O.G., Leontie L., Grimm B., Schrader S., (2007a), Study of thermal conversion and patterning of a new soluble poly (p-phenylenevinylene) (PPV) precursor, *Materials Science in Semiconductor Processing*, **10**, 77-89.

Prelipceanu M., Tudose O.G., Prelipceanu O.S., Schrader S., Grytsenko K., (2007b), Study of oriented growth of oligofluorene–thiophene films onto aligned vacuum-deposited polytetrafluoroethylene layers, *Materials Science in Semiconductor Processing*, **10**, 24-35.

Prelipceanu M., Prelipceanu O.S., Leontie L., Danac R., (2007c), Photoelectron spectroscopy investigations of pyrrolo [1, 2-a][1, 10] phenanthroline derivatives, *Physics Letters A*, **368**, 331–335.

Rodas O., To M.A., (2015), A study on network security monitoring for the hybrid classification-based intrusion prevention systems, *International Journal of Space-Based and Situated Computing*, **5**, 115-125.

Rotariu C., Costin H.N., Alexa I., Andruseac G., Manta V., Mustaţă B., (2010), E-Health system for medical telesurveillance of chronic patients, *International Journal of Computers, Communications & Control*, **5**, 892-901.

Susanna G., Salamandra L., Brown T. M., (2011), Airbrush spray-coating of polymer bulk-heterojunction solar cells, *Solar Energy Matererials and Solar Cells*, **95**, 1775-1778.

Sylvester-Hvid K., Ziegler T., Riede M., Keegan N., Niggemann M., Gombert A., (2007), Analyzing poly(3-hexyl-thiophene):1-(3-methoxy carbonyl) propyl-1-phenyl-(6,6)C61(6,6)C61 bulk-heterojunction solar cells by UV-visible spectroscopy and optical simulations, *Journal of Applied Physics*, **102**, 1-9.

Tang H., Lu G., Li L., Li J., Wangab W., Yang X., (2010), Precise construction of PCBM aggregates for polymer solar cells via multi-step controlled solvent vapor annealing, *Journal of Materials Chemistry*, **20**, 683-688.

Thomas A.M., Moore P., Shah H., Evans C., Sharma M., Xhafa F., Mount S., Pham H.V., Wilcox A.J., Patel A., Chapman C., Chima P., (2013), Smart care spaces: needs for intelligent at-home care, *International Journal of Space-Based and Situated Computing*, **3**, 35-44.

Tmar-Ben Hamida S., Ben Hamida E., Ahmed B., (2015), A new mhealth communication framework for use in wearable WBANs and mobile technologies, *Sensors*, **15**, 3379-3408.

Turcu Cr., Turcu Co., Tiliute D., (2012), The potential of internet of things to improve the quality of healthcare delivery, *Journal of Applied Computer Science & Mathematics*, **19**, 73-78.

Vermesan O., Friess P., (2013), *Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems*, River Publishers, Denmark.

Wang X., (2015), The architecture design of the wearable health monitoring system based on internet of things technology, *International Journal of Grid and Utility Computing*, **6**, 207-212.

Zhang J., Yang T., Zhao C., (2016), Energy-efficient and self-adaptive routing algorithm based on event-driven in wireless sensor network, *International Journal of Grid and Utility Computing*, **7**, 41-49.