AN *AD-HOC* DATA NETWORK FOR MEDICAL DATA COLLECTION AND REDUCTION

Mihai CHEȚAN[1], Alexandru M. MOREGA[2]

Această lucrare prezintă o rețea ad-hoc pentru transmisia telematică, rapidă şi cu acuratețe, a datelor medicale produse de aparate de monitorizare medicale utilizate în mediul medical ambulatoriu. Rețeau de transfer date este utilizată pentru analizarea conceptului de stare "sedentară", care permite elaborarea unui model de referință pentru activitatea desfăşurată de farmacişti. Prevenirea şi tratamentul stării de sedentaritate constiuie priorități pentru sistemul de sănătate, cu efecte asupra tuturor categoriilor sociale.

This paper presents an ad-hoc network that provides for fast and accurate telemetric channeling of data from medical monitoring devices in an outpatient environment. The network is used to analyze the concept of sedentary state that helps providing a model of sedentary state by the pharmaceutical employees. Prevention and treatment of sedentary state are priorities in healthcare providers serving all developmental groups.

Keywords: biomedical signals, Bluetooth network, telemetry, statistical data

1. Introduction

Obesity is rising at an alarming rate throughout world. It forms a pan-European epidemic that presents a major barrier to the prevention of chronic non-communicable diseases. Statistic data shows at least 210 million EU citizens are affected, and in many countries significantly more than half of the adult population is overweight and up to 30% of the adults are clinically obese. While obesity is itself an avoidable chronic disease, it is a substantial risk factor for others (hypertension, type 2 diabetes, cardiovascular diseases, certain types of cancer, and psychosocial problems) [1]. The principal causes of the epidemic overweight and obesity are twofold:

a) The increasing abundance of "energy-dense" food and beverages – "snaking" culture.

b) The public and commercial developments reduce physical activity leading to an almost universal sedentary state.

Sedentary behavior is induced by few demands for physical exertion at

[1]PhD. Eng., SC. MED.CO SRL, Bucharest, Romania
[2] Prof., Faculty of Electrical Engineering, University POLITEHNICA of Bucharest, Romania, amm@iem.pub.ro

work and at home, automation devices, computers and television have eliminated the most part of daily movement.

2. A modular system using an *ad-hoc* Bluetooth network

The system we developed involves personal devices for measuring blood pressure, weight and body fat, blood pressure and pulse.

The personal devices transmit the measured values by a rapid wireless connection to a laptop, which, *via* the Internet, sends the data to a medical centre. A specialized program helps analyzing the data and drawing a user health profile, also giving some common suggestions useful in prevention, underlining the eventually cardiovascular risk factors, or advice for diet and physical activity.

This system is conceived as an open and extensible platform, which might include in the future more testing parameters, allowing the user to assess and assume his/her health problems from an early stage, thus saving long term resources by avoiding medical treatments [2].

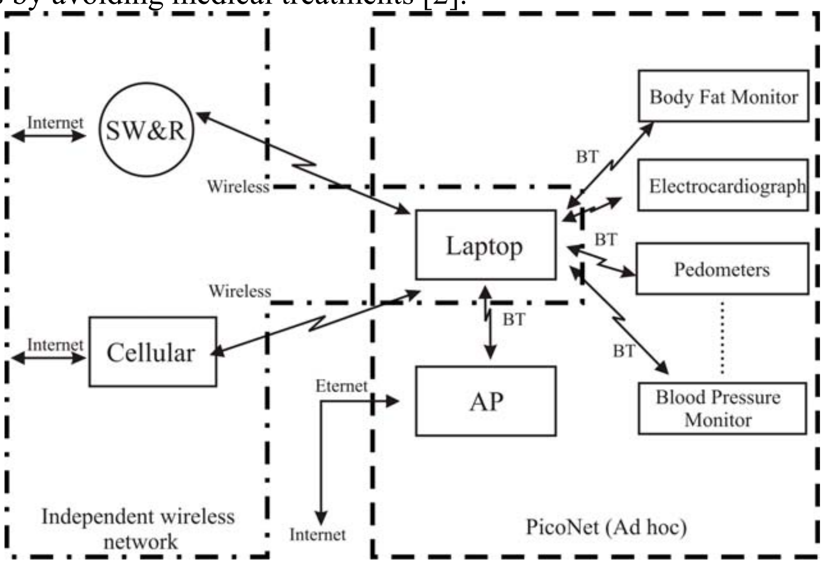


Fig.1. The diagram of a modular system using an *ad-hoc* Bluetooth network

Fig. 1 shows a networking concept for obesity and cardio vascular data assistance, where personal devices convey acquired, related physiological data by a rapid wireless connection, *i.e.*, Bluetooth, to a laptop that may implement data reduction analysis. The laptop may then forward the data *via* either the regular Public Switched Telephone Network (PSTN), or mobile telephony, or the Public Data Switched Network (PSDN) [3] to a specialized, medical decisional centre. An individual personal health profile may be drawn, and useful suggestions of preventing actions with special references to the obesity and the potential cardiovascular risk are added to it.

3. Bluetooth characteristics

Bluetooth is a short-range communications technology intended to replace the cables connecting portable and, or fixed devices while maintaining high levels of security [11], [12]. The key features of the Bluetooth technology are robustness, low power, and low cost. The Bluetooth specification defines a uniform structure for a wide range of devices to connect and communicate with each other.

Designed as a replacement for the cable connections between several devices, the Bluetooth technology operates through radio bands. In fact, it is a WiFi version with a smaller speed than the IEEE 802.x standards. It operates within the 2.4 GHz Industrial Scientific Medicine (ISM) range, and transmitted data rate is 1 Mbps. Even if such a kind of network is relatively slow compared with the transfer speeds ruling in the now a day computer network, the speed needs required by medical rules, being completely covered tacking account of the small volume of data collected from the monitoring devices (*i.e.*, ECG has 5,400 bytes).

In order to provide for data protection and confidentiality, the system is designed with secure data at the *application* level, as well as at the *connection* level [12]. In every Bluetooth unit, the authentication and cryptic routes are implemented in the same way.

The transmission scheme (FHSS) provides another level of security in itself. Instead of transmitting over one frequency within the 2.4 GHz band. Bluetooth radios use a fast frequency-hopping spread spectrum (FHSS) technique, allowing only synchronized receivers to access the transmitted data.

4. Internet connection

The PicoNet shown in Fig. 1 presents a number of possibilities to reaching access to the Internet [4], *i.e.*, *via*:

a) Access point – with supplementary delivery priorities and security for critical data transactions. Thin AP architectures allow information technology staff to manage the entire wireless network from a single point.

b) SW&R (switch and router) + laptop – to connect to the Internet through a wireless, local area network (WLANs, 802.11)

c) Cellular phone and laptop – to improve data transfer by e-mail.

5. Network devices used for collecting specific medical data

Network body composition monitors. Body composition is used for determine the percentage of fat, bones and muscles from the human body. This analysis is importance in family medicine practice, and clinical nutrition research. Bioelectric impedance, in correlation with anthropometric indexes, is one of the most common methods utilized by the devices aimed at determining the body composition, at a tangible price.

BIA method used by the body composition monitors, relies on the fact that for healthy adults and young people the content of the water in the free fat mass (FFM) is relatively constant: 0.732 *l*/*kg*. Thus, any technical measurement based on the assessment of total water contents (TBW) indirectly provides an estimate for FFM. The body fat percentage may be defined like [6]

$$\%Fat = \frac{100 \cdot \left(W_t - FFM_{TBW}\right)}{W_t}, \tag{1}$$

where W_t is the total weight.

Modules for estimating the quantity of water in the body have been designed taking into account the electrical proprieties of the tissues. The level of fat tissue is calculated by a predictive formula, whose parameters are determined based on the patient personal data and on the ethnic group's specific characteristics

$$m_a = m_c - \left(a_1 \cdot H + a_2 \cdot V + a_3 \cdot R + a_4\right), \tag{2}$$

$$m_a(\%) = m_a / m_c, \tag{3}$$

where m_a = fat (kg), m_c = weight (kg), H = height (cm), V = age (years), R = the resistive component of the impedance (Ω), and $a_1, \ldots, a_4$ = empiric coefficients.

The measurements accuracy provided by such a device is closely linked to the accuracy of the coefficients (a_1, a_2, a_3, a_4) that are obtained by clinical studies based on the results obtained with a method of reference [7].

Network pedometers. Basically, a pedometer measures the distance covered during a walk. To do this, the device counts the number of steps and analyzes the up and down position of the waist during the motion. For measuring the walking distance, it is necessary to set the stride length. The modern pedometers calculate also the consumed calories and "burned" fat quantity, the number of aerobic and normal steps and the duration of walk. Consequently, there are more parameters that have to be set (*i.e.*, weight, date, local time) [8].

The pedometers of latest generation are provided with accelerometer sensors along two axes, and may accurately determine the number of steps, whether the movement takes place in either normal or aerobic style.

The angles α and θ are equal, so the stride length may be calculated by multiplying the vertical balance of the hip by a factor k (fig. 2). The vertical balance may be larger or smaller, depending on the height. The following assumptions are made:

a. the foot is actually a single point (or a ball);
b. the impact of each foot on the ground is perfectly elastic.

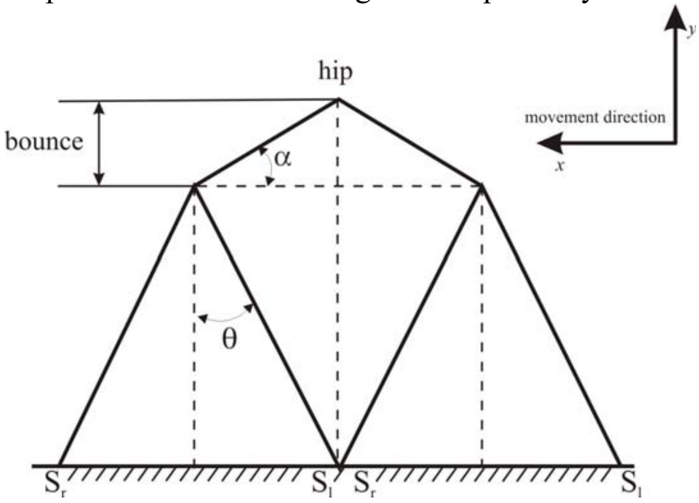


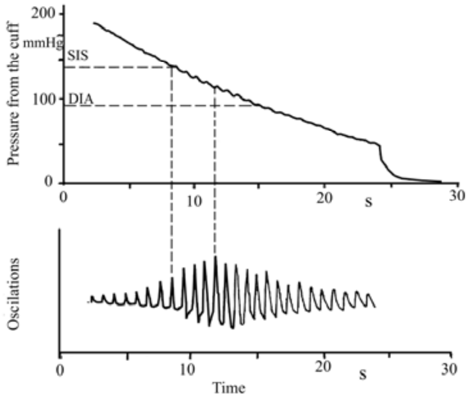
Fig.2. Hip trajectory during walk

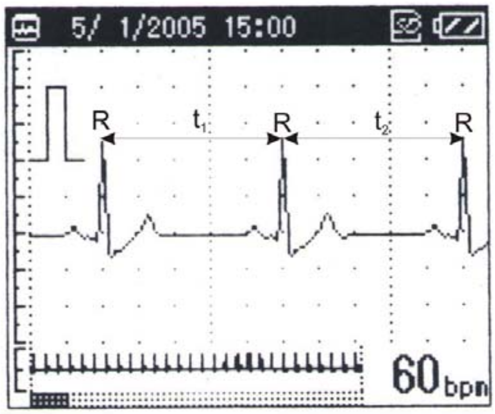
The formula for the distance is

$$d = k\frac{(a_{med} - a_{min})}{(a_{min} - a_{min})}, \tag{4}$$

Here, d = distance, $a_{med}, a_{\min}, a_{\max}$ = average, minimum, maximum acceleration per step, k = multiplication factor [9].

Network blood pressure monitors. Blood pressure (BP) and the heart rate are dynamic parameters concerning the blood, which reflect all the fluctuations throughout the day caused by physical or mental stress. The daily measurements obtained with the self-measuring monitors (SMM) at home or even in the workplace can have greater prognostic value than those obtained in the physician's surgery. Most of devices for monitoring the blood pressure at home use the oscillometric method, which involves attending the next steps: cuff around the upper arm, pressure inflation and close artery with cuff; during deflation the pressure sensor controls the pressure characteristic; when the artery opens the pressure is increasing because the artery pressure on the cuff is proportional to the systolic blood pressure; each beat of the heart is recognized; each heart beat produces one oscillation; pressure oscillations are recorded (oscillometric method); when oscillations disappear, artery is fully open = diastolic blood pressure. Fig. 3a shows the pressure variation from the cuff, during the measurement.





a. The pressure variation from the cuff. **b.** The R-R interval.

Fig.3. Blood pressure (BP) and the heart rate are dynamic parameters monitor output

The device's microprocessor analyses by a specific algorithm the pressure oscillations from the cuff and gives the results.

Network Electrocardiograph. Since many years the deaths by cardiovascular causes are invariably in the top of mortality statistics. Therefore besides primary prevention early diagnosis and adequate therapies are necessary. Electrocardiograph readings have an important role in diagnosis. The events registration of heart rate disorders that have an intermittent character, by a portable ECG without wires, is more and more common. These portable small devices, easy to operate, may be used daily, as needed: *e.g.*, either in abnormal condition, or 3-4 times daily, when the asymptomatic arrhythmia is present. An electrocardiograph with one channel is very convenient for the patient. The results are stored on the device memory card, and later downloaded on the doctor's computer.

The analysis of the instantaneous heart rate using the interval R-R (R-R tachogram) – Fig. 3,b – is called "the analysis of the heart rate variability – HRV", providing the means to evaluate several cardiovascular diseases. Experiments shown that, in certain situation, these pocket devices may be used successfully by doctors in clinics, offices, and in home visits. Similar to the self-measurement of blood pressure, blood glucose values and coagulation, it is now possible for the patient to obtain an ECG diagram by him(her)self.

In the scientific medical research, the heart behavior is analyzed using different mathematical methods. Among them, Fourier and Wavelet transform are the most commonly used methods.

Fourier transform is usually used for analyzing the heart rate variability.

However, it has limitation due to the stationary hypothesis. Conversely, wavelet transform gives a significant better analysis due to its ability to study the non-stationary signals, and to provide novel temporally localized information. For example, with Fourier transform, the variability of heart rate has to be calculated as a set of events in the interval R-R, which cannot capture the sudden changes in the R-R signal. The wavelet transform removes these limitations, and offers also complementary interesting features:

- access to heart rate variability under crisis situation (*e.g.*, anesthesia, pharmacological interventions) that may change the system equilibrium;
- a better fit shape for analyzing the signal than the fixed sinusoidal Fourier shape, allowing for better measurement.

Wavelet transform. Sometimes, there is a need to extract either the characteristic frequencies or the specific oscillation of a signal out of the interval R-R. Like Fourier or Laplace transforms, the analysis of the signal by wavelet transform requires an integral function, named "mother function" defined as [10]

$$\Psi_{a,b} = \left(|a| \cdot \Psi\left[\frac{(x-b)}{a} \right] \right)^{-\frac{1}{2}}, \ a \in R^{*} b \in R, \tag{5}$$

where a is a real number different from zero, b is a real number and x is the abscissa on which the signal is analyzed. The wavelet transform of a signal f is

$$W_{f(a,b)} = \langle f, \Psi_{a,b} \rangle, \ a \in R^{*} b \in R, \tag{6}$$

where <, > denotes the L^2 scalar product of f and $\Psi_{a,b}$, *i.e.*, $\int f(\mathbf{x}) \psi_{a,b}(\mathbf{x}) \mathrm{d}\mathbf{x}$.

The calculation of this scalar product is the analysis of f by the wavelet ψ. It allows a local analysis of f and evidences the presence of all members of the family, which are all scaled representatives of the mother function. The calculation of $W_{f(a,b)}$ gives the vector of wavelet coefficients, which represent the evolution of the correlation between the signal f and the chosen wavelet at different levels of analysis (or different rangers of frequencies) all along the signal f [10].

6. Data reduction regarding activity aspects related to the presence of the sedentary state in pharmaceutical employees

The applications of an *ad-hoc* network are numerous, and cover both the aria of patient-doctor relationship and the data collection necessary in the medical decision process (*i.e.*, actions in preventive medicine) of some specialized institutions (*e.g.*, The Healthcare Public Institute).

A sample analysis of data collected is related to physical activity and the prevalence of the sedentary state in the pharmacists' community. The procedure is:

- collect the personal data about the participants at this study (age, gender, height, weight, and the geographical area where they come from)
- study of physical activity for each day of the week by recording the walking distance, the number of steps done, the number of calories consumed and the fat "burned".

The study reported here was performed on a group of 60 pharmacists from different areas of the country. The personal data (weight, height, age, gender, level of studies, geographical area) was voluntary obtained, based on a questionnaire. Each participant received a pedometer and was trained how to use it and how to send – *via* Internet – the measured daily values, to a data collecting center. The data obtained was processed by statistical and mathematical methods, giving: the lowest and highest values, the median, arithmetic mean, standard deviation, coefficient of variation (%) [11]. The calculation formulas are

Arithmetic mean

$$X = \sum_{i=1}^{n} X_i \Big/ N, \tag{7}$$

Standard deviation

$$S_x = \sum_{i=1}^{n} \left(X_i - X\right)^2 \Big/ N, \tag{8}$$

Coefficient of variation

$$CV = \frac{S_x}{X} \times 100. \tag{9}$$

People in this professional group are of ages ranging between 21 and 66 years. The average age is 31 years; the standard deviation is 7.84, CV% 25.59 (meaning an environment with an average uniformity).

Table1

Relevant indicators – age, weight, and height

	A – Age	W – Weight	H – Height
lowest value	21	50	1.5
highest value	66	95	1.78
Median	29	60	1.67
Arithmetic mean	30.75	60.12	1.66
Standard deviation	7.87	9.37	0.06
CV %	25.59	15.34	3.82
n	60	60	60

Their minimum weight is 50 kg, maximum 95 kg, and 60 kg was is the average, standard deviation CV 9.37% and 15.34%, (i.e. a group with uniformity in the average weight). As for the height, the results are as follows: the minimum height is 1.5 m, the maximum of 1.78 m and average 1.66 m; standard deviation CV 0.06 and 3.82% (i.e. with good uniformity of the sample). Table 2 gives the indicators obtained for number of steps and calorie consumption for the first day of the week.

Table2

Indicators obtained during a week

Indicators	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
	Steps	Rating	Steps	Rating	Steps	Rating	Steps	Rating	Steps	Rating	Steps	Rating	Steps	Rating
lowest value	215		422		327		973		535		1600		389	
highest value	9829		11865		12371		11121		11741		11741		9201	
Median:	3646		3500		9099		4278		3800		10462		3612	
Arithmetic mean	4244		4575		4951		4964		4522		4379		4262	
Standard Deviation:	2328	24S 1A 6sA	2915	21 S 2 A 10 sA	3245	23S 6A 4sA	3157	22S 4A 6sA	3059	24S 29A 5sA	3199	14S 2A 7sA	2461	16S 1A 6sA
CV%	54.85		93.71		65.54		63.59		67.64		73.04		57.73	
N	31		33		33		33		30		24		53	

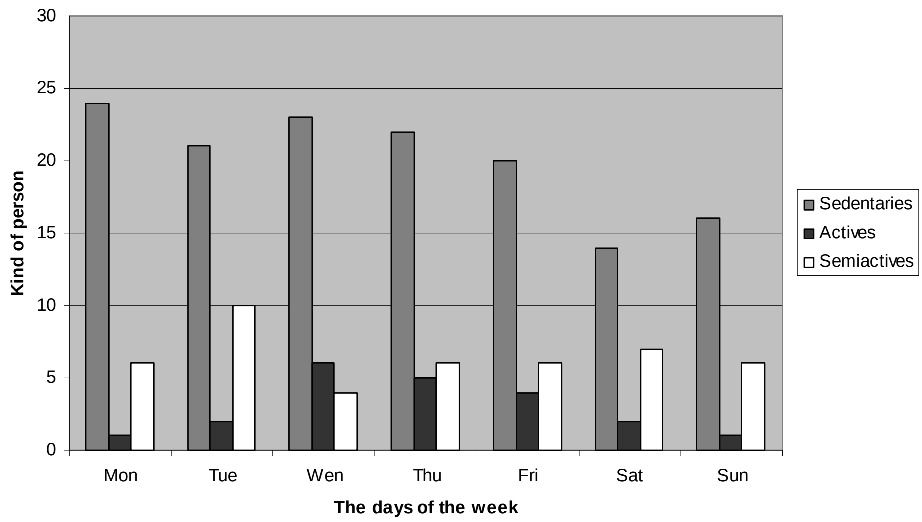


Fig.4. Phisical activity during a week

Fig. 4 shows the data from Table 2, but based on each day of the week. Synthesis data: pharmacists as a group of specialists have high sedentary life (60.8– 77.4%); the variation of the number of steps during the days of the week is not significant and the variation of the burned calories each day week is not large too.

7. Conclusions

Bluetooth network for collection and analysis of biological parameters develops innovative telemedicine technology and services that improve healthcare management for:

- *homecare service*: biological monitoring of different parameters in ambulatory allows obtaining large amounts of information that help the physician to optimize the medial treatment.
- *remote patient monitoring*: network's flexibility allows a very easy adaptation at the bed-ridden patients needs for monitoring parameters and a significant reduction in costs of medical care for this category of patients.
- *diseases management program* – low cost of such a network makes it ideal for collecting data for extensive areas (for specialized institutions).

Acknowledgments

The work was conducted in the Laboratory for Electrical Engineering in Medicine, with the support of OMRON Healthcare Europe B.V.

R E F E R E N C E S

[1] *Ph. James, N. Finer, T. Lobstein, K. Baillie, L.R. Jackson, F. Scarrott, N. Rigby,* (International Obesity TaskForce), V. Hainer, M. Frelut, J. Seidell, and members of the EASO Task Force Groups on management, childhood obesity and prevention (European Association for the Study of Obesity), *Obesity in Europe – The Case For Action*, London, September 2002

[2] *M. Chetan, A.M. Morega*, Medical data transfer technologies, Rev. Roumaine Sci. Techn. Electrotech. et Energ., **53**, 3, 339-348, 2008

[3] *R. Panko*, Business Data Networks and Telecommunications, 6th Ed., Prentice Hall 2007

[4] *S.D. Baker, D.H. Hoglund*, IEEE Engineering in Medicine and Biology, Magazine, **27**, 2, 86-95, 2008

[5] http://www.omron-healthcare.com (accessed on June 1st 2008)

[6] *D. Sirbu, D. Curseu, M. Popa, A. Ionutas, D. Vlassa*, Non-invasive measurement of body composition in young people, 1st International Conference on Advancements of Medicine and Health Care through Technology, MediTech 2007, 27-29 Sept. 2007, Cluj-Napoca

[7] *P. Deurenberg, M. Yap, W.A. Van Steveren*, Body mass index and percent body fat: a meta analysis among different ethnic groups, Intl. J. of Obesity, 22, 1164-1171, 1998

[8] http://www.heartmonitors.com/pedometers/index.htm (accessed on April 28, 2008).

[9] *J. Scarlet*, Enhancing the performance of pedometers using a single accelerometer, Analog Dialogue, **42**, May 2008, ISSN 1552-3284

[10] *V. Pichot, J. Gaspoz, S. Molliex, A. Antoniadis, T. Busso, F. Roche, F. Costes, L. Quintin, J. Lacour, J. Barthelemy*, Wavelet transform to quantify heart rate variability and to assess its instantaneous changes, J. of Applied Physiology, **86**, 081-1091, 1999

[11] *L. Morari*, The contemporary study methods of the socio-medical multi factorial problems, Ed. Medro, ISBN 973-8487-0103, 2003

[12] *J. Frihat, F. Moldoveanu, A. Moldoveanu,* Impact of using upper layers security techniques in ad-hoc wireless networks,U.P.B. Sci. Bull., **vol. 71**, Iss. 2, pp. 63-74, 2009.