Web-based Personal Health Systems – Models and Specifics

Grisha Spasov, Galidia Petrova
Technical University of Sofia, branch Plovdiv, Plovdiv, Bulgaria

Abstract: *In modern concepts for development of Personal health systems (PHS) one of the main directions in research is the employment of mobile communications, Internet and Web technologies. On the other hand, the advances in bio-sensors technologies and applications enable continuous efficient monitoring of some physiological parameters of a patient. In this paper the general model of development of a PHS' architecture, consisting of three main components – Body sensor network, Patient server and Point-of-care server is described. The paper presents an overview of current stage in possible architectures for realization of PHS, discussing various models, strategies and specifics. It is focused on discussions that summarize the trends for realization of Web-based multi-tier PHS. An example for implementation of wireless intelligent bio-sensor for monitoring of heart and respiration rates is presented.*

Keywords: *Personal Health System (PHS), Body Sensor Networks (BSN), Web-based PHS, Three-tier architecture, Four-tier architecture.*

1. INTRODUCTION

In modern concepts for development of e-health one of the main directions in research is the employment of Internet technologies, Web technologies and Web services. This tendency is enhanced in the last ten years and it is emphasized in Lisbon' strategy i2010 and EC initiatives for development of e-health systems [1].

Personal Health System (PHS) is one of the supplementary directions in the e-health concept. PHS is a relatively new concept, introduced in the 1990s. PHS places the individual citizen in the centre of the healthcare delivery process. PHS can bring significant benefits in terms of improved quality of care and cost reduction in patient management, especially through remote monitoring and management applications. PHS are seen as key components for bringing continuity of care in terms of location (extending care outside hospital settings to ordinary living environments) and time (continuous, anytime monitoring) and assisting the shift towards preventive, personalized and citizen-centered care [2, 3].

PHS covers a wide range of systems including wearable, implantable or portable systems, as well as Point-of- Care (PoC) diagnostic devices [4, 5]. The functioning of PHS is related to three layers:

- 1st layer: Acquisition of data and information related to the health status of a patient or healthy individual through the use of sensors and monitoring devices.
- 2nd layer: Processing and analysis of the acquired data to identify what information is clinically relevant and useful in diagnosis, management or treatment of a condition. This entails processing of data at both ends: locally at the site of acquisition and remotely at medical centers. Data processing takes into account the established medical knowledge and professional expertise where appropriate.
- 3rd layer: Communication between various actors, in a loop: from patient/individual to medical centre; from medical centre that analyses the acquired data to doctor/hospital; and back to the patient/individual from either the wearable/portable/implantable system itself or the doctor or the medical centre (in the

form of personalized feedback and guidance to the patient, adjusted treatment via closed loop therapy, control of therapy devices).

These layers are interconnected, and the links between them are of as equal importance as the layers themselves.

Several research groups and commercial vendors have started developing remote medical monitoring systems. They have common threads in their architectures, but they differ significantly in the specific purposes they serve [6, 7].

This paper presents an overview of current stage in possible architectures for realization of PHS, discussing various models, strategies and specifics. It is focused on discussions that summarize the trends for realization of Web-based multi-tier PHS.

2. PLATFORM ARCHITECTURE

In modern concepts for development of PHS one of the main directions in research is the employment of mobile communications, Internet and Web technologies [8, 9]. On the other hand, the advances in bio-sensors technologies and applications enable continuous efficient monitoring of some physiological parameters of a patient [10]. The general model for development of a PHS' architecture is illustrated on Fig. 1 [11].

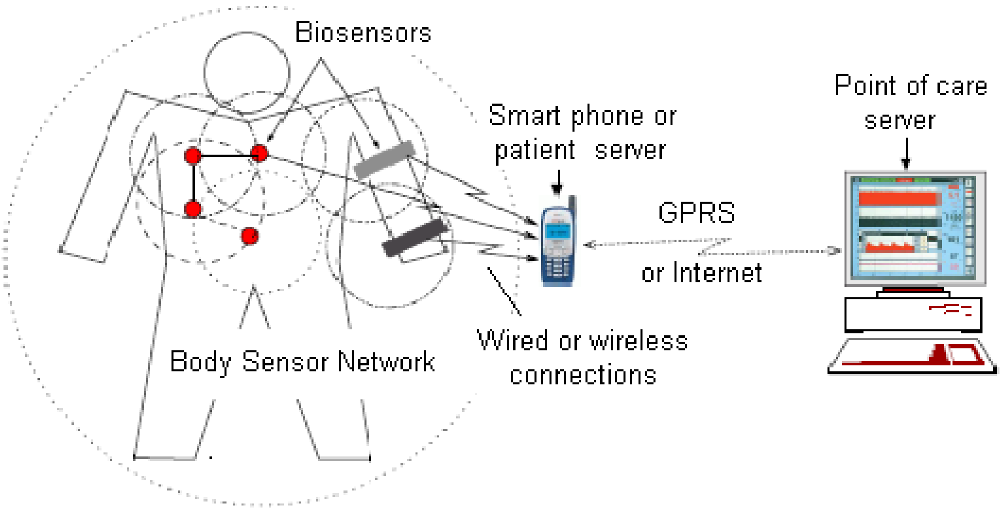

Fig. 1. General model of a PHS' architecture

The PHS consists of three main components:

- Body sensor network (BSN) consisting of wearable bio-sensors and actuators that are inter-connected using wired or wireless media. The bio-sensors collect information for important patient' vital parameters like ECG signal, Heart and Respiration rates, Blood pressure, Oxygen saturation, Body temperature, Glucose level and etc. Every node of BSN performs signal pre-processing including detection, amplification, filtration and discretization. In some cases it is possible to perform digital signal processing which involves analyzing the data to detect abnormal disease situation and creating alerts. This feature is important for cases when there exists a risk of disconnections with patient server;
- Patient server (mobile patient monitor or PDA or smart phone) is used to collect data from BSN, to perform high-level data processing, analysis and temporary local storage, to convert data in appropriate format of packets and transmit them to the Point-of-care server via mobile communication network or Internet. Here is

the second point where data analysis involves detection of crucial situations, creating and transmitting an alarm message.

- Point-of-care server (PoC) typically is situated in medical center where medical services are provided. The PoC server supports electronic patient records (EPR) for observed patients, which are accessible by different players of medical services providers, including general practitioners, specialists or doctors from clinics in hospitals. All of them can observe the current patient state. When PoC server receives an alarm message from a Patient server it registers emergency situation and immediately directed it to the responsible medical service provider to take the corresponding actions. The PoC servers support some elements of telemedicine functionality.

In practical realization of general model of PHS different realizations of client/server platform are employed. Some of them are based on mobile communications as GSM 2,5G or 3G-GPRS or UMTS, while others used traditional Internet and Internet applications. For example, in [9] PoC server is realized as Web-based application and in [6] both Patient server and PoC server are realized employing Web services.

In general, the choice of particular architecture and its realization is determined mainly by interaction of PHS with other sub-systems in e-health, the openness of PHS and the requirements for its adaptability to meet new trends for development of e-health.

The concepts for development of Web-based three-tier or four-tier architectures of PHS in accordance with the presented general model are discussed in the next sections.

3. THREE-TIER ARCHITECTURE

The models of multi-tier architectures of PHS realized till the present moment are based on the architecture presented in Fig.2. The number of tiers depends on the employed data processing model and the functionality envisaged for every tier.

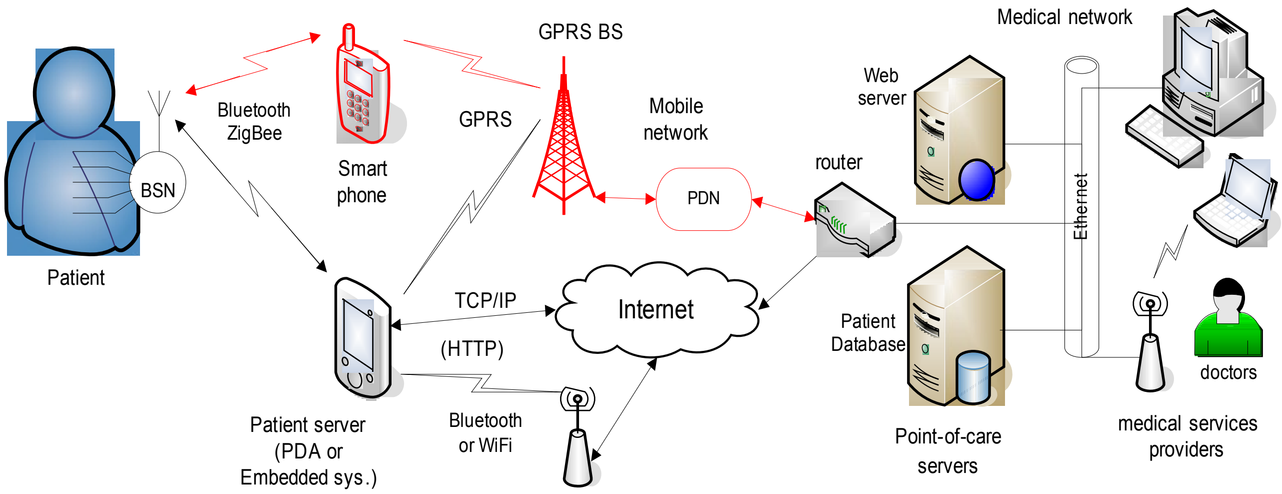

Fig. 2. Basic architecture for realization of a multi-tier Web-based PHS

The three-tier model is based on client/server architecture with Web-server, which follows directly the general model of PHS. Here PoC server is realized as Web-based application server (Web portal) and Database with electronic records of the observed patients. The Client tier is implemented with Internet browser which allows access of different players from medical services providers to EPR and the necessary data. These two tiers are comprised by the Medical network for health services. The Data tier in this model, where the data are collected, locally processed and visualized, includes BSN and the Patient server. In PHS, the three-tier model is adopted from the traditional three-tier architecture of business information systems. However, in PHS the Data tier is different, because it is dynamic and generates data in real time.

To the moment, two main realization of three-tier model depending on the Patient server type and the employed communication with PoC server are popular:

- Application of Smart phone as Patient server. In this realization the functionality of Smart phone is extended with Java MIDP-based application [12], which is responsible for: receiving the data from BSN via Bluetooth, performing data processing, activating the alerts in case of necessity, visualizing the current physiological parameters of the patient, converting data in appropriate format of packets and transmitting them to the Point-of-care server via mobile communication network. The main advantage of this realization is the mobility of patient in the range of whole mobile network. The essential drawbacks are the comparatively high price for data transmission in mobile network and the insufficient bandwidth, which makes difficult the real-time image transmission (one of the main functions in tele-medicine systems).
- The second realization employs PDA or custom-designed microcontroller as Patient server, which partly overcome the drawbacks of the first realization. Except Bluetooth or ZigBee, in custom-designed microcontroller a GPRS module for mobile communication and modules for wired and wireless communication to Internet have to be embedded. Then in home, office and hospital environment the advantages of Internet as wide bandwidth and low-cost for data transmission could be used and more of tele-medicine functions could be realized.

The access to data for patient's current state, for definite period of time or crucial situations is realized via Web server (Web portal) in Medical network by means of creating dynamic HTML pages for particular medical applications.

The three-tier model of PHS architecture is applicable for group practices of general practitioners and clinics in hospitals. In this model the patients are committed to particular medical center and particular mobile network. Obtaining the health services from other specialists and healthcare providers in real time thought the e-health system is difficult to be applied in the presence of incompatibilities in personal health systems and sub-systems developed by different producers. One possible way to integrate PHS based on three-tier model to other sub-systems in e-health concept is to organize and present EPR in XML format and development of Web-based services for their integration to the other sub-systems. Other approach for PHS opening and integration is the transition to four-tier models of architecture based on Web-services.

4. FOUR-TIER ARCHITECTURE

The necessity the observed patients to be more flexible and mobile from the point of view of monitoring and delivering of healthcare services from different medical centers and hospitals, depending on patient health status, and employing the full potential of e-health system, is a premise for appearance of four-tier model of PHS architecture. It takes advantages from the variety of mobile, wired and wireless Internet connectivity.

The architecture of four-tier model for PHS is adapted from the existing four-tier models of Web-based distributed information systems. In these systems there are four basic tiers – Client tier, Presentation tier, Service tier and Data tier. In PHS four-tier models could be realized based on architecture from Fig. 2 by introducing specific changes in the first three - Data, Service and Presentation tiers that allow the observed patient to be integrated to different medical centers depending on the place of patient's position and its health status – Fig.3. It means that from one site, the data from Patient server containing information from BSN for patient current status and alarms to be transmitted to the medical center where the patient is associated at that particular moment, and from the other site, the Presentation tier of this medical center to have access to EPR stored in PoC server in Basic medical center, where the patient is initially registered. These specific features predetermine the Patient server to undertake the functions of Service tier. In order to ensure the whole functionality, the Patient server has to meet all requirements as described in second realization of three-tier model in previous section and in addition needs more computational resources.

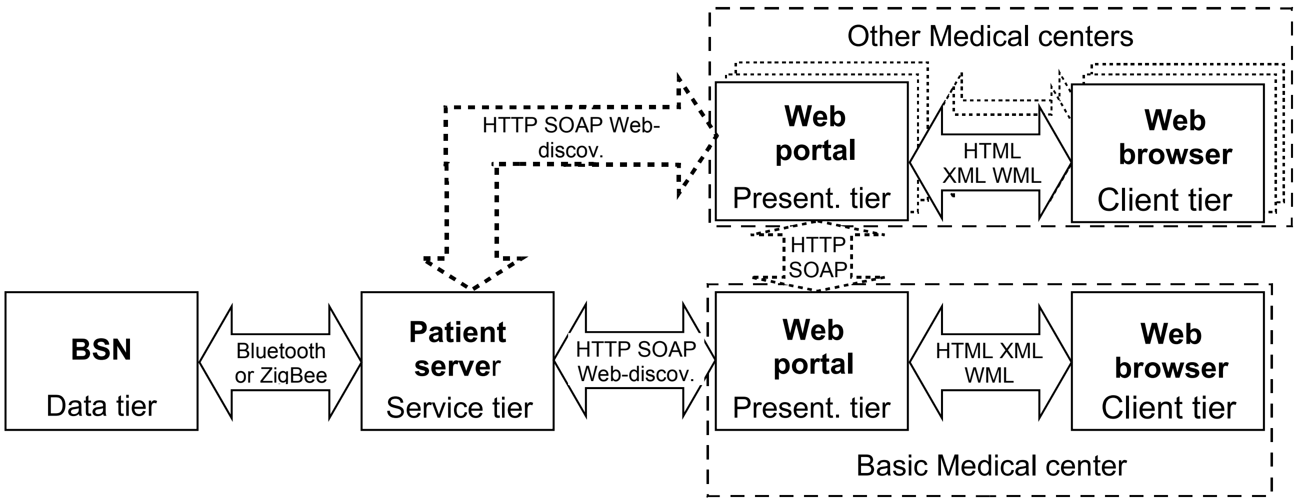

Fig. 3. Tiers' functions and interconnections in four-tier model of PHS architecture

In the four-tier model the functions are distributed between the tiers as follows:

- Data tier – BSN. It performs: collection of biological data, first level data processing and transmission via wireless media (Bluetooth or ZigBee) to Service tier;
- Service tier – Patient server. Its functions include: control of data exchange with BSN, second level data processing and visualization, data transmission to Presentation tier. The data are transmitted in XML format and the functions are realized on the basis on Web services in order to be accessible to all Presentation tiers in medical centers, involved in the observation process of a particular patient. This approach in realization of Service tier assures the openness and flexibility of PHS and allows easy integration of systems developed on different platforms and different producers.
- Presentation tier – Web portal. Its functions include: control of data exchange with Patient server by means of Web services, management and support of Database with electronic records of observed patients; creating dynamic HTML pages for particular medical applications in the process of health services; data

exchange of EPR between medical centers, ect. All these functions are realized on the basis on Web services and the data are transmitted in XML format.

- Client tier – Web browser. It performs the same functions as in realizations of three-tier model.

As we have already notice, the presentation of data in XML format and application of Web services in functional realization of Service and Presentation tiers in four-tier models of PHS make them easy compatible with other sub-systems in e-health concept. Even if the process of development of PHS starts before the development of national e-health strategy and the corresponding standards for structure of EPR and patient file, the missing structures, interfaces and functions could be supplemented by means of converters and gate-ways based on Web services.

5. AN EXAMPLE REALIZATION OF WIRELESS INTELLIGENT BIO-SENSOR FOR MONITORING OF HEART AND RESPIRATION RATES

In this section we will present an example realization of one node in BSN developed as wireless intelligent bio-sensor for monitoring of heart and respiration rates – two physiological parameters, which are important in observation of patient health status. Previous research [13] proves that the respiration signal could be extracted from ECG signal because it modulates the peak-to-peak amplitude of QRS complexes. In addition, the extracted respiration signal in not so much affected by the movement of the body, which makes this method reliable and convenient for application in PHS.

The main goal in design and realization of this bio-sensor was to cover acceptable distance for data transmission to the Patient monitor together with low power consumption. In the same time the module should be as small as possible in size and weight in order not to make difficulties for the observed patient. It is attached on a suitable place of the belt. The two disposable electrodes used for sensing ECG signal are attached to the human body in abdominal area close to the heart, in parallel with the first ECG lead (I bipolar lead). Audio-signalization when the monitored physiological parameters go out of two pre-adjustable thresholds is envisaged, also.

The block diagram and functions of wireless bio-sensor are presented on Fig.4. The module consists of: analogue front-end, presented by one ECG channel for bio-potential detection, amplification and filtration; microprocessor with embedded ADC for signal discretization and first-level processing, and a broad-band (ISM range) radio frequency transceiver for wireless data transmission of the registered signal to the Patient monitor.

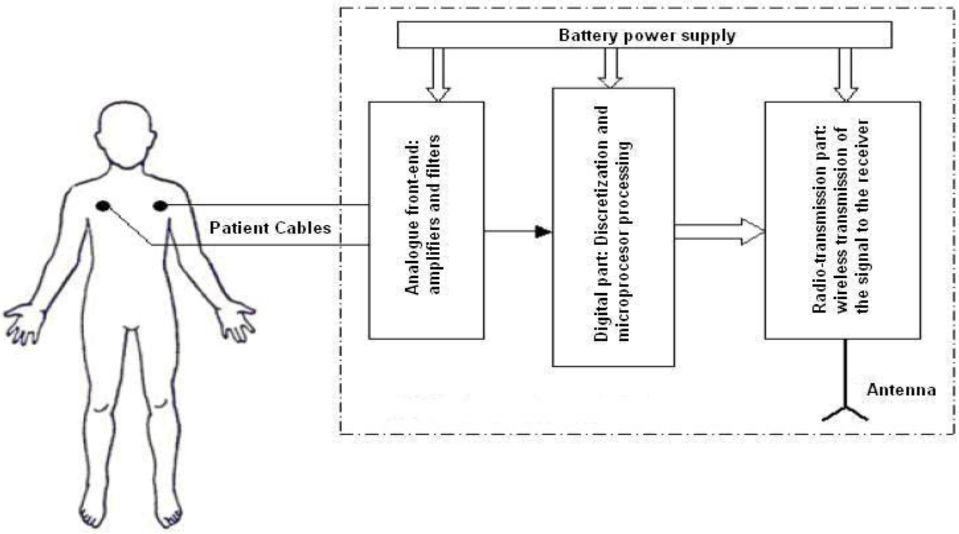

Fig. 4. The block diagram and functions of bio-sensor module

For design of the whole analogue part low-power consumption and low noise operation amplifiers are used. The design of digital part is based on microprocessor MSP430F1232. Its main features are ultra low power consumption, low power voltages and JTAG system interface for programming. The radio-transmission part is based on RF transceiver CC1100, which is designed especially for wireless devices with very low power consumption. The experiments showed that without external antennas the developed bio-sensor module covers a straight distance of 20-25m for wireless data transmission. More details about realization of this bio-sensor and experimental results about its performance and monitored parameters are presented in [13].

In summary, the developed bio-sensor supports all functions associated with Data tier in PHS, comprising: collection of data for ECG signal; signal pre-processing including detection, amplification, filtration and discretization; digital signal processing with data analysis to detect critical situations and activating the alarms, data transmission to the Patient server.

6. CONCLUSIONS AND FUTURE WORK

The paper presents an overview of current stage of multi-tier architectures for Web-based PHS and the special attention is paid on the employment of XML data format and Web services for tiers' realization.

A future work includes analysis of the data flows in the context of multi-tier architecture and development of Programmable services components allowing easy and flexible configuration and customization of Service and Presentation tiers. The aim is to satisfy the new needs of medical monitoring and the health service providers.

Another scope for future research refers to optimization of communication between BSN and Patient server, from one point of view, and information interaction between different services working on Service tier and Web portal from another point of view.

Additional investigations should be directed to development of new bio-sensors which supports all functions associated with Data tier in PHS and optimization of power consumption in BSN and in wireless networks between BSN and Patient server.

7. ACKNOWLEDGMENTS

The presented work is supported by National Science Fund of Bulgaria project – "ВУ-966/2005", entitled "Web Services and Data Integration in Distributed Automation and Information Systems in Internet Environment", under the contract "ВУ-МИ-108/2005".

8. REFERENCES

[1] Purcarea O., Perspectives of e-Health in EU, Unit ICT for Health DG Information Society and Media EU Commission, *3th National Conference National Discussion Forum „E-HEALTH" Regional Health Networks. Public Electronic Services. Electronic Health Record*, Under the aegis of Ministry of Health, Feb. 13th 2008, Sofia - www.ehealth-bg.org/bg/list_documents.php.

[2] Kolitsi Z., Umpierrez M., Personal Health Systems: Deployment opportunities and ICT research challenges – Conference report, February 12-13, 2007, Brussels, http://ec.europa.eu/information_society/ehealth.

[3] European Commission, Accelerating the Development of the e-Health Market in Europe, *e-Health Taskforce report* 2007, ISBN-13-978-92-79-07288-8, Brussels, http://ec.europa.eu/information_society/ehealth.

[4] Stut W., Wartena F. and Van Steen M., A distributed shared data space for personal health systems, *Medical Informatics Europe*, Maastricht, August 2006.

[5] Frost J., Massagli M., Social Uses of Personal Health Information Within PatientsLikeMe, an Online Patient Community: What Can Happen When Patients Have Access to One Another's Data, *Journal of Medical Internet Research*, Vol. 10, No 3, May 2008.

[6] Jurik A., Weaver A., Remote Medical Monitoring, *IEEE Journal of Computer*, Innovative Technology for Computer Proffesionals, April 2008, ISSN 0018-9162, pp.96 – 99.

[7] Dagtas S., Pekhteryev G., Sahinoglu Z., Cam H., Challa N., Real-Time and Secure Wireless Health Monitoring, *International Journal of Telemedicine and Applications*, Volume 2008, Article ID 135808.

[8] Paradiso R, Loriga G, Taccini N. Wearable system for vital signs monitoring, *Studies in Health Technology and Informatics*, 2004, 108, pp. 253-259.

[9] Chakravorty R., Mobi Care: A Programmable Service Architecture for Mobile Medical Care*, Proceedings of the 4th annual IEEE international conference on Pervasive Computing and Communications Workshops*, March 2006, Italy, ISBN:0-7695-2520-2, pp. 532-545.

[10] Hsu Y., Yang C., Tsai T., Cheng C., Wu C., Development of a Decentralized Home Telehealth Monitoring System, *Telemedicine and e-Health*, Vol. 13, No.1, February, 2007, pp. 69-78.

[11] Mozil R., Cil V., Personal Health Systems, *PHS 2008 Consultation Workshop*, Tampere Finland, 30-31 January 2008.

[12] Trossen D., Pavel D., Sensor Networks, Wearable Computing and Healthcare Application, *IEEE Journal of Pervasive Computing*, April-June 2007, pp.58-62.

[13] Petrova G., Bojkov P., Spasov G., Design of Wireless Device for Remote Monitoring of Heart Rate and Respiration Frequency, *Proc. of 6th International Conference "CHER21'08"*, 4-7 June, 2008, Sozopol, Bulgaria (in press).