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Applications of e-Health Standards in Personalized Healthcare Systems

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Abstract – **The paper presents an overview of e-Health standards used for implementation of Personal Healthcare systems (PHSs). Interoperability issues on the technical level are discussed addressing data formats and transmission protocols standardization. At the end, some recommendations for application of specific standards for development of PHSs are given. The directions for future development of e-Health standards are discussed.**

Keywords – **Personal Healthcare Systems, data exchange, e-Health standards, interoperability.**

I. INTRODUCTION

Recent advances in Information and Communication Technologies (ICT) and more specifically in wireless communication technologies and mobile computing have driven new directions in the development of e-Health sector. New and emerging concepts like mobile health (m-Health) and Personal Health Systems (PHSs) are expected to revolutionize the way the healthcare services are delivered. They are opening the way for new healthcare and wellness applications by giving the individual person a more central role in its treatment and prevention process, and by giving healthcare professionals an access to data, collected under natural activities and environment [1, 2].

One of the critical point for providing timely care for the home monitored patients is the integration of the information systems for remote health status monitoring to the hospital and clinical information systems. The important role in the integration process play the healthcare standards employed.

The goal of this paper is to provide an overview of e-Health standards applicable for implementation of PHSs and to trace future directions for development of these systems.

II. BACKGROUND

A. Personal Healthcare Systems - use case scenario

The PHSs are concerned with the individualization of treatment, prevention and well being procedures available through the healthcare system. The patient is placed in the center of the health delivery process. The main goal of PHSs is to bring continuity of care at all levels of healthcare delivery through applications for remote monitoring and remote management, spanning from location, to ambiance, and time. This continuity of care is a prerequisite for the delivery of preventive, personalized and citizen-centered health care [1]. In implementation of PHSs and Tele-heath monitoring systems employing open architecture is widely accepted approach. On Fig. 1 the basic three-tier architecture of a PHS is presented [2].

The first tier is represented by the wireless body sensor network (WBSN) which comprises sensors attached to the patient body for measurement of vital physiological parameters, and sensors in the close proximity of the patient for measurement of ambient parameters. The second tier includes Personal monitor (server) or Hub playing the role of Home Gateway. It coordinates the sensor network, derives the values of measured parameters, performs the raw data processing and sends data to the third tier. The third tier is represented by the medical servers of remote medical centers, healthcare providers, caregivers, emergency, etc. where the data are received, processed, analyzed and stored.

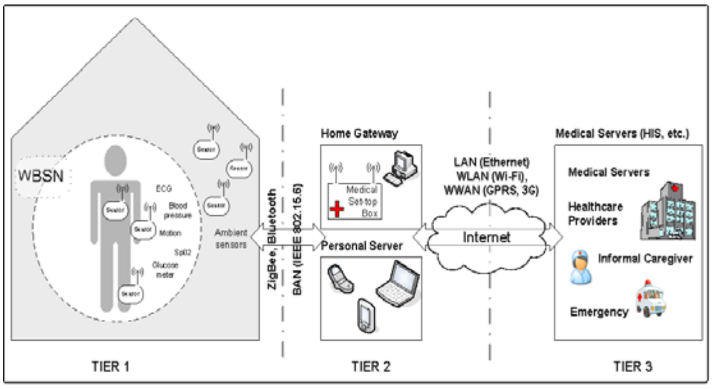

Fig.1. Basic architecture of PHS

B. Wireless Body Sensor Networks

WBSN consists of a network of miniaturized, low cost, and wireless wearable or implantable bio-sensors and actuators that are interconnected to provide continuous monitoring of the patient's physiological and contextual parameters (e.g. ECG, EEG, Heart and respiration rates, blood pressure, oxygen saturation (SpO2), body temperature, glucose level, spatial location, etc.) [2]. Every node of WBSN performs signal pre-processing including detection, amplification, filtration and discretization. In some cases, it is also possible to perform digital signal processing for analyzing the data in order to detect abnormal disease situations and creating alerts.

It is well known [3, 4] that for realization of wireless communication in WBSN the use of standard communication technologies is preferred. This approach enables compatibility on physical layer between bio-sensors of different producers to be achieved. According to [3, 4, 5] the most frequently used standard wireless technologies for implementation in WBSN are: the group of wireless local networks (WLAN – IEEE 802.11a/b/g), the group of wireless personal networks (WPAN)

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represented by IEEE 802.15.1 (Bluetooth), IEEE 802.15.3 (UWB), IEEE 802.15.4 (ZigBee), and the group of mobile cell communications (GSM, GPRS, UMTS, 3G, 4G). The choice of appropriate standard is based on the parameters specific for the particular application, while the optimum working of this application is dependant on the correct configuration of the wireless network.

C. Body Sensor Network Gateway

The BSN gateway or Personal server fulfils several main functions in the PHS. A part of these functions comprises the interfaces to the WBSN tier, the tier of medical servers and the local user interface [6]. The other part of gateway functions includes initial data processing, filtration and normalization of the values of measured physiological and ambient parameters. Finally, the gateway is also responsible for converting the format of data to be exchanged with the medical servers. For realization of the BSN gateways usually smart phones or embedded systems with additional functionalities are used [2].

Taking into consideration the interface with the medical servers, the gateway is responsible for local data storage when there is no connectivity to Internet. It is also responsible for building of reliable channel for transmission of locally stored or received in real-time data to the remote medical servers.

D. Healthcare Web Portals (medical servers)

The third tier of PHS (medical servers) is located in the respective medical center, which provides health services accessible through Internet. The main functions of the third tier include: maintaining DataBase with the Electronic Health Records (EHRs) of the associated patients and corresponding Personal Health Records (PHRs); providing local and remote access to the DataBase for reading and/or writing data for different groups of users as general practitioners, medical doctors, Clinical and Laboratory information systems (CIS and LIS), and patients themselves; as well as providing access to some additional services offered by the respective medical center. Generally, the data exchange between the PHSs and EHRs systems of CIS and Hospital information systems (HIS) for the associated patients is realized on this tier of PHS [5].

Nowadays [7], web-technologies and in particular web-services are the most preferable on the middleware level technologies for development of PHSs. Several developments exist [8] which ensure compatibility between the Service-oriented Architecture (SoA) standards and the requirements of PHS. Basically, they use computer languages for description of the web-services and the interaction between them. Typical characteristics of SoA are the untied interaction and dynamic re-configuration based on XML format of the massages.

It is worth to notice that from one side, the PHSs give new possibilities and have advantages for realization of e-Health systems and services. However, from the other side there are a number of unsolved problems and challenges related to the implementation of separate tiers and information interaction between them in the open architecture of PHSs.

The main problems which have to be solved are:

- The large number of wireless bio-sensors from different producers using variety of protocols for data exchange and various message formats;
- Frequently in the process of generation of Personal Health Records the data are not presented in the same standard as in EHRs which do not allow direct data exchange with EHRs systems of clinical and hospital information systems;
- Often for the sake of convenience, in realization of the PHSs it is preferable to generate unique web application protocols based on HTTP XML which are not directly compatible with the standards regulating the presentation and exchange of medical data in development of e-Health information systems.

In conclusion, it is worth to notice the necessity to integrate Personal Healthcare Systems to Clinical and Hospital information systems employing approved standards for PHRs and EHRs [9]. From one side, it is necessary to make compatible data exchange protocols and messages between the separate components of these systems. From the other side, it is necessary to regulate the health services provided, especially when the patient moves from one place to other.

These issues are highly topical for Bulgaria, in view of the fact that clinical paths for remote monitoring of the patients in hospitals or similar activities for the general practitioners and medical centers still are not envisaged.

III. PHS Existing Standards

According to [9] "Interoperability in e-Health systems is important for delivering quality healthcare and reducing healthcare costs. Some of the important use cases include: coordinating the care of chronic patients by enabling the co-operation of many different e-Health systems such as Electronic Health Record Systems, Personal Health Record Systems and wireless medical sensor devices; enabling secondary use of EHRs for clinical research; being able to share life long EHRs among different healthcare providers".

On Figure 2 [10] the interoperability framework of PHS and other systems and structures within the e-Health domain is shown.

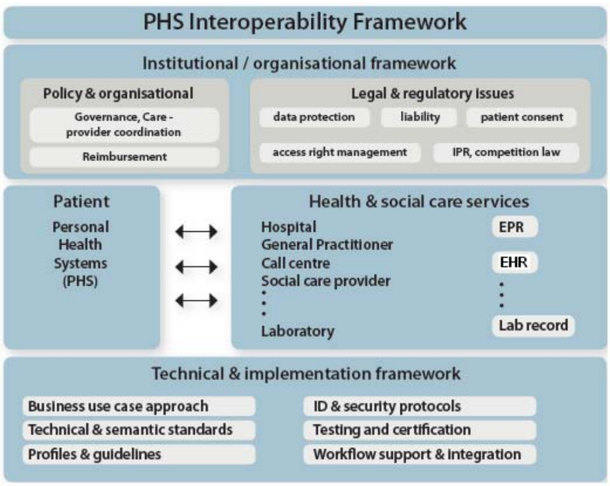

Fig.2. Interoperability framework of PHS with other e-Health systems

The characteristics of PHS are similar with these of heterogeneous distributed systems. The main tasks in their development are to achieve compatibility between separate components as well as to assure universal and smooth exchange of information between tiers in the system architecture. These issues trace the path and put the emphasis on the development of common standards for PHS.

In the last decade several projects have been lunched for development of e-Health standards with the idea to allow much better compatibility between PHSs, PHRs systems and EHRs systems. The efforts and activities ware directed to the following three major areas:

1. Applying PHS devices for measurement of vital data and personal activities;
2. Collecting and converting these data via a data hub which may be in the home or mobile;
3. Analyzing the data provided and acting upon the results by health service providers.

One of these research projects funded by the EC in 7th Framework Programme is 'SmartPersonalHealth' [11]. Main partners in this project are: Continua Health Alliance (CHA), Integrating the Healthcare Enterprise (IHE) and European Telecommunications Standards Institute (ETSI) [10, 11]. The work was based on the basic scenario in PHSs and the patient data are transferred from personal devices through a data hub (home gateway) to health services systems, e.g. electronic patient record, electronic medical record, a hospital information system or a General Practitioner patient system as illustrated on Fig. 3[10].

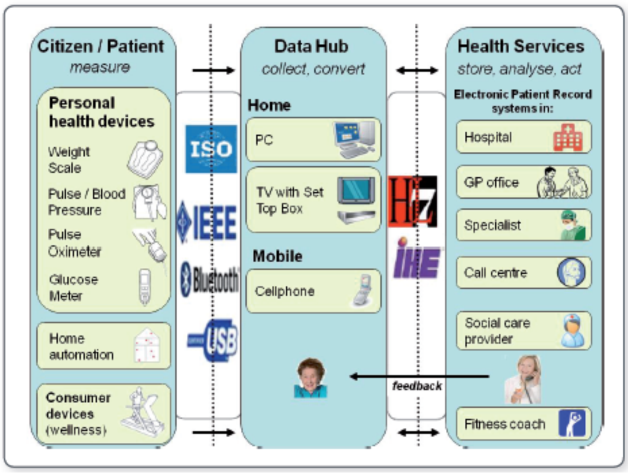

Fig. 3. Examples of personal devices and data exchange in PHS-based healthcare services

In the development of the project the e-Health standards HL7, IEEE 11073 and IHE are used [11].

- HL7 (Health Level Seven) defines a standard for exchange of medical, financial and administrative information between HIS, clinical laboratories, enterprise and pharmacy systems;
- IEEE 11073 (Medical Information Bus - MIB) standardize the physical and transport characteristics of communication between medical devices for providing of plug and play interoperability at the point of care. It facilitates the exchange of medical data acquired by patient connected medical devices.
- IHE (Integrating the Healthcare Enterprise) within the scope of the "Device Enterprise Communication (DEC)" Profile [3], provided a mapping of the IEEE 11073 Domain Information Model to HL7 version 2.5 Message format.

In order to standardized the process of measurement and transmitting data from personal health devices to the Data hub the standard IEEE 11073 is used with additional specifications of protocols for every bio-sensor. On Figure 4 [11] the Continua Health Alliance device connectivity standards are presented.

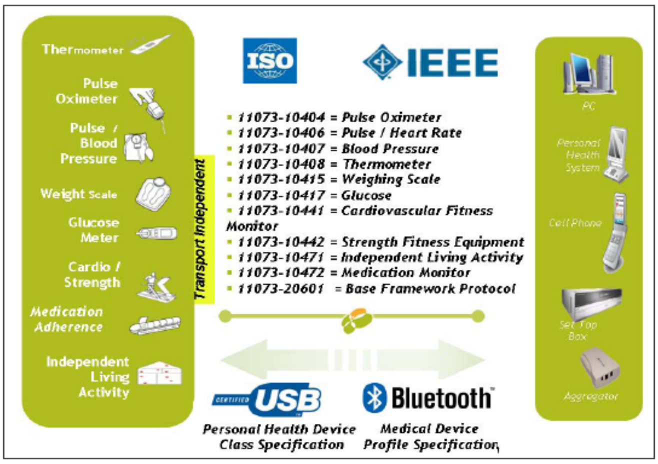

Fig. 4. Continua device connectivity standards

The lower level protocol standards for communication are constrained to USB and Bluetooth. In order to optimize the exchange of information in the personal area network interface, the ISO/IEEE 11073-20601 standard version 1.0 Personal Health Device Communication is selected. In this way the interoperability between the devices and Data hub (gateway) is achieved.

On the contrary, it is difficult to achieve the interoperability between Data hub and health services provider because the producers of PHSs and personal health devices usually are not providers of PHRs and EHRs systems [10, 11]. To facilitate this, a messaging standard supported by IHE that certify electronic health record systems was chosen (IHE's Cross-Enterprise Document Reliable Interchange (XDR) profile). To facilitate the accurate transfer of both coded patient results from personal health devices and textual summary results from patient caregivers, the HL7 Personal Healthcare Monitoring Report document format standard was chosen. This standard is close to the widely used Continuity of Care Document (CCD) standard with specific changes to accommodate device data monitoring.

General conclusion is drawn that IHE/Continua standards, from a technical point of view, provide solid and proven tools to build a modern PHS and PHRs system [5].

The main disadvantages of the device connectivity standards, developed in the frame of SmartPersonalHealth project and Continua Health Alliance, are that they are not free and comprise only USB and wireless interfaces Bluetooth and ZigBee [10,11]. Thus the application domain is restricted mainly to health monitoring in hospitals and hospices. As well, the new standard IEEE 802.15.6 directed to wireless body area networks (WBAN) divided into medical and non-medical applications [12] is not covered.

Alternative approach is employed in development of the Tele-health monitoring system for Ambient Assistant Leaving [13]. In this system using Bluetooth wireless interface the data from bio-medical sensors are send to Smart phone, which play the role of Home gateway. The Smart phone performs initial data processing, filtration and normalization of measured physiological parameters, and finally converts the data in XML format. As it is shown on Fig. 5 [13] after local storage the data are transmitted to the server of Web-based Tele-health service system which is responsible for receiving data uploaded by measurement devices, re-processing and saving the data to the corresponding DataBase location. For health management and tele-care services, the server enables the users, the families, and the healthcare providing unit access to the users' physiological conditions at any time through the Internet using personal computers or smart devices.

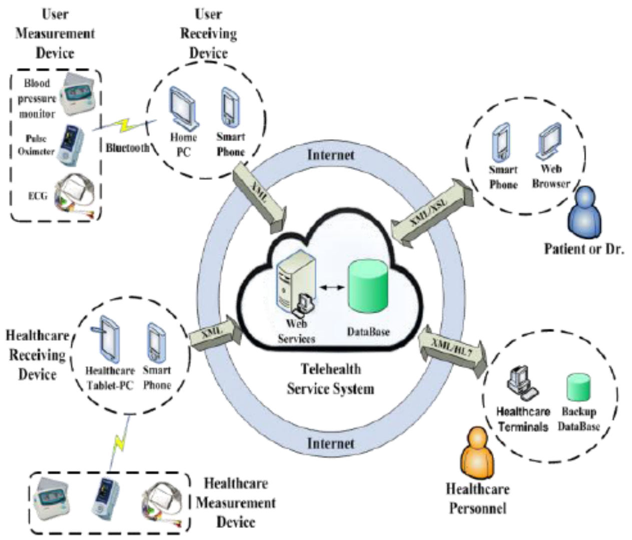

Fig. 5. Tele-health XML/HL7 systems

EHRs are transformed into XML format by obtaining the required information from the Tele-health Service DataBase, and the information is converted into a uniform standard XML data through XML/XSL. The output of the standard information formats can be divided into two types: EHRs of the HL7 format, and XML format defined by HIS. As shown on Fig. 6, the self-defined XML format is used for data transmission and information exchange.

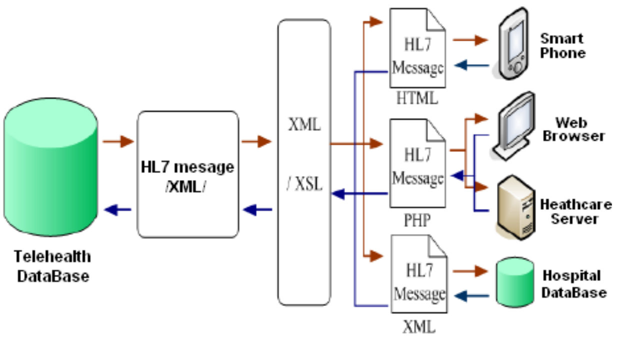

Fig. 6. The transmission and transformation of information

In this way the information is converted into a format that conforms to the HL7 standard via XML, and therefore can exchange messages with various independent hospital information systems.

Similar approach is employed in development of Home Healthcare Monitoring System (HHMS) [14]. In this project the PHS comprises from the one side a Home Healthcare Monitoring System which includes WBAN and home gateway. HHMS supports patients' daily healthcare and their quality of life by collecting useful medical and daily routine information. From the other side is the tier of medical servers represented by Hospital Management Information System (HMIS). HMISs are compliant to different healthcare standards therefore require data in standardized format. In order to solve the problem with the interoperability on the data level for information exchange among HHMS and different HMISs a mediator represented by Interoperability Mediation System (IMS) is proposed [14]. The Interoperability Mediation System behaves as a bridge between HHMS and HMIS and its working model is presented on Fig. 7. HHMS collects information in raw sensory format and stores it in XML format while HMIS follows standard structure of information based on its compliancy with the two healthcare standards - Health Level Seven Clinical Document Architecture (HL7 CDA) and openEHR. The HL7 CDA is a document markup standard that specifies the structure and semantics of "clinical documents" for the purpose of exchange, while openEHR is an open standard that describes the management and storage, retrieval and exchange of health data in EHRs. Both standards concern presentation of information in EHRs systems with specific protocols and data formats. By interoperability service of IMS sensors information in XML form is converted to HL7 CDA and openEHR instances and afterwards communicated to HMISs.

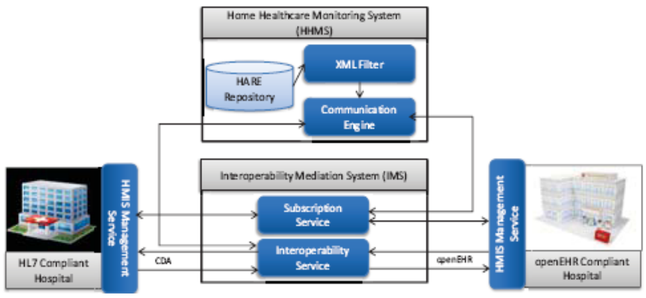

Fig. 7. IMS Working Model [14].

In this overview of the projects addressing e-Health standards used for implementation of Personal Healthcare Systems two main approaches for achieving compatibility between components and standards, and interoperability on the technical level of data formats and transmission protocols are presented. The first approach deals with the development of specifications of standards and protocols addressing WBAN tier from one side, and the interaction and information exchange between WBSN and second tier (Home gateway) from the other side. The final goal is to have common standards for producers and users of bio-medical sensors and devices as well standardization of information in PHS and EHRs systems. In this case the proposed specifications and standards by Continua Health

Alliance for compatibility between the first two tiers and the medical servers tier are the most complete.

The second approach does not deal with the standardization in the first two tiers of PHS. It allows the development of heterogeneous WBSNs employing different protocols and messages' formats. The compatibility with the standards from the medical servers tier is achieved by means of information transformation through XML. This allows successful realization of data exchange between CIS, HIS and EHRs systems which use different standards for presentation of patient data.

Both approaches employed in the described e-Health projects demonstrate practically achievable compatibility allowing development of efficient PHSs. At the moment, the described approaches for compatibility and standardization of data exchange cover only the area of various e-Health systems which could be pointed is a common drawback. Still, there are no interconnections and integrations with developments as Smart House and Smart City, and developments in the new areas of Internet-based systems for monitoring and intelligent sensor networks as Internet of Things (IoT) and Machine-to-Machine communications (M2M) [15, 16].

IV. Conclusion and Future Work

In this paper the employed approaches for integration of e-Health standards in implementation of Personal Healthcare Systems are discussed. They trace the directions for future research activities in this area.

In general, the realization of PHS and PHR systems in accordance to international standards should be preferred. However, at this point in time the examples show that projects usually need to fulfill some individual local requirements on country or organizational level.

The progress in development of standards in the area of PHSs compatible with the common standards for EHRs, CIS and HIS is the crucial point for complete integration of various e-Health systems.

The new concepts for development of Internet-based systems for monitoring and distributed automation based on IoT and M2M from one side, and integrated systems as Smart House and Smart City from the other, need the development of new complementary standards and approaches comprising and integrating the e-Health domain with them.

Acknowledgments

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References

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

[2] Shopov M., Spasov G., Petrova G., *Architectural models for realization of Web-based Personal Health Systems*, ACM International Conference Proceeding Series; Vol. 433, Proceedings of CompSysTech'09, 2009, pp. III B. 5-1-6, ISBN: 978-1-60558-986-2.

[3] Latre, B., B. Braem, I. Moerman, Ch. Blondia, and P. Demeester, *A survey on wireless body area networks*, Journal of Wireless Networks, vol. 17, no.1, 2011, ISSN: 1022-0038, pp. 1-18.

[4] Movassaghi S., at al, *Wireless Body Area Networks: A Survey*, IEEE Communications Surveys & Tutorials, Vol. 16, No. 3, Third Quarter 2014, ISSN: 1553-877X, pp. 1658-1686.

[5] Urbauer Ph., Sauermann S., Frohner M., Forjan M., Pohn B., Mense A., *Applicability of IHE/Continua components for PHR systems: Learning from experiences*, Elsevier journal of Computers in Biology and Medicine 59 (2015), pp. 186–193, http://dx.doi.org/10.1016/j.compbiomed.2013.12.003.

[6] M. Hanson, H. Powell, A. Barth, K. Ringgenberg, B. Calhoun, J. Aylor, J. Lach. *Body Area Sensor Networks: Challenges and Opportunities*, IEEE Computer Magazine, 2009, pp. 58-65.

[7] Kart, F, G. Miao, L. Moser, P. Melliar-Smith, *A distributed e-Healthcare system based on the Service Oriented Architecture*, IEEE International Conference on Services Computing (SCC 2007), ISBN: 0-7695-2925-9, pp. 652-659.

[8] Shaikh A., at al, *The Role of Service Oriented Architecture in Telemedicine Healthcare System*, IEEE International Conference on VLDB Endowment 2012, Vol. 5, No. 12, ISSN: 2150-8097, pp. 2026-2027.Complex, Intelligent and Software Intensive Systems, 2009, ISBN: 978-0-7695-3575-3, pp. 208-214.

[9] Dogac A., *Interoperability in eHealth Systems*, Proceedings of the 38th International Conference on Very Large Data Bases,

[10] V. Stroetmann, R. Thiel, P. Wilson, M. Romao, C. Parisot, M. Zoric, M. Strübin, K. Stroetmann, *Enabling smart integrated care: Recommendations for fostering greater interoperability of personal health systems*, Continua Health Alliance 2011, http://www.continuaalliance.org/

[11] V. Stroetmann, R. Thie1, K. A. Stroetmann, P. Wilson, M. Romao, M. Strubin, *Understanding the Role of Device Level Interoperability in Promoting Health – Lessons Learned from the Smart Personal Health Project*, IMIA Yearbook of Medical Informatics 2011, pp. 87-91.

[12] Ullah S., Mohaisen M., Alnuem M., *A Review of IEEE 802.15.6 MAC, PHY,and Security Specifications*, International Journal of Distributed Sensor Networks, Volume 2013, Article ID 950704, 12 pages, http://dx.doi.org/10.1155/2013/950704.

[13] Ching-Sung Wang, *The Implementation of a Tele-Homecare System with Service Oriented Architecture and HL7 Message Transmission Standard*, American Journal of Public Health Research, 2013, Vol. 1, No.1, pp. 18-26, DOI:10.12691/ajphr-1-1-3.

[14] Khan WA, Hussain M, Afzal M, Amin MB, Lee S., *Healthcare standards based sensory data exchange for Home Healthcare Monitoring System*, Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EBMC) 2012, ISBN: 978-1-4577-1787-1, pp. 1274 – 1277.

[15] Carlos Pereirap, at al, *Integrating Data and Network Standards into an Interoperable E-Health Solution*, IEEE 16th International Conference on e-Health Networking, Applications and Services (Healthcome), 2014, pp. 99 - 104, DOI: 10.1109/HealthCom.2014.7001821.

[16] Elli Kartsakli, at al, *A Survey on M2M Systems for mHealth: A Wireless Communications Perspective*, Sensors, 14, 2014, ISSN: 1424-8220, pp. 18009-18052.