STREAMLINING THE E-HEALTH ECOSYSTEM FOR AN INTEGRATED MANAGEMENT OF SILVER DIGITAL PATIENTS' PERSONALIZED ASSISTANCE

[1]ADRIANA ALEXANDRU, [2]MARILENA IANCULESCU, [3]COARDOS DORA

[1,2,3] National Institute for Research and Development in Informatics, Bucharest, Romania
E-mail: [1]adriana.alexandru@ici.ro, [2]marilena.ianculescu@ici.ro, [3]dora.coardos@ici.ro

Abstract - Globally, national healthcare systems face the challenges of increasing life expectancy, aging population, new findings in the medical field, and the emergence of new technologies accessible to an increasing number of users. Patients are becoming more interested in integrated health services. They call for broaden transparency and access to personalized healthcare, information on their health status and the most appropriate and accessible health services and, last but not least, they are increasingly demanding in terms of the quality of medical records and services. Daily management of the activities, factors and parameters that influence health status and a permanent link with a healthcare provider lead to avoiding senior patients' hospitalization and institutionalization, and provide personalized assistance of health damage. A silver digital patient is a senior with skills, knowledge, literacy and willingness to use e-Health tools and services for being better informed and more involved in managing his/her health status. The e-Health ecosystem involves the convergence of government, academia, industry and health actions concentrated on the patient and aimed to obtain benefits in terms of improved safety, efficient care, access to treatments, development of integrated care, and adoption of solutions for delivering high quality healthcare. The paper presents some issues concerning the way of increasing e-Health ecosystem efficiency in managing silver digital patients' healthcare. MONISAN project[1] is presented in order to emphasize this approach.

Index Terms - E-Health ecosystem, Internet of Things (IoT), personalized assistance, Silver digital patients.

I. INTRODUCTION

According to the definition of the European Commission, "e-Health is the use of ICT in health products, services and processes combined with organizational change in healthcare systems and new skills, in order to improve health of citizens, efficiency and productivity in healthcare delivery, and the economic and social value of health. E-Health covers the interaction between patients and health-service providers, institution-to-institution transmission of data" [1].

Digital technologies are continuously integrated into health care systems as an additional way to establish an effective patient relationship and to support preventive and proactive medicine. Health professionals have more and more effective digital devices and technologies that offer the ability to share medical data with remote experts, access to a huge number of data and information and, last but not least, provide ways to complex processing of these. The therapeutic protocols are streamlined, the waiting time is shortened until a medical decision is taken, the financial resources of doctors, clinics and patients are saved. Digital health proved to be the key market for manufacturers of new IoT (Internet of Things) devices. Google, Apple and Microsoft giants are launching their own platforms to integrate and analyze data relevant to the health of their owner. Finally, the whole health systems will be digitized, cloud-loaded and available on all connected devices. Technological advances must be complemented by a paradigm shift. Digital e-Health ecosystems are one of the paradigms that can better integrate the technical, but also medical, economic and social complexities of digital Health domain. The digital health ecosystem has to reflect the health system and we must study the virtualized concepts of the real world, such as treatment processes understood and implemented in digital. This adds new valences to the concept of digital health, with software developers for medicine being able to use more efficiently the data gathered from the real world. Silver digital patients are the nowadays and future elderly persons with a well-established information technology and health literacy, increasingly aware about the necessity to be broadly informed about possible health services or assistive technology and, more important, empowered to participate, together with the physicians, in the management of their own health status. The present paper highlights the challenges in the personalized assistance in the healthcare domain brought by the growing number of the elderly patients with digital competences. The opportunities of an integrated management inside the e-Health ecosystem are emphasized in line with the supporting current technologies. An on-going research project – MONISAN – is presented in order to demonstrate the efficiency of a patient-centered solution inside the e-Health ecosystem.

II. SILVER DIGITAL PATIENTS AND NEEDS FOR PERSONALIZED ASSISTANCE

The dramatically increase in the pervasiveness of chronic illness in Europe leads to a growing number of people (about 50 million) suffering from many chronic or multimodal diseases, of which 60% are people aged 65 and over [2]. The population is aging globally, people aged 65 and over rising from 17% to 30% of the population, and hose aged 80 and over rising from 5% to 12%. Correlated to the fact that the average life expectancy is higher, it is estimated that the incidence of chronic and degenerative diseases will be increasing and will be reflected in the destabilization of the current care medical systems. All these will have impact on public spending for long-term care. These trends have driven interest in the use of advanced healthcare information systems and e-Health applications to improve care availability while reducing overall costs [3].

Considering the global aging of the population, the rising demand for material and financial resources in the health and social systems, and the increasing accountability of patients to their own health, it has become necessary to implement a new patient-centered health model based on a clear identification of the specific needs, living conditions and life experiences of a particular patient, the real communication between health professionals and the patients involvement in managing their own health.

A silver digital patient can be defined as an older patient that has already integrated eHealth applications and services in his/her everyday life, has become comfortable in using them, and. has an appropriate level of health and IT literacy.

The silver digital patient has the following demands regarding e-Health tools and device [4]:

- To have 24h/7days access to services and information provided by eHealth tools;
- To provide elderly specific facilities such as: design for avoiding the digital-divide, warns in case of critical situations, and access to audio-visual tools that may help silver patients with poor eHealth literacy;
- To collect their own health data in real time (using wearable technology) and to send them to their physician;
- To strengthen the patient-physician communication;
- To obtain accurate and reliable information about health status in order to facilitate a proactive management of it.

National Voices (an organization that supports patients' control over their own health and care) has defined in 2017 five key issues for patient-centered and personalized care [5]:

- Information is the basis for patient involvement in health management, care and medical support. Personalized information is the first step towards "customization";
- Communication between patients and healthcare providers is the main way in which information is transmitted, discussed and adapted, and must take place in both directions;
- Patients participate in decision-making, becoming empowered, responsible and having the opportunity to impose their own values and preferences;
- Personalized planning of health care services allows patients to consider the future stages of their own health care, treatment, access to health services and to control them as much as possible;
- Coordination of medical services for tailoring the care and assistance to the needs of patients and caregivers. The provided services must be centralized and complementary for delivering the benefits and maximum outcomes for the patients.

III. E-HEALTH ECOSYSTEM

The health ecosystem is defined as "a network of a multitude of agents: care providers (physicians, nurses, pharmacists, and other health professionals), health suppliers, together with their organizations and information systems, care consumers, plus the socio-economic environment and including the health institutional and regulatory framework" [6**]**.

A digital health ecosystem transposes the concepts and mechanisms of the natural ecosystems to the digital world. It can be defined as a:

- Self-organized digital infrastructure designed to create a digital network environment for healthcare providers and organizations, to support cooperation, knowledge sharing, and development of open and adaptive technologies and emerging business models in health care;
- Socio-technical system composed of healthcare organizations, service provider professionals, customers, citizens, and patients, industrial companies providing their products and services, technology-mediated platforms for communication, and infrastructures that in collaboration provide value and services" [7];
- "Network of digital health communities consisting of interconnected, interrelated and interdependent digital health species, including healthcare stakeholders, healthcare institutions and digital healthcare devices situated in a digital health environment, who adopt the best-demonstrated practices that have been proven to be successful, and implementation of those practices through the use of information and communication technologies to monitor and

improve the wellbeing and health of patients, to empower patients in the management of their health and that of their families" [8].

In Fig. 1, a collection of heterogeneous, autonomous agents that reproduce the collaboration of individual physicians and healthcare organizations to solve health issues of citizens inside the health system are presented.

E-Health is a component of digital health and refers to the use of internet and web technologies in the provision of healthcare services delivery [9]. In order to achieve an

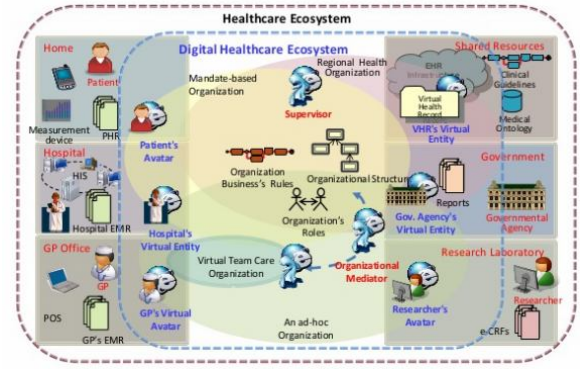


Fig. 1. Healthcare / digital healthcare ecosystems [6]

integral vision of an e-Health ecosystem three main contexts has to be considered (see Fig. 2)

- The human context – requires the participation of physicians, patients, as well as agents that evaluates the physicians' and patients' behaviors;
- The technological context - includes devices and systems used in the processing and delivering of the information required in patients' care (biomedical data, image, video and audio files).
- The economic context – looks at the budgeting aspects of the medical services accomplishment in both private and public health.

The human and technological aspects are related to social and cultural factors. The technologies involved should be user friendly and designed based the requirements of patients and physicians. The relation between human and economic factors includes the analysis of the infrastructure, the elements of the physical context, the quality of life and the living conditions of the population.

IV. INTEGRATED MANAGEMENT FOR E-HEALTH AND SILVER DIGITAL PATIENTS

Health care services are changing radically as a result of the demographic variations, the rise in chronic disease incidence and the increasing financial pressure on health systems to control overall health care spending. In the last decade, digitization initiatives for healthcare have played a key role in expanding the access to quality healthcare services through strategic investment in projects aligned with national e-Health agendas.

Some of the priority areas for future e-health investment opportunities include: interoperable electronic health

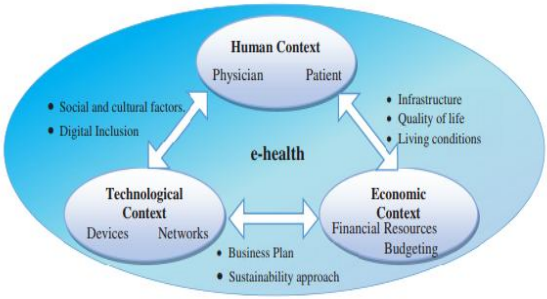


Fig. 2. The e-Health ecosystem [10]

records, cloud computing, migration to web-based applications, intelligent fast track monitoring solutions, e-Prescription, document management, clinical notes, integrated systems of vital signs, mobile applications, data center consolidation; improving clinical compliance and disaster recovery. Transforming paradigm from supplier-centered healthcare to centralized healthcare on patient has brought a significant revolution in how digital health strategies and services are launched. Personalized patient assistance is in line with current trends in international medical and social systems that turn from reactive to preventive, as well as trends in increasing patient accountability to their own health, adapting therapeutic protocols and disease management to specificities and typology an individual. A current trend is the proactive involvement of patients in a better management of their health and a stronger relationship with doctors, i.e. responsibility and empowerment of patients in relation to the medical act. Most of the seniors want to live independent in their own homes as long as possible while receiving care. Nowadays, this is possible due to the use of personal and environmental sensors and ICT-based care devices that include real-time visual and auditory links and relationships between caregivers and users [11]. Home, community and institutional-based services provide physiological monitoring, health management, emergency medical resource referrals, health education instruction, and counseling services for chronic cases, elderly being included. Information platforms facilitate information exchange, integrate healthcare models and information within the healthcare system in order to ensure continuity of care services. E-Health technologies have a significant potential for assisting patients. E-Health applications are used to make patients accountable, to manage the health status, to monitor the vital signs, to provide personalized assistance, and to make individual decisions about health. Integrating the Internet and Cloud Computing into modern medicine applications is a great evolution because large-scale Cloud computing has advantages

such as high reliability, virtualization, high efficiency and scalability. The construction of the public Cloud between hospital and patients can promote resource sharing, cost savings, building a high-performance medical monitoring and management system.

The Internet of Things (IoT) is the network of physical objects or things embedded with electronic devices, software technologies, sensors and network connections, which facilitate the collection and exchange of data to benefit from various services. IoT is a concept of integrating the virtual world into the real-world using Internet technology and mobile devices. Thus, many medical applications can be generated, such as remote health monitoring, health programs, chronic illness and elderly care. This requires different medical devices, sensors, diagnostic and imaging devices that can be seen as smart devices or smart interconnected objects on the network.

The silver digital patients require assistive support at home, using Ambient Assistive Living (AAL) solutions to monitor personal status and environmental conditions. The analysis is performed on a local server or in a Cloud environment (although the latest technology trends couple the two in Edge / Cloud models) because it requires the aggregation of information from different sensors and their correlation. As can be seen in Fig. 3, four entities are involved: sensors (marked with S), possible sources of information (or carriers, C-marked), access points (APs), and the Cloud. In order to explain the diversity of technological choices, we will assume a home-based support using AAL solutions to monitor personal health status and environmental conditions for some residents. The analysis is performed on a local server or in a Cloud environment (although the latest technology trends couple the two in Edge / Cloud models) because it requires the aggregation of information from different sensors and their correlation. Various sensors are used for patients' monitoring. They can be incorporated into residents' environments, leading to the creation of so-called smart environments that integrates environmentally friendly and wearable digital devices, digital devices and technologies capable of delivering services and support for maintaining patients' health, to continuously and remotely monitor daily activities, health and safety. The primary purpose of a smart environment is to create a personalized framework, which allows the patient to continue his life with dignity in a familiar environment while receiving the best health surveillance, treatment and physical assistance that support and / or even optimize daytime living conditions. The support can be reactive, meaning conditional response to dedicated events or proactive, the environment reacting before the occurrence of an event, usually a critical one, especially for elderly people or people with mental or motor deficiencies. In particular, Wireless Mesh Sensor Networks (WMSN) are used to design discrete, interconnected, adaptable, dynamic and intelligent

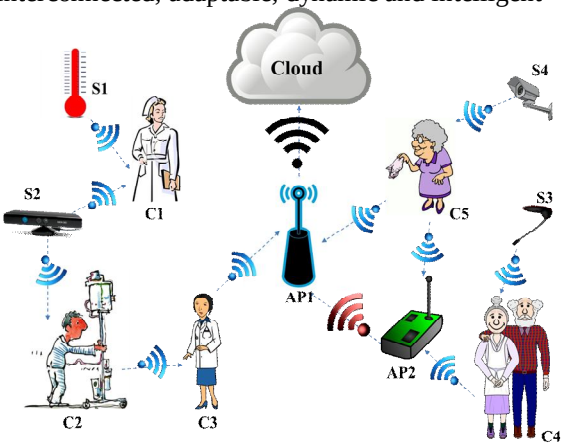


Fig. 3. An AAL scenario for monitoring a residential environment

environments where processing solutions and sensors are embedded in everyday objects (clothes, appliances household, furniture, etc.) [12]. Sensors embedded in such environments are commonly referred to as environmental sensors (as opposed to body sensors), and are used to collect different types of data for detection (monitoring and discovery, reaching the use of assistive learning to dynamically detect various events of interest) the residents' activities and to anticipate their needs in order to maximize the comfort and the quality of life [13]. Some of the most commonly used environmental sensors are summarized in Table 1. In our scenario (Fig. 3), several external sensors can be present (marked with S), such as temperature sensors (S1), motion sensors (S2), microphones (S3) or cameras (S4). These are fixed sensors that are able to collect raw data and send them further.

Internet of Everything (IoE) is a term created by Cisco as a natural evolution of IoT and machine-to-machine (M2M) technology. While M2M communication addresses point-to-point interaction between devices, the Internet of Things also focuses on people (and on devices they carry, such as smartphones or body sensors), while incorporating control systems, sensors and processors for these devices, allowing horizontal communication in an open network of objects [14]. IoE offers the possibility of extracting and analyzing extremely large amounts of data (estimated at about 40 trillion gigabyte of highly unstructured and heterogeneous data), due to the increasing number of people and connected things.

V. MONISAN RESEARCH PROJECT

The project "Innovative Platform for personalized monitoring and assisting in eHealth (MONISAN)" is an on-going research project that will implement an innovative product, which will contribute to the development of services to support patient-centered

improved healthcare. MONISAN project responds to a current and urgent need to improve the range of personalized health services offered to the population through the use of innovative technologies. The technological solutions and services

Table I. Sensors used in Smart Environments

Environmental Sensor	Measurement
Passive Infrared Motion Sensor	Movement
Active Infrared	Movement/People Identification
Radio Frequency Identification	Smart Objects
Pressure	Pressure on mattress, chair, etc.
Smart Tiles	Pressure on floor
Magnetic Switches	Event type Door / Drawer Open / Closed
Ultrasonic	Movement
Camera	Activity
Microphone	Activity

offered ensure the monitoring of the physiological and environmental conditions of the patients and provide advanced mechanisms for visualization, analysis and control of the collected data. The project aims to create a platform to monitor the health of people by using a generic monitoring architecture based on the use of IoT and Cloud technologies. This allows the collection, storage, processing of data as well as the creation of individual and population predictive models. The platform will also provide innovative and personalized, healthcare services based on collected data, as well as services to assist in the development and evaluation of proposed IT solutions. Time Series Analysis is used as a method for predicting the health of the population. This method offers a short, but qualitative characterization of data through a dynamic mathematical model. This model can be used to analyze the system that generated these data and the prediction of its future evolution, including in the event of changes in the environment in which it operates. Information obtained from such an analysis can be used to modify certain factors and variables in the system to control and prevent unwanted phenomena.

MONISAN is designed to be a well-defined agent in an e-Health ecosystem. It aims to provide a reliable support for implementing an integrated management of patients' health status. The preventative, daily or post-hospitalization healthcare approaches confer MONISAN platform an efficient role in providing new types of healthcare services and virtual physician-patients interactions. Taking into consideration the aging of the population, a specific attention is put into implementing features and functions that are appropriate for an easy access of the silver digital patients to online services able to provide and support personalized assistance.

MONISAN has the following specific objectives:

- Advance the status of knowledge in the field of personalized patient monitoring and assistance, by developing, adapting and integrating innovative ICT solutions;
- Advance the state of knowledge in monitoring the health of the population by using time series modeling, simulation and prediction;
- Advance the state of knowledge in assessing the quality and usability of solutions based on mobile, IoT and Cloud technologies in eHealth.
- From the technical and practical point of view, MONISAN has the following specific objectives:
- Design and realize, in a distributed architecture, the MONISAN platform for continuous monitoring of the health status of people with medical conditions (biomedical parameters, environmental parameters, lifestyle and real-time location of the patient etc.);
- Describe the monitoring process and provide automated support for the activities, tasks and methods of the patient monitoring process;
- Develop and implement a set of customized medical assistance services / applications (current treatment, alerts, personalized recommendations, etc.);
- Develop and validate explanatory and predictive models to monitor the health of the population;
- Evaluate the quality and usability of the innovative technological solutions proposed in the project.

The MONISAN Platform integrates advanced methods, procedures and tools and promotes an innovative approach to delivering personalized medical assistance. The following main directions will be the subject of research and of software tools to be developed to achieve the stated objectives, assessing and predicting the health of the population: the mathematical modeling of the phenomenon; the representation of the incidence of typical infectious diseases based on the data available; the mathematical modeling of the phenomenon taking into account external factors (exogenous variables) that influence the data subject of the analysis; the prediction of interest variables and their confidence limits over a fixed time horizon, for the two situations outlined above. The proposed solutions seek to achieve important advantages in relation to the traditional solutions for monitoring and assisting patients, namely: 1) Implementing, integrating and improving existing IoT technologies, 2) Creating a minimally invasive environment for the patient and reducing the cost of care; 3) Facilitating access to services capable of increasing life expectancy and independence.

Healthcare data have a particular importance. Therefore, the data conceptual model of MONISAN platform is organized in three major layers reflecting an optimized succession of data: (a) data collection, (b) data storing, and (c) data processing and using (see Fig 4). Health and environmental data are collected from wearable devices and transferred in cloud. They are analyzed and processed in order to obtain a sustainable support for defining predictive healthcare models, personalized therapeutic protocols, alert triggers in

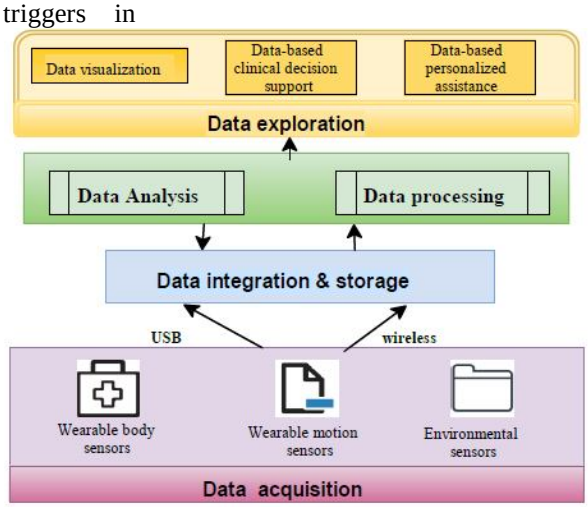


Fig. 4.Data conceptual model of MONISAN platform

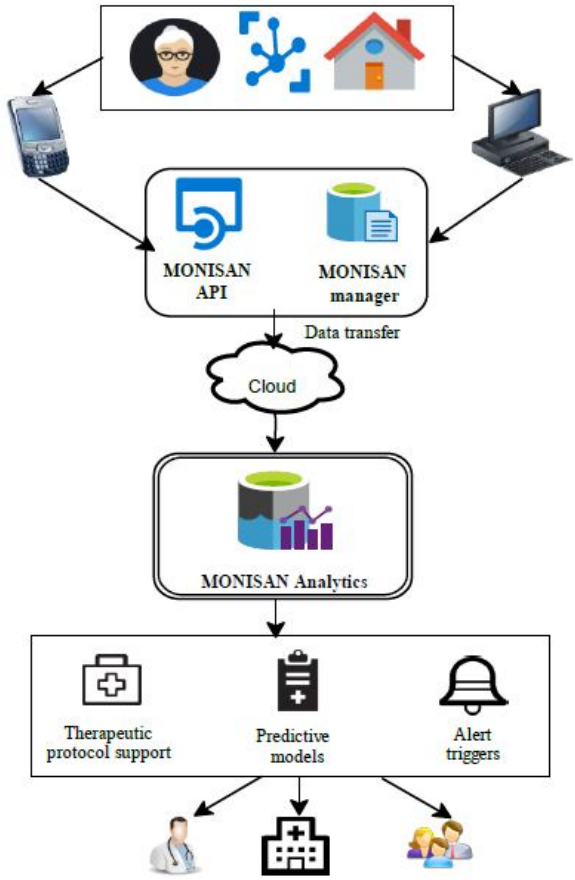


Fig. 5. Workflow of processing phases in MONISAN platform

emergency cases and appropriate assistance for the targeted patient. The comprehensive set of analytics' results is accessible to personal physicians, healthcare entities, family and personal caretakers (see Fig. 5). The potential beneficiaries of the proposed solution in the MONISAN project are: patients with various conditions and age categories; medical and social workers; researchers and IT specialists; decision-makers in the medical system and social assistance. Silver digital patients are seen as a main group of final users due to adapted, accessible and assistive functions and components of MONISAN platform.

CONCLUSIONS

Even if the new technology, research and medical advances have led to an increased life expectancy, the healthcare systems face new challenges to cope the growing issues concerning the complex necessities of taking care of the elderly. Therefore, an integrated approach is compulsory to identify new models of healthcare that imply a better engagement of senior patients in the management of their health status and new e-Health ecosystems able to support improved personalized assistance and facilities for silver digital patients.

REFERENCES

[1] European Commission, "eHealth Action Plan 2012–2020 Innovative healthcare for the 21 st century", COM 736, http://ec.europa.eu/health/ehealth/docs/com_2012_736_en.pdf, 2012.

[2] G. Onder, K. Palmer, R. Navickas, E. Jurevičienė, F. Mammarella, M. Strandzheva, P. Mannucci, S. Pecorelli, and A. Marengoni, „Time to face the challenge of multimorbidity: a European perspective from the joint action on chronic diseases and promoting healthy ageing across the life cycle", European Journal of Internal Medicine, vol. 26, no. 3, pp. 57-59, 2015.

[3] H. Y. Kao, C. W. Wei, M. C. Yu, T. Y. Liang, W. H. Wu, and Y. J. Wu, "Integrating a mobile health applications for self-management to enhance Telecare system", Telematics and Informatics, vol. 35(, no. 4, pp. 815-825, 2018.

[4] M. Ianculescu, and A. Alexandru, "Silver digital patient, a new emerging stakeholder in current healthcare. ProActiveAgeing: a case study", Studies in Informatics and Control, vol 25, no. 4, pp. 461-468, 2016.

[5] S. Hutchinson, "Person-centered care in 2017- Evidence from service users", National Voices' Report, https://www. nationalvoices.org.uk/sites/default/files/public/publications/person-centred_care_in_2017_-_national_voices.pdf, 2017.

[6] L.D. Serbanati, F.L. Ricci, G. Mercurio, and A. Vasilateanu, "Steps towards a digital health ecosystem", Journal of biomedical informatics, vol. 44, no. 4, pp. 621-636, 2011.

[7] VIMARLUND, Vivian. E-Health Two-Sided Markets: Implementation and Business Models. Academic Press, 2016

[8] Iyawa, G. E., Herselman, M., & Botha, A. Digital health innovation ecosystems: From systematic literature review to conceptual framework. Procedia Computer Science, 100, 244-252, 2016.

[9] S.T. Klear. http://es.klear.com/profile/timstraughan.

[10] V.A. Rojas-Mendizabal, A. Serrano-Santoyo, R. Conte-Galvan and A. Gomez-Gonzalez, "Toward a model for Quality of Experience and Quality of Service in e-Health ecosystems", Procedia Technology, vol. 9, pp. 968 – 974, 2013.

[11] D. Barrett, J. Thorpe and N. Goodwin, "Examining perspectives on telecare: factors influencing adoption, implementation, and usage", Med Device Evid Res vol. 8, pp. 11–19, 2015.; J.-C.

Huang, "Innovative health care delivery system—A questionnaire survey to evaluate the influence of behavioral factors on individuals' acceptance of telecare", Comput. Biol. Med., 2013.

[12] D. He, C. Chen, S. Chan, J. Bu, and A.V. Vasilakos, "ReTrust: Attack-resistant and lightweight trust management for medical sensor networks", IEEE transactions on information technology in biomedicine, vol. 16, no. 4, pp. 623-632, 2012.

[13] E.J. Pauwels, A.S. Salah and R. Tavenard, "Sensor networks for ambient intelligence", Multimedia Signal Processing 2007, MMSP 2007, IEEE 9th Workshop on. IEEE, 2007.

[14] J.A. Jaiswal, "IoE vs. IoT vs. M2M: What's the Difference and Does It Matter?", http://blog.aeris.com/ioe-vs.-iot-vs.-m2m-what -s-the-difference-and-does-it-matter, 2015.

★★★