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Internet of Health Things as a Win-Win Solution for Mitigating the Paradigm Shift inside Senior Patient-Physician Shared Health Management

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***Abstract*—**Internet of Health Things (IoHT) has already proved to be a persuasive means to support a proper assessment of the living conditions by collecting a huge variety of data. For a customized health management of a senior patient, IoHT provides the capacity to build a dynamic solution for sustaining the shift inside the patient-physician relationship by allowing a real-time and continuous remote monitoring of the health status, well-being, safety and activities of the senior, especially in a non-clinical environment. Thus, is created a win-win solution in which both the patient and the physician enhance their involvement and shared decision-making, with significant outcomes. Health monitoring systems in smart environments are becoming a viable alternative to traditional healthcare solutions. The ongoing "Non-invasive monitoring and health assessment of the elderly in a smart environment (RO-SmartAgeing)" project aims to demonstrate that the existence of complete and accurate information is critical for assessing the health condition of the seniors, improving wellbeing and quality of life in relation to health. The researches performed inside the project aim to highlight how the management of IoHT devices connected to the RO-SmartAgeing platform in a secure way by using a role-based access control system, can allow the physicians to provide health services at a high level of efficiency and accessibility, which were previously only available in hospitals. The project aims to identify deficient aspects in the provision of health services tailored to a senior patient's specificity and to offer a more comprehensive perspective of proactive and preventive medical acts.

***Keywords*—**Health management, Internet of Health Things, remote monitoring, senior patient.

I. Introduction

A combination of factors like increasing worldwide ageing population, persons living to a very old age, the almost critical shortage of formal or informal caretakers, the growing demands of financial resources for healthcare systems – as elderly's care comprises a substantial percent of expenditure – has imposed the need to identify new ways to deliver healthcare services for senior patients. These patients have lately become better aware about their particular distinctiveness, about their options to be taken care of, with increased health and IT literacy and last, but not least, more interested in being directly involved in their own health management. On the other side, the physicians have acknowledged the empowerment of their senior patients and they have started to share a new type of relationship with them, based on the increasing use of innovative digital technologies.

This paper aims to present "non-invasive monitoring and health assessment of the elderly in a smart environment (RO-SmartAgeing)" project as a proposed conceptual solution for an optimized management of senior patients healthcare, with a focus on the necessity complete and accurate information for evaluating their health condition, enhancing their wellbeing and quality of life.

The remains of the paper are organized as: The impact of global ageing on healthcare systems is evaluated in Section II of the paper. A customized health management approach based on remote health monitoring, smart environment and IoHT are introduced in Section III of the paper. The potential of IoHT to be a win-win solution for both the patient and the physician is emphasized. A proposed conceptual solution for an optimized management of healthcare data is presented in Section IV. The solution is being developed inside RO-SmartAgeing project which is briefly analyzed. Section V presents the conclusions of the presented approaches.

II. Impact of Global Ageing on Healthcare Systems

A. Ageing Population

In the last few decades, there is also an increased life expectancy. The number of persons aged 80 years or over is projected to triple, from 143 million in 2019 to 426 million in 2050. This leads to increased healthcare costs due to an aging population. In Romania, the population over 65 years is expected to be, in 2050, 29.9% of the total population, and those over 80 years at 9.9% [1].

Population ageing is also associated with increases of chronic diseases, disability and involuntary injury [2].

The future of the aging population will be improved by several digital technologies, which are already used in the healthcare and that will become more prevalent in the coming years aiming to reduce costs [3].

B. Empowered Senior Patients with Improved Health and IT Literacy

The continuous evolution of digital technology supports the increasing empowerment and demands of the senior citizens, providing, at the same time, opportunities for identifying new ways for sustaining the ageing population.

Future challenges can only be overcome by accelerating the use of new smart emerging ICT technologies and solutions

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that enhance the capacity of the older people to handle the complex contextual health and wellbeing information and data available as well as the outcomes of the advanced analytics performed on it, to solve more complex problems of everyday life, and to have a better interconnectivity with medical staff, family and friends provided by the IoT capabilities.

C.A New Approach Regarding the Health Management that Leads to Paradigm Shift

In order to obtain better results in ageing population healthcare, physicians need improved access to senior's data and information. The new emerging technologies (new sensors/wearable sensors, healthcare management platforms, mobile devices, etc.) create the necessary framework for collaboration between the medical staff involved in senior care, as well as the patient and his family. Thus, it is possible to provide a senior-centered care or even a proactive one.

Elderly people are better aware about the need to involve themselves in their own health management. Based on the knowledge (even if it is a limited one) in using IT devices/ gadgets, they are able to obtain information, communicate with their families and friends and to send alarms to medical staff if they have health related problems, etc. Thus, it results in shared health management with benefits for everybody, including the healthcare systems. The role of ITC in achieving such results is compulsory for proving information, data, and interconnection between people.

III. A Customized Health Management Enabled by IoHT

A. Remote Health Monitoring

The remote health monitoring of older patients consists in the procedures deployed by using age-friendly technology in hospitals and in non-clinical environments such as homes. Thus, the quality of life of patients can be improved by a better management of the age-related degenerative factors that might increase the co-morbidities and dysfunctionalities of the seniors [4]. Due to a real-time surveillance of seniors' health parameters and daily activities by using IoT devices, it is possible to predict impairments, and to trigger alerts and emergency reactions based on the best appropriate data-based information provided both to medical staff and to patient. Other important benefits of remote monitoring of the health parameters of the senior patients are the reduction of the clinician time and of hospital costs, as well as delay in institutionalization in hospitals or nursing homes, and improvement of the quality of care [5].

B. Smart Environment

A smart environment is "a small world where different kinds of smart device are continuously working to make inhabitants' lives more comfortable" [6]. The **smart**ness of this **environment** is a product of interaction of sensors, actuators, displays, and computational elements, which are "generally embedded seamlessly in everyday objects and networked to each other and beyond (the internet, usually)" [7]. Basically, this environment includes a user interface (smartphones, tablets, or computers), biosensors/wearable sensors for information acquisition, actuators, Internet connectivity, middleware or wireless device communication, and intelligent devices for the provision of enhanced services. A smart environment is performed with the integration of IoT, mobile computing and cloud storage, and a data communication infrastructure.

Smart environments may provide an enhanced environment where a user can "feel at home" while receiving a special care by the use of assistive technologies with positive impacts on health and quality of life for elderly citizens [8]

C. Internet of Things (IoT)

The Internet of Things (IoT) is managing smart objects, which gather information and data from different types of sensors, store data, take autonomous decisions, perform appropriate actions based on actuators, coordinate functions, and share information taking into consideration the connectivity among nodes.

The expectations for the number "things" connected to the Internet by 2020 varies: 25 billion (Gartner), 50 billion (Cisco), and 28 billion (Harvard Business Review) [9].

D. IoHT

The IoHT is "an IoT-based solution that includes a network architecture that allows the connection between a patient and healthcare facilities" [5]. IoT-based e-Health systems provide great benefits to healthcare and well-being being used for monitoring vital signs (pulse, oxygen in blood, body temperature, blood pressure, patient position, etc.) based on biomedical sensors/wearable sensors. The patients' data are collected by sensors and processed by applications that provide access to data and results to medical staff/patients through computers, smart phones, smart watches or embedded devices [10]. IoHT can contribute to the improvement of medical in case of senior patients care, remote monitoring of chronic diseases and management of the private life of an elderly individual.

The most potentially impactful change is home care. The most adults age 65 and older want to stay in their own home, a comfortable and known environment, and community as they age. As a result of providing appropriate homecare, important cost savings can be obtained due to the decreasing or avoiding of expenditures associated with hospitalizations or institutionalization in nursing homes.

E. IoHT as a Win-Win Solution

IoHT has brought large opportunities for mitigating the relationship between the patients and their physicians regarding the health management. The shift of the current type of relation towards a shared one gains a crucial importance in the context of the continuous increasing number of the ageing population due to the empowering of the better-informed senior patients, of the growing scarcity of the caretakers and the translation of the reactive healthcare services to proactive ones.

IoHT facilitate the access to permanent updated data which mainly allows a remote monitoring of the health status of the

patient. Considering the benefits of avoiding as much as possible the institutionalization of the senior in healthcare units, the broader use of IoHT for supporting a familiar age-friendly smart environment is attractive for *seniors* (which perceive it as a support for extending their independent, active, healthy and higher qualitative life), for *physicians* (which can provide improved personalized healthcare service delivery to increased number of patients) and also for the *health authorities* (that are interested in controlling the age-related expenditures and the quality of the healthcare provision).

Among the benefits brought by enlarging the practical usage of IoHT are:

- *a higher degree of seniors' acceptance of the wearable devices* instead of other types of medical devices, as they are non-intrusive, user-friendly, or even less harmful;
- *an improved seniors' engagement in their own healthcare management*, as they can have access to the evolution of their health parameters, and consequently, to a personalized therapeutic protocol;
- *a better diagnosis followed by improved senior patients' outcomes*, as physicians have real-time access to their patients' data so they can take faster and more appropriate healthcare decisions. Furthermore, the medical errors are also eliminated or, at least diminished;
- *an improved access to healthcare providers for non-transportable seniors or for those living in isolated or rural areas;*
- *a more efficient and enlarged access to huge amount of a great variety of health data* based on the IoHT's capabilities of collecting and transmitting it;
- *a growing number of the patients that a physician can properly take care*, which becomes more and more important as there is already a shortage in health specialists' number with adequate age-related skills;
- *a decreasing cost both at the healthcare and social systems, but also at the senior patient's level* due to the improved outcomes of the treatments, the elimination of unnecessary medical evaluations or admissions in healthcare units;
- *an improved workflow in the healthcare supply management* as the healthcare specialists from different departments or even other healthcare units can better coordinate their activities targeting a patient due to the real-time health-related seniors' data and information.

IV. Ro-SmartAgeing, an Illustrative Example For a Shared Management

A. RO-SmartAgeing System

"*Non-invasive monitoring and health assessment of the elderly in a smart environment (RO-SmartAgeing)*" is an is an ongoing project which main objective is to sustain the delivery of more advanced elderly-centered healthcare services by facilitating the shift of medical practice to prevention and personalized assistance.

The main foreseen outcomes of the project are:

- the monitoring of the current health status of the patient for establishing a continuous updated senior's profile;
- the elaboration of a model for tracking the locomotor decline and fall prevention;
- the evaluation of senior's lifestyle and personal safety by monitoring his daily activities and habits;
- alarm trigger functions if an abnormal health parameter is measured or an unexpected potential harmful event occurs;
- an improved facility for the senior's physician for sustaining an earlier diagnosis due to the periodically remote evaluation of the senior's current health status.

The Ro-SmartAgeing system is designed as a multi-dimensional remote health monitoring system based on IoHT, and takes into consideration the real-time processing of a fast-rising amount of data, due to the fact that both health and ambient parameters are collected at a high rate with considerable frequency.

B. Proposed Architecture of RO-SmartAgeing System

In order to achieve all the above presented outcomes of the project, a functional architecture is being assessed and is presented in Fig. 1.

A microservice-based approach has been applied for designing the architecture due to its benefits: increased scalability, fault tolerance, flexibility, maintainability, testability, interoperability, and deployability.

In contrast with the monolithic architecture, a microservice one structures the application on a number of loosely coupled components that have unique associated services. Each service can be independently debugged, upgraded or replaced without interrupting the application's functionality on the whole or it can be associated to other appropriate devices.

The layers of the architecture are presented as follows:

- *Data Acquisition Layer*: health and ambient data is gathered through IoHT, smart ambient sensors or diverse healthcare devices. Health data can also be occasionally provided by access to Personal Health Records. IoHT associated microservices, besides their original functionality, have the potential to be used by other types of IoHT, if necessary.
- *Communication Layer*: is responsible to transferring the collected data. Dedicated servers along with edge/fog-based microservices provide that certain functions like data management, primary data processing or emergency trigger to be performed inside this level. Modern communication technologies such as API gateways, Bluetooth, and 4G are used for making data available to the other layers.
- *Service Layer*: contains specific cloud-based microservices. A database for microservices facilitates a long-term storage in related databases. Analytic microservices and decision support capabilities provides the required complex computing.
- *Application Layer*: provides various specialized or smart healthcare support applications, report generation or regular notifications for a proper monitoring of the patient.

- *Presentation Layer*: comprises presentation microservices able to provide personalized user interfaces for distinctive users (physicians, caretakers, senior patients or their family), for which the smart services, applications and healthcare solutions are designed.
- *Security Layer*: is based on microservices for specific tasks as access control, integrity or encryption/decryption that are compulsory along all the layers.

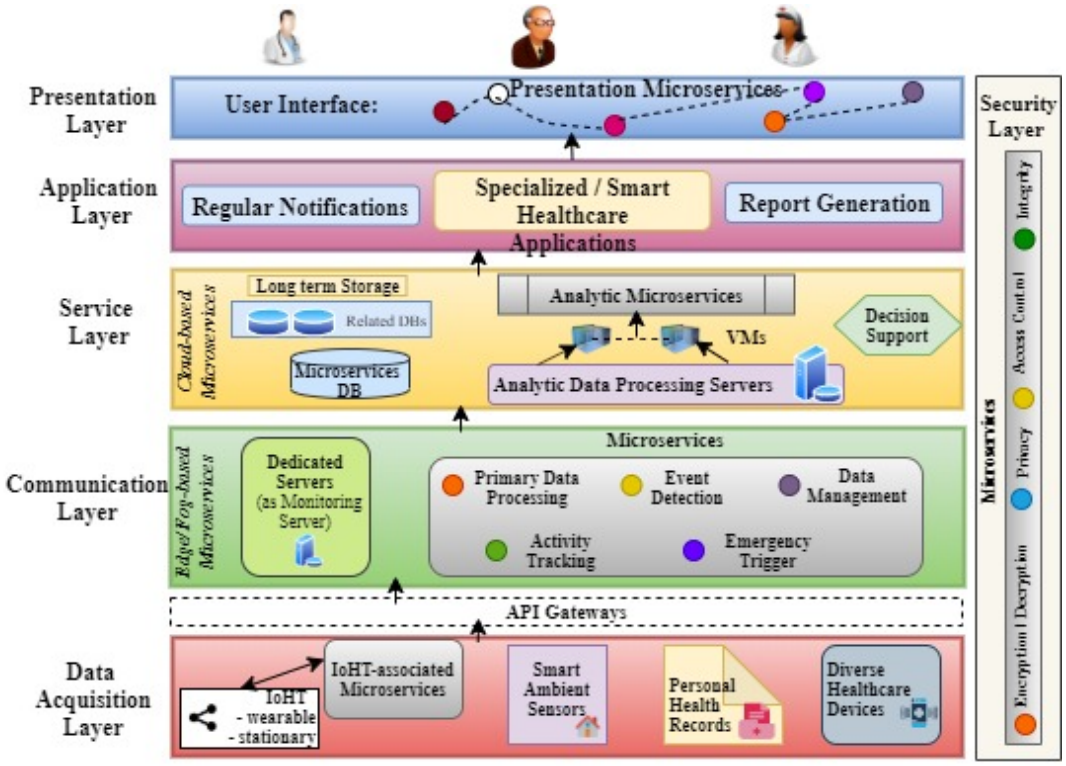

Fig. 1 Proposed functional architecture of RO-SmartAgeing system

V. Conclusions

Continuously emerging digital technology, as IoHT, has proved to be able to directly sustain the shift of the nowadays healthcare delivery from a reactive to a proactive one. Furthermore, other vulnerabilities like the raising costs induced by the global ageing of the population, isolated areas or the lack of appropriate decision support for a better diagnosis, can be solved by implementing personalized solutions based on this comprehensive technology. As seniors become more empowered regarding their own health status, with improved IT and health literacy, they are more interested and demanding to be directly involved in their own health management, together with their physicians.

This paper highlighted the potential of IoHT to address many of the issues in healthcare systems that aim to provide improved age-related health services, like the remote monitoring of the seniors. Moreover, IoHT can represent a fundamental element for enlarging the access to personal data and, consequently, a driver for shared health management between the senior patient and the medical practitioners.

To demonstrate the enounced ideas, the proposed RO-SmartAgeing system is briefly presented, together with its functional architecture based on IoHT and microservices for ensuring a better scalability, flexibility and fault isolation.

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