Opportunities of the Internet of Things for Healthcare through Architectural Layers-Architecture and Technologies

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***Abstract* — The Internet of Things for Healthcare (Healthcare-IoT) includes medical sensor devices as new sources of health information, new technologies and applications for remote diagnostics and monitoring of patients, equipment, drugs. Smart services for healthcare, anywhere and anytime, will bring the future of healthcare services, as a new level of healthcare. This paper considers the Healthcare-IoT through architectural layers and observes the users of the healthcare system in the context of a complex healthcare system which is integrated and whose traditional healthcare services need to be expanded with new functionalities of Healthcare-IoT such as sensing, tracking and monitoring, identification, authentication, automatic data collection. The technologies that should enable an IoT solution for healthcare are presented through architectural layers. The new business model and scenario should include valuable information in the existing healthcare services and choose the technologies that best match the desired model. Sensors and sensor networks, as well as new technologies, need to enable smart objects of healthcare to feel and change the environment, implement activities, communicate in real-time and share information. The data collected should be reliable, safe, processed in real time and analyzed, and they should provide a wealth of intelligence for planning, management and decision-making in the healthcare system. Many challenges for Healthcare-IoT, such as the interoperability during the integration with the inherited systems and electronic health records (EHR), need to be resolved. A holistic approach to designing Healthcare-IoT solutions and interdisciplinary knowledge should remove the gap between individual technology solutions and the integrated healthcare system expanded with IoT functionalities.**

I. INTRODUCTION

This paper considers the opportunities for the Internet of Things in Healthcare with an overview of the existing technologies through the architectural layers and the greatest benefits that can be achieved with Healthcare-IoT.

The main problem which needs to be resolved in this paper is to present the structure and behavior of an integrated healthcare system expanded with the new values of the Healthcare- IoT. New services should be incorporated into the traditional healthcare system by using the most efficient technologies.

The Internet of Things (IoT) is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects – such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, etc. – which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals [1].

The phrase "Internet of Things" was coined at the beginning of the 21st century by the MIT Auto-ID Center with special mention to Kevin Ashton (Ashton 2009) [2] and David L. Brock (Brock 2001) [3].

The Internet of Things is a technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields, from wireless sensors to nanotechnology [4].

A successful implementation of IoT solutions requires a suitable infrastructure.

Wireless technologies are arriving in order to ensure the e-health monitoring for patients everywhere and from any given location. Research and development advances in the e-health community include data gathering and transfer of vital information, integration of human machine interface technology into handheld devices, data interoperability and integration with inherited systems and electronic patient records [5].

In the USA, electronic health monitoring has been given the go-ahead by the Federal Communications Commission (FCC). FCC allows the use of allotted frequencies for sensors to control devices wirelessly in the monitoring of health at hospitals and homes, and has also forecast savings [6].

European Space Agency (ESA) has initiated the Digital Video Broadcasting with Return Channel via Satellite (DVB-RCS) [7], technology enabling almost all potential locations - even the most geographically dispersed and isolated ones - to gain access to broadband services using low-cost Satellite Interactive Terminals (SITs). The technology enhanced with the DVB-S2 knowledge is a mature broadband communications technology with comparable implementation and operational costs to the other broadband terrestrial technologies, effectively satisfying the Quality of Service (QoS) requirements of high demanding applications in electronic healthcare [5].

IoT research is faced with the challenges of non-compliance technology in business requirements, as a gap between technology development and business innovation. Many solutions in healthcare are not included in the value chain which reduced their importance and lack of confidence [8].

The problems of the previous research of Healthcare-IoT are the lack of integration of new devices and traditional services. According to WHO [9], the most common result is a noninteroperable abundance of islands ICT. What is necessary is a holistic design that will effectively integrate the scattered devices and technologies into much more valuable services.

This paper is organized into five Sections. After the Introduction, the Section II presents the greatest benefits of Healthcare-IoT which are grouped into tracking and monitoring, identification, authentication, automatic data collection, sensing, and cross-organization integration. The third Section presents integrated Healthcare system extended with IoT for Healthcare through Architectural Layers: Business Layer, Sensor Layer, Network Layer, Services Layer and Application Layer. The Section IV describes the new technologies and communication solutions that will support the development of Healthcare-IoT. The conclusion stresses the importance and opportunities that can be achieved by expanding the traditional services of the integrated health system with new Healthcare-IoT services presented in this paper through architectural layers.

II. Benefits with Healthcare - IoT

While considering the functionalities of Healthcare-IoT, we can come across a number of concepts that also represent the future healthcare services such as pervasive healthcare (pHelath), ubiquitous healthcare (uHealth)[10], mobile healthcare (mHealth) [11], electronic healthcare (eHealth), telehealth, telemedicine.[12]

The treatment of patients only in medical institutions can be redirected to the treatment at home with complete control, which means that chronic patients will have more freedom and a better quality of life, and that hospitals will get more capacity for emergencies. According to [13], in the coming decade, the model of delivery of healthcare services will be transformed from the present hospital-centric, through hospital-home-balanced in 2020, to the final homecentric.

The Internet of things in the domain of health system includes an increasing number of sensors in the global network. The platform for the Internet of things must enable the processing of new data in real time. User domains differ in the definition of service monitoring of vital functions, administration of appropriate medication depending on the vital parameters of users, monitoring and notification of critical situations. IoT platforms facilitate the sharing of such information among experts in the field of medicine, thus allowing the definition of new procedures for the treatment and diagnosis [14].

One of the prominent areas of research and strategic roadmap of the European Commission for Information Society is the Internet of Things [15].

There are many benefits provided by the IoT technologies for the healthcare domain, and the resulting applications can be grouped mostly into: tracking of objects and people (staff and patients), identification and authentication of people, automatic data collection, sensing, cross-organization integration.[16]

Tracking is the function aimed at the identification of a person or object in motion. This includes both real-time positions of tracking, such as the case of patient-flow monitoring, whose purpose is to improve workflow in hospitals, and tracking of motion through choke points, such as access to designated areas. When it comes to assets, tracking is most frequently applied to continuous inventory location tracking (for example for maintenance, availability when needed and monitoring of use), and materials tracking to prevent left-ins during surgery, such as specimens and blood products [17].

Identification and authentication includes patient identification to reduce incidents harmful to patients (such as wrong drug/dose/time/procedure), comprehensive and current electronic medical record maintenance (both in the in- and out-patient settings), and infant identification in hospitals to prevent mismatching. In relation to staff, identification and authentication is most frequently used to grant access and to improve employee morale by addressing patient safety issues. In relation to assets, identification and authentication is predominantly used to meet the requirements of security procedures, to avoid thefts or losses of important instruments and products [17].

Data collection-Automatic data collection and transfer is mostly aimed at reducing form processing time, process automation (including data entry and collection errors), automated care and procedure auditing, and medical inventory management. This function also relates to integrating RFID technology with other health information and clinical application technologies within a facility and with potential expansions of such networks across providers and locations [17].

Sensing-Sensor devices enable function centered on patients, and in particular on diagnosing patient conditions, providing real-time information on patient health indicators. Application domains include different telemedicine solutions, monitoring patient compliance with medication regiment prescriptions, and alerting for patient well-being. In this capacity, sensors can be applied both in in-patient and out-patient care. Heterogeneous wireless access-based remote patient monitoring systems can be deployed to reach the patient everywhere, with multiple wireless [18].

It is possible to single out some additional functionalities of Healtcare-IoT described in the work [19],[20], such as cross-organization integration. Hospital Information Systems (HIS) should be extended with the patient-house, and can be integrated in a large part of the health system that can cover a community, city or country.

III. Healthcare-IoT through Architectural Layers

Understanding of the IoT is possible through marking the common aspects and new technologies in architectural layers, in order to create complex intelligent solutions in the field of healthcare. New objects are becoming part of the digital process for the realization of remote smart services in the health system.

Known Research Projects which provide different aspects of IoT architecture are OpenIoT [21], IoT @ Work [22], iCore [23], SENSEI [24], PECES [25], SemSorGrid4Env [26], U2IoT [27].

On Fig.1 is presented integrated Healthcare system extended with IoT for Healthcare which consists of several layers: Business Layer, Sensor Layer, Network Layer, Service Layer, Application Layer.

Cloud computing for Healthcare-IoT can provide a stable and low cost Infrastructure as a Service (IaaS) that will support the sensors and actuators, such as Platform as a Service (PaaS) for accessing, processing and placing the big quantities of data.

Architectural layers of Healthcare-IoT enable the monitoring of data collection and transfer of vital information from a patient to a doctor, as well as the tracking of all the resources of the health system, data interoperability and integration with inherited hospital systems.

A. Business Layer

Business Layer should create a clear business model for new services in healthcare, give objective, functionalities, define business processes, roles and extract the technologies that best suit the required task. Some of the possible scenarios that can be modeled are the cases of remote in-home monitoring of chronically ill patients, response to emergencies, monitoring the recovery of patients after treatment, patients' response to treatment, methods of prevention, monitoring of hospital resources. It is necessary to create a new value chain so that existing services in an integrated traditional health system can expand to new services. Business Layer of IoT Healthcare introduces a new level of healthcare which can be called in-home or anywhere, anytime healthcare.

B. Sensor Layer

The lowest layer should provide a new source of information for healthcare. Numerous sensors could be implemented such as Blood Pressure Sensor (sphygmomanometer), Body Temperature Sensor, Glucometer Sensor, Sensor Electrocardiogram (ECG), Pulse and Oxygen in Blood Sensor (SPO2), Patient Position Sensor (Accelerometer), Airflow Sensor (Breathing), Galvanic Skin Response (GSR). Sensors, actuators, gateways and storage systems have the ability to feel or change their environment. Biomedical Signals should be created with the help of special devices attached to the patient's body or special carriers such as wireless body sensors and on / off-body networks technologies. In line with other multimedia information concentrated around the patient, most applications are based on the data collected from video cameras, microphones, movement and vibration sensors.

According to [5], there are several examples of the use of high-tech clothing as sensors. The LifeShirt System is the first non-invasive, continuous ambulatory monitoring system that can collect data as a cardiopulmonary function and other physiological patient parameters, and correlate them over time. The high tech vest uses optical fibers to detect bullet wounds and monitor the body vital signs during combat conditions. The patient monitoring finger ring sensor measures PPG signals, skin temperature, blood flow, blood constituent concentration and the pulse rate of the patient. The data are encoded for wireless transmission by mapping a numerical value associated with each datum to a pulse emitted after a delay of a specified duration, following a fiducial time. Multiple ring bands and sensor elements may be employed to determine threedimensional dynamic characteristics of arteries and tissues. These data may be transmitted wirelessly for further analysis. At this level, there is limited data processing and data selection to save resources. Data can be processed on different layers and software components provide information or allow the activity of the facilities. Processing large amounts of data can be done in the Cloud where the data can be placed and perform complex processing at the user's request [5].

C. Network Layer

Network Layer should provide a high performance of network infrastructure as a transport medium for IoT data. Healthcare-IoT services and applications make considerable demands such as speed transactional services which can be solved by using several networks with different technologies and protocols, and communication requirements for latency, throughput and security. Wireless technologies have the advantage in the realization of the concept of smart services anywhere and anytime. Unfortunately, there are no perfect wireless protocols (Satellite, Cellular, Wi-Fi, Bluetooth, Zigbee), which depend on the current solutions of heterogeneous health applications. Mobile health systems are developed on WiFi (Wireless Fidelity), GPRS (General Packet Radio Service) and 3G UMTS (Universal Mobile Telecommunications System) networking technologies. The current development of new communication technology improves some of the limitations of the existing wireless technologies and offers solutions such as E-Health via High-Speed Satellite Networks, E-Health via High-Speed Mobile Networks, HSPA (High Speed Packet Access), Personal Area Networks: on-body (wearable) and off-body networks [5].

D. Service Layer

Service Layer need to manage data and services of IoT. Data management is the ability to manage data information flow and provide information in the form of events or contextual data. Some events require later processing at certain periods of time, while other events, such as emergencies, require simultaneous processing. Various analytics tools are used to extract relevant information from a massive amount of raw data, which need to be processed at a much faster rate. In-memory analytics and streaming analytics are forms of analytics in real-time. The business and process rule engines should organize healthcare services through orchestration and choreography.

E. Application Layer

Applications are on the top of the architecture and need to export all the system's functionalities to the final user. Through the use of standard web service protocols and service composition technologies, applications can realize a perfect integration between distributed systems and applications [8]. There are various applications that can be involved in Health-IoT. Tele-medicine applications cover the areas of emergency healthcare, homecare, patient telemonitoring such as tele-cardiology, tele-radiology, tele-pathology, tele-dermatology, tele-ophthalmology, tele-psychiatry and tele-surgery, elderly family member monitoring, continuous patient monitoring, monitoring (smart) pills. These applications enable the provision of prompt and expert medical services in underserved locations, like rural health centers, ambulances, ships, trains, airplanes as well as at homes.

The presented integrated Healthcare system should include new healthcare services in the traditional Healthcare system. Interoperability of devices and services from different suppliers, operational workflow should be solved. Security, privacy and trust must be enforced across the whole dimension of the Healtcare-IoT system. Healthcare-IoT solution should involve the technologies that best match the specified model.

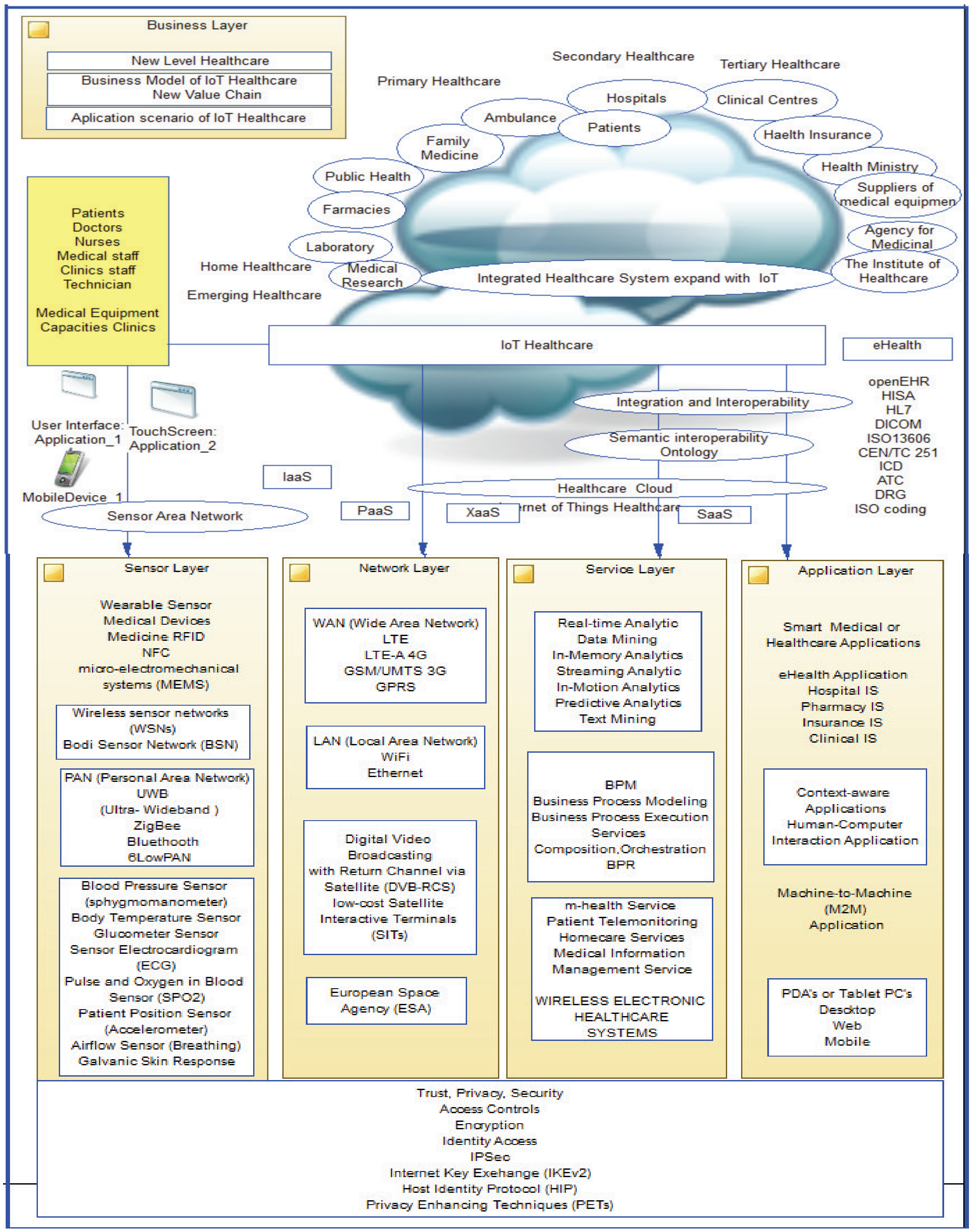

Figure 1. Integrated Healthcare system extended with IoT for Healthcare throught Architectural Layers

IV. Technologies for IoT and communications opportunities

The Internet of Things requires the integration of modern technologies and communications solutions and is a result of synergetic activities in different fields of knowledge, such as telecommunications, informatics, electronics and social science.

Several technology trends will help shape IOT. Here are seven identified macro trends: the miniaturisation of devices, advances in RFID technologies, Internet Protocol version Six (IPv6), improvements in communication throughput and latency, real-time analytics, adoption of cloud technologies and security [12].

Miniaturisation of devices – The size (and cost) of electronic components that are needed to support capabilities such as sensing, tracking and control mechanisms, play a critical role in the widespread adoption of IOT for various industry applications. The progress in the semiconductor industry is spectacular. Due to the decreasing size and cost of technology components, organisations will see greater savings and opportunities in pursuing IOT in the next one to three years.

Radio Frequency Identification (RFID) is a technology of particular importance to IOT since one of the first industrial realisations of IOT, is in the use of RFID technology to track and monitor goods in the logistics and supply chain sector.

Internet Protocol version 6 (IPv6) is the next Internet addressing protocol that is used to replace IPv4. With IPv6, there are approximately 3.4×1038 (340 trillion trillion trillion) unique IPv6 addresses, allowing the Internet to continue to grow and innovate.

Increasing communication throughput and lower latency enhance the infrastructure for the support of data capability and improve network throughput with the addition of General Packet Radio Service (GPRS), Global System for Mobile (GSM), Enhanced Data rates for GSM Evolution (EDGE), Universal Mobile Telecommunications System (UMTS) with High Speed Packet Access (HSPA), Wideband Code Division Multiple Access (WCDMA), Long Term Evolution (LTE). Low latency makes it possible for IOT applications to query or receive quicker updates from sensor devices.

Real-time Analytics – In-memory processing is a form of analytics where detailed data is loaded into the system memory from a variety of data sources. New data are analysed and stored in the system memory to improve the relevance of the analytics content and to augment the speed in decision making. Another form of real-time analytics, such as streaming analytics, uses complex algorithms to instantaneously process streams of event data it receives from one or more sources.

Cloud Computing - Cloud Infrastructure as a Service (IaaS) uses hardware such as sensors and actuators, which can be made available to consumers as cloud resources. Cloud Platform as a Service (PaaS) can provide a platform from which to access IOT data and on which custom IOT applications (or host-acquired IOT applications) can be developed. Cloud Software as a Service (SaaS) can be provided on top of the PaaS solutions to offer the provider's own SaaS platform for specific IOT domains.

Security and Privacy – IPv6 contains IPSec, access control, connectionless integrity, data origin authentication, protection against replays (a form of partial sequence integrity), confidentiality (encryption), and limited traffic flow confidentiality. Other IP-based security solutions such as Internet Key Exchange (IKEv2) and Host Identity Protocol (HIP) are also used to perform authenticated key exchanges over IPSec protocol for secure payload delivery. For technical implementations, there are Privacy Enhancing Techniques (PETs) such as anonymisation and obfuscation to de-sensitize personal data. Extensible Authentication Protocol (EAP) is an authentication framework used to support multiple authentication methods. Protocol for carrying Authentication for Network Access (PANA) forms the network-layer transport for EAP.

The impact caused by the IoT on human life will be as huge as the one that the internet has caused in the past decades, so the IoT is recognized as "the next of internet". A part of the included technologies are sensors and actuators, Wireless Sensor Network (WSN), Intelligent and Interactive Packaging (I2Pack), real-time embedded system, MicroElectroMechanical Systems (MEMS), mobile internet access, cloud computing, Radio Frequency IDentification (RFID), Machine-to-Machine (M2M) communication, human machine interaction (HMI), middleware, Service Oriented Architecture (SOA), Enterprise Information System (EIS), data mining, etc. With various descriptions from various viewpoints, the IoT has become the new paradigm of the evolution of information and communication technology [20].

The combination of sensors, RFID, NFC (near field communication), Bluetooth, ZigBee, 6LoWPAN, WirelessHART, ISA100, Wi-Fi will enable significantly improved measurement methods and monitoring of vital functions (temperature, blood pressure, heart rate, cholesterol, level of glucose in the blood) [5].

Key challenges for IoT according to [28] are: technical, security, privacy, as well as trust, societal, business challenges.

Conclusions

This work has presented the possibilities of expanding the complex healthcare system with new services Healthcare-IoT as a process of creating new values for the health system.

The Fig. 1 has marked the common aspects and new technologies through architectural layers, which enabled the consideration of the application of intelligent healthcare solutions. Business layer should create a clear model of healthcare.

The new models of health care can be called healthcare anywhere and anytime or home healthcare. The existing services in the integrated healthcare system need to be expanded with new services.

This paper has taken into consideration some of the grouped Healthcare-IoT functionalities from the literature. Some of the presented benefits of Healthcare-IoT are: monitoring of patients, staff and equipment of hospitals in order to provide better workflows for hospitals.

Identification and authentication can help to reduce errors, as well as procedures and treatment of patients with the wrong medication. Real-time information about the patient's health indicators, collected from the sensors, may be available to doctors anywhere and anytime.

This paper has also presented the technologies which are under development and which should enable a simple and cheap implementation of IoT solutions. Wireless and sensor technologies promise a reliable and safe collection of health indicators about the patient. There are still many open issues and research challenges to address such as the wide distribution of the objects, dependable communications to work with a weak radio signal, propagation through the human body, efficient data compression, cheaper chips, data rates, real-time processing. Depending on the choice of the business objectives for health care and precisely defined business processes in Business Layer, it is necessary to choose suitable technologies that will enable a successful implementation of IoTs.

This paper has provided a holistic approach to Healthcare-IoT that should remove the gap between individual technology solutions and business innovation in healthcare as an integrated Healthcare system expanded with IoT functionalities.

Further research will be in the field of application of technologies in the form of specific solutions for connecting a particular Healthcare-IoT solution with the existing healthcare system.

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