Reference Design for Smart Collaborative Telehealth and Telecare Services based on IoT Technologies

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Abstract—The demographic development shows aging societies throughout the globe, leading to higher demands on the health and care systems due to age-related disabilities, chronic diseases, etc. Telehealth and telecare services for more efficient support of health and care providers are needed, which can be significantly improved by the continuous technological developments in areas such as sensor devices, Internet of Things (IoT), cloud services, and data analysis.

This paper addresses the potential of selected emerging technologies to make eHealth systems smarter, more collaborative and more efficient. As a result of the analysis of the most promising technological trends, characteristics of future telehealth and telecare services are derived, requirements are identified, and a future eHealth reference design is proposed.

Keywords—eHealth; health informatics; telehealth; secure health cloud architecture; decision support

I. INTRODUCTION

All around the globe the population aged 60 or over is growing rapidly [1], and is expected to increase from 841 million people in 2013 to about 2 billion in 2050. This fact challenges current health and care systems [2], particularly owing to patients with functional limitations, disabilities, and with an increased demand for long-term care for chronic diseases related to longer life expectancy. Higher demands on long-term care and the general economic pressure to control health care expenditures require efficient utilization of medical technologies and increased collaboration within the professional health care sector. Furthermore, the involvement of informal care provided at patient’s home by family members, friends and voluntary organizations has to be intensified [3], with new useful alternatives such as supporting remote care through information and communication technologies.

This paper addresses future telehealth and telecare services for smart and efficient medical routine supervision of patients within their own private environment, aiming at better health and quality of life. Emerging telehealth and telecare systems reveal certain limitations of today’s technologies. In order to overcome them, a way forward towards future integrated and collaborative telehealth and telecare services is described, addressing the cooperation of commercial cloud-based fitness and wellbeing services with the public health and care infrastructures. A reference design for their accomplishment is presented, with special attention on upcoming technologies from the Internet of Things (IoT), data ontologies from Semantic Sensor Networks (SSN), Artificial Intelligence (AI) and Decision Support Systems (DSS). While the initial focus of the reference design is on professional health care services, it will also allow involving and supporting non-professional informal sources of long-term care. A high-level overview of the reference system for the discussed services is illustrated in Fig. 1, consisting of three main system domains (see Table I) with components from a variety of eHealth stakeholders.

Fig. 1. Reference System for Telehealth and Telecare Services
TABLE I. TELEHEALTH AND TELECARE REFERENCE SYSTEM DOMAINS

<table>
<thead>
<tr>
<th>Point-of-Care (PoC) Environment</th>
<th>Health Information Services (HIS) Infrastructure</th>
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<tr>
<td>Information about health status of patients and their context (e.g., location, room temperature) shall be gathered and made available for health and care service providers through a health information service (HIS) infrastructure.</td>
<td>Data from patients are securely aggregated, stored, and made available. Service logic and user interfaces of dedicated tele-health, telecare and social alarm services for the pro-portion of controlled access to required patient data and value added information for the dis-tributed health and care sources.</td>
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<th>Health &amp; Care Sources</th>
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<tr>
<td>Nurses, general practitioners (GPs), medical specialists in hospitals, and providers of informal care as family members of patients and voluntary care providers, need efficient and collaborative access to information from their patients, allowing to carry out routine supervision remotely, provide information and remote health and care support.</td>
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II. TECHNOLOGICAL TRENDS

In this section, an overview of technological trends is given that have the potential to strengthen the characteristics and capabilities of future telehealth and telecare services.

As indicated by sociological trends, the ageing societies demand more flexible, efficient and intelligent solutions for telehealth and telecare services. Today's solutions and services do not sufficiently provide a number of required service characteristics, or have significant limitations. The trends in the following technological areas show high potential to strengthen the technological foundation for future services.

A. Internet of Things (IoT); Smart Sensors; Machine-to-Machine (M2M) Communication

- Paradigm for the integration of several technologies and communications solutions: radio frequency identification (RFID) and tracking technologies, wired and wireless sensor and actuator networks, enhanced communication protocols (shared with the Next Generation Internet), and distributed intelligence for smart objects [4], in particular for the healthcare application domain.

- Smart Sensors: transition of once-inert objects into embedded sensor-laden intelligent devices, analysing and mining their raw data to abstract, more valuable information, being connected to the Internet via heterogeneous access networks, and communicating directly with other system components (M2M) [5].

B. Ontologies and Semantic Sensor Networks (SSN)

- SSN ontology [6]: designed to describe sensors and sensor observations; applied to achieve a standard way of representing sensor data, and to support extensive reasoning together with supplied meta data.

C. Cloud Technologies; Big Data; Artificial Intelligence (AI); Decision Support Systems (DSS); Machine Learning; SOA

- Uptake of Electronic Health Records (EHRs) in clinical environments generates massive data sets (“Big Data”), expanding the capacity to generate new knowledge, helping with knowledge dissemination, and allowing a transformation of health care by delivering information directly to patients [7].

- Research efforts and development investments on AI and machine learning have created a broad theoretical knowledge base, and powerful commercial AI computing platforms as, e.g., Watson from IBM [8], targeting in particular the potential for health care.

III. POSITION

As discussed in previous sections, the increasing demand for technology support for long-term home care with smart and efficient telehealth and telecare solutions cannot be fully satisfied by today's solutions. The utilization of emerging technologies will increase the potential and technical capabilities to develop solutions in the future that can address the needs of all user groups involved. Following, the main characteristics and the technical requirements framework of services are described that overcome today's limitations and can be expected to be introduced in the near future. Finally, a reference system architecture is proposed for the accomplishment of the foreseen services.

A. Future Telehealth and Telecare Services

<table>
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<th>Service Characteristics</th>
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<tr>
<td>Patients are equipped with imperceptible wearable or implanted sensors, that provide information about their medical condition.</td>
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<tr>
<td>Patients are surrounded by or equipped with actuators, remotely controlled by nurses and doctors or supported by an AI system with configurable level of autonomy. By that they positively influence the patients’ medical condition or give other type of on-site support (e.g., medicine dispenser, first-aid robot, cardiac pacemaker, insulin dispenser, breathing control, ...).</td>
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<tr>
<td>Patients and medical professionals are not limited to specific vendors or products, but can select from a range of standards-based, certified products according to the individual health care support requirements. Patients do not actively have to identify and authenticate themselves with user names, passwords, PINs, etc.</td>
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<td>Appliances in the PoC give autonomous advice to patients based on data from specific medical sensors (in particular when devices loose connection to HIS).</td>
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<td>*Patients are not in charge of updating status of sensor and actuator devices (e.g., wireless charging, PV). *Advises and information for patients are presented in an easy-to-use and accessibility-adapted way (e.g., touch screen devices, voice communication, gesture recognition). *Patients are motivated to physical exercise for improved rehabilitation and long-term care by sharing data with relatives and informal care providers via social media. *Information from PoC (e.g., health / medical data, questionnaires, alarms) is securely transmitted in real-time into health information systems. *Teledhealth, telecare and social communication services (e.g., alarms, video consultations) provide access to EHR and P-EHR data, to value-added information and to diagnosis and decision support, using all relevant patient data from the health information systems, and supporting the collaboration between the different health and care sources in charge.</td>
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The following technical requirement domains have to be considered in the design and implementation of the future telehealth and telecare services and their supporting infrastructure components.

### Requirements Framework

#### Flexibility/Integration, Expandability, Scalability

A health care solution must be able to handle expected growth in patient number, services and devices.

#### Security and Privacy, Authentication, Access Control

The solution must be trustworthy and allow for implementing complex, distributed security policies and rules.

#### Interoperability and Interworking

The solution shall enable interactions with other national and international service domains.

#### Usability (patients, medical professionals, informal care)

End-user relevance and intuitive handling will increase user acceptance and error free handling.

#### Reliability, Robustness, Availability

People’s lives and health require a solution with high dependability and low risk of failure.

### B. Future Reference Design

The proposed reference design addresses the scenario for healthcare services in 2020-2030, and considers the utilization of selected emerging technologies. An overview of the underlying system architecture is illustrated in Fig. 2, containing the core components involved in the design of the future services.

#### 1) Point-of-Care

The central component of the Point-of-Care (PoC) environment is the patient device, which carries out the user interaction logic and provides the graphical UI for the patient, takes care for the communication with sensors and actuators in the PoC environment, and serves as communication gateway with the HIS infrastructure. The proposed functional architecture of the PoC device is shown in Fig. 3. Sensors for patients’ health status and context information from the PoC as well as actuators for care support and home control are connected through device-specific smart sensor adapters and handlers. These software modules support the applicable connectivity and communication protocols, can evaluate the sensor data (e.g., by rule-based reasoning) to trigger certain events or produce value-added information, and can be added to the PoC device software on demand. The sensor adapters and handlers forward the data and value added information to the common data integration and exchange module (CDIEM). The underlying database is based on the World Wide Web Consortium (W3C) semantic sensor network (SSN) ontology standard [6], which allows smart evaluation and reasoning based on data semantics, and flexible extension of the database with regards to new sensor or actuator parameters. The CDIEM also provides a subscribe-notification-based exchange of data: any software module carrying out a specific functional logic subscribes to new needed data (utilizing the data semantics), and feeds the results of its operation back into the CDIEM. The layer of software modules for specific functionalities and use cases include a generic communication module for the exchange of data with the HIS Infrastructure through a VPN.
link, a user authentication and access control module, and various modules for user interaction use cases. Besides the data storage module, the reasoning and decision support is another central component of the PoC device software. This provides for complex evaluation logic involving any of the data and information available in the local storage, and can trigger events as alarm notifications to remote care sources (via the CDIEM and the communication module), and can autonomously support the patient via the CDIEM and dedicated user information and interaction modules. By using ontology technology, sensor observations together with other patient history information (e.g., diagnosis) make rule based reasoning and machine learning possible. Additionally, the use of ontologies will improve semantic interoperability and integration. A generic UI module provides the means to realize all user interactions through the service UI in a flexible and modular way.

2) Health Information Services (HIS) Infrastructure

Besides the secured National Health Network (NHN) infrastructure, containing Core-EHR systems and services for the public health sector (as in particular, for the access to and exchange of EHRs), the proposed future HIS infrastructure is extended with a Secured Health Cloud. Based on a common IT infrastructure using cloud technologies, a multitude of services can be hosted and facilitated by dedicated P-EHR systems. The services are operated by commercial service providers as, e.g., social alarm support, telecare providers and commercial vendors of gadgets and services for the online management of health and fitness information. Data in any P-EHR originating from any PoC can be utilized by the public NHN services via secure (authenticated and authorized) access, to extend the available health and context data in the Core-EHR with additional health and context information. Furthermore, each service provider in the secured health cloud uses the P-EHR data from “its” patients and customers for its individual services.

3) Health & Care Sources

A central aspect of the proposed secured health cloud is a common security framework: health and care sources (such as social alarm and informal care service providers, nurses, but also GPs and hospital specialists), can securely utilize the telehealth and telecare services provided (possibly as Web-based information portals) in the secured health cloud through a common authentication and authorization system, allowing both secure and flexible collaboration. Public healthcare sources as GPs and hospital staff can securely access EHR data from Core-EHR systems in the NHN, and directly from different P-EHR systems in the secured health cloud via an encrypted link and the common access control.

IV. DISCUSSION

The strengths of the proposed reference design for future telehealth and telecare services are manifold. The modular SW architecture allows to flexibly integrate new sensor and actuator devices via dedicated handler modules, which support specific communication technologies, and support intelligence on sensor level (“SmartSensors”). The event-based (subscribe, publish, notify) data exchange on top of a central data storage supports the integration of software modules for new use cases and functionalities. Furthermore, a reasoning and decision support component operating directly on top of the central data storage allows for complex evaluation tasks of patients’ health and context data, leading e.g. to fast emergency notifications, and autonomous patient support.

The secure inter-connection of the two HIS domains - “Secured NHN” for the public health system, and “Secured Health Cloud” for commercial service providers – is the basis to make data from the patients’ PoC available for more efficient public health services in a secure and privacy-protecting way, while securing a closer collaboration between all health and care sources. The compliance with the right standards by the P-EHR systems (as Continua Health Alliance, HL7 and CEN/ISO EN13606) will be key to enable the described exchange of data.

V. CONCLUSION AND OUTLOOK

The proposed reference design shows how emerging technologies can help to boost the development of eHealth service infrastructures and future telehealth and telecare services using them. The development of a proof-of-concept prototype system (ongoing by end of 2015) includes a more detailed elaboration of the security system for the secured health cloud, as well as details of the standards to be considered for the P-EHR systems and their accessibility. Taking the prototype a step further towards a trial system will allow to carry out research about the social acceptance and usability of the described future telehealth services, and further technological details of the future infrastructure.

REFERENCES