Integrating Smart Items and Cloud Computing in Healthcare Scenarios

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***Abstract*-Use of cloud computing in healthcare is a promising trend, particularly in utilization of smart items. Access, affordability and quality to proper healthcare is a great challenge in world society. With the utilization of smart sensors, there are possibilities to improve the quality of healthcare services whenever needed. Hence, such smart items services lead to economic advantages for the whole healthcare system. Keeping in mind these opportunities as well as challenges such as security or legal issues, it is important to bring healthcare and IT together. As a result, healthcare business processes need to be modeled in order to provide IT solutions tailored for practice-oriented applications. In this paper, we present a three-level architecture for a smart healthcare infrastructure. Our approach is based on recent literature work and results from conducted expert interviews with healthcare specialists and IT professionals. To demonstrate the applicability of this architecture model, we provide an example use-case as a template for any kind of smart sensor-based healthcare infrastructure.**

Keywords-sensors; cloud computing; smart healthcare; business processes; reference model.

I. INTRODUCTION

During the time of its emergence, it was believed that cloud computing might not be successful for long. But against all the predictions made by IT pundits, cloud computing turned into a big success and kept benefitting different sectors which is continue till today [1]. Cloud computing is the focus of interest for institutions with different backgrounds, including pharmaceuticals, healthcare outfits and medical researches where institutions are highly engage in finding cure and solutions for chronic diseases. Integration of cloud computing with smart items which allows healthcare professionals to monitor the patients' treatment is a significant achievement, which was difficult a decade ago. One reason for its success is the economical features. Sophisticated Information and Communication Technology (ICT) is often expensive and not affordable for medium size businesses including hospitals, where smaller budget hinder the adaptation of latest ICT [2]. Contrary to other ICT, cloud computing and smart items are relatively cost effective and easily adaptable [3]. Adopting cloud services can relatively reduce the burden of infrastructure and save the maintenance cost and provide relieve while maintaining the infrastructure. The usage of smart items like collaborative radio frequency identification (RFID) solutions in the textile and medical industry have already shown a positive impact, such as continuous quality improvement [4]. Furthermore, patients can privately maintain it in a private environment which is supportive to medical adherence. A report issued by world health organization (WHO) states that there is a majority of patients who do not adhere with their medical prescriptions as they are supposed to which results in delay or failure in the treatment of the diseases [5]. In such scenarios smart healthcare items can support in monitoring patient adherence and support the better treatments by providing solutions to such challenges like smart pill boxes, which come up

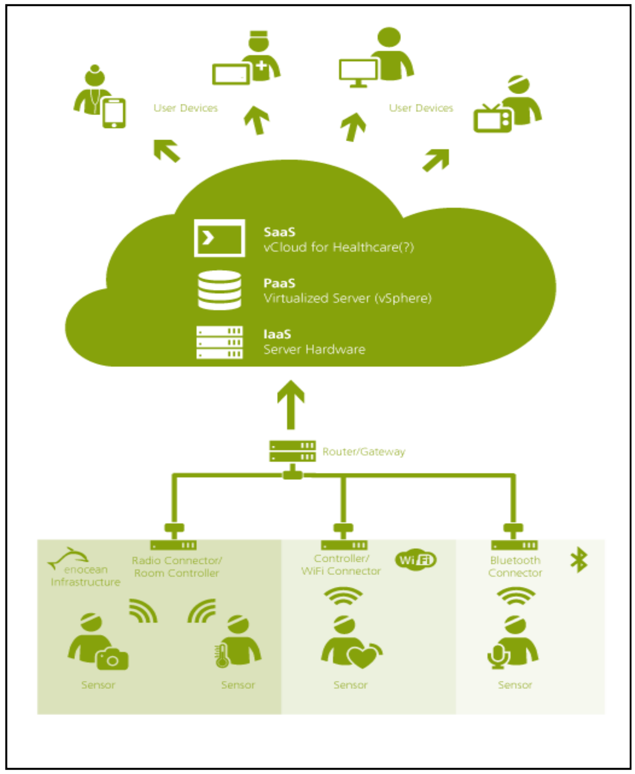

Figure 1. OpSIT architecture prototype

with solutions like opening at accurate time and recording of pill time. Furthermore smart healthcare items like physiological parameter monitors can automatically record the health parameter and update it to the cloud, which become available for patient and the healthcare staff who can make comparison with record history and can take corrective decisions on behalf it.

While the economic opportunities of cloud computing in healthcare are quite promising and often subjects of recent research [6], optimization of smart items infrastructure for healthcare processes is underrepresented in research [7]. There exist approaches that define composability for such embedded architecture [8] with a specific focus on dependability in distributed environments [9]. In this regard the approach of architectural translucency [10] [11] aims to offer standardized ways of controlling such architectural properties via an architecture-wide view while using standardized measures such as replication [12] [13]. Applications range from position sensing [14] to project portfolio management [15] and consider applications in the healthcare domain specifically [16] [17].

The project “Optimaler Einsatz von Smart-Items-Technologien in der Stationären Pflege”, Germany (OpSIT) builds on these existing works and is conducting literature research, workshops, and expert interviews with healthcare specialists as well as IT professionals to model reference processes for practice-oriented cloud applications in the healthcare domain. Figure 1 shows an overview of the working mechanism of the project. In smart environment, smart sensors are responsible for monitoring different vital signs of human health, and upload and update it to the respective cloud server where the data become available and accessible for individuals who are involved in the treatment process or directly related to the patient.

The aim of this paper is to introduce an architectural approach for smart items in healthcare environments that is being developed as part of the research objectives of the OpSIT project. In Section II, we will introduce the benefits of sensors in healthcare. Subsequently, we will explain how sensors are used in cloud computing environments (Section III). As a consequence, in Section IV, we will define eHealth in the context of cloud computing. Section V presents our architecture model, including an application example and how it can be modified for individual purposes. Managerial implications will be presented in Section VI for smart homecare and in Section VII for smart stationary care. We will finish the paper with a compact conclusion in Section VIII.

II. BACKGROUND

The use of smart items has successfully been practiced in the hospitals and other healthcare institutes. Nowadays, sensors are embedded in a variety of instruments for use at home, elderly houses, clinics, and hospitals and providing a critical evaluation of physiological, physical and mental state of the patients. Most of the diagnosis will not be possible nor affordable without using even simple sensors, such as thermometer, blood glucose monitors, electrocardiography, electro-encephalography etc.

These sensors are composed of transducers and capable of detecting electrical, thermal, optical, chemical, genetic and other signals with physiological origin. Signal processing algorithms can help to calculate, forecast and measure different features of human health based on input from these sensors. Measuring the vital state of a patient is also important for devices like pacemakers and insulin pumps [18].

The dimensions which are helping in advancing computer technologies in healthcare can be structured as follows:

- **Sensing:** Involvement of new, effective and cheap technologies with the ability to diagnose and provide immediate results and solutions to the healthcare and public sectors on promising basis. For example, a non contact electrocardiogram can be helpful in detecting the symptoms like heart diseases, [19].
- **Cost:** During past few years, mostly available sensors were quite expensive and hardly affordable for small clinics. But now, the revolution in this industry and availability of cheap sensors, such as RFID, made it possible for clinics to afford it even making personalized treatment possible.
- **Size:** The sensors are quite handy and easily adjustable in pockets which facilitate to carry them anywhere. These devices are available in different shapes and types like blood pressure

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monitors, pulse reading wrist watches, blood glucose monitors, etc.

- **Data:** Data collected by the sensors are relatively in mass, and require proper evaluation by experts from time to time. The only solution in this regard is to transfer it to the cloud, which is the best solution to handle and maintain the big data.
- **Cloud services:** The three fundamental cloud services models which are available to any type of businesses are also available to healthcare to support the industry in their information systems management [19]:

  a) IaaS: Enables the healthcare service provider to rent the fundamental cloud resources like storing, processing, and networking.

  b) PaaS: Helps the healthcare service providers to deploy their own or rented applications, software, libraries and tools on cloud infrastructure.

  c) SaaS: Configured software running on cloud infrastructure is available where healthcare institutes can subscribe under the management of the cloud contractor.

III. Cloud Computing and Smart Items

A large variety of definitions for cloud computing exists, but there is no single universal upon agreed definition. Authors and experts define cloud according to their own understandings. The most commonly used definition comes from NIST (National institutes of standard and technology) "*Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service providers interaction*" e.g., networks, servers, storage, applications, and services that can be rapidly provisioned and released with minimal management efforts or service providers interaction [20]. The utilization of the word "cloud" gives reference to the two essential concepts [21]:

- **Abstraction:** The notion of the technology is not disclosed to the users and developers. Unspecified physical systems are used to run the applications, location of the data is undisclosed, further it allows to delegate the administration of the infrastructure while maintaining ubiquitous access of the users.
- **Virtualization**: It is a pool of resource sharing. Centralized storage capability offers storage provisioning and can be done when required. The cost model is similar to utility model. Moreover it offers multi tenancy, while providing dynamic resource allocation.

When we speak about cloud computing in healthcare, it becomes very obvious that like for other industries, healthcare can also take full advantage out of it. Internally it can ease the burden of the infrastructure and number of people associated with it [22] and allows the institutes to focus on their core competencies. Synergistically cloud computing and smart items are helping patients, clinics and insurance providers to access the health records of the patient whenever needed. As a result, the development in smart healthcare technologies such as mobile healthcare, wireless sensors and cloud computing lessen the requirement for visiting medical facilities and consultation, which can be remotely fulfilled and significantly reduce the manpower requirements, while providing quality treatment to the patient by making remote treatment and consultancy possible and achievable [19]. However, the implementation of such technologies implicates different challenges such as security and privacy issues [23], technological restrictions, or management and governance issues [6].

On one side, it's highly important to understand the evolving business processes occurring in healthcare environments before developing a cloud and smart items infrastructure. On the other side the technical possibilities and requirements needs to be understood to create an architectural approach for smart healthcare.

Wireless sensors can easily be deployed in any environment and with the help of cloud computing, the information can be gathered and saved from these sensors at any time. Smart devices are evolving at a rapid pace in health monitoring, while meeting the needs and demands of assisted living and healthcare providers. This system focuses on the different features for a mobile healthcare system.

The active smart systems with the help of mobile devices collect physiological signals such as body temperature, pulse rate, etc. Once the data collection is completed, it will be transmitted through Wi-Fi or another compatible system network, which will be stored, synchronized, and shared instantaneously on a server. Health symptoms can be diagnosed continuously and immediately. The collected health

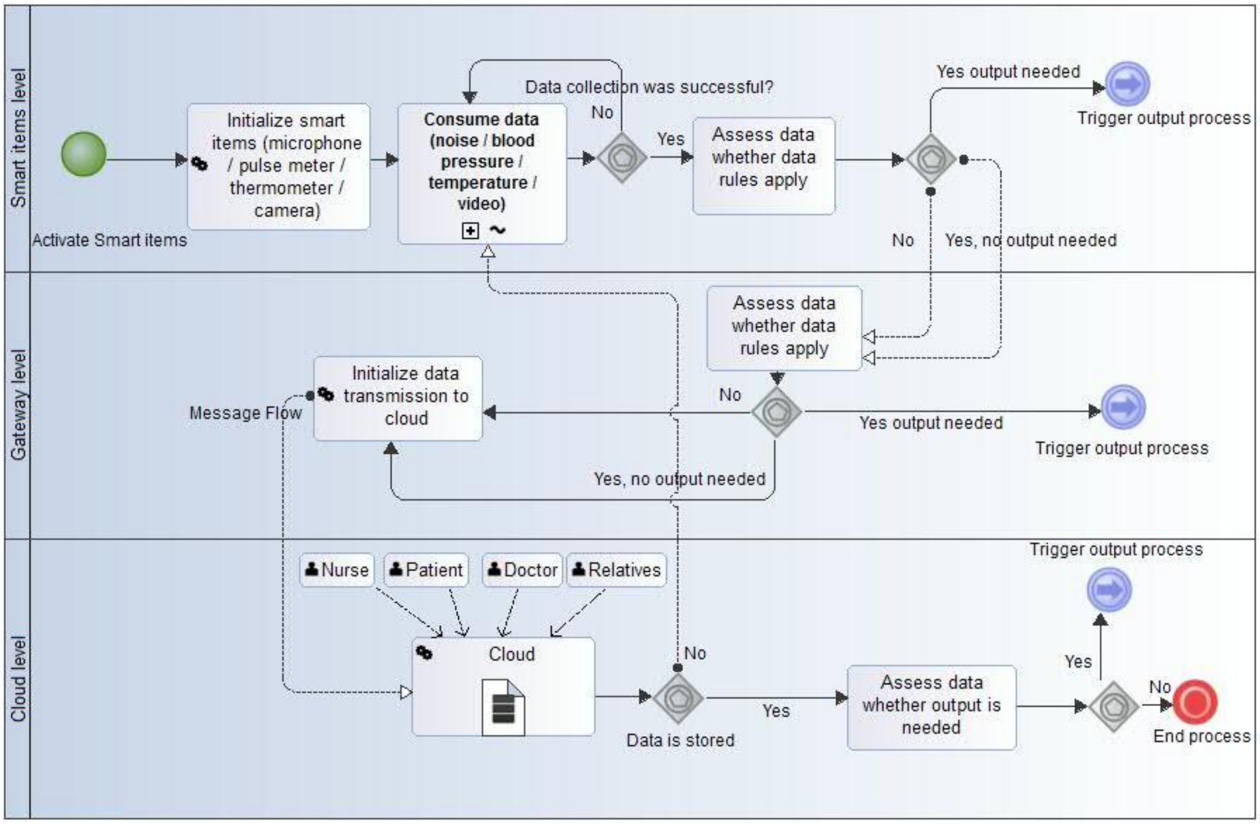

Figure 2. BPMN Model of process steps of the application scenario

data can be consolidated and accessed with a cloud service in order that health professionals can analyze the information and continue patient treatment on the conclusion of the collected data.

IV. eHEALTH AND CLOUD GOVERNANCE

WHO defined health as a *"state of complete, physical, mental and social well-being and not merely the absence of infirmity"* [24]. As a consequence, healthcare can be defined as the maintenance of physical and mental well-being, supported by available medical services. Finally, eHealth is the maintenance of physical and mental well-being while employing computer technology resulting in improved and better quality of services.

Cloud Governance denotes the idea of applying corporate governance concepts to the world of cloud computing [25]. This can be of particular relevance for healthcare, due to the complex requirements regarding data privacy and information security [26]. Furthermore, aspects of performance evaluation [27] or ensuring the reliability of systems, e.g., through replication [12] [13].

V. COMMUNICATION IN A SMART ITEM ENVIRONMENT

Communication among the devices is empowered by proper communication channels between them. In the past, when sensors' connectivity was isolated to an integrated user interface, it was difficult to connect with. Contrary to that, modern day sensors are capable of connecting with a large number of interfaces, such as wired, RS 232, USB and Ethernet as well as wireless ones, including Bluetooth, Zigbee, UWB for short distance and Wi-Fi, radio frequency, or ZigBee for longer range [18] [28]. Some devices come with the capability of connecting directly to Smartphones and computers allowing sensors to save data in the non-volatile memory and make them available for later usage.

It is a recursive process, where the respective sensors remain active and observe even minor changes in the pattern of human body which human cannot easily observe. As shown in Figure 2, this process is divided in three different levels. In each level, devices are responsible to perform the assigned tasks and forwarding the data to the further level, or triggering directly an output process. The entire process accomplish in a short period of time (in nanoseconds) making it very fast while helping human to have good control over their health and take corrective measures and steps as soon as possible.

In general, Figure 2 shows the process flow modeled with Business Process Modeling Notation (BPMN) based on the working mechanism of smart sensors architecture from the OpSIT project. As BPMN is an established way to analyze and design operational process flows regarding multiple kinds of resources [29] it is utilized in the presented architecture which aims to enhance current healthcare processes. Moreover, the architecture model can be seen as a process flow template for any specific use-case, importing it and revising its tasks with modeling software such as Modelio.

As a very basic example use-case, we consider a blood pressure measurement process in home care. To analyze the traditional process, it is important to keep in mind three different levels matching with the levels presented in our approach. Hence, the “smart items level” can be entitled in the traditional process as “measuring device level” where a patient uses the blood pressure gauge that directly outputs the data on a display. The “gateway level” can be compared with a “short-term storage level” where the patient will be manually note down the value shown on the display. The “cloud level” illustrates permanent access and evaluation of the data, while its equivalent in the traditional process may be called “evaluation level”, when the doctor receives the patients’ data in order to evaluate whether medical intervention is necessary or not. This simple comparison points out the disruption within the traditional process flow. Obviously, every level in the traditional process ends with an output task and is not directly connected to the next level. Analyzing this problem is made possible by considering the proposed BPMN model even at the stage of modeling the status quo process.

VI. SMART HOMECARE

Mobile networks give rapid access to the patient data provided by the servers of the healthcare cloud computing environment.

Smart healthcare items benefits are broad range and dual natured (benefiting healthcare providers as well as the patients). These are the physically interconnected hardware performing their tasks seamlessly through a network. For healthcare providers, it is valuable for several reasons: At first, it reduces the number of labor due to the replacement of human based monitoring. Moreover, it reduces the chance of human error. Secondly, wearable sensors are capable of sensing even very small changes in vital signs and recording it, which a human cannot easily observe, such as pulse and blood oxygen level. Thirdly, on-time measurement can help in saving lives while collected health data of the patient stored in the cloud can support in decision making process whenever needed as enabling the doctor in making well informed decisions. And last but not least human physicians will be able to get valuable assistance from the "electronic physician" [30].

Patients will be benefitted in several ways. They can get quality healthcare treatment at home within their own private environment while living close to their family members while feeling more comfortable and relaxed resulting in less mental stress. Other significant factors involved are dignity and convenience which are highly supported while the patient gets treatment at home.

VII. SMART STATIONARY CARE

Most of the smart items available in the healthcare sector can be utilized in stationary care scenarios as well. Due to cost pressure, hospitals as well as intensive care units or other patient care facilities, are facing challenges like less financial resources. As a result, reduction of labor cost becomes the critical criterion for the implementation of smart items infrastructure in a stationary setting.

According to a study conducted by the European Commission, the large majority (81%) of the hospitals within the EU are connected to the internet and two third (66%) of all surveyed hospitals have an in-house wireless infrastructure, an increase of twelve percents points within two years. Moreover, most of the used IT services are managed in-house which means that qualified IT staff is generally available [31]. Consequently, the basic infrastructure for smart items implementation is already provided in the majority of hospitals. The ongoing challenge is the integration of IT professionals and medical experts to realize smart items solutions supporting healthcare processes in a proper way.

VIII. CONCLUSION

Cloud computing based smart healthcare solutions and stationary items can play a vital role in improving the quality of health services in near future by remarkably supporting care staff in fulfilling their tasks in a well managed manner.

Wireless communication channels between sensors, gateways and other devices enables continuous data transfer to the cloud and making it available for doctors, care staff and patient to access the health status and maintain the records time to time. Hence, synergistic combinations among smart healthcare solutions and cloud help the doctors and other care staff in making highly informed decision and produce better output with quality of care service provided.

Understanding healthcare processes and modeling them for IT application is an inevitable task to create practice-oriented cloud solutions with the aim of providing high quality smart healthcare services. The approach presented in this paper can be used as a basic design for further developments.

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