A Portal for Ubiquitous Access to Personal Health Records on the Cloud

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Abstract. Recently, there has been a remarkable upsurge in activity surrounding the adoption of Personal Health Records (PHRs) whose architectures are based on the fundamental assumptions that the complete records are centrally stored and that each patient retains authority over access to any portion of his/her record. Although the consumer/patient is the primary beneficiary and user of PHRs, healthcare professionals stand to benefit from their use as well. In particular, the integration of leading-edge networking technologies, such as cloud-based services and mobile communications, with PHRs has the potential to improve delivery of healthcare by rendering PHRs ubiquitously accessible. This paper presents a portal application which provides access to PHRs on the cloud. Cloud-based services can prove important in healthcare provision, but the inherent nature of medical records underscores the need for clouds to be private to ensure data security is better maintained. Thus, the proposed portal application comes with a suitable security mechanism, in order to ensure secure access to healthcare information.

Keywords: Personal Health Records, cloud computing, web services, ubiquitous access, access control, portal.

1 Introduction

Throughout their lives individuals may receive care by various providers and under various circumstances, resulting in patient data being scattered around disparate and geographically dispersed information systems hosted by different healthcare providers [1][2]. The lack of interoperability among these systems, as is often the case, impedes optimal care since it leads to unavailability of important information regarding a patient health status when this is mostly needed (e.g. in case of an emergency).

Recently, there has been a remarkable upsurge in activity surrounding the adoption of Personal Health Record (PHR) systems [2] as both patients and healthcare providers have realized that their use may entail a number of benefits, such as better access to information, increased patient satisfaction and continuity of care [2][3]. A PHR is a consumer-centric approach to making comprehensive electronic health records (EHRs) available at any point of care while fully protecting patient privacy [4][5]. In particular, a PHR can be defined as a set of tools that allow patients to access and coordinate their lifelong health information and make appropriate parts of it available

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to those who need it. PHR data can come from EHRs or directly from the patient – including non-clinical information (e.g. exercise habits, diet, etc) [6]. The key difference between PHRs and EHRs is that, unlike traditional EHRs that are based on the "fetch and show" model, PHRs' architectures are based on the fundamental assumptions that the complete records are held on a central repository and that each patient retains authority over access to any portion of his/her record [3] [4]. Thus, an entire class of interoperability is eliminated since the system of storing and retrieving essential patient data is no longer fragmented.

Although the consumer/patient is the primary beneficiary and user of PHRs, healthcare professionals stand to benefit from their use as well [7]. In particular, healthcare professionals, due to the high level of mobility they experience, require ubiquitous access to relevant and timely patient data in order to make critical care decisions [8]. The integration of leading-edge networking technologies, such as cloud-based services and mobile communications, with PHRs can meet this requirement since it can enable easy and immediate retrieval of PHRs from anywhere, via almost any device. Hence, healthcare providers are increasingly considering migrating to cloud computing in an attempt to increase flexibility and agility of patient data access, processing and storage and enhance quality and safety of patient care [9-10]. In this context, protection and confidentiality of personal data must be ensured owing to the inherent nature of medical records.

Along these lines, a prototype web portal is presented, namely NefeliPortal, which provides a web interface to workflow-based healthcare processes. In particular, NefeliPortal provides pervasive and ubiquitous access to healthcare processes which are modeled as flows of cloud-based web services that provide access to PHR data, residing within a cloud infrastructure. The aforementioned processes may involve access to medical data by authorized users or triggering a new healthcare process, such as the e- prescribing process.

2 Motivating Scenario

The basic motivation for this research stems from our intervention in a recent project concerned with designing and implementing a PHR system in the context of a prototype e-prescription system developed for the needs of the Greek Health and Social Security System. Essentially, the system assumes that an effective drug prescription mechanism should be based on providing a rich picture of the patient's heath record so that quality of care improvement and cost containment are both met concurrently.

Suppose a healthcare delivery situation where an individual is transferred to the emergency department (ED) of a hospital. Upon arrival to the ED, the patient registration procedure is performed by specifying the patient's identity somehow and by undergoing through triage to determine the nature and severity of his/her case. Upon completion of emergency case management, which may have involved drug prescription and/or administration, the patient is either admitted to the same hospital (e.g., to a clinical department, the Intensive Care Unit - ICU) or transferred to a more specialized hospital or even discharged. As ED visits are unplanned and urgent, there is a need to ensure that information regarding patient's health status (e.g. health problems, allergies, medication history, recent diagnostic and therapeutic procedures) is

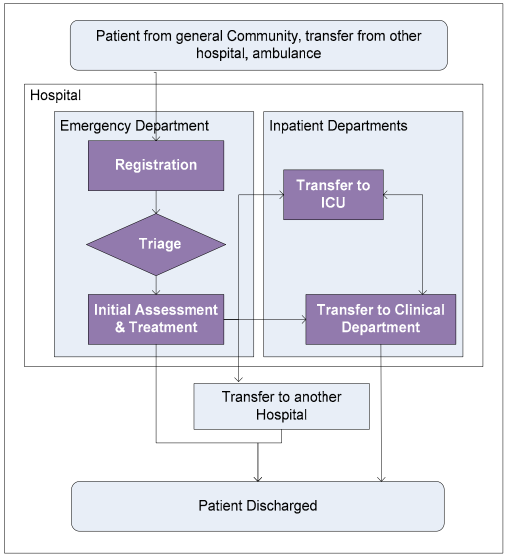

Fig. 1. Emergency Patient Flow

automatically made available to ED physicians. Thus, care inefficiencies, in the form of redundant testing, care delays, and less-effective treatments prescribed are eliminated and quality of care is enhanced [11-20].

Figure 1 shows an indicative high-level view of the patient flow from the time of arrival to a hospital's ED to the time of leaving the ED. Two of the roles participating in the emergency patient's care are the roles of the ED physician and specialized ED nurse.

3 System Architecture

Figure 2 shows a high-level view of the cloud PHR architecture that underlies NefeliPortal, where patient data are accessed via web services deployed through Business Process Execution Language (BPEL). It is essentially a cloud-based system architecture that coordinates reliable, secure and high-performance deployment of NefeliPortal services and comprises software elements on the mobile device (i.e. a Personal Digital Assistant - PDA) and on the cloud.

The PDA client is running an HTTP(S)-based client, which is the PDA's web browser and provides user interaction with the system. The cloud, which essentially constitutes the NefeliPortal's environment, consists of the following software components:

- **PHR platform:** it is a platform used for the implementation of the PHR system. The platform comprises:

i. *a data repository* - it stores PHR data on a cloud data storage system which relies on a number of data centers.

ii. *a portal* - it allows patients to access and coordinate their lifelong health information and make appropriate parts of it available to those who need it. Authorization propagation may be performed by either patients themselves or by an assigned "gatekeeper" (e.g. next of kin) [21].

Depending on the PHR vendor, this portal can provide the following categories of services: decision support, social networking, provider-patient interaction, disease/health management, and financial services. Thus, patients can actively manage their own health and authorized healthcare professionals (e.g. general practitioners) can timely access up-to-date patient data (e.g. drug prescription data).

- **Web Services:** healthcare processes can exchange data with the PHR platform through a series of software interfaces based on web services standards.
- **BPEL Engine:** it handles the execution of BPEL-based healthcare processes provided in the healthcare settings. The role of the BPEL engine is, given a BPEL process definition and a set of inputs, to instantiate the healthcare process, executing the tasks by calling the various web services, accessing PHR data and routing the data between them.
- **Web Portal:** it provides a web-based front end to healthcare processes and, in turn, to PHR data accessed through the execution of these processes. It consists of a JSR-168 [22] compliant portlet container that hosts and manages the main portlet of NefeliPortal, namely NefeliPortal BPEL portlet, as well as the portlets of the workflow (BPEL) applications. A portlet is a java web component that generates dynamic content in response to processed requests [23]. NefeliPortal BPEL portlet provides the Web browser-based portal user interface to the BPEL Engine where all healthcare processes are deployed. Thus interaction with the corresponding workflows is enabled. This interaction is performed through certain portlets developed to facilitate the physicians' interaction with the relevant tasks of the workflows.
- **Web/Application Server:** it provides the hosting environment to the aforementioned components.

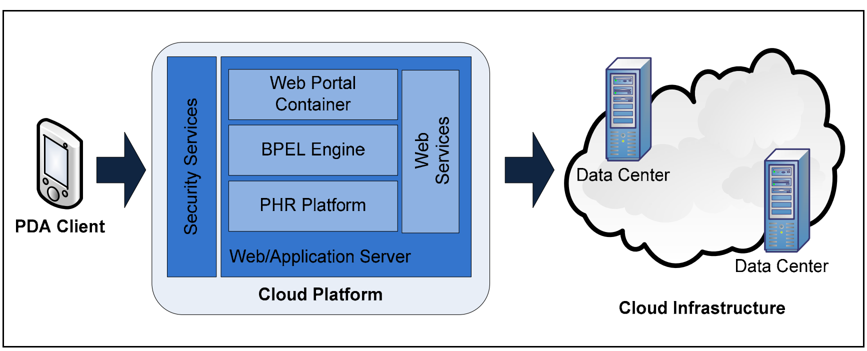

Fig. 2. System Architecture

4 Implementation Issues

The prototype implementation of the proposed portal application has been developed on a laboratory cloud computing infrastructure. The system has been developed as a web application using the Apache/Tomcat as Web/Application Server. The BPEL engine used for the execution of BPEL healthcare processes is ActiveBPEL [24], an open source BPEL Engine [24]. NefeliPortal that provides access to this engine is based upon IBM WebSphere portal framework [25], a JSR-168 compliant portal [22]. The platform used for the generation of sample patient records is Care2X Integrated Healthcare Environment [26]. Although Care2X is not a PHR platform but an open source Web based hospital information system, it has been considered sufficient for the purpose of our research. As illustrated in Figure 2, PHR data are stored on multiple data centers on the cloud. To this end, the cloud storage model is used. Essentially, cloud storage is a model of networked online storage where data is stored on multiple, virtual servers, generally hosted by geographically dispersed third parties, rather than being hosted on dedicated servers [27]. In our prototype, these servers lie behind a firewall (i.e. the cloud is private) and serve as large data centers that are exposed as storage pools, which healthcare providers can use to store PHR data objects.

Access to data stored in Care2X repository is achieved by means of web services which make use of the Care2X Application Programming Interface (API) and are deployed on the cloud computing infrastructure. One of the web services developed is the PHR access enabler (PHRE) which encompasses the tasks that are concerned with ED physician accesses to patient record data.

Development of cloud computing applications that provide readily access to integrated healthcare information at the point of care introduces security risks especially with regard to authorization and access control. To this end, a suitable security mechanism is embedded into the proposed cloud portal application, which ensures authorized data access through the invocation of relevant web services. Authorization decisions are made subject to the constraints imposed by the execution context.

When on duty, an ED physician needs to gain access to the PHRs of the patients he is treating. To this end, each time the ED physician needs to view the PHR of a patient he attempts to invoke PHRE. Thus, a request for the invocation of this web service is issued which is identified by the authorization and access control mechanism incorporated in NefeliPortal. At the same time, the collection of relevant context information (e.g. physician id, patient id, time of attempted access, location of attempted access) is initiated and the acquired values are passed to the security mechanism, which, in turn, evaluates the relevant contextual constraints and decides whether access to the PHRE should be permitted or denied.

Due to lack of space, more details regarding the implementation of NefeliPortal and the security mechanism incorporated in it are presented elsewhere.

5 Concluding Remarks

Healthcare organizations are faced with the challenge to improve healthcare quality, preventing medical errors, reducing healthcare costs, improving administrative efficiencies, reducing paper work and increasing access to affordable healthcare. A Personal Health Record (PHR) is a way for patients to have control of their own health data, while providing an interoperable platform for sharing relevant clinical data between providers. Moreover, if deployed on a cloud computing infrastructure, PHRs can provide readily access to integrated healthcare information at the point of care. To this end, suitable cloud computing applications need to be developed which will streamline and automate healthcare processes and will provide timely access to the relevant PHRs. This paper presents a cloud portal application, NefeliPortal, which renders medical information immediately available to people who need it via remotely accessible, secure and highly usable PHRs. NefeliPortal is portlet-based and accessible via any portable device (e.g Personal Digital Assistant - PDA).

The evaluation of the proposed architecture requires its application in a wider spectrum of healthcare processes in order to reveal its potential strengths and weaknesses. This is a task to be undertaken in the near future.

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