Introducing a Patient-Centered e-Health Record Over the Cloud

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***Abstract*— The aim of this paper is to highlight the Patient-Centered e-Health (PCEH) concept, introduce its importance and demonstrate a multidisciplinary project that combines advanced technologies. The project combines several aspects of PCEH functionality, such as: (a) homecare telemedicine technologies, (b) e-prescribing, e-referral, e-learning and (c) state-of-the-art technologies like cloud computing and Service Oriented Architecture (SOA), will lead to an innovative integrated e-health platform that delivers many benefits to the society, the economy, the industry and the research community. This paper provides insights of the PCEH concept and the current stages of the project. In doing so, we aim to increase the awareness of this significant work and disseminate the knowledge gained so far through our effort.**

Keywords-Personal Healthcare Record; Cloud Computing; Healthcare Information Systems Integration.

I. INTRODUCTION

Healthcare Information Systems (HIS) integration has been associated with various aspects, amongst others: strategic, social, and/or organisational [1]. In this respect, there is a common trend to address HIS integration by an overall approach, seen as integrated patient centered care [2]. Integrated patient centered care reflects on integrated HIS (with elements as e-health services) requiring coordination across professionals, facilities, support systems that is continuous over time and between patient visits [3]. This approach is observed on national healthcare strategies that encourage patient involvement in their healthcare treatment. Moreover, in the USA and Europe, online personal health records that allow patients to manage their health data have emerged [4]. For example, in Finland, this integration trend can be observed in a legislation that allows citizens to access and interact with their own Electronic Healthcare Records (EHRs), ePrescriptions and audit-logs via the Internet [5].

Following similar legislative opportunities worldwide, patients increase their involvement with HIS. This is a growing involvement, seen in parallel with mechanisms for the collection of information (obtained by mobile and other sources) in order to develop an enhanced, complete and integrated view of citizens health status. The latter is reflected in EHRs and Personal Health Records (PHRs), which are being enriched and exploited by different actors and stakeholders (i.e., health and care professionals, citizens, nutrition experts, hospitals, etc.) in the health ecosystem. Three general PHR models have been proposed [6]: a) the stand-alone model, b) Electronic Health Record (EHR) system, and c) the integrated one, which is an interoperable system providing linkage with a variety of patient information sources, such as EHRs, home diagnostics, insurance claims etc. The main types of health information supported by PHRs are problem lists, procedures, major illnesses, provider lists, allergy data, home-monitored data, family history, social history and lifestyle, immunizations, medications and laboratory tests [7][8]. Widely known PHR platforms in terms of centralized web-based portals include Dossia and Microsoft Health Vault platforms. Many systems presented in literature offer integration with already established PHRs platforms [9][10]. Early experiences from the adoption of PHR-based systems have been found to be positive, showing that such systems can be feasible, secure, and well accepted by patients [11]. Nonetheless, today's EHRs and PHRs are far from being what the citizens consider as of value to their health, since for the public view, health means more than being disease-free.

Following this trend for patients' empowerment, academics, practitioners and patients advocate in favor of the patient centered healthcare systems. Still the aforementioned advocates have not yet reached a concise definition of Patient-Centered e-Health (PCEH) that is shared across the research disciplines that focus on health and Information Technology (IT) [12]. The lack of consensus can be attributed, amongst other, (a) on the number of challenges that are involved in transitioning healthcare delivery to a more patient-centered system and (b) the lack of proof-of-concept through well-documented and effective PCEH projects.

Healthcare is unique and complex ecosystem that poses several challenges on developing PCEH [13]. The healthcare ecosystem consists of several networking organisations that constantly interact with each other, but also differentiate amongst them. The differentiation can be noted in issues, such

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as: (a) medical specialisations, (b) socio-technical and IT capacities, (c) organisational cultures, (d) structures, (e) actors and (f) business process [1]. More precisely, healthcare tasks are distributed between several actors (physicians, nurses, residents, and other clinical support staff) and artefacts (information technology, healthcare specific machines, paper notes) [14].

Thus, the challenge to integrate and redesign existing healthcare systems towards a more patient-centered exists [2]. This challenge is emphasized when integration efforts as the PCEH projects try to leverage the different actors and their sub-sequential attributes. Apparently, the professional healthcare actors with their many years of training, qualifications and expertise have much more medical knowledge than their patients. As a result, a paternalistic system has evolved where physicians expect, and patients expect them, to make the decisions about, or at least recommend, an appropriate course of treatment [15]. Therefore, an integrated system of personal healthcare information that is governed by the patient him/herself contradicts the established norms and highlights new challenges (e.g., validity and royalty of medical data, decision making culture etc.). For example following a more shared decision making or interpretation of the enclosed data, as the PCEH entails, requires (a) a plethora of the necessary medical data integrated in an easily accessible and comprehensible platform adequate for decision-making and (b) the physicians' arbitration to support or contradict those decisions. This requires well-developed sophisticated systems with clear boundaries on decision-making, responsibilities and availability of data.

Regardless the challenges, moving toward patient-centeredness is important [12]. To this end, this paper aims to introduce: (a) the main concepts surrounding the PCEH and (b) a PCEH project utilizing cloud computing. These are depicted in the following sections.

II. PATIENT-CENTERED E-HEALTH (PCEH)

Most developed countries are facing important overall problems regarding health care services, such as: (a) aging population with increased demand on specialized health care services (e.g., Chronic diseases), (b) need for increased efficiency with limited financial resources (e.g., Staff /bed reduction), (c) requirements for increased accessibility of care outside hospitals (e.g., home care) to name a few. To these problems, advances in information and communication technologies have provided considerable assistance in the form of EHRs [6]. Yet, it seems that traditional EHRs, which are based on the 'fetch and show' model, provide limited functionality that does not cover the spectrum of the patients' needs. Therefore, new solutions as the PHRs appeared to narrow this gap. In more detail, PHRs' data can come from various sources like EHRs, health providers (e.g., e-Prescibing, e-Referal), and/or directly from the patient him/herself – including non-clinical information (e.g., exercise habits, food and dieting statistics, etc.) [16].

The PCEH concept is a new multidiscipline area of research, with crucial aspects as it deals with the wellbeing of patients.

However, due to the length limitations of this paper we briefly present up-to-date research on the field, with the intention to fully present and analyse our rigorous research in a future publication. In this paper, we focus mainly on Wilson's *et al.,* (2014a) views. In more detail, Wilson *et al.*, (2014b) depicts that the PCEH should integrate three themes:

- **Patient-focus** - In many cases, e-health developers have created systems designed for patients' use that is not patient-focused but rather focused on healthcare organizations' objectives. Patient-focus requires PCEH strategies to be centered first and foremost on the requirements and perspectives of patients. To this extent if the patient require e-health services tailored to their needs, developers need to accommodate these needs. For example, young web-savvy patients expect their e-health applications to be responsive to their medium of choice (mobile, tablet, etc.), while more unexperienced elderly patients require a more user friendly environment.

- **Patient-activity** - Patient-activity requires comprehensive, interactive input by patients in providing data about themselves and representing their own perspectives as well as consuming information of interest to them. Yet, achieving high patient-activity in other e-health services may require reconceptualization of healthcare processes and information flows in order to provide opportunity to patients to add information they perceive to be relevant. The PHR is an example of such an e-health application.

- **Patient-empowerment** - in a technological perspective the empowerment happens through information-sharing, offering the patients a visual overview of their course of treatment, letting the patients take their own measurements, and letting them provide verbal and written inputs. From the PCEH perspective, however, patient-empowerment centers on providing similar levels of control via e-health that exist for patients in other modes of interaction with their healthcare providers.

The value of the three introduced characteristics is to ascertain the generalizability and abstraction properties of patient-focus, patient-activity, and patient-empowerment to the theoretical domain and to explore relationships among the PCEH characteristics [17]. Although at an early stage Wilson *et al.,* (2014b) arguments provide helpful guidance in the emerging issue of patient-centered e-health and can be of value in the development, design and evaluation of PHRs. These issues are included in our research agenda as well.

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To this end, we introduce in this paper our own practical involvement with a PHR project and provide a brief introduction in the following section.

III. Providing Integrated e-Health Services for Personalized Medicine utilizing Cloud Infrastructure (PINCLOUD)

PINCLOUD seeks to integrate different application components, leading to the provision of an end-to-end personalized disease monitoring and medical data service "anytime, anywhere", which ensures an independent living regardless of age [18].

The scenario upon which PINCLOUD is based, as seen in Figure 1, is a patient governs his\her PHR that can be remotely monitored by a physician located either at a hospital or at an individual medical office. Complementary to the PHR's stored information the doctor monitors the patient using a home care platform that receives and analyses patient's medical data. The proposed home care platform will include among others the following services: (a) Asthma or Chronic Obstructive Pulmonary Disease (COPD) disease management; (b) Hyper-tension disease management; (c) Diabetes monitoring; (d) Electrocardiogram (ECG) monitoring; (e) Video/ Audio Access to physicians for remote consultation; (e) Remote picture and text archiving and communication service (back-up/long term archiving complementary to infrastructure operated by hospitals) and (f) Fall Prevention and Detection Services. The doctor can access the patient's PHR on-line through a cloud computing service. The latter can support the doctor in decision making and results in better quality of health service. In more detail, the doctor retrieves and updates the patient's medical data and can also use the proposed on-line system to: (a) prescribe a new medicine; (b) fill in an e-referral for specific exams (e.g., blood test); (c) inform and advise his/her patient or (d) ask the patient to visit the hospital. Following the doctor's advice, the patient visits a pharmacy, or a diagnostic centre or a hospital. At the final stage, the healthcare service providers (doctors, hospitals, diagnostic centres) and pharmacies interact with the health insurance organisation to compensate all outstanding orders and medical actions.

Currently, PINCLOUD [19] is in its implementation phase, upon which the various components, such as: (a) PHR platform, (b) e-prescribing and e-referral, and (c) homecare applications, are being developed and tested.

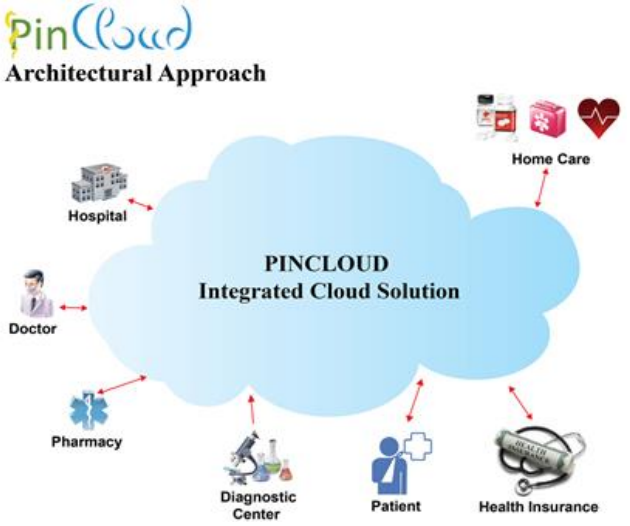

Figure 1. Providing Integrated e-Health Services for Personalized Medicine utilizing Cloud Infrastructure (PINCLOUD)

IV. Main Ideas

Service and data availability is crucial for healthcare providers who cannot effectively operate unless their applications are functioning properly and patients' data are available in a consistent manner. This is also the case for PINCLOUD. PINCLOUD's services (e.g. E-Prescription, E-Referral, Home-Care and PHR) ought to be available continuously with no interruptions or performance degradation since they will be used for decision making regarding the patients wellbeing.

New research projects, as PINCLOUD need to reinsure service availability to the participating healthcare providers and other organizations. In addition, hardware and software installations, upgrades, and reconfigurations have to be managed and maintained without any service interruptions that may cause problems. In order to achieve the availability in a cost efficient way the use of Cloud-Computing seems to be the appropriate solution and thus the PINCLOUD was designed based on its features. These features as cost-saving, agility, efficiency, resource consolidation, business opportunities and Green IT are relevant and applicable to the healthcare sector.

Besides, PINCLOUD potentially will be responsible for the governance of a big volume of medical data. The protection and integrity of such data is vital for both the patients' privacy and their wellbeing. At this stage of the project the protection of these data is achieved with a Private Cloud delivery model. A Private Cloud model is operated by a single organization. In the private cloud, the technology resides within an organization's own data center and the resources are deployed as needed to the different departments. In our project, a private IT company which is part of the consortium has provided the Private Cloud's infrastructure. Thus, the developers can overcome the

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challenges associated with other Cloud models (e.g., Public, Hybrid) since the ability to manage and control sensitive patient data remains within the organization.

PINCLOUD is based on the well-known Cloud-Computing three service models' structure, namely: (a) Software as a Service (SaaS), (b) Platform as a Service (PaaS) and (c) Infrastructure as a Service (IaaS). Respectively, PINCLOUD provides the user interaction through SaaS. In theory, SaaS is the capability provided to the consumer to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. PINCLOUD offers four applications, such as (a) E-prescription, (b) E-referral, (c) Home-Care and (d) PHR. These applications provide the main functionality required and are being consumed by End-Users (e.g. Patients, Doctors, Hospitals/Labs and Insurance Bodies). All these users access the PINCLOUD through user interface provided as a service. For example, a PINCLOUD registered user can have access to his/her medical record online.

In addition, PINCLOUD takes advantage of PaaS service model. Literature presents PaaS as the capability provided to the consumer to use and or deploy into the cloud infrastructure consumer-created or acquired applications created using programming languages and tools supported by the provider (NIST). Accordingly, it takes advantage of the PaaS model and provides open source components as Web-Services and Application Programming Interfaces (APIs) that facilitate the integration with third (3rd) parties (e.g., Medical Data Providers, Hospitals). For example, when a hospital decides to be integrated in the PINCLOUD system, it can allocate and consume the Web-services' API created.

The processing and storage capability of PINCLOUD is based on IaaS model. IaaS is the capability provided to the consumer to provide processing, storage, networks, and other fundamental computing resources while the consumer can deploy and run arbitrary software, which can include operating systems and applications. PINCLOUD takes advantage of the IaaS and provides data processing and storage of medical data. IaaS consists of multiple Virtual Machines (VM), Medical Data Base and Network Infrastructure. In the given case, multiple VMs are utilized with each one dedicated to one service (e.g. Database, Access Control, Backup).

V. EXPECTED BENEFITS

The project shall build a reliable, secure and extensible platform warranting stakeholder collaboration and enjoying public trust. The expected benefits for all participant organizations include amongst others: (a) the development of integrated healthcare services that improve quality of service and reduce costs; (b) business process reengineering, improvement, simplification and integration; (c) enhanced decision making for health organizations and significant reductions to medical errors; (d) standardization, automation, synchronization, better control and communication; (e) improved coordination, management and scheduling of specific health supply chains and services; (f) development of monitoring systems that improve quality of care of patients at home; (g) establishment of an infrastructure that provides up-to-date information; (h) development of an innovative organizational environment for the participating hospital using horizontal processes instead of the traditional hierarchical organization; (i) implementation of an extensible and maintainable infrastructure that can be enriched with other medical services; (j) development of an appropriate, sustainable technological framework that can be deployed and applied in other relevant situations and environments; (k) investigation of state-of-the art technologies and novel research that extends the body of knowledge; (l) significant research outcomes and publications of excellent quality; (m) production of new platforms, infrastructures and solution that can be further exploited, (n) knowledge and expertise gained can lead to competitive advantage and (o) production and export of technical know-how for all the participants.

The results of the proposed project are of great importance for the businesses that deal with the medical/health sector as they will gain the potential to gain competitive advantages through the project. The area of healthcare is significant and the need for advanced and innovative IT solutions in this area is apparent too. Thus, the participant enterprises will have the opportunity to: (a) develop an integrated platform that can be used by other organizations in the future; (b) better understand and analyze the complexities of the Greek healthcare environment; (c) experiment and implement innovative integrated solutions that can be turned into products; (d) gain expertise and know-how on a complex area; (d) sell these products and know-how at national and international level since PINCLOUD seeks to develop an innovative solution; (e) obtain and reinforce experiences that can be used for the development of other network-oriented systems and (f) extend their business activities.

The benefits for both healthcare organizations include among others: (a) specifications of processes for the management of healthcare processes; (b) simplification and acceleration of business processes; (c) better management of healthcare tasks; (d) personalized disease monitoring and cost calculation; (e) more efficient operation and (f) economies of scale.

The academic institutions' participation in the project is equally important and include benefits, such as: (a) knowledge exchange and transfer; (b) engagement in innovative research; (c) investigation of state of the art technologies; (d) opportunity to publish research articles of high quality; (e) prospect to conduct applied research and combine theory and practice.

PINCLOUD will deliver the following benefits to the national economy and society: (a) enhancement of occupation and working activities for the participating partners; (b) the reinforcement of scientific research; (c) improved delivery of healthcare services at reduced cost; (d) patients' and next of

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keen satisfaction; (e) the development of innovative and state of the art healthcare systems; (f) more efficient allocation and management of computing resources; (g) the development of new products and jobs; (h) reduction of medical errors and consequently the amount of people that are affected or die due to them; (i) the reduction of the cost as an immediate effect of the reduction of medical errors; (j) technical, scientific and research benefits; (k) reduction of the amount of prescriptions and referrals and the associated cost; (l) improvement of the quality of life of people who live in islands or rural areas.

VI. CONCLUSIONS AND FUTURE RESEARCH AGENDA

This paper introduces a Patient-Centered e-Health (PCEH) conceptual aspects alongside a multidisciplinary PHR project that combines state of the art technologies like cloud computing, Service-Oriented-Architecture (SOA), homecare telemedicine technologies, e-Prescribing, e-referral and e-learning in healthcare environment. The aim of the project is to create an integrated PHR platform that delivers many benefits to the society, the economy the industry and the research community. To this end, various technologies (e-health, cloud, etc.) and healthcare issues (e.g., complexity, PCEH, etc.) were presented. Additionally, our intentions on the way we propose to address and combine these issues were explained and depicted. In the previous section the benefits of such an endeavor alongside the steps taken so far to realize the implementation of a secure and reliable system, were analyzed. Yet, further research is required both in the testing and evaluation of our design and implementation.

To this end, the Research and Development (R&D) team engineered several mechanism to test and evaluate PINCLOUD and its components. For example, a proof-of-concept test will be implemented to check the communication of various sensors with the main PHR. The results of this test will be examined by healthcare professionals and provide initial evaluation of the technologies used. Additional, testing mechanism have been designed for other components (e.g., e-prescribing and e-referral) as well. Besides, PINCLOUD will be implemented in two different cloud IaaS providers so as to study the interoperability in two different settings. The results of this test will again provide insights into the utilized technologies and if needed reconfigurations and adjustments will be implemented. The authors expect the results of this test to be the subject of our next publication.

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