A Cloud Based Patient-Centered eHealth Record

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Abstract - **This research focuses on the Patient-Centered e-Health (PCEH) concept by introducing its importance and demonstrating a multidisciplinary project that combines advanced technologies. The project links 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 work.**

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, 2]. In this respect, there is a common trend to address HIS integration by an overall approach, seen as integrated patient centered care [3]. 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 [4]. 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 [5]. 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 [6].

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 [7]: 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 [8, 9]. Widely known PHR platforms in terms of centralized web-based portals include Dossia [10] and Microsoft Health Vault [11] platforms. Many systems presented in literature offer integration with already established PHRs platforms [12, 13]. 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 [14]. 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) [15]. 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 [16]. 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 as: (a) medical specialisations, (b) socio-technical and IT capacities, (c) organisational cultures, (d) structures, (e) actors

and (f) business process [2]. 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) [17].

Thus, the challenge to integrate and redesign existing healthcare systems towards a more patient-centered exists [3]. 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 [18]. 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 [15]. To this end, this paper aims to introduce: (a) the main concepts surrounding the PCEH and (b) a PCEH project utilizing cloud computing.

With this section introducing the reader to the research the rest of the paper is structured as follows; Section II presents the Patient Centered E-health (PCEH) theory, Section III lists relevant PHR and cloud computing projects, Section IV depicts the PINCLOUD project, Section V addresses the main ideas behind the PINCLOUD project, Section VI analyses the E-referal business process, Section VII highlights the expected benefits and Section VIII presents the conclusions and future research agenda.

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.) [19].

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 [15, 20] views. In more detail, [15] 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 [20]. Although at an early stage [20] 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.

III. PHR/EHR CLOUD-COMPUTING PROJECTS

Literature includes various examples of PHR and EHR approaches with different themes, addressing various aspects and produced in diverse settings (e.g., industry, academia etc.). This composes a mosaic of different examples that individual researchers of the field and/or developers need to consider before embarking in the Cloud-Computing e-health journey. Studying past endeavors one may learn from the successes and diverge from the mistakes of others. Therefore, our intentions for presenting such examples extent from providing a helpful list of recent PHR/EHR projects to illustrate unique techniques to implement Cloud services, describe ways to resolve the integration challenges faced, provide recent advances from academia and industry and highlight lessons learned and recommendations. The authors acknowledge that this is not an exhaustive list of examples but a suitable one for the theme and audience of this Journal.

To provide a better illustration and help the reader understand this important integration issue, the authors researched the literature and depict herein a twofold categorization of the findings, such as: (a) PHR/EHR solutions and/or (b) PHR/EHR components. This provides a useful categorization in the current ongoing PHR issues discussion. Starting with the PHR/EHR below the identified projects are presented in an alphabetical list.

CareCloud offers several approaches ranging from SaaS, to data analytics and IaaS. It offers healthcare practices a way to manage their practice with a plethora of tools. CentralCloud allows the management of patient records, appointments, billing and reporting. Charts solution provides an easy to use EHR system. CareCloud also has solutions for doctor – patient virtual interaction [21].

ClearHealth Office is a solution for small practice (fewer than ten physicians or 20,000 encounters per year) that can be distributed in two forms. The one is on premise and the second is cloud based. The first one (on premise), requires hardware and detailed setup processes. The second one is a cloud solution that removes the need for hardware and the problems with detailed setup. It is called HealthCloud and promises to deliver ready-to-go installations of ClearHealth Office on fully managed and secured datacenters owned by Amazon. This service is suitable for US practitioners, interested in self-serving their installations [22].

EMC Electronic Health Record Infrastructure Solutions consist of integrated, validated solutions with industry-leading healthcare (Independent Software Vendor) ISV partners [23], clinical applications, and best-in-class hardware, software, and services to help caregivers to move forward with their EHR deployment. EMC provides the supporting IT infrastructure aligned with clinical services needs for the highest levels of performance, availability, security, virtualization, and integration [24].

Healthcare Trustworthy Platform is a multilevel Personal Health Record (PHR) platform based on the Trustworthy Cloud Technology that allows people to share health data while guaranteeing security and privacy. It aims at the integration of third party applications and give them access to user's health data (e.g., view, add and update). It also provides a high security model, which allows the patients to decide how and with whom to share data [25].

The most popular solution in our list is the well-known HealthVault. It is being distributed through Windows Azure cloud server, which is already widely implemented in business environments and in some public administrations. Microsoft HealthVault provides one place to store and access of health information online. It supports interoperability with other healthcare providers. There is a growing list of devices such as pedometers, blood pressure monitors, blood glucose monitors, and even weight scales, which work with HealthVault. In that way, the users do not have to enter anything by hand, just upload their data directly to HealthVault from compatible devices [26].

Medscribler is a SaaS solution for recording patient data. It uses mobile technologies such as tablets and smartphones and handwriting recognition software to allow ease submission of patient data. It is an EMR solution that provides a quick and intuitive way to update medical records of patients. These records can be stored in a cloud. This solution provides an innovative approach to the problems of mobile practicing of medicine. The doctor is able to update patient records via a network connection and thus has no need for bulkier equipment than a tablet computer [27].

OpenEMR is a free and open source Electronic Health Records (EMR) and medical practice management application that can run on multiple platforms. OpenEMR is supported by a community of volunteers and professionals. This software can be implemented into a cloud as SaaS. It supports cloud structures, encryption, remote access and web browser access [28].

SOFTCARE is a multi-cloud-enabled platform, which has developed a prototype of a monitoring system for seniors that allow caregivers (formal and informal) and senior users to get real-time alarms in dangerous or potentially dangerous situations and warnings on long-term trends that could indicate a future problem. It is based on Artificial Intelligence techniques that allow the recognition of daily activities based on the data obtained from an accelerometer (bracelet device) and location information [29].

Another integration platform is X1.V1. It offers effective tools to generate reports about (a) the general healthcare status of the population, (b) the quality of healthcare performance and (c) the financial costs. In that way, it

facilitates the cooperation among the different caregivers in the provision of diagnosis and treatment. Another intuitive feature is that enhances epidemic diseases and cancer detection rate [30].

Zappa is an open source, extensible, scalable and customizable cloud platform for the development of e-Health/m-Health systems. It aims at delivering resources as services over Internet (Cloud-Computing). Moreover, the platform is intended to provide uninterrupted monitoring with the goal of obtaining some information that can be subsequently analyzed by physicians for diagnosing. Two e-Health applications have also been developed based on that platform: (a) Zappa App, (b) Cloud Rehab.

Having described the PHR/EHR solutions, the second part of list, the PHR/EHR components are depicted.

Cloud Rehab is a full m-Health system that is used to monitor the daily activities of patients with severe brain damage. It is a component to the Zappa cloud platform mentioned above. Cloud Rehab consists of two applications (a) web application and (b) Android application. Web application is being used by the medical staff to manage patients' medical information. Whereas, Android application is being used by the patient. The mobile application monitors heart rate and sends the data to the cloud [23].

DAPHNE is a Data as a Service (DaaS) platform for collecting, managing and analyzing wellness data in order to provide healthy lifestyle and preventive medicine [31]. DAPHNE platform is open to hardware and software developers, providing data for different personalized health services, both for the citizen and the service provider.

EMC Collaborative Healthcare Solutions provides a patient-centric infrastructure to "content-enable" Picture Archiving and Communication System, Hospital Information System, and Electronic Medical Record applications for accessing all relevant clinical, financial, and operational data. Based on open standards, the solution is in accordance with the Integrating the Healthcare Enterprise initiative that promotes the coordinated use of established standards. Their solution enhances operational agility through the abstraction of applications and infrastructure, improves financial performance by managing physical and virtual assets with highly automated tools, and secures access to and prevents loss of protected health information [21].

VIGOR++ is an international research project that aims to create a personalized gastrointestinal tract model, which facilitates accurate detection and grading of Crohn's disease.

VIGOR++ processes multi-scale information from patients, including laboratory, MRI, colonoscopy and microscopy (histopathology) data. Its techniques are integrated in the 3DNetMedical.com medical imaging cloud service, to make them immediately available in a clinically usable environment [32].

Zappa App is an m-Health system used to monitor the heart rate, temperature and blood pressure of the patient. It is a component to the Zappa cloud platform, which is mentioned above. In addition, Zappa App is able to save the vital sign values, detect health problems and share information with a doctor or medical staff that are in the same place that the patient (Bluetooth) [23]. The aforementioned categorized list is presented in Table I. The first column is an arithmetic count of the projects, the second the name, the third the type based on our categorization, the fourth the description and the last column the reference for each.

The aforementioned PHR/EHR solutions utilize the Cloud-Computing advances to achieve common goals, therefore they hold similarities such as: (a) integration, (b) interoperability and (c) lower business expenses. All of the aforementioned approaches try to integrate different systems to manage medical information based on a centralized system hosted on cloud. Furthermore, they try to provide users with the ability to access the systems through different type of operating systems (e.g., Windows, Linux, and MAC OS) and devices (e.g., desktop, laptop, tablet, smartphones, and medical sensors). The solutions presented in Table I leverage Cloud-Computing benefits to lower expenses both on Operating Expenditure (OPEX) and Capital Expenditure (CAPEX) at the health section. For example, solution number 7 can run in different systems, while 1, 4, 9 support integration of different type of systems resulting to lower business expenses.

Apart from the similarities, the above mentioned solutions also have differences between them, such as: (a) different type of users, (b) different target territories and (c) different type of devices. For example, solution number 8 is designed for senior people, 2 for small practices and 11 for patient with severe brain damage, 2 targets USA practitioners and 11, 15 address mobile devices implementations.

The aforementioned Cloud-Computing solutions hold several merits and aim at the same goal, provide better e-health services. Yet, due to the critical nature of healthcare and the importance of successful implementation of such endeavors, there is still need for rigorous research that can carefully examine the development steps and provide "best-fit" technologies. To accommodate this need the authors' involvement in a multidiscipline e-health integration project that utilizes Cloud-Computing. This endeavor is analyzed in the following section.

Table I. PHR Projects

	Name	Type	Description	Reference
1.	CareCloud	EHR	An easy to use EHR system which provides solutions for doctor – patient virtual interaction.	(SUCRE, 2014)
2.	ClearHealth Office	EHR	Provides an open source solution for running a small practice.	(ClearHealth, 2013)
3.	EMC Electronic Health Record Infrastructure Solutions	PHR/ EHR	Provides clinical applications, hardware, software, and services.	(EMC, 2014)
4.	Healthcare Trustworthy Platform	PHR	PHR platform for sharing securely health data and providing integration with 3rd party applications.	(Tclouds, 2014)
5.	HealthVault	PHR	Provides one place to store and access all health information online.	(Microsoft, 2014)
6.	Medscribler	EHR	SaaS solution providing intuitive way to solve the mobile's practicing issues of medicine.	(Medscribbler, 2014)
7.	OpenEMR	EHR	Free and open source Electronic Health Records (EHR) and medical practice management application that can on multiple platforms.	(OpenEMR, 2014)
8.	SOFTCARE	PHR	Multi-cloud-enabled platform monitoring senior people.	(AAL, 2013)
9.	X1.V1	PHR/ EHR	Integrated platform with intuitive features statistical reports about patients, caregivers and financial costs)	(Deadalus, 2014)
10.	Zappa	PHR/ EHR	Extensible, scalable and customizable cloud platform for the development of e-Health/m-Health systems.	(Ruiz-Zafra et al., 2013)
11.	Cloud Rehab	COM /NT	M-health system monitor daily activities of patients with severe brain damage	(Ruiz-Zafra et al., 2013)
12.	DAPHNE	COM /NT	Data as a Service (DaaS) platform for collecting, managing and analyzing wellness data in order to provide healthy lifestyle and preventive medicine	(Daphne, 2013)
13.	EMC Collaborative Healthcare Solutions	PHR/ EHR	Provides a patient-centric infrastructure to "content-enable" Picture Archiving and Communication System, Hospital Information System, and Electronic Medical Record applications.	(SUCRE, 2014)
14.	VIGOR++	COM /NT	Personalised gastrointestinal tract model, which facilitates accurate detection and grading of Crohn's disease.	(Vodera, 2014)
15.	Zappa App	COM /NT	M-health system for monitoring the heart rate, temperature, blood pressure of patient	(Ruiz-Zafra et al., 2013)

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.

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

PINCLOUD is a multidiscipline research project involving partners both from academia and industry that 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 [33].

The scenario, upon which PINCLOUD is based, is depicted in Figure 1 and involves a patient that governs his\her PHR, which is also remotely monitored by a physician located either at a hospital or 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.

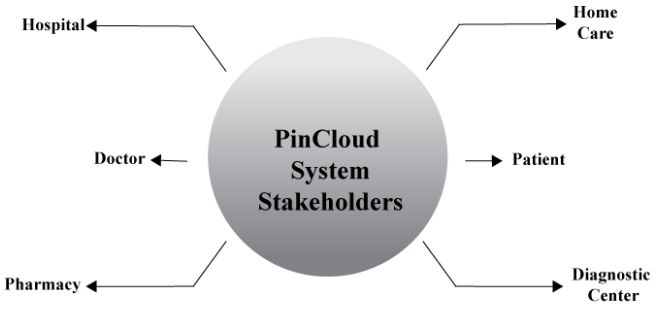


Figure 1. Providing Integrated e-Health Services for Personalized Medicine utilizing Cloud Infrastructure (PINCLOUD)

V. Main Ideas

Service and data availability is crucial for healthcare providers who cannot effectively operate unless their

applications are functioning properly and patients' data is 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 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).

VI. E-REFERALL BUSSINESS PROCESS

This section familiarizes the reader with the PINCLOUD architecture and provides a detailed account for one of its main services, the E-referral service, as seen in Figure 2. In more detail, Figure 2 demonstrates the three service models, upon which PINCLOUD platform is based, namely: (a) Software as a Service (SaaS), (b) Platform as a Service (PaaS) and (c) Infrastructure as a Service (IaaS). Additionally, the E-Referral Service Business Process flow is exposed in its main functionality (e.g., Login, find, open etc.).

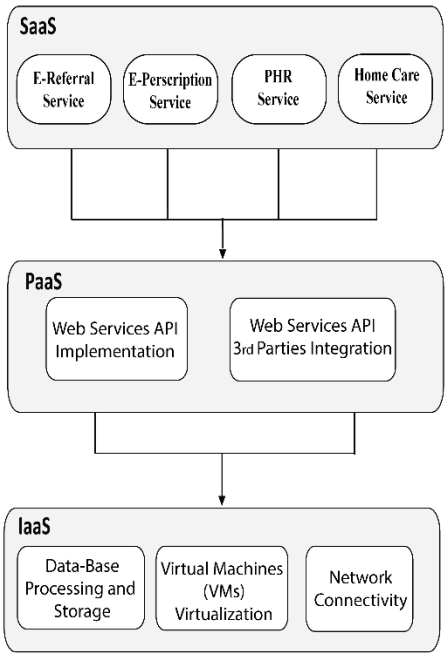
As shown in Figure 2, SaaS provides all the PINCLOUD's services such as: (a) Personal Health Record (PHR), (b) Home-Care, (c) E-referral and (d) E-Prescribe. The PHR is accessible by PINCLOUD's Services (E-Referral, E-Prescribe and Home-Care), but also by thirty party services and entities, which have access to the patient's PHR. Such thirty party services are the (a) Insurance Bodies, (b) Diagnostic Centers, (c) Trainers, (d) Medical Devices and manually submitted data by patient and access is granted with the patient's approval, as he is the owner of the PINCLOUD system.

The different web services (e.g., E-Referral, E-Prescription and Home-Care) are depicted in PaaS and can run independently and exchange information between each other. More specifically PICNLOUD provides two kinds of APIs, such as: (a) interconnectivity between the different provided services and storage and (b) providing access to thirty parties to connect with PINCLOUD, exploiting the advantages of PaaS Cloud models.

PINCLOUD is also using the IaaS Cloud model for: (a) Storage for the databases the platform is using, (b) The Virtual Machines where the PICNLOUD platform services are hosted and running and (c) The Network that is responsible for the interconnectivity between the different services and the different Virtual Machines of PINCLOUD.

It is worth mentioning that the PICNLOUD platform exploits several advantages from Cloud models such as the (a) Scalability (b) Elasticity and the (c) Lower Total Cost of Ownership (TCO), but also ensures the medical data integrity.

Figure 2. E-Referral implementation in PINCLOUD Platform



In a closer look of the E-Referral Service, an analysis of the Business Process flow is presented in the following paragraphs and depicted in Figure 3.

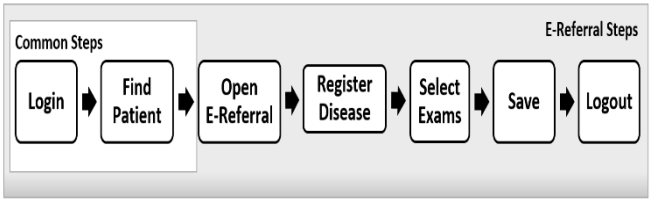
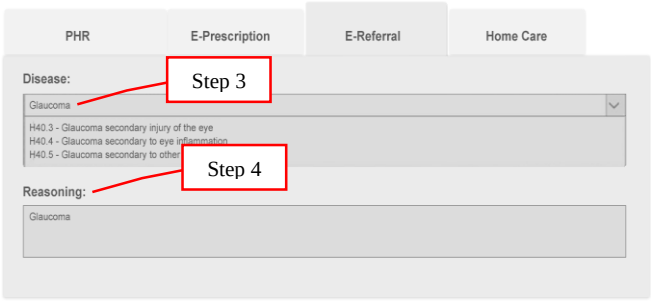


Figure 3. E-Referral Process

The E-Referral Service is one of the four main services the PINCLOUD platform offers as mentioned earlier in this section. The E-Referral Service is a complex web service consisting of several simple web services multiplexed together. In the diagrammatical flow shown in Figure 2, common (white border) and E-Referral steps (gray border) exist. The common steps referred to the steps which the doctor has to walk through despite the PINCLOUD service he/she executes (e.g., they are common for E-Prescribe as well). The first common step is "Login", in which the doctor provides his/her credential in order to gain access into the PINCLOUD platform. In the second step, "Find Patient" the doctor searches for the patient using the patient's SSN number, which is a unique key identifier for each patient as it shown in Screenshot 1.

Screenshot 1. The Doctor initiates the search for the patient's information

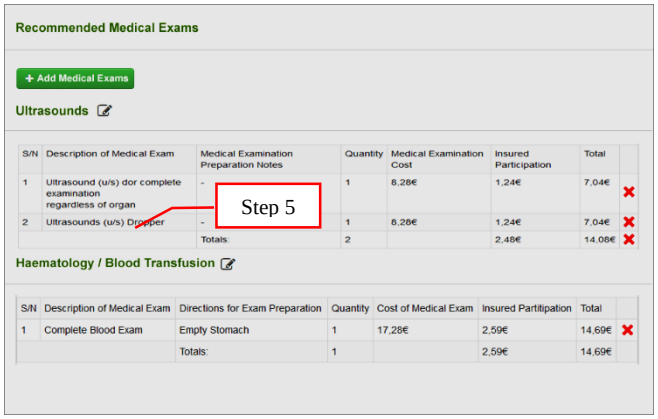
Moving on, the doctor selects between the offered services, such as: PHR, Home-Care, E-Referral and E-prescription, as depicted in Figure 2. In the next step (step 3), the doctor is able to create/open a new E-Referral ("Open E-Referral"). The "Open E-Referral" is followed by "Register Disease" in step 4, where the doctor obligated by the system to write the disease diagnosis with any comments (e.g., free text) as a guideline for the patient (Screenshot 2). The diagnosis for the patient's disease is encoded based on the Worlds Healthcare Organization International Statistical Classification of Diseases and Related Health Problems that is now at its 10th Revision (e.g., ICD 10).



Screenshot 2. Diagnosis

Moving on in the E-Referral flow in step five, the doctor is able to select all the required exams for the patient in order to issue the E-Referral. This step named "Select Exams" by the authors as shown in Screenshot 3. The exams, which the doctor is able to select are also based on the ICD10 standard. It has to be mentioned at this point that, the PINCLOUD platform provides efficient mechanisms in order to prevent medical errors. To this direction in the current Service (E-Referral) the system is able to ensure the disease to medical exams interactions by providing appropriate alerts in such cases. Thus, the doctor is able to select up to ten different medical Exams for each E-referral. Finally, the doctor is

ready to issue the E-Referral and save it in step six "Save" and logout.



Screenshot 3. Available Medical Exams

VII. 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 increase 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 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.

VIII. 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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REFERENCES

[1] K. Koumaditis et al., *"Introducing a Patient-Centered e-Health Record Over The Cloud,"* in *The Third International Conference on Global Health Challenges (GLOBAL HEALTH 2014)*. 2014, IARIA: Rome, Italy.

[2] D. Finnegan and K. Hamid, "*Information systems (IS) integration approaches in healthcare: a critical review in Integrating Healthcare With Information and Communications Technology*," W. Currie and D. Finnegan, Editors. 2009, Radcliffe Publishing: London. pp. 35-63.

[3] T. Leventhal et al., "*The Patient-Centered Medical Home and Health Information Technology,*" Telemed J E Health. , 2012. **18**(2).

[4] S. Singer et al., "*Defining and measuring integrated patient care: promoting the next frontier in health care delivery,*" Med Care Res Rev, 2011. **68**(1): pp. 112-127.

[5] A. D. Black et al., "*The Impact of eHealth on the Quality and Safety of Health Care: A Systematic Overview,*" PLoS Med, 2011. **8**(1): p. e1000387.

[6] Ruotsalainen, P., A. Iivari, and P. Doupi, "*Finland's strategy and implementation of citizens' access to health information,*" Stud Health Technol Inform., 2008. **137**: pp. 379-85.

[7] D. Detmer et al., "*Integrated personal health records: transformative tools for consumer-centric care,*" BMC Medical Informatics and Decision Making, 2008. **8**: pp. 45.

[8] P. Tang et al., "*Personal Health Records: Definitions, Benefits, and Strategies for Overcoming Barriers to Adoption,*" Journal of the American Medical Informatics Association, 2006. **13**(2): pp. 121-126.

[9] J. Halamka, K. Mandl, and P. Tang, "*Early Experiences with Personal Health Records,*" Journal of the American Medical Informatics Association, 2008. **15**(1): pp. 1-7.

[10] *Dossia Persnonal Health Record*. 2015 [cited 2015 May]; Available from: http://www.dossia.org/.

[11] HealthVault, M. *Microsoft HealthVault*. 2015 April]; Available from: https://www.healthvault.com/gr/en.

[12] S. Reti, H.J. Feldman, and C. Safran, "*Governance for Personal Health Records,*" Journal of the American Medical Informatics Association, 2009. **16**(1): pp. 14-17.

[13] F. Zhou et al., "*Mobile Personal Health Care System for Patients with Diabetes*, in *Aging Friendly Technology for Health and Independence*," Y. Lee, et al., Editors. 2010, Springer Berlin Heidelberg. pp. 94-101.

[14] P. Jennett and M. Watanabe, "*Healthcare and Telemedicine: Ongoing and Evolving Challenges,*" Disease Management & Health Outcomes, 2006. **14**(1).

[15] V. Wilson and D. Strong, *Editors' "Introduction to the Special Section on Patient-centered e-Health: Research Opportunities and Challenges,"* Communications of the Association for Information Systems, 2014. **34**(15).

[16] K. Koumaditis et al., "*A Proposition of Critical Sucess Factors Influencing SOA Implementation in Healthcare*, in *European Conference on Information Systems,*" 2012: Barchelona, Spain.

[17] T. Kannampallil et al., "*Considering complexity in healthcare systems,*" Journal of Biomedical Informatics, 2011. **44**(6): pp. 943-947.

[18] S. Sherer, "*Patients are Not Simply Health IT Users or Consumers: The Case for 'e-Healthicant' Applications,*" Communications of the Association for Information Systems, 2014. **34**(17): pp. 351–364.

[19] V. Koufi, F. Malamateniou, and G. Vassilacopoulos, "*An Android-Enabled PHR-based System for the Provision of Homecare Services,*" International Journal of Measurement Technologies and Instrumentation Engineering (IJMTIE), 2013. **3**(2): pp. 1-18.

[20] E. Wilson, W. Wang, and S.D. Sheetz, "*Underpinning a Guiding Theory of Patient-*

Centered E-Health," Communications of the Association for Information Systems, 2014. **34**(16).

[21] SUCRE. *Sucre State of the Art Report*. 2014 [cited 2014 13.04.2015]; Available from: http://www.sucreproject.eu.

[22] ClearHealth. *ClearHealth Smart. Simple. Sustainable*. 2013 [cited 2014 15.04.2014]; Available from: http://clear-health.com/.

[23] A. Ruiz-Zafra et al., *Zappa: "An Open Mobile Platform to Build Cloud-Based m-Health Systems*, in *Ambient Intelligence-Software and Applications,"* 2013, Springer. pp. 87-94.

[24] EMC. *Electronic Health Record Infrastructure Solutions*. 2014 [cited 2014 17.04.2014]; Available from: http://greece.emc.com/industry/public-sector/electronic-health-record-infrastructure.htm.

[25] Tclouds. *TClouds - Trustworthy Clouds Healthcare Scenario*. 2014 [cited 2014 15.04.2014]; Available from: http://www.tclouds-project.eu/downloads/factsheets/tclouds-factsheet-15-healthcare.pdf.

[26] Microsoft. *HealthVault*. 2014 [cited 2014 15.04.2014]; Available from: https://www.healthvault.com.

[27] Medscribbler. *Medscribbler*. 2014 [cited 2014 16.04.2014]; Available from: http://www.medscribbler.com/.

[28] OpenEMR. *OpenEMR a Free and Open Source electronic health records* 2014 [cited 2014 15.04.2014]; Available from: http://www.open-emr.org.

[29] AAL-Europe. *AMBIENT ASSISTED LIVING catalogue of projects 2013*. 2013 [cited 2014 18.04.2014]; Available from: http://www.aal-europe.eu/.

[30] Deadalus. *Interoperability Platform X1.V1*. 2014 [cited 2014 17.04.2014].

[31] Daphne. *Daphne Data-as-a-Service Platform for Healthy lifestyle and preventive medicine*. 2013 [cited 2014 April 15th]; Available from: http://www.daphne-fp7.eu/node/21.

[32] Vodera. *VIGOR++ virtual gastrointestinal tract*. 2014 [cited 2014 15.04.2014]; Available from: http://www.vigorpp.eu/.

[33] M. Themistocleous, K. Koumaditis, and G. Vassilacopoulos. "*Providing Integrated e-Health Services for Personalized Medicine utilizing Cloud Infrastructure*. in *European, Mediterranean & Middle Eastern Conference on Information Systems," 2013 (EMCIS2013), October 17-18*. 2013. Windsor, United Kingdom.