# Chapter 10

# Cloud Computing for Context-Aware Enhanced m-Health Services

**Carlos Fernandez-Llatas, Salvatore F. Pileggi, Gema Ibañez, Zoe Valero, and Pilar Sala**

## Abstract

m-Health services are increasing its presence in our lives due to the high penetration of new smartphone devices. This new scenario proposes new challenges in terms of information accessibility that require new paradigms which enable the new applications to access the data in a continuous and ubiquitous way, ensuring the privacy required depending on the kind of data accessed. This paper proposes an architecture based on cloud computing paradigms in order to empower new m-Health applications to enrich their results by providing secure access to user data.

**Key words** Cloud computing, m-Health, Smartphone, Electronic Health Record, Personal Health Record

## 1 Introduction

The deep penetration of smartphones in current society has exponentially increased the presence of applications that are used on mobile devices. The existing applications available in mobility are not only focused on leisure and entertainment but also, health management and m-Health applications [1] has recently increased dramatically its presence in smartphone application market. As a proof of that, the offer for m-Health applications in smartphones has increased a 700% in 2011 [2]. In this scenario, m-Health applications demand more storage capabilities, higher reliability, scalability, sustainable QoS in order to be competitive. Therefore, the user need to have the information at any point to take the right decision wherever he/she is.

The access to health information is a problem that has been deeply discussed in the literature [3, 4]. Since the early 1990s, the need for a common representation of medical records in order to provide access from anywhere to health centers and professional

Carlos Fernández-Llatas and Juan Miguel García-Gómez (eds.), *Data Mining in Clinical Medicine*, Methods in Molecular Biology, vol. 1246, DOI 10.1007/978-1-4939-1985-7_10, © Springer Science+Business Media New York 2015

was detected. As a result of that, the creation of an Electronic Health Record (EHR) [3, 4] is a common goal not only in European Union countries but also at a world scale.

However, the appearance of new personal devices and the new role of the patient as a continuous data provider [5, 6] offer new opportunities to health applications in order to build more personalized applications and approach more wide environments that usually take into account the current legacy Health Systems. Those applications need information that is not available in EHR systems. For that, it is needed to find new information sources for those systems. Personal Health Records (PHR) are called to fill this gap.

PHR [7] is an electronic record intended to provide patients a complete and accurate summary of their clinical staff, adding important personal parameters for the care of their health and well-being, such as nutritional aspects, family history, and others, involving more people in their care.

In addition to provide the data, it is needed to provide a tool to allow a deployment of this data making that information available continuously and ubiquitously. Cloud Computing [8] is a powerful framework that provide infrastructure to store and deploy PHRs and EHRs through the internet.

PHR as well as EHR has important legal restrictions. While EHR only can be accessed by Authorized Health professionals, PHR is owned by the patient and only him/her should have the power to enable the availability of that information to third-party applications outside the public health authorities. For that, the access to this information must be authorized and authenticated. In this way, it is a key point the fact that the deployed platform was role-based, allowing the patient to take the total control of the applications, as concerns sensible information of patients.

In this paper, an architecture that uses a cloud computing based architecture for providing a combined and secured access to EHR, PHR, and contextual information for third-party applications is presented. The paper is structured as follows. First in Related Work section a state of art on EHR and PHR existing works is made. After that, a Health information model that summarizes the author's vision of the combination of data that should be available for m-health smartphone applications is presented. Then, the Cloud based architecture is proposed, and finally the paper is concluded.

## 2 Related Work

The ICT are more and more present in Health Technologies. The basis of the creation of e-Health technologies is to allow an access to the data available about the patients. EHRs are the former solution available called to deal with this. EHR is formally defined as

the systematic collection of electronic health information about individual patients or populations [9]. In literature, there are lots of studies about EHR available. These studies are models that should cover that technologies in different fields [4]; the definition of different standards of EHR [10] for the unification of different existing models; the creation of systems to interoperate among different EHR [11]; fact standards defined by autonomous governments [12] and studies about the practical deployment of EHR [13], and the impact of the use of EHR by the Health professionals [3].

As it is defined, the EHR store all relevant data, in order to know the health status of the patient in real time, but only from the medical point of view. Nevertheless, with the penetration of m-Health technologies, it is more and more common that the health application not only made use of data from the medical point of view, but also they use information about the personal actions of the patients (Activity, Diet, etc.) and the Context information (Weather, temperature, etc.).

Context information can be usually gathered from data available on smart spaces or through internet, but the gathering of personal health data is a more complex problem. In this way, a new approach health record where health data and information related to the care of a patient are entered by himself is needed [7]. This approach is called Personal Health Record (PHR). There are available emerging commercial technologies for PHR population. HealthVault [14] is a Microsoft initiative that allows to connect monitoring devices and to develop services related to the data. Other example is INDIVO [15] which is an extension of Personal Health Folder. It incorporates health data from different sources and it is free and open. Moreover, it has been designed to be improved and personalized by the users. For example, they can connect their records to a third-party application which improves the management and analysis of the health data.

In order to provide access to those storage services, it is needed an infrastructure that facilitate a scalable, ubiquitous, and continuously accessible way to deploy them. Cloud computing [8] is a technology though to approach this problem.

Cloud computing describes a novel consumption and delivery model for IT services enabling dynamic and scalable environments for the sharing of virtual resources. Cloud computing is Web-based processing, whereby shared resources, software, and information are provided to computers and other devices on demand over the Internet. Details are abstracted from the users that are supported by the technology infrastructure “in the cloud.” The term “cloud” is used as a metaphor for the Internet, based on the cloud drawing used in the past to represent the telephone network, and later to depict the Internet in computer network diagrams as an abstraction of the underlying infrastructure it represents. Most cloud

computing infrastructures consist of services delivered through common centers and built on servers. Clouds often appear as single points of access for consumers' computing needs. The last generation of Cloud Technology allows users to feel remote resource and software remotely running as part of its own computation resource. Cloud vision enables several innovative business scenarios that assume customers do not own the physical infrastructure. Cloud Computing has become a scalable services consumption and delivery platform in the field of Services Computing.

In [16] some unsolved problems of cloud computing in health are explored. Recent researches that has been focused on use PHR in cloud computing [17, 18] do not consider the inherent problems of security issues from a role based computing point of view.

## 3 Context-Aware Health Record

The common concepts of EHR and PHR can be extended by using context information. This integration significantly extends the potential application field of the records since it provides rich information about the record owner behavior. Context information can be managed by end-user applications in order to provide extended and improved capabilities in terms of data analysis.

### 3.1 CA-HR Modules

Merging EHR and PHR, as well as the context-aware understanding of the health records, advise a modular structure for the resulting record (CA-HR). CA-HR implicitly defines a semantic understanding of the context meaning. The context provides stand-alone information as well as links to EHR and PHR.

Figure 1 shows the model proposed for the CA-HR. In this model, there are different data repositories that are responsible of different kind of information. Each one of the repositories could offer access to different modules depending on the scope of the application. The three repositories share a common semantic layer in order to provide a common way of the access. A common semantic framework ensures the extensibility of the model allowing the incorporation of new modules to fulfill the future new needs.

In that framework, m-Health applications are supposed that can work independently of the permission gathered. Nevertheless, the more access the application have, the more personalized the result is. For example, supposing a diet manager as third-party application, it can propose general recipes to a user if it does not has permission to access to any part of the CA-HR model. If the application have permission to access the context, the recipes could be refined according to the ingredients available at the smart space (i.e., Patient's Home). If the patient has enabled the access to the PHR for the application, the application can use the activity per-

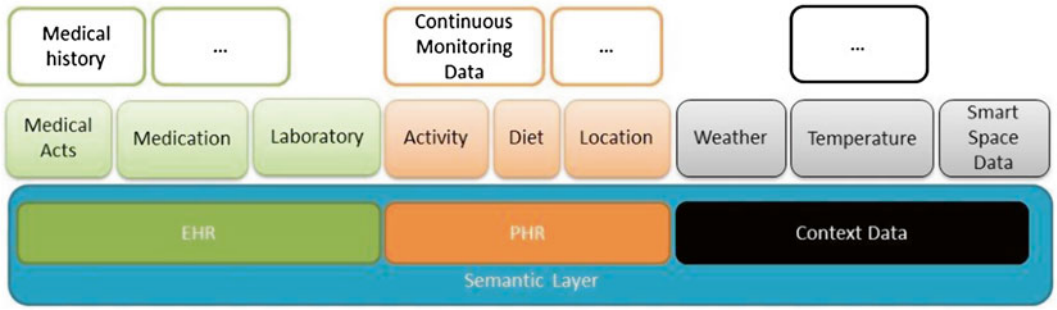


**Fig. 1** CA-HR model

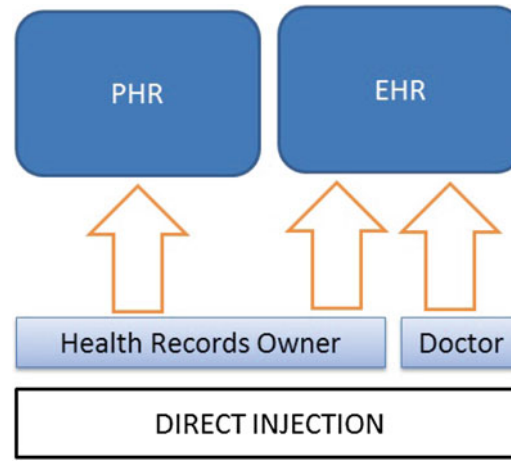


**Fig. 2** Direct data injection

formed by the user in order to calculate the amount of user calories wasted in order to build the most adequate recipe for each day. Finally, if, in addition, the application has access to EHR, the recipes can be selected avoiding the ingredients that user is not able to ingest due to allergy problems.

An extended analysis of the model is out of paper scope.

### *3.2 Context-Aware Data Injection*

In the common meaning, the data injection in the PHRs is an action always directly driven by the owner. The data injection in EHRs can be driven by the owner or explicitly authorized stakeholders (e.g., medical doctors). The normal action on health records as previously described (Fig. 2) is referred as direct data injection.

The CA-HR enables a further interaction mode (Fig. 3) in which an explicitly authorized application can inject data in PHR and/or EHR both with the related context data. This is the typical case in which the records owner is part of some kind of ecosystem

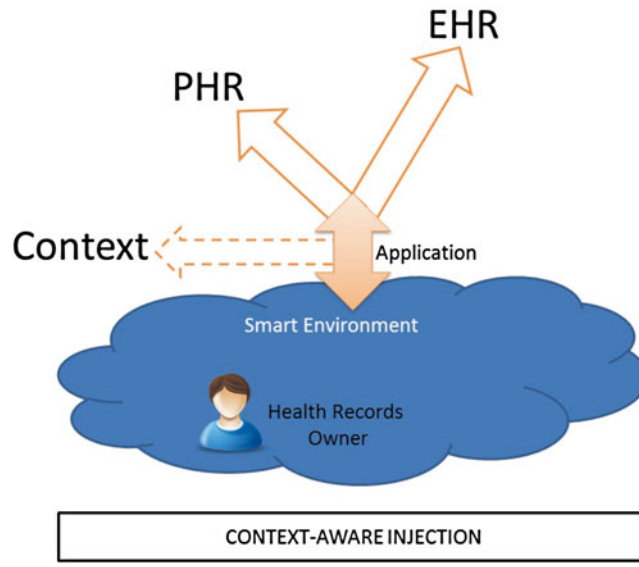


**Fig. 3** Context-aware data injection

that assumes the existence of active smart environments able to monitorize and detect personal and/or environmental situations.

## 4 A Cloud Platform for Context-Aware Enhanced m-Health Services

### *4.1 Overview*

The Cloud Platform model is shown in Fig. 4. An exhaustive overview at the architecture design (as well as a detailed analysis of functional layers) is out of the paper scope. A short description of the main functional actors composing the platform is provided. The proposed model is composed of four main components:

- **CA-HR Virtual Repository:** CA-HR is understood as a shared resource among heterogeneous third-party applications. Regardless by the physical storage location (the different modules could be distributed, as well as the context information), the platform assumes a virtual repository that makes CA-HR records available for the third-party applications.
- **Enablers:** They have the critical role of allowing the access to the modules information. In practical case, a refinement of the enablers could be required: the information related to a single module could not be atomic and so the enabler could allow the access to a part of the fields, denying the access to other fields. A concrete combination of the enablers defines, at the same time, the rights of a concrete application on the information, the role of the application user, as well as the privacy contract between the CA-HR owner and the application.

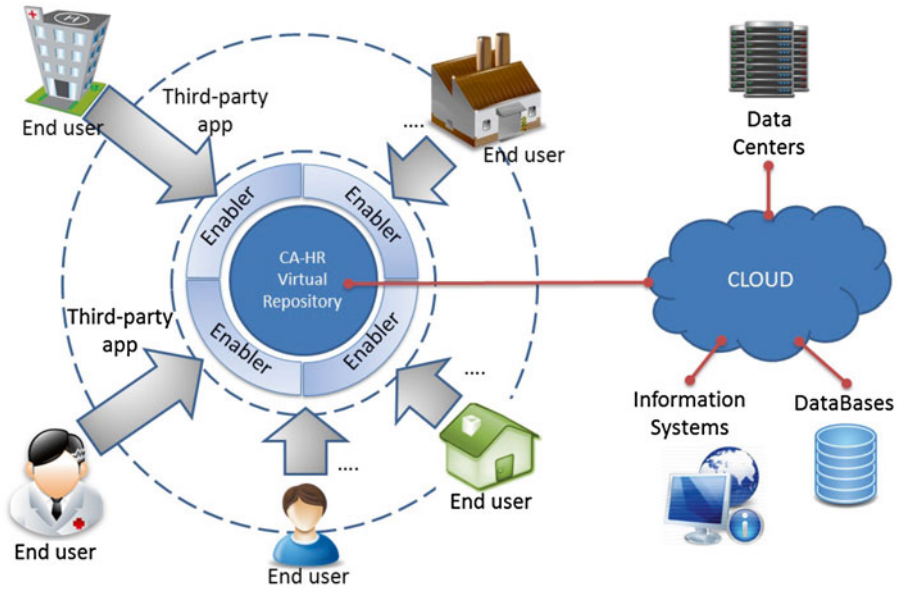


**Fig. 4** Cloud platform

- **Third-Party Applications:** Applications that explicitly sign a rights contract (enabled by the Enablers) with the end-user and so they are allowed of using and/or managing CA-HRs information (or part of it).
- **Application Users:** Users of third-party applications. In practice they are the final users.

### *4.2 Cloud Approach*

In order to allow an effective and efficient use of shared resources (CA-HRs) in a context of economic competitiveness and sustainability, the platform is implicitly referring to cloud infrastructures. This approach also provides a significant support in order to assure law restrictions about the privacy are respected, as well as a high security. The interaction with CA-HRs has different phases or modes (data collection, data delivery, data analysis). For each of these modes, the cloud approach plays a fundamental role:

- Data collection can happen as a direct data injection or as a context-aware data injection (as described in the previous sections). In both cases, cloud infrastructures allow a virtual understanding of the information: distributed information sources are available in the platform as a unique virtual repository. Furthermore, sensor devices (as well as any other kind of active actor able to associate observations or measurements to the record owner) just need an authorized gateway (e.g., a mobile device) to load new information or updates.

- Data delivery is driven by Enablers. Enablers are for instance a centralized concept that can be effectively applied to distributed environments by using virtualized resources. This virtual view is implemented on large scale by using cloud technologies.
- Data analysis could be a critical issue for the privacy and other related issues. The cloud approach fully supports "code injection" and similar techniques able to assure that third-party applications just access the output data and not the intermediate information produced in the process. Furthermore, in the case of complex analysis, additional resources for data processing in the cloud could be integrated allowing the execution of final applications in smart devices.

### *4.3 Role-Based Computation*

The modular and extensible features of CA-HRs both with the dynamism assured by the Enablers provide a powerful environment for role-based computation. For example, a hospital could have, for instance, basic rights on the CA-HRs. These rights could be automatically extended to be full rights if the situation requires it (an urgent situation for example). This dynamic switching of rights has to be carefully monitored and logged in order to assure the privacy of the owner is respected according to the law restrictions. The cloud approach, by this point of view, enables a centralized view of the activity in the platform and on the platform. Role-based computation facilitates both the application deployment and the platform management.

## 5 Conclusions

The use of cloud computing technologies to ensure m-Health applications a ubiquitous and continuous access to users data can be the solution to new need in this research field. Nevertheless, to ensure the privacy of that information allowing the user to have the total control over their data a role-based computation approach should be deployed. In this paper, a reference architecture for defining CA-HR model that involvers EHR, PHR, and context data is presented proposing a unified, scalable, and extensible solution for a role-based access to user data ensuring their privacy.

### References

1. Istepanian RSH, Pattichis CS (2006) M-health: emerging mobile health systems. Birkhäuser, Boston
2. Research2Guidance. Mobile Market Health Report 2011 http://www.research2guidance.com/the-market-for-mhealth-application-reached-us-718-million-in-2011/
3. Poissant L, Pereira J, Tamblyn R, Kawasumi Y (2005) The impact of electronic health records on time efficiency of physicians and nurses: a systematic review. J Am Med Inform Assoc 12(5):505–516
4. DesRoches CM, Campbell EG, Rao SR, Donelan K, Ferris TG, Jha A, Kaushal R, Levy DE, Rosenbaum S, Shields AE, Blumenthal D (2008) Electronic health records in ambulatory care—a national survey of physicians. N Engl J Med 359(1):50–60

5. Merilahti J, Pärkkä J, Antila K, Paavilainen P, Mattila E, Malm E-J, Saarinen A, Korhonen I (2009) Compliance and technical feasibility of long-term health monitoring with wearable and ambient technologies. J Telemed Telecare 15(6):302–309
6. Rashvand HF, Salcedo VT, Sanchez EM, Iliescu D (2008) Ubiquitous wireless telemedicine. IET Commun 2(2):237–254
7. Tang PC, Ash JS, Bates DW, Overhage JM, Sands DZ (2006) Personal health records: definitions, benefits, and strategies for overcoming barriers to adoption. J Am Med Inform Assoc 13(2):121–126
8. Buyya R, Yeo CS, Venugopal S, Broberg J, Brandic I (2009) Cloud computing and emerging IT platforms: vision, hype, and reality for delivering computing as the 5th utility. Future Gener Comput Syst 25(6):599–616
9. Gunter TD, Terry NP (2005) The emergence of national electronic health record architectures in the United States and Australia: models, costs, and questions. J Med Internet Res 2005; 7(1):e3
10. Eichelberg M, Aden T, Riesmeier J, Dogac A, Laleci GB (2005) A survey and analysis of Electronic Healthcare Record standards. ACM Comput Surv 37(4):277–315
11. Maldonado JA, Moner D, Boscá D, Fernández-Breis JT, Angulo C, Robles M (2009) LinkEHR-Ed: a multi-reference model archetype editor based on formal semantics. Int J Med Inform 78(8):559–570
12. Cerdà-Calafat I, Continente-Gonzalo M, García-López C, Guanyabens-Calvet J (2010) Personal health folder. Medicina Clínica 134(Suppl 1):63–66
13. Maldonado JA, Costa CM, Moner D, Menárguez-Tortosa M, Boscá D, Giménez JAM, Fernández-Breis JT, Robles M (2012) Using the ResearchEHR platform to facilitate the practical application of the EHR standards. J Biomed Inform 45(4):746–762
14. Microsoft Health Vault (2014). http://www.healthvault.com/
15. IndivoHealth (2012) The personally controlled health record. Last access: 28th March 2012. http://indivohealth.org/
16. Klein CA (2011) Cloudy confidentiality: clinical and legal implications of cloud computing in health care. J Am Acad Psychiatry Law Online 39(4):571–578
17. Kikuchi S, Sachdeva S, Bhalla S (2012) Applying cloud computing model in PHR architecture. In: Proceedings of the 2012 joint international conference on human-centered computer environments, HCCE '12. ACM, New York, pp 236–237
18. 2010 Ayia Napa MobiHealth. 2 (2011) Wireless mobile communication and healthcare: second international ICST conference; revised selected papers. Springer, Berlin