Analysis of the Cloud Computing Paradigm on Mobile Health Records Systems

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Abstract— **The cloud-based solutions can be also applied on e-Health services. To analyze it we have researched several publications about the implementation of some e-Health services based on the Cloud mainly through Medline. In this paper, concepts of Cloud Computing and mobile health records systems are explained. Moreover, the benefits, constraints, issues and requisites of a Mobile Health Record System implemented on the Cloud are analyzed. The mobility and sharing that Cloud-based solutions provide is one of main advantages, but there are some barriers like the security that must be overcome. Cloud Computing is still a technology under development, which means that in a near future the services it offers us will be greater.**

Keywords: Benefits, Cloud-Computing, Mobile Electronic Records, Analysis.

I. INTRODUCTION

The availability of Internet almost everywhere means the chance of getting all the data stored in the net from any device, which has an Internet connection. The growing of mobile devices with Internet connection also supposes the access to these data from even a smart-phone or tablet.

Health Organisms have to try to take this chance of having their data available every time at anyplace. This 100% availability of the medical resources can provide the patients and medical staff several advantages. To get those advantages first of all the resources have to be in an electronic format. In this paper we work with Mobile Health Records (MHRs). The next step to get these advantages is to host the MHRs in the Cloud. Here's the point where Cloud Computing is essential to offer us his services.

Hiring a Cloud solution our data will be hosted on the net and Cloud clients will be able to access their data with just an Internet connection. But also there will be some barriers that must be overtaken like security and awareness of the patients.

The rest of the paper is organized as follows. Section II presents a background related with mobile health records and cloud computing. Section III presents a cloud solution for mobile health records management system and section IV concludes the paper.

II. MOBILE HEALTH RECORDS AND CLOUD COMPUTING

Firstly the concept of the MHRs and the paradigm of Cloud Computing must be explained.

A. MHRs

EHR is the acronym of *Electronic Health Record.* This fact means that now the health record files are in an electronic format, so they can be used by the medical staff in order to store the clinical record of each patient in an efficient and easier way [1-3].

MHR is a similar concept of quoted above but it refers to *Mobile Electronic Record.* It supposes an improvement of the MHRs themselves because, as we will explain later, hosting those MHRs in the Cloud mobility will arise as one of the main advantages. Those MHRs are shared by different medical departments, so they can be consulted by any medical specialist who needs to access to this clinical information to treat the patient. These clinical records include a great deal of information such as personal and familiar medical background, previous treatments and medications, patient's allergies, blood test data and demographic and social facts. Another advantage of this method of MHRs is their ability of real-time updating because, after every medical surgery, the medical staff will update the MHR of the patient, so that the other medical specialist will be able to access this updated information [4-5].

The target of this paper is not to deepen in technical details of MHRs but is essential for the understanding of this technology to know that the MHRs must be standardized for a proper operation. The EHRs and MHRs are ruled by the American Standard HL7 (*Health Level 7*). This standardization is necessary so as to the EHRs can be interpreted and managed by any authorized medical personnel [6].

The use of the MHRs means a number of advantages over the traditional health records that we are going to describe below [7].

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- *Mobility and improved accessibility:* Storing the patient's clinical records in an accessible database for the medical stuff the process to access to that information is easier.
- *Greater data recording:* The use of MHRs allows the medical personnel to access to a greater amount of data about the patient. Due to this digitalization of the patients' medical records is easier to collect information and get stats about the needs of the patients.
- *Improvement of Quality of Service (QoS):* The implementation of these management systems of MHRs means an improvement of the services offered to the patients. Now, with these systems, the medical personnel is able to offer more efficient treatments.
- *Lower Cost:* The digitalization of this great amount of data means savings for the Health Care Organisms.

The implementation and growing of the EHRs and MHRs management systems supposes one of the biggest achievements of the e-Health. In the Figure 1 we can observe the global growing of the scientific papers publications related about the EHRs. This growing reflects the increase of the implementation of EHRs management systems since 1991 to 2011 [8].

B. Cloud Computing

At this section the paradigm of Cloud Computing is introduced. Cloud Computing is not exactly a new technology, but rather it's a combination of several technologies, which used in a certain way, can provide some kind of services that we are going to describe below. But, first of all, in order to understand this new technology, it's interesting to know that Cloud Computing means a radical change in storage and electronic resource management.

With Cloud Computing, instead of having the data stored in private servers, the customer hires a third-company, which provides him the storage of his data in his servers. This company will also provide their clients the maintenance of the servers and the access to their data. So, now, the resources and data will be obtained from the global net. That fact means that with this new method the clients hire just the services they need, which implies economical savings for the management of their electronic resources. Cloud Computing is based on a layered architecture depending on the services and functions which each layer offers. In Figure 2 the four layers of this architecture are shown. The function of each layer is described below [9].

SaaS (Software as a Service): This layer is on the top of the Cloud Computing's architecture stack. This layer allows the user to run applications remotely from the Cloud. So this layer is the software strictly speaking. Running these applications remotely from the Cloud the necessity of having installed any software in our computer it's avoided. With just an Internet connection users are going to be able to manage and handle their electronic resources. This issue

means a great advantage because now the user can get their resources from any computer, which also implies a huge mobility, because the clients can manage our data wherever we are.
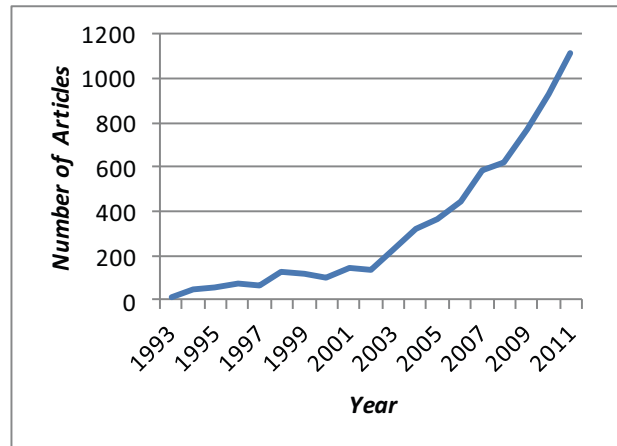

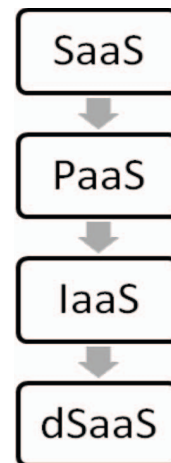Figure 1. Articles published about EHRs from 1993 to 2011.

Figure 2. Stack of Cloud Computing Architecture.

For example, in the case of a MHRs management system, Cloud Computing will allow the authorized medical staff to access the patient data from any computer without the need of having installed any kind of software.

IaaS (Infrastructure as a Service): This layer of the stack provides the storage and computation resources as a service. In this case Hospitals don't have to own their private servers in order to store and handle the data.
This layer includes virtualized computers with guaranteed processing power and reserved bandwidth for the storage, which allows the access via Internet.

PaaS (Platform as a Service): This layer immediately below the *IaaS* layer is based in the same idea, but applying it to hardware instead of the application (software).

PaaS layer adds to the *IaaS* an operative system and services for the apps which are running in the Cloud. It also includes the security and recovering data mechanisms and provides us a scalability system flexible to our needs. So it can be said that *PaaS* is *IaaS* with a custom software stack for the given application.

Virtualization: The concept of the virtualization of data is essential in the Cloud Computing's architecture. Although Virtualization is not a layer strictly talking it supposes a fundamental step for the correct operation of the other layers. This new concept allows the user a better use of the available resources, e. g: It allows the data storage of different applications, even if they are for different operative systems, in the same server.

dSaaS: (data Storage as a Service): The layer at the bottom of the stack constitutes the server itself. This layer provides the user the storage hired services and the needed bandwidth to access the resources.

For further understanding of this new concept of Cloud Computing the different kinds of Clouds in which users can host their resources will be explained next. This sorting depends of the "owner" of the Cloud. There are three kinds of Clouds depending on the property of the net in which they are implemented:

Public Cloud: In this kind of Cloud computing resources are dynamically provided over the Internet via web-applications from a third-party provider. This cloud is also called external Cloud. This provider stores the resources of all of his clients in his servers. So, this type of Cloud is the less secure since the resources are stored in the servers of another company. That fact means that if there are sensible or confidential resources, the client must have total confidence in the third-party company that is storing their data. Some examples of *Public Cloud* are the services provided by *Amazon Web Services, Google AppEngine or Microsoft Azure* [10]. In the case of a MHRs management system the privacy of our clinical records is going to play an essential role, because the medical information stored in the patients' records is confidential, and if Cloud providers can't guarantee that privacy, they will violate the patient's privacy.

Private Cloud: This concept is referred to Cloud Computing on private networks. These types of Clouds are built for the exclusive use of one client. This client will have full control over data, security and quality of service. This kind of Cloud Computing is also called external Cloud.

In this kind of clouds the problem mentioned above about the security of our resources doesn't exist, because now the client is the only one who can access to these resources. But this sort of Cloud Computing is more expensive than the mentioned above, because now an enterprise is hired to develop an infrastructure which will be only used by one client, so the customer assumes the entire cost.

Hybrid Cloud: It arises as an intermediate solution for those mentioned above. The development of these hybrid clouds consists in the application of the public and private cloud. Therefore, Hybrid Cloud is the proper alternative for a company which doesn't want to make an important initial inversion but have sensible data that must be protected. So in this model the sensible and confidential data is hosted in the private cloud and the remaining resources in the public one [10]. In Figure 3 we can observe the scheme of the three types of clouds.

III.   CLOUD SOLUTION FOR A MHRs MANAGEMENT SYSTEM

In this section the requisites, issues, benefits and constraints are that a Cloud solution can provide the client in a MHRs management system are studied. It is good to emphasize the change of mind that this new way of using technology means and those Cloud-based solutions maximize all the resources at our disposal. Several of the requisites, issues, benefits and constraints are common applying Cloud Computing on other fields different from the e-Health, but we will try to particularize these facts to for the MHRs field. It is important to consider that, depending on the agency responsible of the implementation of Cloud infrastructure the Health Organism should look for the most proper solution. Because it's not the same to manage the medical records on a large Hospital than in a primary care center.

Taking care of this information previously quoted above the requisites, issues, benefits and constrains of our method are described below.
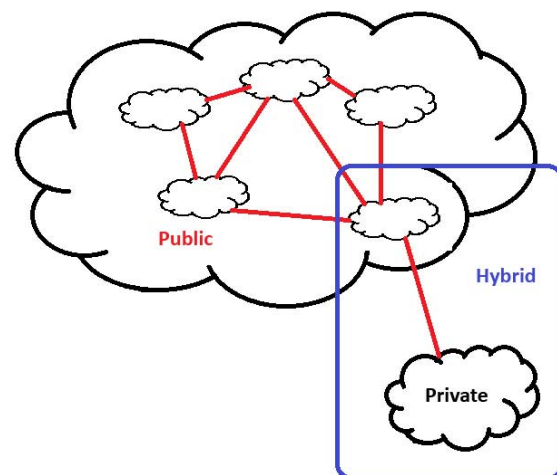

Figure 3. Illustration of the Types of Clouds .

A.   Requisites

To deploy a Cloud-based MHRs' management system several requirements should be fulfilled:

Bandwidth Internet Connection: This is the essential requirement to implement any type of Cloud-based solution.

Without such connection medical staff wouldn't be able to access the resources and services provided by the Cloud supplier, so in order to work in a fast and reliable way in the Cloud a broadband Internet connection is needed.

Standardized MHRs: Those records must be ruled by the international adopted standards in order to work properly with them into the Cloud. This fact is relevant because if physicians need to share their electronic records with another health care centers or medical personnel, which is one of the main advantages that Cloud Computing provides us, the fact that those MHRs are supported by other systems must be guaranteed. This standardization of EHRs will also be required by the web-applications in order they can handle those electronic records.

Customization of the Server by the Cloud Provider: Many Cloud computing providers offer their clients the same services regardless of their framework, offering barely customization options. To work with MHRs a specific e-Health site is necessary.

Management MHRs' Web-application development: To work with the MHRs that we have hosted in the Cloud will be necessary to develop and implement a web-application to manage, view or update them. There are some providers of Cloud Computing that just allow us to work with predefined applications, such as *Google Apps.* But there are also providers like *Amazon Web Services, which* develop applications based on their Cloud system to manage any kind of solution regardless of the framework.

B. Issues

There are some issues that a Cloud-based system can offer us in order to improve the MHRs management:

Cloud Computing as an evolution of MHRs: The MHRs migration to the Cloud supposes the next step after the conversion of the medical records to the electronic format. With a Cloud-based solution patients and physicians can get more advantages and better yield from those digital files.

Connecting different Health Care Centers: Through the Cloud MHRs will be shared in an effective and quick way. This means that small primary care centers and hospitals with the same deployed Cloud solution will be able to form networks of health-information exchange, giving the medical staff the chance of sharing their patients' medical records with other medical specialists from other centers in order to consult about their patient's treatments. So this change will speed-up many of the queries between the different doctors of each health care center, improving in that way the service offered to their patients. This health information network will be more important in the case of rural primary care centers in which this external support is more necessary than in a large hospital.

Providing Medical Staff a large number of services to improve the QoS: The deployment of Cloud Computing has as main purpose the improvement of the care received by patients. This issue will be more noticeable providing to the medical staff a number of tools to help them in such action.

This improvement in the quality of service is the result of all the benefits that the Cloud-solution offers, which will be discussed later.

Improving communication with patients: The idea of deploying a Cloud solution on a MHRs management system enables the access of the patients to their medical data. This technology allows the implementation of web-platforms like forums or private messages systems to improve the communication between patient and physician. This advance supposes a faster way to contact with the physician in order to resolve patient's doubts avoiding sometimes unnecessary medical appointments.

C. Benefits

Cloud Computing can provide four main advantages on a MHRs storing and management system:

Scalability and Flexibility: Thanks to the virtualization concept previously explained, Cloud Computing systems can be adapted to the amount of data the users need. So, due to this issue, both, hospitals and primary care centers will hire a third-company provider of Cloud solution to provide them only the services they need. So this third-company provides resources and services for users on demand. If, after a length of time, the number of patients increases, Health Care Organisms just will need to contact with his Cloud Computing provider to increase the hired services and adapt the system in order to manage more medical records.

Without Cloud solution, before implementing the system, it would be needed an estimation of the number of patients that the center will have to handle in a future. If the estimation fails, the health center will have to increase the number of servers, which means a large economic cost.
With Cloud Computing the highest utilization of the available resources is guaranteed, which wouldn't happen if the medical center had his own server's installation, because, surely in the beginning of its operation would not operate at a peak performance. Therefore, scalability and flexibility that Cloud Computing offers supposes an economic benefit on a MHRs management system.

Increased efficiency: With the deployment of this system the efficiency of medical personnel will increase, because with Cloud solution medical staff will work in a quick and effective way. Due to this fact the health system waiting lists could be reduced.

Economic Savings: As we have seen in the advantage above, the adaptive capacity offered by Cloud Computing paradigm supposes a saving in economic terms for the health care system. Moreover, it's important to mention that the use of Cloud Computing avoid a large initial investment in the infrastructure, which is impossible to face for some Health Care Organisms. Without a based-on-Cloud system the health organization must afford a large amount of money to implement his ECRs management system. This saving gives them the chance of being more ambitious developing and implanting new systems, because if that systems do not

work properly as they expected, they just have to contact the Cloud Computing provider and cancel these services. This means that the loss of money will not be as large as in the case of having developed the infrastructure without Cloud technology.

Cloud Computing supposes also savings in maintenance terms. With all the resources stored in the Cloud hospitals do not have to hire maintenance staff in charge of taking care of the servers. Now the Cloud provider is the responsible of the maintenance of the system. In this maintenance are also included software upgrades and migrations of databases that the Cloud provider does. So, with Cloud the client only has take care about having a bandwidth connection to the Internet to access to the resources. This service provider is also directly responsible for the failures that may occur on their servers, so if that were the case he would be in charge of solving these problems.

Ease of Use and High Availability: Deploying Cloud Computing on MHRs management system means access those records only with just an Internet connection and a credential. The number of mobile devices that are connected to the Internet is increasing, so the opportunities that Cloud services offer in terms availability at any place are enormous.

The authorized medical staff can access their patients data anywhere they have an Internet connection. Due to this issue, web-applications development plays an essential role in Cloud Computing in order to provide a feasible and simple access to the medical records from any mobile device with Internet connection.

These Web applications have to be functional so that the medical staff can easily become familiar with them, in order to they can access MHRs in an easy way, even with their *Smartphones*, in such a way that the doctor will be able query and even update their patient's MHRs in a quickly and easily way from any place with an Internet connection. As above-mentioned, the storage of resources in the Cloud offers high mobility and access from almost anywhere. Despite of these advantages previously quoted, there are also several barriers and constraints at the time of applying Cloud Computing to store the patient's medical records.

D. Constraints

Four barriers that may compromise the implantation of a Cloud solution on a MHRs management system are found.

Confidence in the Cloud provider: The outsourcing of the resources to another third-company implies to do this process with confident companies. In the studied case, the medical records contain private and sensitive data of our patients, so that it's important to guarantee the confidentiality of such data, since it's a third-company who manages that information.

Development of a legal framework and collaboration with Justice Organisms: The use of private resources must be unique to the customer (health organism) and the patient itself. Due to this fact Cloud Computing providers must abide to the Personal Data Protection laws in order to guarantee the patient's privacy. Moreover, all the operations and management over the resources must be transparent to the Justice Organisms responsible of taking care of Data Protection to avoid improper use of such data by the provider.

Another problem that has to be covered by legal mechanisms is the possibility of disappearing of the cloud provider. In this case these Cloud providers must be forced to offer their customers a range of options and guarantees for migration of their data to another Cloud company provider.

Data security: Cloud Computing Company must guarantee the privacy of their customers' resources in order to any unauthorized person could illegally access Cloud company servers to maintain their customer's data confidentiality.

Mobile-platforms *standardization:* To provide more facilities to the authorized physicians and medical personnel would be necessary to create a standard for web-platforms of Cloud Computing MHRs management systems, just as it happens with MHRs.

IV. CONCLUSIONS AND FUTURE WORK

First of all it is important to emphasize the radical change that Cloud Computing paradigm supposes in a large variety of fields like the e-health. This change must be featured by the Cloud providers as a viable option for the health organizations interested in migration of its MHRs to the Cloud. So these Cloud providers must persuade his customers that a Cloud-based solution is a cost-effective way to maximize their resources and saving costs. Another fact to take into account is that Cloud Computing is still under development and in a near future it will provide us customized services depending on the field that we are going to work.

An essential question that Cloud providers must answer to the health organizations is the problem about the privacy of the health records. Cloud companies must win the trust of their clients providing them security legal guarantees in property and privacy terms.

The fact that medical records are in possession of a third-company, different from the health-care organization may cause reluctance on the patient. In order to change the patient's mind the health organization and the Cloud provider have to convince them about the security and privacy of patient's data. The Cloud provider must also secure the MHRs against potential external attacks with security mechanisms which avoid that a non-authorized person could access to private data. So overcoming those problems Cloud-based solutions will offer the advantages quoted before and Cloud customers will be able to get a great mobility and accessibility.

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