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Analysis of Cloud-Based Solutions on EHRs Systems in Different Scenarios

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Abstract Nowadays with the growing of the wireless connections people can access all the resources hosted in the Cloud almost everywhere. In this context, organisms can take advantage of this fact, in terms of e-Health, deploying Cloud-based solutions on e-Health services. In this paper two Cloud-based solutions for different scenarios of Electronic Health Records (EHRs) management system are proposed. We have researched articles published between the years 2005 and 2011 about the implementation of e-Health services based on the Cloud in Medline. In order to analyze the best scenario for the deployment of Cloud Computing two solutions for a large Hospital and a network of Primary Care Health centers have been studied. Economic estimation of the cost of the implementation for both scenarios has been done via the Amazon calculator tool. As a result of this analysis two solutions are suggested depending on the scenario: To deploy a Cloud solution for a large Hospital a typical Cloud solution in which are hired just the needed services has been assumed. On the other hand to work with several Primary Care Centers it's suggested the implementation of a network, which interconnects these centers with just one Cloud environment. Finally it's considered the fact of deploying a hybrid solution: in which EHRs with images will be hosted in the Hospital or Primary Care Centers and the rest of them will be migrated to the Cloud.

Keywords Cloud computing · Economic analysis · Electronic Health Record (EHR) · Requisites · Solutions' topology

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Introduction

Nowadays, the availability of wireless Internet connection means a great advantage for accessing any information with a mobile device. With Cloud Computing data will be hosted in the Internet and medical staff can access it wherever and whenever they need it. But, can health Organisms take advantage of this fact in e-Health terms? Using the Cloud in order to implement e-Health services will improve the quality of service (QoS) offered to the patients, offering them some advantages that will be described later.

First of all it's essential to know the two technologies that are involved in this paper. Patients' data in an electronic format suppose several advantages such as greater data recording and improvement of QoS [1–5]. Moreover, combining the Electronic Health Records (EHRs) with the Cloud Computing paradigm will improve these advantages. But first it's interesting to introduce the concept of Cloud Computing.

With Cloud Computing a third-company provides the storage of the data in its servers and the maintenance of the system. So now users are going to get their resources and data from the net. That fact means that the customer just hires the services he needs, which implies economical

savings for the management of the electronic resources [6]. In order to get the best efficiency the Health Organism must evaluate all the available options to make the process of outsourcing of his data [7].

This method will be also suitable in the Emergency Medical System (EMS) in order to improve the agility and coordination between the different emergency care processes [8].

Several examples of Cloud-based solutions on e-Health services will be quoted in order to show that a lot of Health Organisms hire these solutions to improve the services they provide to their patients and the efficiency of their workers.

Then the requisites, issues, benefits and barriers to deploy a Cloud-based solution are cited in Results section. Moreover, two scenarios of implementation of Cloud-based EHRs management system, such as a large hospital and several primary care centers, will be analyzed.

Adopting these solutions they will get several advantages like mobility, economical savings, increase of the efficiency of the medical staff and more benefits that will be explained later. On the other hand there will be some critical problems that must be solved, as the privacy of the patients' records. Finally, the viability of the proposed solutions will be discussed giving several future lines of research as a way of improving the proposed solutions.

State of art of cloud computing solutions over e-Health services

As it's shown in the section above, Cloud Computing offers a new way of implementation of a wide variety of systems. But, Cloud Computing can be used to offer e-health services? To answer this question some examples of running e-health solutions with Cloud Computing in several Hospitals around the world are shown next.

In July 2011 Chelsea and Westminster London's Hospital set a Cloud Computing system to manage and store their EHRs. With this system patients have full control over who has access to their health records. However the Cloud provider company must prove the security of his system. To solve this problem they have implemented a security mechanism in which users have to pass multiple ID checkpoints to access the database [9].

Another example of Cloud Computing and e-Health services is found at the Italian Hospital of Bambino Gesú. This hospital, placed in Rome, is famous for being one of the largest research and treatment centers in the field of pediatrics. Since they are using Cloud they have experienced advantages such as: better collaboration between the medical staff, better connection with patients and more free time for the IT group [10].

In Spain we have the "Plan Avanza" with projects like the application of Cloud Computing at Hospitals radiotherapy treatments.

There are also examples in which mobility means the main advantage, such a Cloud environment that collects people's health data, such as ECG data, and disseminates them to a Cloud-based information repository, facilitating the analysis of the data using software services hosted in the Cloud [11]. But, is this method only relevant for developed countries? There are some studies that support the viability of Cloud Computing e-Health services in underdeveloped countries of South America. The results of these studies show the feasibility of the implementation of this system for health care [12].

Moreover, some American Health non-profit organizations are purposing Cloud Computing solution to provide the patients access to their medical records.

Finally one case closely related with this paper: The study of the United States government to apply Cloud Computing in a EHRs management system [13].

Methods

To obtain all the data referred to Cloud Computing we have resorted to several articles published searched in Medline mainly. Several publications which show the feasibility of the implementation of Cloud Computing solution on e-Health services have been found in order to look for the state of art of this new method. Most of them show the advantages that Cloud-based solutions can provide to the e-Health systems in different scenarios.

In order to analyze the best scenario for the deployment of Cloud solution we have supposed a large Hospital with about 250,000 patients and a network of Primary Care Health centers with approximately 10,000 patients each one. To perform this study we have supposed one of the two hospitals of a city with 300,000 habitants and the health primary centers available in it. To make an economic estimation of the cost of the implementation for both scenarios the Amazon calculator tool has been used [14].

Suggestions

In order to ease the deployment of Cloud-based solutions some suggestions to take in mind from the point of view of the Health Organisms are cited below:

To deploy the properly solution for each Health Center a deep study of the amount of data which will be transferred to the Cloud is needed. This estimation will help the Health Organism to hire just the needed services and save money.

Another fact to take into account is regarding of the Cloud provider confidence. Health Organisms must look for the proper provider which offers them several guarantees in terms of security and privacy of the data.

The Health Organisms also have to inform their patients of the migration of their data to the Cloud, because maybe some of them will be reluctant of the fact that a third-company handles their medical data.

Results

Firstly, some of the benefits, barriers, issues and requisites of a Cloud-based solution on EHRs systems are shown in Table 1. Then, two examples of this solution will be described: One of them applied to a large Hospital and the other one applied to primary care centers. Both scenarios have been analyzed because the number of patients is one of the most important parameters to take into account hiring a Cloud-based solution.

To deploy a Cloud Computing solution the size of the medical center and the amount of data that is going to be transferred to the Cloud must be taken into account, so that just hire the necessary services. If in the future more services are needed, medical centers just have to contact with the Cloud provider and increase those resources. This information will be obtained knowing how many EHRs handle each center and the size of each EHR. An estimation of the time that the solution will be available for the users is also needed. For the explained solutions a total availability of the service will be supposed. Two different cases in terms of size of the health care center are studied: a large hospital solution and a primary care center network solution.

Cloud-based solutions

Solutions' topology

Next a Hospital which offers health care services for 250,000 patients and a group of three primary care centers with about 10,000 patients is analyzed. It's supposed that the hospital has 350,000 medical appointments per year and the each health center 15,000.

This information is essential to know the amount of data transferred to the Cloud service, supposing that in each medical appointment the doctor consults and updates the EHR. For the case of the large Hospital a unique Cloud solution has been deployed (see Fig. 1). So the EHRs will be hosted in the Cloud and the medical staff will access them through an Internet connection of the Hospital network. This Hospital connection must be fast enough to provide a quick access to the Cloud so the medical personnel will obtain the EHRs immediately.

The Fig. 1 also shows that the medical staff will be able to access the EHRs through two different ways: Via the Hospital network which will be used by the medical staff during their working days and via Internet with any mobile device with Internet connection. The patient will access his medical records using credentials from these devices.

For the case of a primary care centers' network the solution which is shown in Fig. 2 is deployed. In this scenario each center uses the same Cloud solution and access to the EHR through his Internet connection. The same Cloud solution is used for several primary care centers is due to the fact that, in this case, each center has to host fewer resources than in the case of the large Hospital. More primary care centers can be added to the Cloud solution because of the scalability of Cloud Computing. To add another center or increase the capacity of the database of one center health Organism has just to contact his provider to increase the hired services.

The patients and medical staff have the same ways of connection that in the first scenario, but this network provides a connection between primary care centers.

Economic analysis

In order to estimate an economic analysis it's supposed that Health Organisms only will host in the Cloud EHRs without images because of his large size. It's known that an EHR without medical images has a size between 20 and 100 KB [15, 16].

To work with EHRs with images (DICOM images in EHRs has a size between 1 and 20 GB more or less) the

Table 1 Main benefits, issues, requisites and barriers of a cloud-based solution on an EHRs system

Requisites	Issues	Benefits	Barriers
Bandwidth internet connection	Cloud Computing as an evolution of EHRs	Scalability and flexibility	Confidence in the Cloud provider
Standardized EHRs	Connecting different Health Care Centers	Increased efficiency	Development of a legal framework
Customization of the server	Improvement of QoS	Economic savings	Data security
Management EHRs' web-application development	Improving communication with patients	High availability	

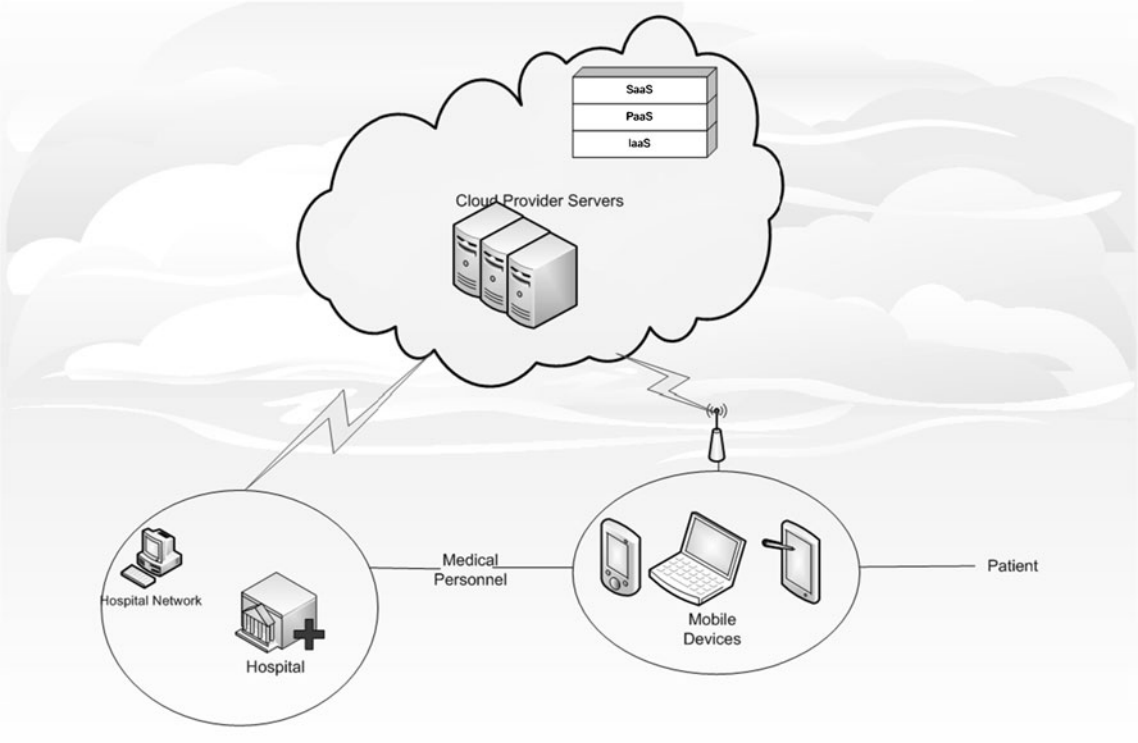

Fig. 1 Cloud-based solution for a large Hospital

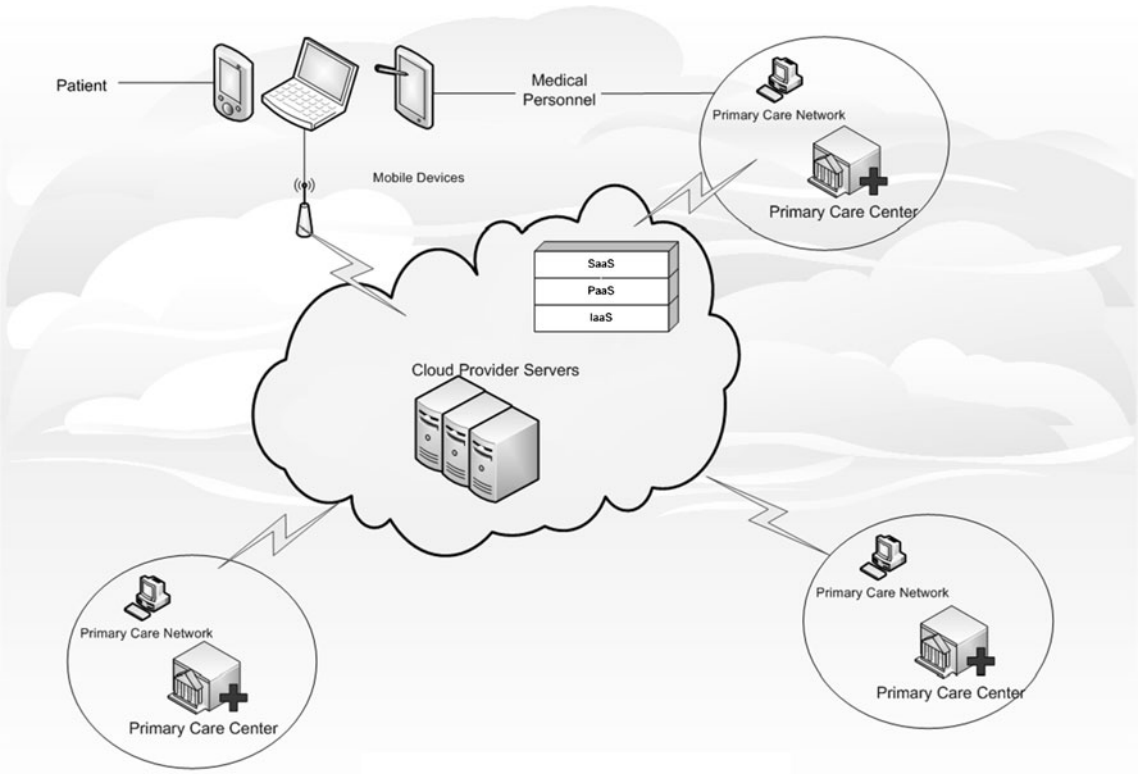

Fig. 2 Cloud-based solution for a Primary care centers network

Table 2 Amazon EC2 On-Demand Instances hired for a large Hospital vs. primary care centers network solution

Large Hospital					Primary care centers network			
Instances	Description	Operating system	Instance type	Hours/day of use	Description	Operating system	Instance type	Hours/day of use
1	Database	Linux/Open Solaris	Extra large	24	Database	Linux/OpenSolaris	Extra large	24
1	App servers	Linux/OpenSolaris	Large	24	App servers	Linux/OpenSolaris	Large	24
1	Web servers	Linux/OpenSolaris	Large	24	Web servers	Linux/OpenSolaris	Large	24

Cloud-based solution would be less feasible because Hospitals and Primary Care Centers would need a large bandwidth to interchange these files with the Cloud. To solve this problem a hybrid solution could be deployed, hosting the EHRs without images in the Cloud and the other EHRs in the Health Center's servers.

To analyze the economic aspect it's supposed that the Cloud-based solutions will be deployed with the Amazon Web Services provider, using its tool to estimate the monthly bill that health Organisms have to pay with the data mentioned above. Through this tool assuming that a Web-Application, with access to a database in which the EHRs will be hosted, will be deployed. So that, it's necessary to hire the Amazon Web Services below:

Amazon EC2 services: EC2 means Elastic Compute Cloud and it is the main core of the Cloud Services provided by Amazon [17]. Table 2 shows the obtained results in each scenario.

Amazon EBS Volumes provides block level storage volumes for use with Amazon EC2 instances where the patients' data will be hosted [18]. It's supposed that each EHR has an average size of 60 KB. The results for a large Hospital and for a primary care centers network can be seen in Table 3.

To know the amount of transferred data with the Cloud it's assumed that the medical staff query or update the medical record in each appointment and each record is queried by the medical staff 10 times per month, calculating it with the number of medical appointments per month.

In the case of the large hospital the customer need about 20 GB of transferred data which means a monthly-bill of 842.83€. In the second scenario the client need 2.15 GB of transferred data supposing 876.13€ per month.

Conclusions and future work

To deploy both solutions just the EHRs with no images have been migrated to the Cloud environment, because of the large size of the DICOM images. To solve this problem an estimation of the maximum size of the EHRs that can be hosted in the Cloud and accessed immediately by the medical personnel or patients is needed. This factor will depend on the bandwidth of the center and the amount of money that health centers want to spend; because with these large EHRs will be necessary to hire more services.

To implement the hybrid solution with the EHRs with images hosted in hospital servers and the rest of the EHRs in the Cloud environment, it's essential to look for a way of connecting both platforms, in order to provide the medical staff a quick and easy access to all the resources.

The economic analysis studied in this paper is done via an Amazon Web-application, which is developed for helping their customers to make an estimation of the monthly bill they have to pay if they hire any kind of Amazon Web Services. In order to make a deeply estimation of the cost of the solution it would be interesting to make a stronger study of the amount of data which will be transferred to the Cloud per month. Another fact in which health centers can save money is the time that the solution will be running. Health Organisms have to study if a 24/7 solution is feasible for them.

Despite all the barriers quoted in this paper, it's important to keep in mind that Cloud Computing paradigm is still under development but with a lot of chance of being a revolution in a lot of fields. In a near future there will be more services and the development will be greater.

Table 3 Amazon EBS Volumes hired for a large Hospital vs. primary care centers network solution

Large Hospital			Primary care centers network		
Volumes	Description	Provisioned storage	Volumes	Description	Provisioned storage
1	Patients' data	15 GB-month	**3**	Patients' data	1 GB-month

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