Cloud Computing System for Integrated Electronic Health Records

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Abstract. *The application of Information and Communication Technology in healthcare environment facilitates healthcare process and improves its service quality. However developing healthcare via technology innovations usually faces many challenges such as fear of cost, maintenance difficulties and security threats. Electronic Health Record systems showed great effects on developing healthcare outcomes and many are adopting it, but still many others fear to use it or face problems during its implementation and maintenance. Cloud computing technology is a new technology that has been used in different life environments and showed large positive changes. Despite the great features of Cloud computing, they haven't been utilized fairly yet in healthcare industry. This paper presents an innovative Healthcare Cloud Computing system for Integrated Electronic Health Records (EHRs). The proposed Cloud system applies Cloud Computing technology on EHR system, to present a comprehensive EHR integrated environment. The proposed Cloud system is composed of three main components; first is the Cloud's Central Database that represents the data repository for EHR's. The second part is the Unifier Interface Middleware; this component remains in the Cloud and responsible for masking the heterogeneity and standardising the communication between different EHR standards and the Cloud EHR system. Third component represents the web portal for the Cloud, it issues request messages and receives responses from the Cloud system via secured network connections.*

Keywords: Cloud Computing, Electronic Health Record, Integration**,** Middleware

1 Introduction

As healthcare remains one of the most important and expensive sectors in any community; many technologies have emerged and been funded by governments to improve healthcare delivery outcomes. The most common technologies that are designed to improve healthcare services are MHR (Medical Health Record), PHR (Personal Health Record), and EHR. EHR has many definitions, such as the electronic record that stores patient's medical history information in a health record system, accessible and managed by care providers [1]. Despite its positive impact on healthcare services; its adoption progress is slow in most healthcare institutions in worldwide; especially in developing countries due to several common challenges. Several studies found that the main barriers for its adoption are: 74% because of its high purchase costs, 44% for its high maintenance costs, physician's resistance 36%, Unclear return on investment 32% and Shortage in skilled IT staff 30% [2]. Patients in developing countries or in rural areas suffer from travelling to large hospitals carrying their paper health records and crossing the land to reach the specialized physicians and medical care in large hospitals with EHR systems. Moreover, patients registered in independent EHR systems in different hospitals also suffer from transferring their files to other hospitals. Such difficulties can be defeated by integrating EHR systems in healthcare institutions. But EHR integration (the process of patient information sharing among health care providers and exchanging them over the internet with other healthcare providers) remains a challenge and a serious concern since it is exposed to theft, security violation, and standardization difficulties [3].

Cloud computing technology is considered to be the new, most interesting and comprehensive solution in the IT world. Its main objective is to leverage Internet or Intranet for users to share resources [4]. The National Institute of Standards and Technology (NIST) defined it as:*"a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*"[5]. Cloud computing is a cost effective, automatically scalable, multitenant and securable platform that is managed by the cloud provider. Recently researchers have started to utilize Cloud computing services to solve many problems in healthcare IT adoption. But, not many researches entered the field of integrating EHR with the cloud services yet. A proposed system by Mohammed D., et al.[6] ,which represents a private Health Cloud

eXchange (HCX) system; this system outlines a distributed web based infrastructure for EHR sharing on the cloud among both local clients and third party healthcare information system. *NefeliPortal* is designed as a cloud EMS/PHR prototype architecture proposed by Koufi V., et al. [7]. Another paper presented *Artemis Cloud* computing framework by McGregor, C. [8]; for patients with critical care units (CCU) in rural and remote centers. It captures/process the real-time medical monitoring data with EHR data from the clinical information system. Some other researchers have implemented Cloud computing for Medical Image systems such as Yang C., et al.[9], they proposed MIFAS (Medical Image File Accessing System). There are more researches concentrating on patient's information security during exchange among the cloud's platform and other health institutions such as *EHR security reference model* by Zhang R.[10]. Healthcare and human life care comes in the first priority to get advantage of such technology. Therefore, this research is proposed to prove that the above challenges can be defeated by applying Cloud Computing technology to integrated EHR system. This paper is divided into three parts, the first part describes the proposed system components and its process, and then the discussion part explains the system impacts on healthcare institutions and discuses the system advantages. The paper ends with the conclusion.

2 Proposed Cloud system for EHR integration

A new healthcare Cloud system has been proposed for unification and integration of EHRs. The proposed system utilizes all features of Cloud computing combining them with EHR system features to gain one unified central system that controls electronic health records in the cloud infrastructure. And represent the solution for all hospitals in the region with an opportunity to use and share EHR. The Cloud system components are explained bellow, where different situations and scenarios for using the cloud and sharing EHR's are explained.

2.1 System components

The proposed public cloud infrastructure include: 1) a Central Database server that represents the clouds' IaaS data repository that communicates with the sharing hospitals through 2) a Unifier Interface Middleware (UIM). as an intermediary tool between the clouds central Database server and the sharing hospitals systems, 3) and the Cloud EHR Web Portal; that represent the cloud's SaaS for retrieving and displaying any required patient information.

2.1.1. Central Database server

The IaaS cloud Datacenter contains the Central Database server as the data repository for storing EHR's and retrieving patient information. The information is stored in XML format as a unified standard which can be stored and retrieved via query commands sent and resaved from the sharing hospitals Web Portal (web browser/EHR) system passing through the Unifier Interface Middleware (UIM). The Datacenter is managed by the Cloud Provider, and the Central Database applies virtualization techniques on its resources, where the hypervisor schedules the requests and handles the load balancing on each resource in the cloud datacenter.

2.1.2. Unifier Interface Middleware (UIM)

This part of the cloud provides an Interface that masks the heterogeneity of all sharing hospitals EHR standards, to facilitate the communication transactions between the Central Database and hospitals systems. It holds all types of EHR standards, so it recognizes any type it communicates with. It remains in the cloud infrastructure and communicates with the sharing hospitals via network connections. This is beneficial because rather than each hospital have to generate its own mask interface to benefit from the health cloud system; one interface will reside on the cloud and handle the heterogeneity from there. This interface handles two conditions;

2.1.2.1. Hospitals host their own EHR system locally

The UIM receives the Request message, and translates it into XML format. Then resend it to the cloud's Central Database.

2.1.2.2. Hospitals host their EHR's on the cloud (without local EHR system)

The UIM receives the Request message then resends it to the cloud's Central Database.

The request message (Req.msg) has three parameters, shown as: *Req.msg (T N, CPID/LPID, NN):*

- *T N*: Source Hospital ID composed of two parts: 1) *T*=EHR Type, either *0* if in cloud, or *1* if local, 2) *N*= hospital name 5 characters at most.
- *CPID/LPID*: this holds the patient ID number either in the Cloud (CPID) which is equivalent to the national number (NN), or the independent hospital local patient ID (LPID).
- *NN:* this holds patient national number; but this parameter is null when CPID exists.

The response message (Resp.msg) has four parameters, shown as *Resp.msg (CPID/LPID, NN, PCMH, PLMH):*

- *CPID/LPID*: Patient ID (either in Cloud or Locally) in the responding hospital.
- *NN:* this holds patient national number, null if CPID exists.

- *PCMH:* this parameter holds Patient-Medical history stored in the cloud's EHR database, can take null value if patient do not have EHR in Cloud database. Only one EHR (PCMH) exists for each patient registered in hospitals with Cloud EHR.
- *PLMH:* this parameter holds Patient-Medical history stored in the local EHR system, can take null value if patient do not have EHR in local systems. PCMH and PLMH are collectively exhaustive. Each patient can have more than one local EHR, if he is registered in different hospitals with local EHR.

2.1.3. Cloud EHR Web Portal

This is the third part of the cloud (top layer). This layer provides an application (SaaS) for EHR systems. The proposed Health Cloud system presents for end users a configurable EHR web portal for the Central Database. The web portal is responsible to issue send messages and receive response messages between the UIM and the hospital system. If a hospital has its own EHR system the web portal offers the user two tabs, either enter the hospital's local EHR system, or to the cloud Central Database. This web page provide the user with the ability to retrieve, update and receive EHR information from the cloud's Central Database EHR with limited access depending on the end user's privileges. The user can also, know from the retrieved information displayed on the web portal, if the requested EHR for a specific patient from a specific hospital exists inside the cloud or on the target hospital's local system. And can choose to view EHR information about the patient even from locally independent hospitals connected to the cloud.

2.2 System process

The system process starts when the cloud's Central Database receives the request message via the UIM, issued by end user via the web portal, It analyzes the Request message (Req.msg**)**, and response (Resp.msg) in different ways according to:

- *If Req.msg (0 #, CPID=NN) is true then the request message comes from a hospital that has its EHR on the cloud.* It matches the CPID to retrieve patients EHR information stored in the cloud. Where all hospitals that doesn't have a local EHR, they will have the same record for the same patient inside the cloud. So, only one online record for each patient with the visited hospitals names is stored in the cloud. The Central DB searches for a match for patient's National number since he might have EHR files stored in other hospitals with local EHR, if so: It resends a request message to the (match) found hospitals via UIM. The UIM reformat the request message according to the target hospital EHR standard format. The UIM send the reformatted request message and receives the response message, via network connection. After the UIM reformats the response message to XML format it sends it back to the clouds EHR. The central database combines the response message PLMH with the PCMH. Create a final response message in an XML format and send it to the requesting hospital.
- *If Req.msg (1 #, LPID, NN) is true then the request message is issued by an independent EHR system:* The UIM resends the request message in an XML format to the Central Database. The Database start searching for a mach for the NN from the request message to a CPID; if it finds a mach this means the patient have visited hospitals that have the clouds EHR, and then determine those hospitals. Then the Database start searching a mach for the NN from the request message to NN column for other hospitals connected with the cloud; if it finds a mach, this means the patient have visited hospitals that have their EHR locally. In this case the Central DB reformats a request messages to the matching independent hospitals, for gathering the patient's medical history. And send them via UIM that will reformulate the message type depending on the target hospital EHR standard type. Then the response messages will pass through UIM via network connection and reformed again into XML format and passed to the Central Database. The Cloud's Central Database will combine the existing (cloud's) EHR with the received medical history and form a complete report for the patient EHR in an XML Response message format. Finally the UIM will resend the final response message to the requesting hospital via network connection and a matching standard format. See figure1.

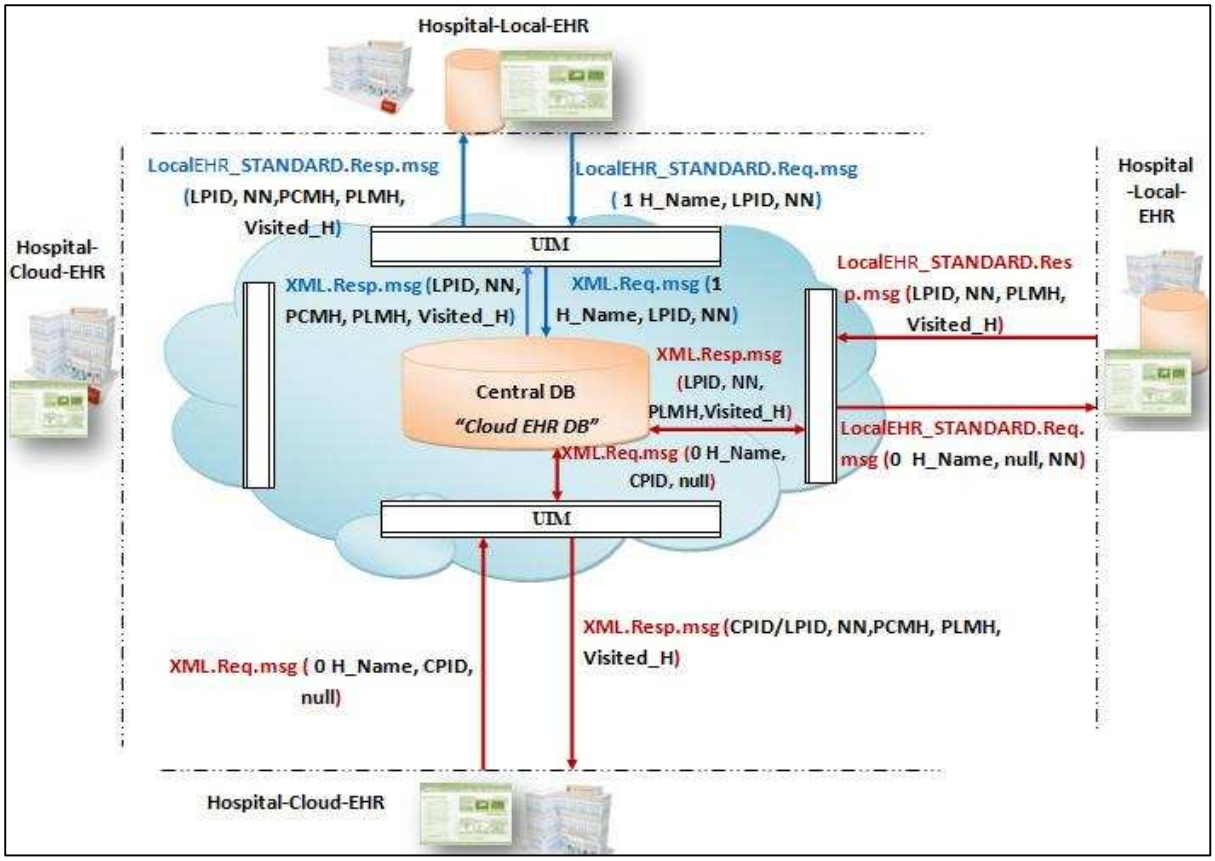

Figure 1 the proposed Healthcare Cloud system processes

3 Discussion

Cloud Computing can be applied to EHR system to facilitate EHR adoption for all types of healthcare institutions. Health Cloud features such as multi-tenancy, automatic scalability, securable connections and authorized data transactions managed by the cloud's provider; gives to many healthcare providers the ability to share a unified EHR system that handles as much users as possible with high performance. In fact the whole city is able to integrate into the cloud's EHR system without disk space, maintenance and security worries. Many other features of the health cloud such as pay as you go, solves high costs barriers for small healthcare institutions to adopt EHR technology ready from the cloud. Moreover, the proposed health cloud system showed that it is possible to integrate different kinds of EHR systems using the UIM tool that eliminates the burden of masking heterogeneity for healthcare institutions to share their local EHR system and share the clouds EHR in the same time. Thus, the proposed system provides a standardised unified environment for different EHR systems to communicate freely without any barriers.

The proposed system overcomes the challenges of implementing EHR systems for many hospitals such as maintenance complexities, staff training and high cost. In all cases the proposed system has the following advantages: Present a comprehensive and successful healthcare service. It allows' many healthcare providers to communicate and easily share patients EHR information among the healthcare cloud. Moreover, It overcome the challenges of EHR system integration such as network security concerns and information standardization difficulties. And present a configurable and scalable EHR system in Cloud computing platform for healthcare providers. It also, maximizes healthcare services quality outcomes, by releasing them from technology problems. It offers the opportunity for any kind of healthcare institution especially; rural and small sized hospitals or clinics to use EHR and join the cloud. Finally, It release patients' from suffering to find and move to the specialized healthcare providers they need, facilitate healthcare delivery process and then offer patients more easy, reliable and corporative healthcare life.

4 Conclusion

This paper proposed a novel solution for healthcare institutions to use EHR systems and overcome its challenges. The proposed system is composed of three main components, and applies cloud computing technology on EHR system integration. It provides a ready EHR system for all

kinds of hospitals. Irrespective of the number or the size of hospitals that join the cloud; the system is capable to work in integrity and it will offer healthcare providers the ability to communicate in a controlled, scalable, safe and cost effective way under the cloud. Future work will focus on completing the implementation and on evaluating the system.

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