CLOUD COMPUTING BASED HETEROGENEOUS PATIENT MEDICAL INFORMATION SYSTEM USING WEB SERVICE CLIENTS SERVING AS AGENTS

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Abstract: Cloud computing based Heterogeneous Patient Medical Information System that will allow various authorized users to securely access patient records from various Care Delivery Organizations (CDOs) such as hospitals, urgent care centers, doctors, laboratories, imaging centers among others, from any location. Such a system must seamlessly integrate all patient records including images such as CT-SCANS and MRI'S which can easily be accessed from any location and reviewed by any authorized user. In such a scenario the storage and transmission of medical records will have be conducted in a totally secure and safe environment with a very high standard of data integrity, protecting patient privacy and complying with all Health Insurance Portability and Accountability Act (HIPAA) regulations.

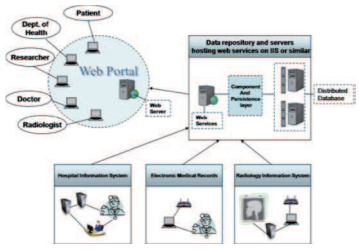
The sharing of medical records, specifically radiology imaging databases with CDOs will have potential to drastically reduce medical redundancies, exposure to radiations, costs to patients. It is essential to use the cloud computing in this application since it would allow the CDOs to address the challenge of sharing medical data that is overly complex and highly expensive to address with traditional technologies. In addition to providing community of care, proposed system can also serve as a valuable tool in clinical research, medical decision-making, epidemiology, evidence-based medicine, and in formulating public health policy.

Introduction : This System focuses on the development of architecture for integrating heterogeneous medical information systems such as (Hospital Information System, Radiology Information System, and Electronic Medical Records among others).These systems in their current form do not transfer information from one system into another outside a network. The proposed approach for a global medical informatics system would allow all medical records to be completely portable. In the current system a significant amount of delay is involved in transmitting medical records from one CDO to another, leading to repetitive medical testing and increased cost of healthcare to the patient, insurance companies and federal government. The development of a cloud based service oriented architecture that will provide all patients with an interactive view of all their medical records. Such a system would provide all patients with the ownership of their medical records, thereby eliminating the need to repetitive procedures.

The proposed system architecture drastically reduces the Medicare spending for imaging services. The sharing of medical records, specifically radiology imaging databases, will drastically reduce medical redundancies, and exposure to radiations. Total national healthcare spending is in excess of $2.6 Trillion or about 17% of our Gross Domestic Product. The proposed architecture would significantly contribute the reduction in national healthcare spending by eliminating the repetition of procedure due to unavailability of medical records. In year 2006 itself various medical imaging services accounted for 58% of Medicare's physician office spending.

In order to control this spending on medical imaging, the "Deficit Reduction Act" (DRA) was created in year 2005 to reduce medical imaging spending by $2.8 Billion by 2011. This system will allow various CDOs to share the medical records and imaging thereby, eliminating the need to repeat the procedures during a defined time period thereby, serving the objectives of Deficit Reduction Act. Please note with the current technology radiology imaging can be shared within a CDO, however not among various CDOs. The development of a lossless accelerated presentation layer would allow to access all radiology images residing on a cloud based distributed database in a lossless manner through a web-based DICOM viewer. This layer would provide a seamless access to all radiology imaging from any location in real-time thereby increasing the efficiency of overall medical record systems. Centralizing medical records can also create new and more intelligent perspectives in medicine. Such database with medical information will be extremely valuable for advanced data mining in clinical research. This will have potential to analytically evaluate and innovate new disease information and test methods that will improve the health care delivery and lead the exploration of new preventive treatment. In addition, the proposed system also serves the criteria of national Health Information Technology agenda.

Figure 1 shows a high level simplified overview of the proposed system



Related Work

1. To discuss an approach that would allow us to shift from institute centered hospital information system towards a regional/global medical information system by developing standards based Service-Oriented-Architecture (SOA) for interfacing heterogeneous medical information systems such that it would allow real-time access to all medical records from one medical information system to another 1].
2. To discuss a brief architecture and implementation plan to develop a "Lossless Accelerated Presentation Layer" that will allow one to view all radiology images (Digital Imaging and Communication in Medicine (DICOM) objects) that reside in a cloud based distributed database2]. This component would further allow the radiologist to annotate the image through a web-based viewer and store it back into the distributed cloud based database. Such layer would provide an instantaneous lossless access to all DICOM objects thereby, eliminating the download time. The current solutions do not provide the lossless view of the DICOM objects.
3. To discuss the architecture for web-based interface that will provide a holistic view of all medical records to every patient. The proposed environment will be scalable and reside on the cloud. Such a system would empower all patients with the automated ownership of their secure personal medical records. This interface can be extended to provide an anonymous view for all medical records for research purposes to scientific community and organizations such as department of health.
4. To discuss the strategies and architecture for the design of a distributed architecture that would ensure data consistency/integrity 3].The proposed architecture would provide autonomous scalability to allow dynamic growth of the cloud based medical information system.

3. System Architecture

The system must provide a simple user interface for all entities (users) involved. Inability to achieve this may prohibit users in using the system there by reducing the potential impact of the proposed informatics system. Government Compliance: The most important system requirement is security and the HIPAA compliance. The system must support both. Each workflow must be carefully designed such that it meets the HIPAA standard.

3.1 Architecture Description and Research Methods

Currently clinical data, in standardized format, is distributed among Care Delivery Organizations (CDO) such as hospitals, pharmacies, insurance companies among others. Creating and authorized & secured sharing of this data repository on cloud(s) based distributed database is the goal of proposed project. This paper is focused on several critical research components such as architecture of distributed database, load balancing algorithms for traffic management on cloud computing system, system integration, development of lossless presentation layer for image viewing and performance evaluation.

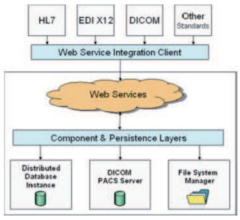
3.1.1 Objective 1: A Service Oriented Architecture for Interfacing Medical Messages

This section discusses the approach that has been adopted for interfacing several medical systems in order to centralize all patient records. The proposed solution does not focus on the developing yet another standard which would try and enforce other organizations to comply with. Rather the federated approach was selected, based on a set of already existing healthcare industry standards through which medical messages are transferred between different information systems. Currently medical messaging standards enable data transfer between systems in a request – service manner, where in the data is sent from one system to another directly or via a modulator like an EDI VAN service provider. Such data transfer is occurs only upon the request and is not based on the occurrence of an event such as admission of patient.

Through service oriented architecture various medical information systems can be integrated by collecting standardized data on a cloud based distributed database repository. In this architecture Web-services will be hosted securely on a cloud while the Web service clients serving as agents will be running on various health information-systems. In order to facilitate a seamless integration of various medical information databases the schemas of the distributed database residing on cloud(s) will imitate the existing schema of healthcare standards like HL7, EDI and DICOM.

During initial setup of the web-service clients, the schema of the existing HIS or EMR systems will be mapped to the proposed cloud based distributed database schema. This would allow the agent to periodically query the client databases through established connections which will facilitate the transfer of data to the cloud(s) over secure HTTP connection.

Figure 2 Layered view of the proposed service oriented architecture for interfacing medical messages



Web-Services (WS) is major, service-oriented; connection technologies which are specifications based and mostly open. In addition to its open source development potential in a technology neutral environment, major vendors are embracing World Wide Web Consortium (W3C) and the Internet Engineering Task Force (IETF) efforts. Significant advantages of using WS on top of any existing middleware solution are location transparency, language and platform independence, in addition to their adoption by big vendors and wide acceptance. WS, with their XML roots, open the door for the next generation, loosely coupled, coarse-grained, document oriented architectures. Security should not be considered an afterthought but it should be built into the communication platform itself. WS were originally considered as an easy way to do business across the Internet since it allows tunneling through the hypertext transfer protocol that usually bypasses corporate firewalls. The use of transport layer security may not be enough to provide the desired levels of authentication, authorization, and trust.

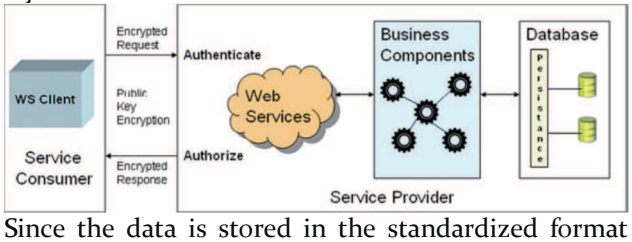
3.1.2 Objective 2

Lossless Accelerated Presentation Layer for Viewing DICOM Objects on Cloud a key requirement for DICOM viewers is lossless image coding; users accessing DICOM images should receive lossless image to rule out any compression artifacts 4].

3.1.3 Objective 3

Web Based Interface for Patient Health Records Patient health records stored in a centralized data repository over the distributed cloud(s) can be instantly viewed by any authorized user connected to this system through a web-based interface designed as part of the proposed system. The data can be accessed by existing health information systems with the help of remote calls to cloud hosted web services as shown in Figure. The proposed SOA would allow various medical information systems to interface with these web-services through their interfacing clients. All clients will go through a standard layer of authentication and authorization through public key encryptions standards.

Fig. 3.2 Service oriented architecture for presentation layer



Since the data is stored in the standardized format (HL7 or EDI) on the cloud based GHIS database, we must present the data in a readable format. The web portal can provide all users with the ability to search for a patient's identity given asset of demographic criteria and retrieval of all the related health and medical information pertaining to the patient under consideration. Additional filtering of patient data will be possible if the consumer of the service is only restricted to view some parts of the patient's medical records. This will be accomplished by the use of user roles and access grants. Secured logins to access patient records for authorized users such as physicians, radiologists, laboratory technicians among others can be created using the existing methods like one-time passwords (OTP).

A web-based ImageJ interface can be easily made available through this web portal system for viewing DICOM objects. ImageJ is a public domain Java image processing program inspired by NIH ImageJ for the Macintosh 5]. It was designed with an open architecture that provides extensibility via Java plug-ins. ImageJ will be integrated with a PACS server on the cloud to read DICOM objects residing on the distributed database. The user interface of ImageJ viewer application would depend upon the role of the accessing user. For instance, a radiologist will have the permission to alter the DICOM object that will be stored as a new version in form of a separate image layer. A web-browser presents the remote "desktop" from which an authorized user may launch ImageJ to open DICOM objects. Users interact with ImageJ directly using the controls provided by ImageJ. As the views of ImageJ change, a view encoder based on the TightVNC server compresses the "desktop" and transmits this to the user. Tight VNC uses the standard Remote Frame Buffering (RFB) protocol for desktop sharing and control 6]. Since lossless compression will be used in the View Encoder, the users will see images that are identical to the images rendered by ImageJ.

4. System Implementation:

System implementation can be done with the help of Globally Distributed Dynamically Scalable Cloud Based Application Architecture .The proposed medical information system concept is for patients, doctors and other care providers to have immediate access to medical records, images and other digital resources. Once connected to information system, the services available to a consumer will be filtered depending upon the Consumer's role and type.

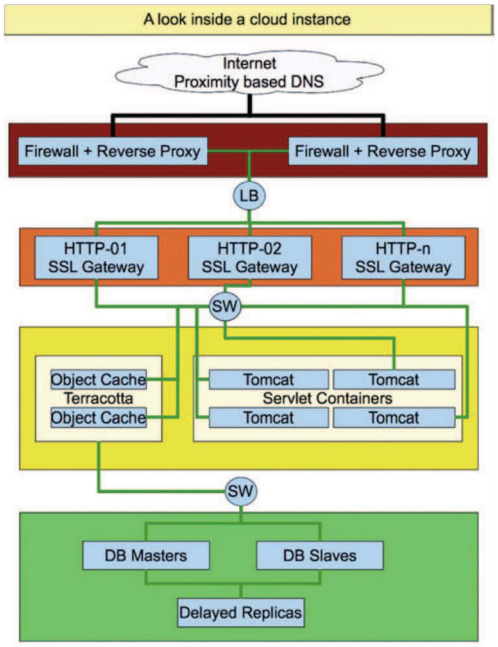
Figure 4.1 shows high level layered architecture for a proposed globally distributed dynamically scalable cloud that will be used for storing all medical data.

4.1 Implementation details by tier wise

Every tier in the Fig 4.1 includes multiple instances in the local and geographically distributed clouds.

4.1.1Tier 1 (Security Tier)

Tier 1 of each application partition would include firewall with VPN, traffic filtering, statistical



reporting and balancing functionalities and capabilities. In order increase efficiency of the tier, one would explore combining few of these services together on the same host or device, though cross-cloud Virtual Private Network (VPN) services will reside on isolated hosts 7]. Additionally, due to the sensitive nature of the Internet Protocol Security (IPSEC) hosts and to ensure data security, this separation is considered necessary.

4.1.2Tier 2 (Presentation Tier)

Tier 2 represents a web server for serving of http clients. Ultimately each instance on this tier should be able to detect a failed node on its tier and take over the load in order to provide fault tolerance in our overall proposed system. This can be accomplished by using the "Linux-Ha" clustering software in an active/active configuration (http://www.linux-ha.org/GettingStarted/TwoApaches). Secure Socket Layer (SSL)/Transport Layer Security (TLS) and http proxy services are somewhat compute intensive therefore their impact on overall performance is close to linear 8]. Thus, resources on this layer can be estimated based on number of connections.

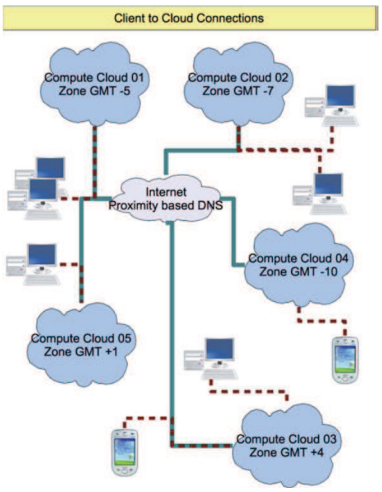
4.1.3Tier 3 (Application Tier)

Tier 3 is the actual application/business logic tier. The primary platforms in this tier are Apache Tomcat and Sun Java. Since the load balancing will be done mostly on the outer perimeter and http tier, high availability becomes the primary concern at this level. It being a healthcare domain, one of our prime objectives are to ensure the application availability all the time. Being data critical, healthcare applications cannot afford to lose the connection even during the major hardware outage of x-1 nodes (where x is the number of nodes serving the application via Apache Tomcat), the layer would ensure the constant availability of all applications.

4.1.4 The final Tier, Tier 4 (Database Tier)

The final tier of the server systems is the database systems.

5. Cloud Computing based Heterogeneous Patient Medical Information System using Web Service Clients serving as Agents .



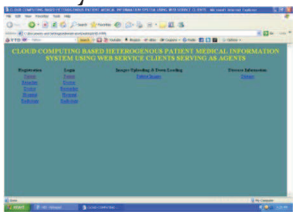
6. Preliminary Results Analysis

This research paper is work towards defining preliminary version of cloud computing based heterogeneous patient medical information system using web service clients serving as agents (CCHPIMSWCA). A Prototype as part of the suggested system has been build and some of the above mentioned features have been implemented now.

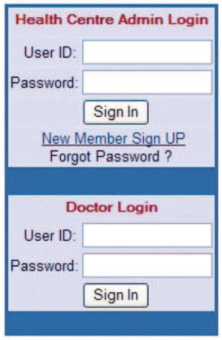
They include

- Patient and Researcher Registration Form
- Radiology and Doctor Registration Form
- Hospital Information Registration Form
- Insurance Company Registration Form
- Patient and Researcher Login Form
- Doctor and Radiology Login Form
- Hospital Information Login Form
- Insurance Company Login Form
- Patient Information Storing Form By Hospital
- Image Uploading and Downloading Form
- General Disease Information Form

Home page of the System.



Login Form



Conclusion : Although user authentication and authorization will reside in the application and integration services, the GMIS Infrastructure must be developed in such a way so as to ensure trustworthy use of the cloud systems and networks. GMIS security components and layers will be enforced on any internet capable platform. The existing security methods such as use of firewalls with a minimum necessary access policy and Public key infrastructure will be deployed in order to ensure secured access to the healthcare cloud. Further, one must aim at certifying all clients by GMIS Root Certificate Authority which in-turn may be certified by a third party.

7. Future Scope

This system can extended with public key infrastructure should be used for accessing the services and applications using Transport Layer Security (TLS) and require the servers to provide their credentials to the client. Additionally, by requiring the client also to present their security credentials (or certificate) we can easily establish a low level trust and assume that both parties are very likely to be who they claim. One must further configure the SSL/TLS processing servers with an HTTP based reverse proxy and Intrusion Detection suite.

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