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PROPOSAL OF SHARING MEDICAL IMAGES IN AN OPEN-SOURCE CLOUD COMPUTING SYSTEM

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ABSTRACT

The Hospital Information System incorporates an integrated computerized clinical information system for improved hospital administration and patient health care. It also provides an accurate, electronically stored medical record of the patient. The medical equipments used in the hospitals mostly generate the medical images in the form of DICOM (Digital Imaging and Communications in Medicine).Such medical images are mostly supported by the high-end medical imaging system. For a small township hospital it is incapable of constructing an independent information system which resulted in high construction costs and waste of resources. And also the equipment used in town hospitals will not support the DICOM images when patients change the different branch hospital which is not having high-end imaging system. In order to provide the unified standard for medical

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images our proposal system provides the conversion that is supported the low-end medical imaging system. In existing Hospital Information System the sharing of information is only within the same hospital. The proposal is based on the concepts of cloud computing. The medical image information sharing, exchanging and high-end processing is available in the "Cloud". The information (Medical Images) present in the cloud can provide the necessary details to the doctors and the patient can seek the treatment in different branch hospital, reduce the information and computational resource maintenance in the hospital. Furthermore, existing medical equipments can be rebuilt to be more efficient and low-cost as medical terminal units.

KEYWORDS

Cloud Computing, DICOM, Electronic Medical Records, Hospital Information System.

I. INTRODUCTION

Cloud computing is the delivery of computing as a service rather than a product, whereby shared resources, software and information are provided to computers and other devices as a utility (like the electricity grid) over a network (typically the Internet). Cloud computing provides computation, software, data access, and storage services that do not require end-user knowledge of the physical location and configuration of the system that delivers the services. Parallels to this concept can be drawn with the electricity grid, wherein end-users consume power without needing to understand the component devices or infrastructure required to provide the service.

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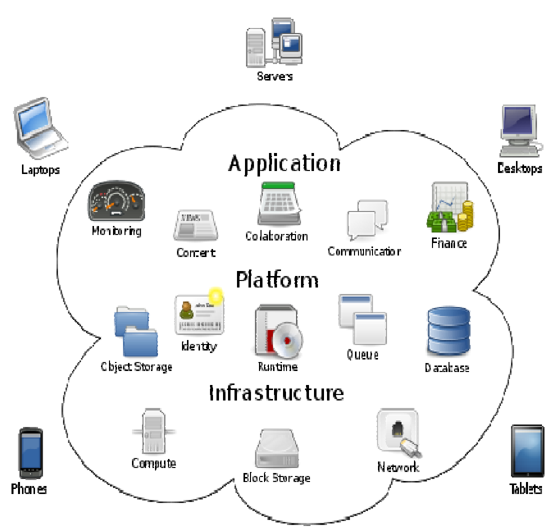
Cloud Computing represents a new way of delivering computing resources in the high end computing environment. As with all major disruptive changes in technology and Internet revolution, cloud computing represents a true democratization of Web computing and it is not only changing the business models and the way IT infrastructure is being delivered and consumed, but also the underlying architecture of how we develop, deploy, run and deliver applications.

The concept of cloud computing fills a perpetual need of IT: a way to increase capacity or add capabilities on the fly without investing in new infrastructure, training new personnel, or licensing new software. Cloud computing encompasses any subscription-based or pay-per-use service that, in real time over the Internet, extends IT's existing capabilities [1].



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VOLUME 2 ISSUE 2 March 2012

Figure 1.The Cloud Computing System

2. MOTIVATION

2.1. Problems of Traditional HIS

2.1.1 Lack of uniform standards for data-sharing

HIS is realized and widely applied based on Computer- based Patient Records (CPR); but before carrying out CPR system, it is most important to work out the problem such as the data storage and transmission standards. Unified format and content of data storage are the basis for communication between systems. Since the patients would not seek treatment in a fixed hospital, and in the present case of hospitals with independent information systems, it can cause information non-recognition and incompatibility between information systems during the referral process of the CPR.

At the same time, within hospital there are a large number of medical equipment such as ultrasound, CT, radiology equipment, monitoring equipment, anesthesia equipment etc., producing a large number of data of different storage forms and encoding methods. Information classification and data standards are not of strictly uniform. Although there are interfaces among different systems, it is very difficult to realize the integration between various subsystems. Therefore it directly causes the information unable to be shared effectively among different hospitals, even between different departments in the same hospital, thus resulting in duplication and waste of resources.

2.1.2 High cost for independent construction

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It costs much for any hospital to set up a complete platform combining all aspects such as hardware, software, management, maintenance, for the existing HIS construction. Township hospitals in particular, are neither possible nor necessary to establish a set of independent system, but It bears the important burden to provide medical services to rural residents. Even for medium and large hospitals, the independent construction of HIS is a heavy burden, such as the construction for Picture Archiving and Communication System (PACS). From the short term, PACS framework could not save medical costs but increase the burden of hospital expenditures. Thus the hospitals with not abundant capital prefer to continue using film and paper materials to record the clinic information.

2.1.3 Difficult to Management, Upgrades and Maintenance

Separate HIS requires separate management and maintenance for hospitals. With the problems arising during operation, such as technical shortage, incorrect use of software, or lack of experts, the management and maintenance of HIS requires continuous investment, which is a great cost to hospitals. Besides, different scale or specialized hospitals produce kinds of individual needs for HIS. The request for upgrade also comes up in usage. But independent HIS requires the maintenance and upgrade separately to progress in each hospital, thus a lot of HIS cannot get proper technical services [1, 2].

2.1.4. Why is cloud computing attractive to healthcare IT?

Many healthcare providers and insurance companies today have adopted some form of electronic medical record systems, though most of them store medical records in centralized databases in the form of electronic records. Typically, a patient may have many healthcare providers, including primary care physicians, specialists, therapists, and other

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medical practitioners. In addition, a patient may use multiple healthcare insurance companies for different types of insurances, such as medical, dental, vision, and so forth.

Currently, each provider typically has its own database for electronic medical records (EMRs).Sharing information between healthcare practitioners across administrative boundaries is translated to sharing information between EMR systems. The electronic records sharing between different EMR systems are called electronic health records (EHRs). The interoperation and sharing among different EMRs has been extremely slow. Cost and poor usability have been cited as the biggest obstacles to adoption of health IT, especially Electronic Health Records (EHR) systems. Cloud computing provides an attractive IT platform to cut down the cost of EHR systems in terms of both ownership and IT maintenance burdens for many medical practices.

It is widely recognized that cloud computing and open standards are important cornerstones to streamline healthcare whether it is for maintaining health records, monitoring of patients, managing diseases and cares more efficiently and effectively, or collaboration with peers and analysis of data. Many predict that managing healthcare applications with clouds will make revolutionary change in the way we do healthcare today.

Enabling the access to healthcare ubiquitous not only will help us improve healthcare as our data will always be accessible from anywhere at any time, but also it helps cutting down the costs drastically. A fundamental step for the success of tapping healthcare into the cloud is the in-depth understanding and the effective enforcement of security and privacy in cloud computing [3].

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VOLUME 2 ISSUE 2 March 2012

3. TAXONOMY OF HEALTHCARE CLOUDS

Its represent the taxonomy of healthcare clouds based on the cloud service models and the cloud deployment models. Based on cloud service models, we can divide healthcare cloud product offerings into three layers:

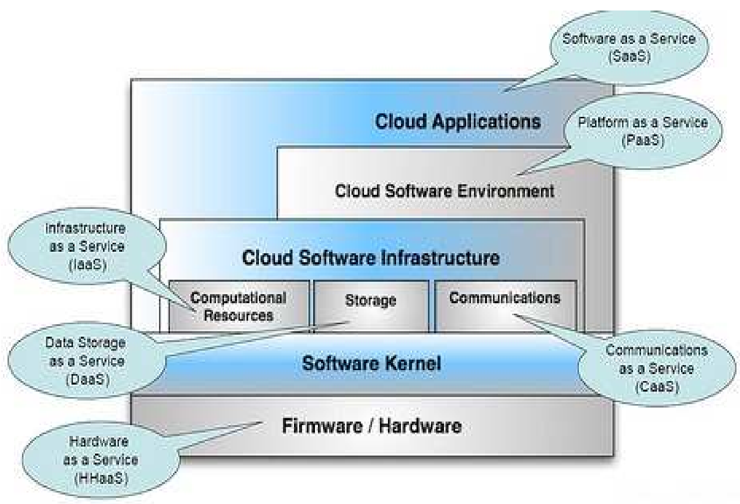

Figure: 2 Taxonomy of Cloud

Applications in the cloud (Software as a Service – SaaS). This layer provides capability for consumers to use the provider's applications running on a cloud infrastructure. For instance, the applications are accessible from various client devices through a thin client interface such as Web browser. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities. In this type of cloud service model, the security and privacy protection is provided as an integral part of the SaaS to the healthcare consumers.

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VOLUME 2 ISSUE 2 March 2012

Platforms in the cloud (Platform as a service – PaaS). This layer offers capability for consumers to deploy consumer- created or acquired applications written using programming languages and tools supported by the cloud provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations. In this type of cloud service model, two levels of protection for security and privacy are required. At the lower system level, the cloud provider may provide basic security mechanisms such as end-to-end encryption, authentication, and authorization. At the higher application level, the consumers need to define application dependent access control policies, authenticity requirements, and so forth.

Infrastructure in the cloud (Infrastructure as a Service – IaaS). This type of cloud service model provides the capability for consumers to provision processing, storage, networks, and other fundamental computing resources, in which consumer is able to deploy and run arbitrary software, including operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components (e.g., host firewalls). In the Infrastructure cloud model, the healthcare application developers hold full responsibility for protecting patients' security and privacy. We can also use the cloud deployment models below to give the taxonomy of healthcare clouds.

Private cloud. The cloud infrastructure is operated solely for a healthcare delivery organization (CDO). It may be managed by the organization or a third party and may exist on or off premise. In this type of cloud deployment model, the cloud provider provides the same capability in terms of security and privacy protection as those in the EMR system running by a CDO.

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VOLUME 2 ISSUE 2 March 2012

Community cloud. The cloud infrastructure is shared by several CDOs and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It is most likely managed by the third party or the CDOs and may exist on or off premise.

Public cloud. The cloud infrastructure is made available to the general public or a large industry group and is owned by a cloud service provider. In this deployment model, the healthcare application developers and consumers hold full responsibility for protecting patients' security and privacy.

In summary, security and privacy are more than just user privileges and password enforcement. It is a multidimensional business imperative, especially for platforms that are responsible for customer data. Cloud-computing platforms must have detailed, robust policies and procedures in place to guarantee the highest possible levels of physical security, network security, application security, internal systems security, secure data-backup strategy, secure internal policies and procedures, third-party certification.

In healthcare cloud, security should be the top priority from day one. We argue that patients' data is protected with comprehensive physical security, data encryption, user authentication, and application security as well as the latest standard-setting security practices and certifications, and secure point-to-point data replication for data backup[7,3].

4. RELATED WORK

Cloud computing model provides a new way to solve foregoing problems. Some studies have been performed recently in an attempt to employ Cloud method in medical affairs.

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VOLUME 2 ISSUE 2 March 2012

The work in [5] introduces the concept of Medical Image File Accessing System on cloud computing. This uses the Hadoop platform to solve the exchanging, storing, and sharing issues in Medical Images.

The work in [5] proposes a solution for collecting the patient's data in Health Care Institution using Cloud Computing.

The work in [6] introduces the concept of Secure Electronic Medical Record Sharing Mechanism in Cloud Computing Platform.

5. OPEN SOURCE CLOUD COMPUTING TOOLKIT

We have selected a Open source product which we consider to have a viable future for applications in enterprise environments.

5.1 Overview of OpenNebula 3.0

OpenNebula is the industry standard for on-premise IaaS cloud computing, offering a comprehensive solution for the management of virtualized data centers to enable private, public and hybrid (cloud bursting) clouds. OpenNebula interoperability makes cloud an evolution by leveraging existing IT assets in your data center.

Some of the main principles which guided the design of OpenNebula are full openness of architecture and interfaces, adaptability to various hardware and software combinations, interoperability, portability, integration, stability, scalability and standardization. Its main features include data-center or cluster management with Xen, KVM

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VOLUME 2 ISSUE 2 March 2012

or VMware virtualization. It leverages the most common cloud interfaces Amazon AWS, OGF OCCI and VMware vCloud, and provides user management with authentication, multiple user rolling, secure multi-tenancy and quota management.

In the scope of cloud management a rich set of storage, virtual image, virtual machine and virtual network management features is provided. It supports cloud-bursting with Amazon EC2, simultaneous access to multiple clouds, and cloud federation. Standardization and interoperability are supported through abstraction from infrastructure and modular approach. Standard APIs includes Ruby, Java and XMLRPC. Security concerns are addressed with internal and external SSL communication and LDAP integration.

OpenNebula EcoSystem adds a set of tools, extensions and plug-in to OpenNebula Cloud Toolkit components enabling integration with existing products, services and management tools for virtualization, clouds and data centers.

Telecom and hosting market and respectable scientific organizations like CERN adopted OpenNebula.

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VOLUME 2 ISSUE 2 March 2012

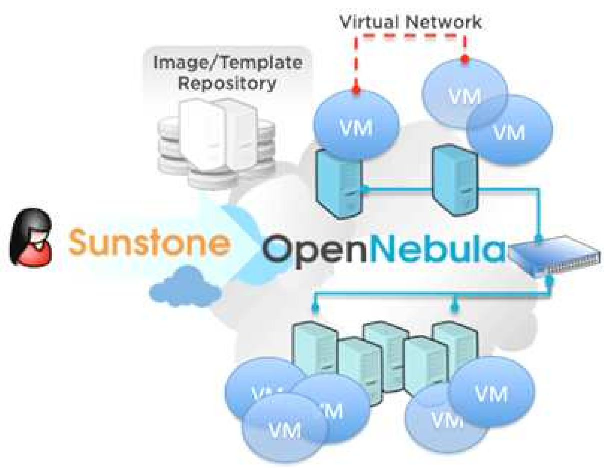

Figure: 3 Overview of OpenNebula

5.2 What does OpenNebula offer?

OpenNebula provides a powerful, scalable and secure multi-tenant cloud platform for fast delivery and elasticity of virtual resources.

- The Image Repository system allows setting up and sharing images, which can be operative systems or data, to be used in Virtual Machines easily.
- The Template Repository system allows registering Virtual Machine definitions in the system, to be instantiated later as Virtual Machine instances.
- Virtual Networking is provided to interconnect Virtual Machines; they can be defined as fixed or ranged networks.
- Once a Template is instantiated to a Virtual Machine, there are a number of operations that can be performed to control their lifecycle, such as migration (live and

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VOLUME 2 ISSUE 2 March 2012

cold), stop, resume, cancel, etc. These operations are available both from the CLI and the Sunstone GUI.

5.3 What are the main components?

- **Interfaces & APIs**: OpenNebula provides many different interfaces that can be used to interact with the functionality offered to manage physical and virtual resources. There are two main ways to interface OpenNebula: command line interface and the Sunstone GUI. There are also several cloud interfaces that can be used to create public clouds: OCCI and EC2 Query. In addition, OpenNebula features powerful integration APIs to enable easy development of new components (new virtualization drivers for hypervisor support, new information probes, etc).

- **Users and Groups**: OpenNebula supports user accounts and groups, as well as various authentication and authorization mechanisms. This feature can be used to create isolated compartments within the same cloud, implementing multi-tenancy. Moreover, a powerful Access Control List mechanism is in place to allow different role management, allowing a fine grain permission granting.

- **Networking**: An easily adaptable and customizable network subsystem is present in OpenNebula in order to better integrate with the specific network requirements of existing datacenters. Support for VLANs and Open vSwitch are also featured.

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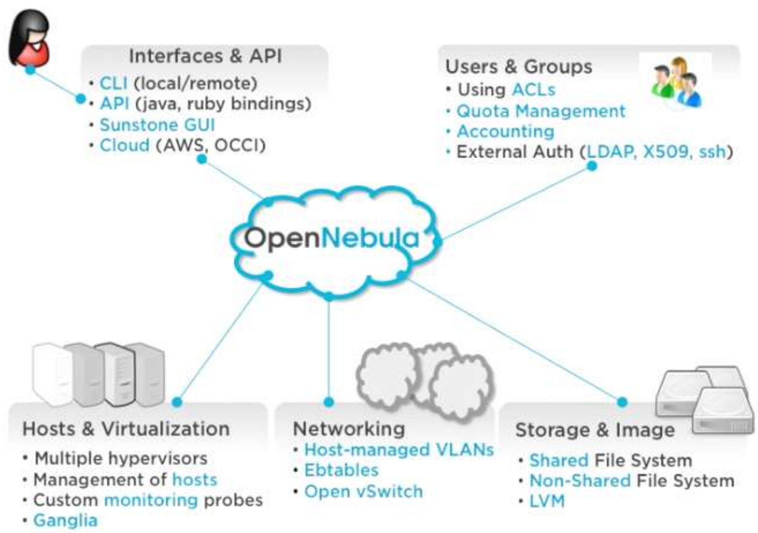

Figure: 4 Different Services of OpenNebula

- **Hosts and Virtualization**: Various hypervisors are supported in the virtualization manager, with the ability to control the lifecycle of Virtual Machines, as well as monitor them. This monitorization also applies to the physical hosts.

- **Storage and Images**: OpenNebula aims to be flexible enough to support as many different image storage configurations as possible. The Storage subsystem can be configured to support non-shared and shared file systems, as well as a broad array of different arrangements of the image servers.

5.4 How the System Operates

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VOLUME 2 ISSUE 2 March 2012

OpenNebula orchestrates storage, network, virtualization, monitoring, and security technologies to enable the dynamic placement of multi-tier services (groups of interconnected virtual machines) on distributed infrastructures, combining both data center resources and remote cloud resources, according to allocation policies:

- **Management of the Network, Computing and Storage Capacity**: Orchestration of storage, network and virtualization technologies to enable the dynamic placement of the multi-tier services on distributed infrastructures.

Management of VM Life-cycle: Smooth execution of VMs by allocating the resources required for them to operate and by offering the functionality required to implement VM placement policies.

- **Management of Workload Placement**: Support for the definition of workload and resource-aware allocation policies such as consolidation for energy efficiency, load balancing, affinity-aware, capacity reservation.
- **Management of Virtual Networks**. Support for the definition of virtual networks to interconnect VMs.
- **Management of VM Images**: Exposing of general mechanisms to transfer and clone VM images. Images can be registered before execution. When submitted, VM images are transferred to the host and swap disk images are created. After execution, VM images may be copied back to the repository.
- **Management of Information and Accounting**. Provision of indicators that can be used to diagnose the correct operation of the servers and VMs and to support the implementation of the dynamic VM placement policies.

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VOLUME 2 ISSUE 2 March 2012

- **Management of Security**: Definition of security policy on the users of the system, guaranteeing that the resources are used only by users with the relevant authorizations and isolation between workloads.
- **Management of Remote Cloud Capacity**: Dynamic extension of local capacity with resources from remote providers to build hybrid or federated cloud deployments.
- **Management of Public Cloud Servers**: Exposing most common cloud interfaces to support public cloud computing deployments.

6. PROPOSAL

6.1 Proposed system for exchanging medical images:

Our proposed system stores the Medical images in the cloud and the hospitals can access those details via virtual private network (VPN) and public Internet access. Fig.5 is the proposed construction of cloud-based HIS. The health department establishes interface to store and manage important information such as computer-based patient records, etc.

This framework is easy to realize by adding a network module or control center just attached to existing systems. The network module is to connect within the cloud, and can use the resources in cloud to achieve hardware, software and data-storage according to the need. Using this method to optimize and reduce existing HIS gradually, thus obtains adjustable flexible structure. It's very affordable to use cloud computing in medical IT services, many hospitals can share the infrastructure formed by connecting large number of systems together, thus the hospitals can become more efficient, and construction costs can be reduced.

At small hospitals like township hospitals, most business can be processed within the cloud, so as to get rid of the heavy burden of complete construction and management. They

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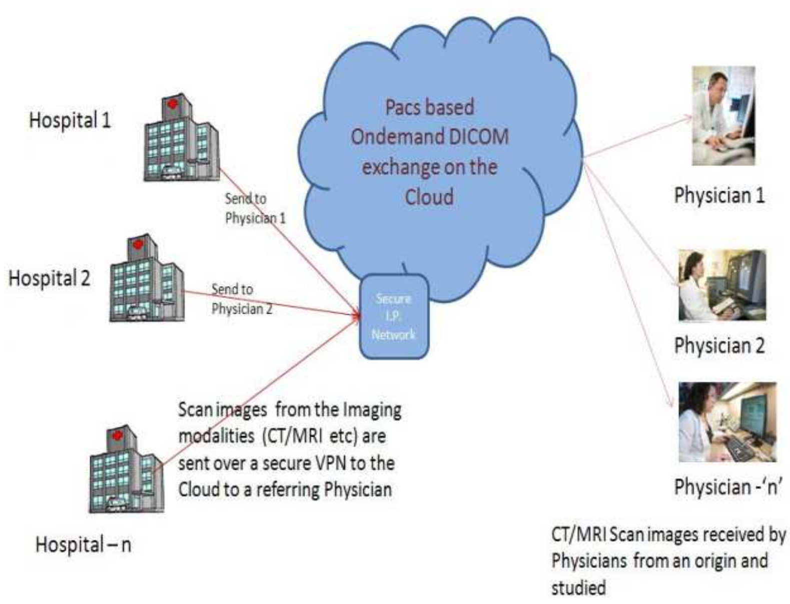
VOLUME 2 ISSUE 2 March 2012

only need to complete the patient's information collection and result display, the others that including management, storage, maintenance, and even disease diagnosis can be achieved in the central servers. Also large hospitals reduce its costs from this flexible and extensible framework.

While there is a global context for a solution like this, Particularly in India where there is a proliferation and explosion of medical imaging. With a huge middle income population, the healthcare sector here needs affordable solutions to archive, access, exchange and collaborate on medical images between physicians anytime in a location agnostic manner, irrespective of where they were created.



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VOLUME 2 ISSUE 2 March 2012

Figure: 5 Proposed Cloud service for Medical Image Exchange and Management.

Mostly, In India and perhaps in other countries, scanned images are sent manually or by land mail as DVDs. Sometimes, images are sent over slow FTP connections that takes significant time and streamlining at send/receive ends. These methods are quite disconnected also. A Cloud based Image exchange could help resolve such issues and streamline to provide physicians with 24 * 7* 365 access to medical imaging studies, easily accessible through Internet.

Secondly, a number of small and medium size hospitals and imaging centers mostly having CT or MRI modalities are constrained to have their own internal PACS infrastructure in-terms of the costs and IT resources needed to run and maintain it. An on-demand cloud based medical imaging exchange solution could help obviate such needs and can provide a model for such entities to connect their modalities and rent such services without the need to invest upfront on the PACS infrastructure and then the resources to run and maintain the PACS related IT operations.

Essentially, the Cloud based solution is a PACS on-demand facilitating a DICOM imaging exchange between Hospitals/Imaging centers and Physicians.

In figure 5 the following workflow will take place when a doctor wants the patient information.

- A Scalable Cloud Image exchange service is run. It is available on-demand and can connect with multiple medical Image producers (Hospitals or Physicians) and Image consumers (Physicians). They can be located anywhere.

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VOLUME 2 ISSUE 2 March 2012

From Hospital 1the medical images are sent to Physician1 for studies in a secure manner.

- Physician1 connects to the Cloud service through the Internet to receive and access the images for studies and reporting.
- From Hospital-2, medical images are sent to Physician 2 for studies.
- Physician2 connects to the Cloud to receive and access the images for studies and reporting.

In this scenario, the medical images can be optionally stored and managed securely in scalable cloud storage for later studies or for disaster recovery. This scenario also applies well to large healthcare institutions having multiple imaging and medical centers spread out across the geographical locations.

6.2 Conversion of medical images to unified format

DICOM (**Digital Imaging and Communications in Medicine**) is a standard for handling, storing, printing, and transmitting information in medical imaging. It includes a file format definition and a network communications protocol. DICOM files can be exchanged between two entities that are capable of receiving image and patient data in DICOM format. This format will not support the low-end medical imaging system available in the small township hospital.

A DICOM data object consists of a number of attributes, including items such as name, ID, etc., and also one special attribute containing the image pixel data (i.e. logically, the main object has no "header" as such: merely a list of attributes, including the pixel data).

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A single DICOM object can only contain one attribute containing pixel data. For many modalities, this corresponds to a single image. But note that the attribute may contain multiple "frames", allowing storage of cine loops or other multi-frame data. Another example is NM data, where an NM image by definition is a multi-dimensional multi-frame image. In these cases three- or four-dimensional data can be encapsulated in a single DICOM object [10].

For the simulation purpose the sample DICOM image is downloaded from the internet. This has the image size of 38MB.

The DICOM images usually in larger size duo its tag values and number of frames inside the single DICOM image. During the conversion process which eliminates the tag values and captures the image for the diagnose purpose and it comes to PNG (Portable Network Graphic) format. This PNG image has the size of 229KB.Which is the unified format needed for the low end medical imaging system.

After the conversion of unified format which will be stored in the private cloud storage which is created by the Open Nebula cloud computing toolkit in UBUNTU Linux platform for accessing the images in different cloud node. This process is similar to accessing images in different branch hospital for the patient referral process.

6.2 Conversion process:

1. DICOM conversion has four buttons for loading DICOM Image, view DICOM Tags, Save DICOM image to PNG, and to Reset the Image window or level.

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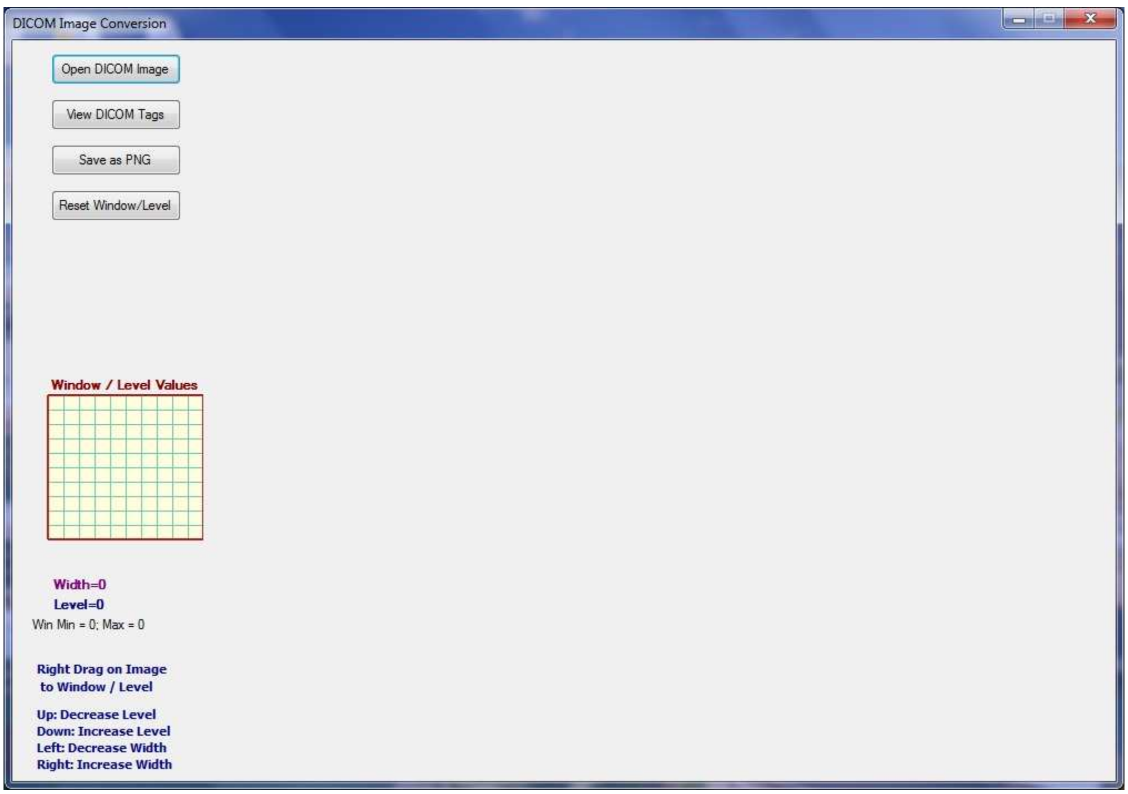

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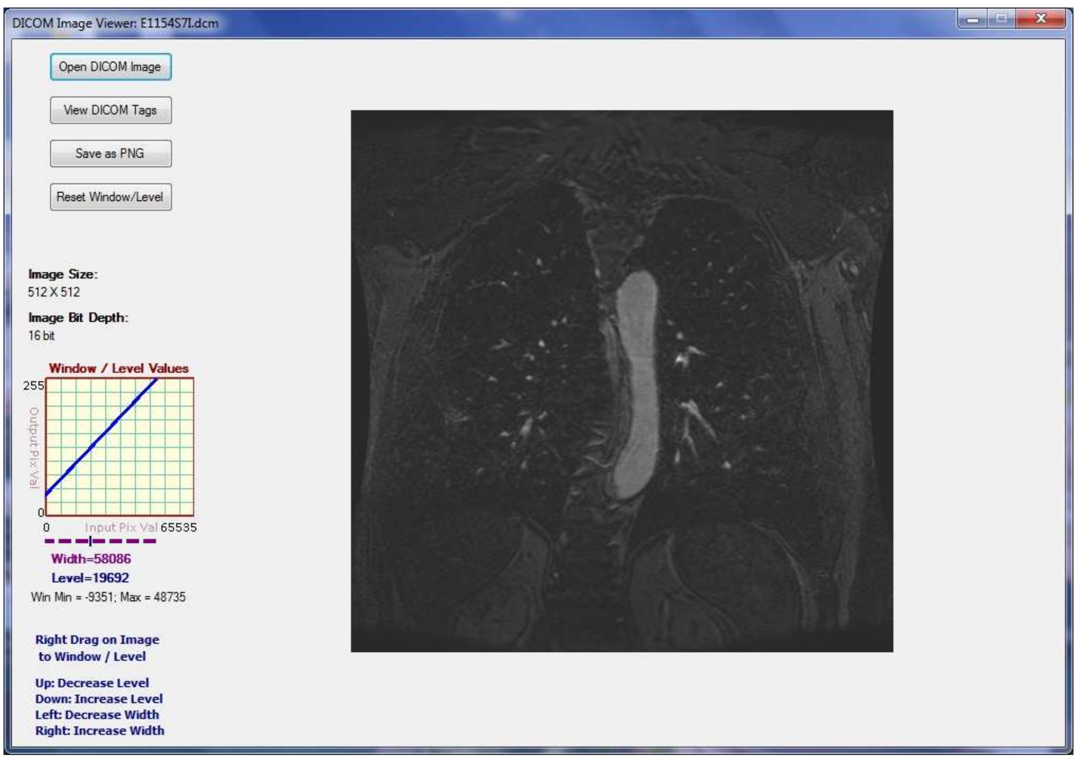
VOLUME 2 ISSUE 2 March 2012

2. After loading the DICOM image the image view level and brightness can be adjusted



3. In this window the DICOM Image Tags can be viewed

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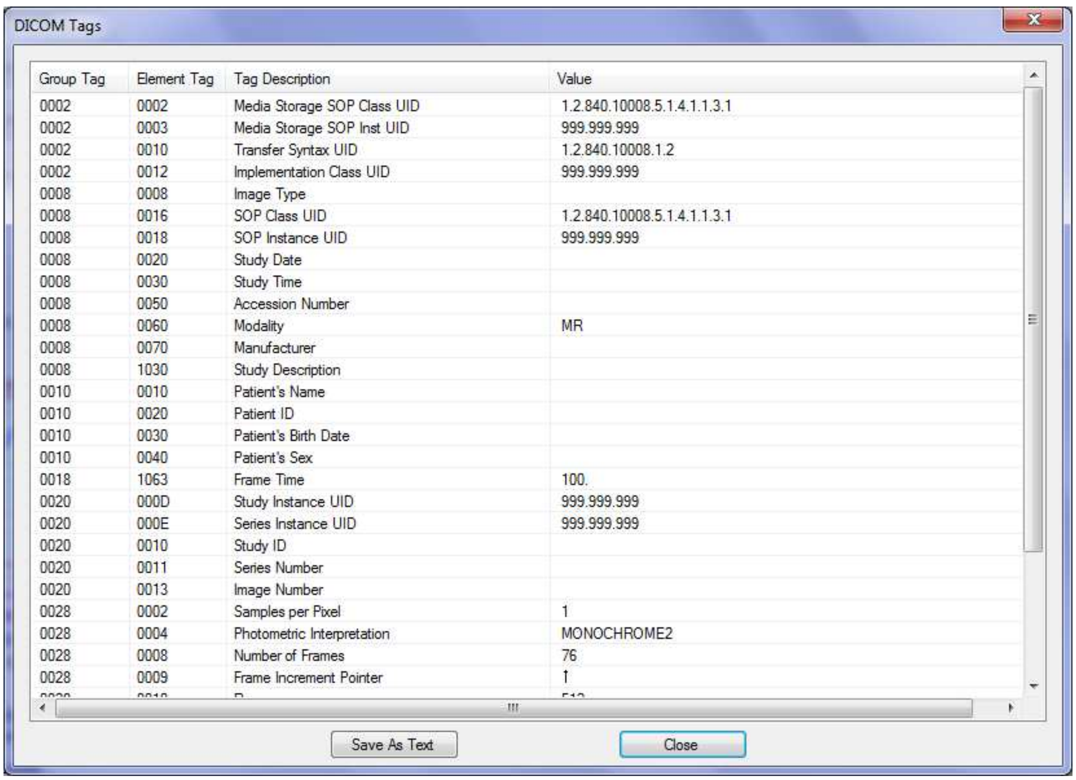

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0002	0003	Media Storage SOP Inst UID	999.999.999
0002	0010	Transfer Syntax UID	1.2.840.10008.1.2
0002	0012	Implementation Class UID	999.999.999
0008	0008	Image Type	
0008	0016	SOP Class UID	1.2.840.10008.5.1.4.1.1.3.1
0008	0018	SOP Instance UID	999.999.999
0008	0020	Study Date	
0008	0030	Study Time	
0008	0050	Accession Number	
0008	0060	Modality	MR
0008	0070	Manufacturer	
0008	1030	Study Description	
0010	0010	Patient's Name	
0010	0020	Patient ID	
0010	0030	Patient's Birth Date	
0010	0040	Patient's Sex	
0018	1063	Frame Time	100.
0020	000D	Study Instance UID	999.999.999
0020	000E	Series Instance UID	999.999.999
0020	0010	Study ID	
0020	0011	Series Number	
0020	0013	Image Number	
0028	0002	Samples per Pixel	1
0028	0004	Photometric Interpretation	MONOCHROME2
0028	0008	Number of Frames	76
0028	0009	Frame Increment Pointer	↑

4. Converted DICOM Image such as PNG Image

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6.4 Advantages in this implementation

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VOLUME 2 ISSUE 2 March 2012

- Reduce the costs: Using cloud computing technology, hospitals can get the services provided by millions of servers in the cloud, but pay a little, then higher efficiency, lower cost can be achieved. Compared with spending lots of money to buy a dedicated server, using cloud services is clearly more cost-effective.

- Flexible and extensible framework: The cloud framework supports heterogeneous equipments and alterable system scale. Small hospitals can first set up a simple system with necessary component. As the hospital becomes bigger and bigger, it can easily scale up the cloud in a short time.

- Better information sharing: Through the cloud model, the health and medical institutions can work together to build information-sharing space of medical resources. This can share infrastructure without having to update the related hardware, reduce costs while efficiency is greatly enhanced.

- Reduce maintenance expenses: The user terminal architecture is unlimited in cloud computing model; therefore, the technical staffs do not have to pay much attention to upgrading the hospital hardware, while the daily maintenance of the server is also provided by the cloud service provider, and thus they have more time to undertake other work.
- Reliable operation of the server: The data of hospital daily business are concentrated in the server in the present hospital information systems, so the hospital cannot work normally once a server failure occurs; seriously key data will be lost in extreme cases. The cloud computing model can quickly copy data in the failed server to

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VOLUME 2 ISSUE 2 March 2012

another server, and start the new server to provide services, that obtains real continuous security services.

7. CONCLUSION

The proposed system describes the Medical Image Exchange on cloud computing which realizes the flexible, extensible and practicable framework by regarding all the hardware, software and data of hospitals as resources acquirable from the cloud. It has not only significantly reduces the construction cost and provides wide medical application for village and town hospitals, but can realize the information sharing and effective use of resources to the greatest extent. Meanwhile, it reduces hospital operating costs and significantly improves operating efficiency. The infrastructure of "cloud" contributes to help hospitals save the time and efforts required for IT systems. Moreover, we suggest further applications of this architecture such as the construction of Health Information System. And based on the new platform and depending on powerful servers, it can be realized of the medical images to be automated diagnosed. Besides, cloud Infrastructure not only makes updating and application of new technologies simpler, but also can be the unified base for hospital system construction.

8. FUTURE ENHANCEMENT

In this system the cloud created is private. It was developed using Open Nebula cloud computing toolkit in Ubuntu Linux system for simulation purpose. In future the same application can be developed using the public cloud services provided by the Google, Amazon and Salesforce etc. And the DICOM image conversion can also be improved by capturing multiple frames of the same DICOM image. There by we can analyze the entire image for unified conversion.

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