# A Medical Image Archive Solution in the Cloud

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## ABSTRACT
A cloud is a virtual space available for the users to deploy their applications. A cloud service has three distinct characteristics that differentiate it from traditional hosting. It is sold on demand, typically by the minute or the hour; it is elastic. A user can have as much or as little of a service as they want at any given time; and the service is fully managed by the provider (the consumer needs nothing but a personal computer and Internet access). Significant innovations in virtualization and distributed computing, as well as improved access to high-speed Internet and a weak economy, have accelerated interest in cloud computing. Information technology for healthcare providers needs long-term image archive solutions that balance cost, image volume, storage capacity and access demand. Computing and storage in the cloud seem to be a natural solution to many problems we face today for long-term medical image archives. It includes a Digital Imaging and Communications in Medicine (DICOM) server to store/query/retrieve requests; this intern stores the data onto the SQL Azure database using DICOM image indexer. The web user interface is used for searching and viewing archived images based on patient and image attributes.

## General Terms
Image Processing, Indexing.

## Keywords
Cloud computing, DICOM.

## 1. INTRODUCTION
Based on the current trend, it is estimated that over one billion diagnostic imaging procedures will be performed in the United States during year 2014, which will generate about 100 Petabytes of data [2]. The high volume of medical images is leading to scalability and maintenance issues with healthcare roviders' onsite picture archiving and communication system (PACS) and network.[1]

Traditional healthcare IT stores and manages image archives onsite using the internal hospital network that is protected by a firewall from the outside. However, the rising capital and management cost of onsite systems as well as the lack of disaster recovery provision have motivated alternative offsite solutions.[1]

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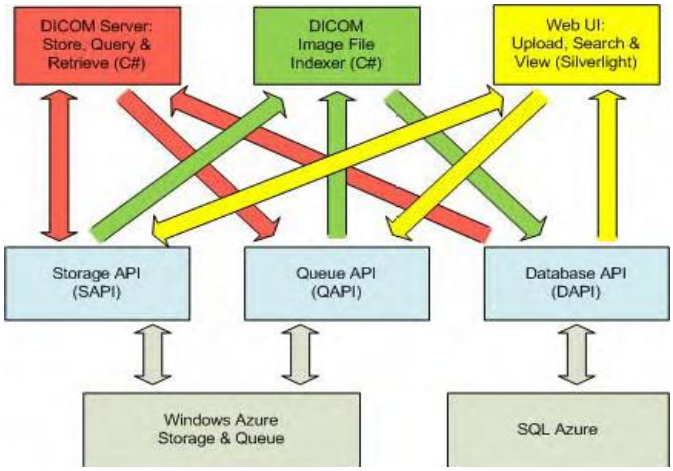


**Fig. 2. System block diagram of the DICOM image archive services**

The prototype system includes: 1) a DICOM server which handles standard DICOM store/query/retrieve requests; 2) a DICOM image indexer that parses the metadata (tags) and store the information a SQL Azure database; 3) a web user interface (UI) implemented in ASP.NET technologies that allows users to search and view archived DICOM images based on any and combination of DICOM tags. The DICOM server and indexer are implemented in C# programming language based on the open source project DICOM# [4] which implements the DICOM server communication protocol. The programming language support, rich functionality and tool set has shown that Windows Azure is an excellent platform for developing and deploying a service oriented application such as this. Figure 2 [5] shows the DICOM image archive services.

## 2. BACKGROUND RESEARCH
Cloud computing is emerging as a new trend in computational and storage resource allocation and provisioning technology. Many market researchers had projected multi-billion dollar growth in the industry [6][7] as it promises lower cost and higher scalability to customers who need flexible and on demand access to computing resources. It is basically virtual servers available over 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. Users can access and use through a web browser as if they were programs installed locally on their own computers.

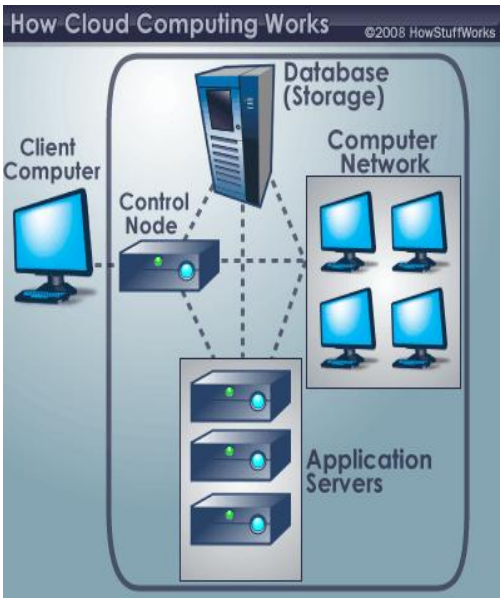


Fig. 1. Working of cloud computing

Cloud application services or "Software as a Service (SaaS)" deliver software as a service over the Internet, eliminating the need to install and run the application on the customer's own computers and simplifying maintenance and support. Cloud platform services, also known as platform as a service (PaaS), deliver a computing platform and/or solution stack as a service, often consuming cloud infrastructure and sustaining cloud applications. Figure 1[1] shows the working of cloud computing.

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. The communication protocol is an application protocol that uses TCP/IP to communicate between systems. DICOM files can be exchanged between two entities that are capable of receiving image and patient data in DICOM format. The National Electrical Manufacturers Association (NEMA) holds the copyright to this standard. DICOM enables the integration of scanners, servers, workstations, printers, and network hardware from multiple manufacturers into a picture archiving and communication system (PACS). DICOM has been widely adopted by hospitals and is making inroads in smaller applications like dentists' and doctors' offices. DICOM differs from some, but not all, data formats in that it groups information into data sets. That means that a file of a chest X-Ray image, for example, actually contains the patient ID within the file, so that the image can never be separated from this information by mistake. 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). A single DICOM object can only contain one attribute containing pixel data. Figure 3 [8] shows the already developed application for DICOM.

## 3. SYSTEM OVERVIEW

There are three major components in our prototype system:

- DICOM server: a UI-less Worker role which communicates with clients using standard DICOM protocol through external TCP connections. It responds to client's requests such as querying, storing or retrieving of DICOM images. This is implemented in C# programming language based on the open source project DICOM#.

- DICOM file indexer: also a UI-less Worker role which parses the header of DICOM files as they are uploaded from the client through DICOM server or Web UI. Values of standard attributes (tags) are extracted from the header and stored in a SQL Azure database, where the image files are indexed by their attributes or metadata. This is also implemented in C# based on DICOM# project [4].

- Web UI: a Web role component which provides user interface to upload images on a web page or via HTTP. Users can also search and browse archived DICOM images through a search page implemented in ASP.NET. This provides the convenient connectivity to non-DICOM client to upload, search and browse images.

### 3.1 Implementation Details

In order to take advantage of the built-in scalability of Windows Azure fabric, this system is designed based on asynchronous programming design pattern and stateless dataflow architecture. That is, each instance of execution, either Web Role or Worker Role, does not save any state information. The Web UI and DICOM server will receive a file upload request from the client and send an indexing message to the indexer through the Azure message queue. An instance of the indexer will wake up and pop the indexing message from the queue, parse the newly uploaded DICOM file and store the metadata in the SQL Azure database. The indexing message will only be removed if the indexing process is successful. In case the instance terminates abnormally before completing the indexing, the message will be made available for other instances and get another chance to be processed. The mechanism provides a level of transactionality and robustness. The UI-less DICOM server worker role instances communicate with standard DICOM clients through external TCP end points provided by the Azure .NET layer. Azure also provides an IP filtering mechanism to prevent connections from unintended clients.

### 3.2 Database Schema

Diagnostic imaging procedures usually produce DICOM images as studies and series. Clinicians also usually query and view images as studies and series. Metadata of the images are stored and indexed for fast retrieval in common scenarios and minimize the size of the data store.

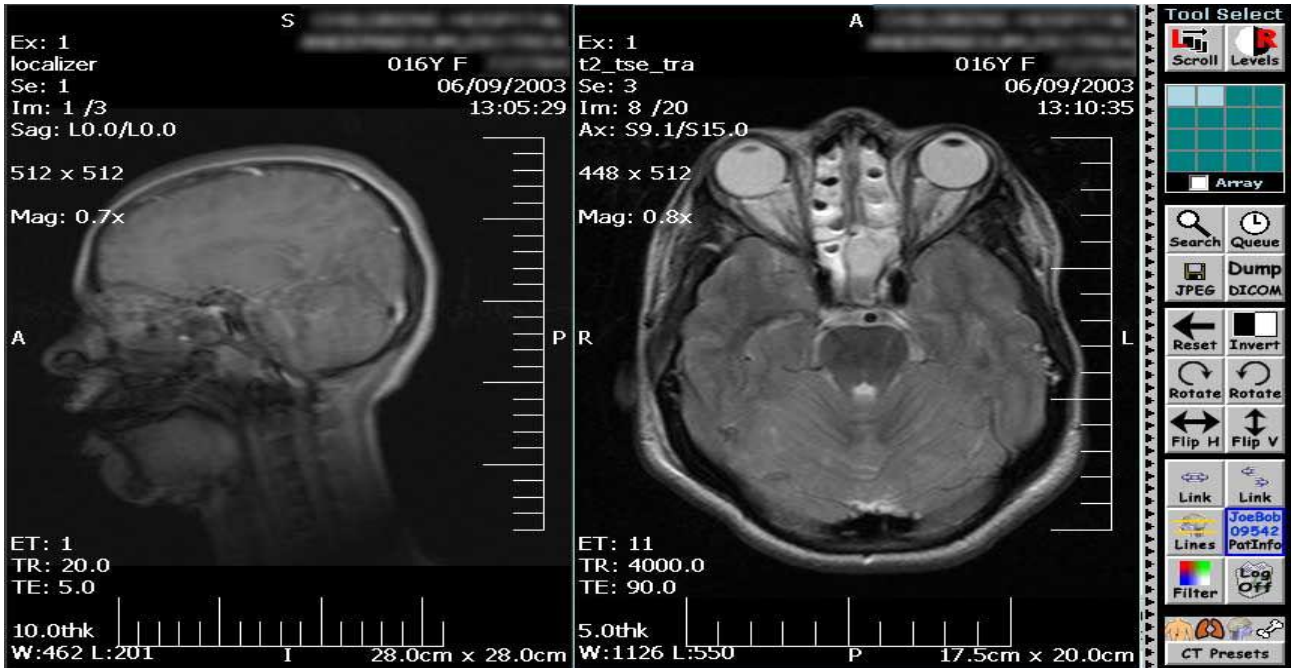


**Fig 3: DICOM application**

## 4. CONCLUSION AND FUTURE WORK

The design and implementation of this prototype system demonstrated the feasibility of using the cloud computing platform to provide a long term offsite medical image archive solution. It has the potential to lower the cost of storage and management and to increase disaster recoverability. The rich feature set, advanced tools and extensive library support made Azure an ideal cloud computing platform for rapid development. Each healthcare provider can easily customize the system to serve their unique requirement.

In addition to transaction of image report files and text report files, the provision for audio medical transcription files can be made in the system.

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