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Multi-provider Architecture for Cloud Outsourcing of Medical Imaging Repositories

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Abstract. Over the last few years, the extended usage of medical imaging procedures has raised the medical community attention towards the optimization of their workflows. More recently, the federation of multiple institutions into a seamless distribution network has brought hope of increased quality healthcare services along with more efficient resource management. As a result, medical institutions are constantly looking for the best infrastructure to deploy their imaging archives. In this scenario, public cloud infrastructures arise as major candidates, as they offer elastic storage space, optimal data availability without great requirements of maintenance costs or IT personnel, in a pay-as-you-go model. However, standard methodologies still do not take full advantage of outsourced archives, namely because their integration with other in-house solutions is troublesome. This document proposes a multi-provider architecture for integration of outsourced archives with in-house PACS resources, taking advantage of foreign providers to store medical imaging studies, without disregarding security. It enables the retrieval of images from multiple archives simultaneously, improving performance, data availability and avoiding the vendor-locking problem. Moreover it enables load balancing and cache techniques.

Keywords. Medical Imaging, Cloud, PACS, DICOM

Introduction

Medical imaging procedures have been so widely used, that even small healthcare institutions can produce a significant number of examinations [1]. PACS (Picture Archive and Communications System) is the common designation for information systems that manage the storage and distribution of medical image studies [2]. They present clear advantages, when compared to their analogic contenders [3].The DICOM standard [4] figures as a crucial part of any PACS, interconnecting archives, acquisition devices and visualization workstations [2, 5]. Since DICOM is vendor neutral and generally supported by every acquisition device, it is the most important standard in the medical image distribution field.

The integration of multi-domain medical imaging repositories has recently suffered major incentives through the XDS-I (Cross-Enterprise Document Sharing for images) and the IHE initiative [6]. They aim at the interoperation of multiple institutions on a broader level, by sharing performed studies, patient records or medical infrastructures. The DICOM standard is integrated in these initiatives as a lower level protocol for

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communications and data definition. However, this proposal targets the outsourcing of intra-institutional PACS archives to the Cloud. We consider intra-institutional processes all the transactions between different sites that have the same governance.

In this scenario, medical institutions face the difficult task of selecting on which Cloud infrastructures to deploy their PACS resources, namely their repositories. Traditionally, medical institutions deployed their archives in in-house solutions [7], because it reduces latencies in study storage and retrieval, and promotes security as sensitive data is stored inside the institution. On the downside, there are great financial costs associated with the maintenance of an in-house datacenter, demanding significant IT expertise and dedicated facilities. Therefore, outsourcing storage of medical imaging studies to foreign providers seems a more valid option to small-medium institutions.

Nowadays, Cloud providers are natural solutions because they offer elastic storage and optimal data availability, even disaster recovery facilities. Moreover, neither IT expertise, nor adequate facilities are required [7]. However, regardless of these benefits, medical institutions are still reluctant in outsourcing their archives, namely because these entities gained fame of exploring clients data and usage profiles to their benefit. Furthermore, current solutions fail to integrate in-house with outsourced solutions, as absent in the standard.

In this document, we present a multi-provider architecture that makes the use storage services from distinct Cloud providers possible, providing a service abstraction layer and ensuring DICOM interoperability. For instance, it is possible to use multiple archives simultaneously to store and retrieve the same study or image. The solution involves the splitting of medical images into segments. Our DICOM Router Platform is able to recombine the image fragments and present them seamlessly to the users through a native DICOM interface. As a result, it allows the improvement of study transference performance and enables load balancing techniques for PACS archives.

1. Background

DICOM is an application layer protocol which uses the TCP/IP for transport. DICOM applications are addressed by AETitle (Application Entity Title), messages exchanged by applications are called DIMSE (DICOM Message Service Elements) [5]. The Standard follows a client/server architecture. It uses the concept of services, in which a SCP (Service Class Provider) application provides a predefined functionality to others, the SCU (Service Class User). The standard provides a set of services that support the general usage of an institutional PACS, such as, Query/Retrieve, Storage and Printing.

Query/Retrieve and Storage are the most common services associated with image transference. The Storage service is used to upload images to a repository, for instance, by acquisition devices. In the Storage Service, the SCU sends to the SCP a C-Store-Rq (Request) containing the DICOM objects, usually an image, to be stored. The SCP acknowledges the reception of the objects by replying with a C-Store-Rsp (Response).

On the other hand, the Query/Retrieve is used to search and download images from a repository, for instance, when a physician reviews a study. It involves two commands, C-Find and C-Move. The C-Find request allows the SCU to query about the existence of objects, by meta-data fields, such as patient name or modality. In the Retrieve service, firstly, the SCP sends a C-Move request, selecting which objects to move. When the SCP receives a C-Move request, it sequentially starts a Storage session for each image, as previously described. The C-Move session terminates when every image is transferred to the SCU.

However, the DICOM standard has demonstrated some performance inefficiency when ported to Internet environments [8-10]. In public environments, such as Internet, the traffic might be disallowed and connectivity difficult to achieve without expertize or permissions [11]. As such, the Standard also defines a set of web services called WADO (Web-Access to DICOM Objects). However, it supports more rendering functionality, instead of the full Query-Retrieve, which makes it unpractical to be used standalone by physicians. Nevertheless, in 2011, new REST web services were introduced, namely the STOW-RS [12] and the QIDO-RS [13]. These services have turned the protocol more compliant with the IHE initiative, although their compatibility with acquisition equipment is still reduced. As such, storage directly on foreign providers may be troublesome.

Recently, there has been a considerable effort in applying the Cloud computing paradigm to PACS storage. Cloud computing facilities, such as storage space, may be used as a highly reliable commodity [1, 7, 11]. Nevertheless, none of them takes advantage of multiple storage providers to excel medical image transference in terms of performance, reliability and scalability. Moreover, in security terms, proposed solution gives additional thrust to healthcare professionals, as they may limit the ability of external providers to assemble the image files by not outsourcing part of the image.

2. Proposal

2.1. DICOM Router Platform

In the past few years we have developed a distributed PACS architecture that supports geo-distributed institutions interconnected by common Internet connections [1, 11]. Our goal is to share the same PACS between multiple institutions, promoting tele-radiology by easing access to PACS archives from outside institutional boundaries without requiring extensive IT knowledge from the medical personnel. Moreover, it provides anytime-anywhere access to the PACS, and solves the no direct connectivity issue when the applications are behind restrictive network configurations (see Figure 1).

Our architecture is based on two main software components, the DICOM Router (a) and the DICOM Bridge Router (b). It enables remote calls to standard DICOM Query/Retrieve and Storage services by offering a proxy, which implements an

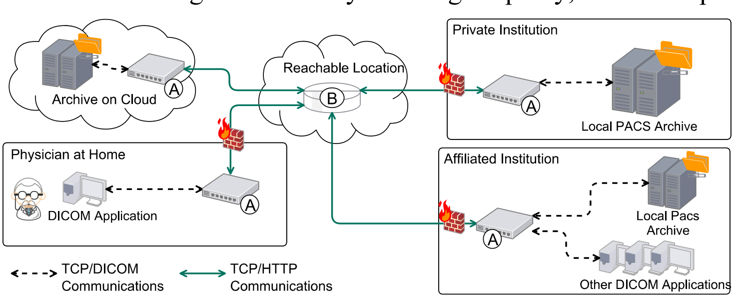

Figure 1. DICOM Router Platform sample deployment scenario.

optimized transference algorithm [8], to the remote application. DICOM Routers communicate via the well-known HTTP/SSL Protocol its broad usage has conducted

network security managers to allow this traffic to cross firewalls. The DICOM Bridge Router relays communications between routers and provides security functionalities to the PACS, namely router authentication and application advertisement. Absent the Bridge Router, peer-to-peer communications would be hard to achieve, as the HTTP is inherently client-server oriented and the majority of institutions connected to Internet often use NAT (network address translation).
Foreign Applications services are discovered by advertising the AETitle of appended applications to every router. Therefore each router creates a routing table matching AETitles to routers. As a result, when a router receives a request, it looks up in its routing table for the SCP AETitle presented in the request.

2.2. Integration of multiple repositories

In order to take full advantage of multiple repositories, we used a file splitting technique. This method divides DICOM images in portions called chunks, enabling more flexibility when dealing with image data. For instance, it is possible to divide images into two distinct repositories. Moreover, it is possible to outsource only a portion of the image to an untrustworthy provider. This is very helpful when handling large images, such as CT. Nevertheless it supports every modality. As conventional archives do not support incomplete images, the DICOM Router implements an innovator cache mechanism. It indexes the DICOM meta-data before splitting the image file and discarding the undesirable parts. Along with file splitting, it also uses compression to optimize both storage space and the transference performance.

Figure 2 describes the proposed method for integrating multiple repositories in the DICOM Retrieve Service. The process is initiated by an institutional client application which sends a C-Move RQ to the Intranet Router that immediately forwards the request to the Bridge. The DICOM Bridge Router broadcasts the request to every DICOM Router advertising the requests' SCP AETitle. This procedure initiates a small C-Move session, which orchestrates the transference, namely, it defines which chunks each archive has to upload. This is performed in parallel, as such: the overhead introduced by the increasing number of archives is minimized. See stage 1.

When a SCP Router receives a request, it queries its archive about the images contained in the desired study. The archive responds with a list of images, which actually need to be transferred to the SCU Application. If the archive does not have an entire image, the router only sends information of the available chunks. This list is sent back to the Bridge. This procedure is executed simultaneous in every router. See box A.

After receiving all Routers' responses, the Bridge has all the necessary information to schedule the transference, i.e. to assign which router will upload which chunk. The scheduling algorithm is implemented in an external plugin. By doing so, we virtually support every scheduling behavior possible. This is very important, as different institutions have different intentions towards the Platform. Upon finishing the scheduling, a message is sent to every router with a list of images or chunks that the router needs to upload. In parallel, the Bridge also sends an informative message to the SCU Router with information about the images that will be transferred. See stage 2.

When each SCP Router receives the upload list, it immediately starts uploading the images to the SCU Router. If the Router has all the requested chunks cached, it avoids requesting the image from the Archive, compressing and splitting its data. Once again, this procedure is parallel to every router (see block B). While receiving the image data, the SCU Router immediately assembles the completed images and sends them to the

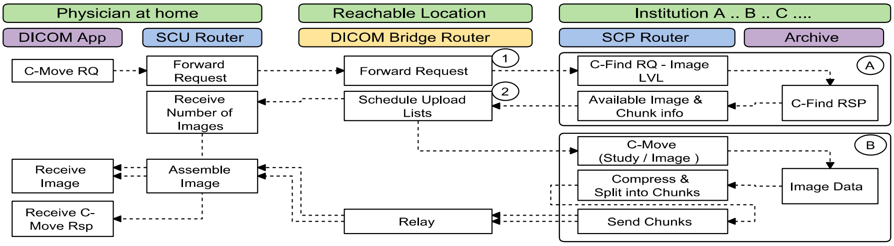

Figure 2. Image retrieval workflow on multiple repositories.

SCU application. When every image is moved, the router finally closes the association sending the C-Move RSP message.

3. Conclusions

This document proposes a multi-provider architecture for Cloud outsourcing of medical imaging repositories. The solution provides an abstraction layer for DICOM Storage and Query/Retrieve services. Moreover, it also enhances the performance in image retrieval and enables load-balancing techniques. By offering a native DICOM interface, it assures the full compliance with other vendor neutral solutions. The institutions are enabled to deploy in-house archives and outsourced solutions seamlessly. For instance, our affiliated institutions are using this solution to support services in two distinct locations. There is an in-house archive in each institution along with a central repository deployed in a private cloud provider. Physicians can review studies in external locations, retrieving data from multiple repositories in simultaneous.

References

[1] Silva LB, Costa C, Oliveira J. A PACS archive architecture supported on cloud services. Int J CARS. 2012;7(3):349-58.
[2] Huang HK. PACS and Imaging Informatics: Basic Principles and Applications: Wiley; 2010.
[3] Srinivasan M. Saving time, improving satisfaction: the impact of a digital radiology system on physician workflow and system efficiency. Digital Medicine. 2012;1(1).
[4] ACR-NEMA. Digital Imaging and Communications in Medicine (DICOM). Rosslyn, VA: National Electrical Manufacturers Association; 1993.
[5] Pianykh OS. Digital Imaging and Communications in Medicine (DICOM): A Practical Introduction and Survival Guide: Springer; 2008.
[6] Gibaud B. The quest for standards in medical imaging. European journal of radiolgy. 2011;78(2):190-8.
[7] Ukis V, Tirunellai Rajamani S, Balachandran B, Friese T, editors. Architecture of Cloud-Based Advanced Medical Image Visualization Solution. Cloud Computing in Emerging Markets (CCEM), 2013 IEEE International Conference on; 2013 16-18 Oct. 2013.
[8] Godinho TM, Silva LAB, Viana-Ferreira C, Costa C, Oliveira JL, editors. Enhanced regional network for medical imaging repositories. 8th Iberian Conference on Information Systems and Technologies (CISTI 2013), Lisboa, Portugal; 2013.
[9] Maani R, Camorlinga S, Arnason N, Eskicioglu R, editors. A practical fast method for medical imaging transmission based on the DICOM protocol2010.
[10] Maani R, Camorlinga S, Arnason N. A Parallel Method to Improve Medical Image Transmission. Journal of Digital Imaging. 2012;25(1):101-9.
[11] Silva LB, Costa C, Oliveira J. DICOM relay over the cloud. Int J CARS. 2012:1-11.
[12] Nema ACR. DICOM Supplement 163: STore Over the Web by REpresentations State Transfer (REST) Services (STOW-RS). 2011.
[13] Nema ACR. DICOM Supplement 166: Query based on ID for DICOM Objects by Representational State Transfer (REST) Services (QIDO-RS). 2011.