A DICOM RELAY SERVICE SUPPORTED ON CLOUD RESOURCES

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Abstract: Over the past decades, healthcare institutions adopted Picture Archive and Communication Systems in their workflows. The exchange and interaction between different equipment is performed with Digital Imaging Communication in Medicine (DICOM), which is a very extensive protocol covering many areas of imaging laboratories. However, the communication of a wide domain composed by several medical institutions is not well supported. This paper presents a solution to share DICOM services across healthcare institutions. The proposed implementation is supported on public cloud resources, creating the opportunity to exchange information between medical devices across several institutions.

1 INTRODUCTION

The adoption of collaborative work has greatly increased in healthcare in the past over decade and the exchange of medical data across institutions is already quite common in several modalities (Huang, 2004). Its importance has increased due to cost saving for the medical institutions and also because it can be used in several areas, such as expertise consultation, cooperative environments and sharing of images between multiple image centres.

Nowadays, PACS (Picture Archiving and Communication System) is one of most valuable tools to support medical decision and treatment procedures. A PACS is a key point to store, retrieve and distribute medical images in the various steps of the clinical practices. Digital Imaging Communication in Medicine (DICOM) supports the distribution of the medical imaging, although this standard is oriented to a single institution. The communication of a wide domain composed by several medical institutions is still a challenge. Commonly, the image repositories or PACS archives are not shared between medical centres due to technical challenges and security concerns.

Although DICOM standards support SSL/TLS layers, there are many medical devices that do not support these features. Moreover, DICOM networks are blocked by the firewall to access from outside of the institutions to keep data safety in the intranet. This prevents users located outside the institution from accessing the PACS archive. Medical institutions often use VPN (Virtual Private Networks) to share medical resources. However, this solution requires point-to-point configurations, which is not scalable. Other possibilities to exchange exams between medical institutions are processed through CD/DVD delivered, for instance, by conventional mail or using email.

Cloud computing is largely used to share files over the Internet and allow users to communicate with each other using external infrastructures. This technology allows access to applications and data without any infrastructure inside the medical institutions (Rimal and Choi, 2010). However, there are also some important issues that must be considered during the implementation of a solution (infrastructure and/or application) in a public Cloud provider (Rosenthal et al., 2010). There are critical concern related with data security and privacy.

The main idea of this paper is to promote DICOM inter-institutional communications, allowing the establishment of shared workflow and exchange of documents across them. The proposed DICOM relay service aims to be a communication broker, allowing search, store and retrieve of medical images over a group of hospitals, in different sites. This solution allows, for instance, remote access to the institutional PACS storage. The communication between different islands is supported on the cloud services, but it keeps the

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interoperability with the devices adopted by the medical community. The proposed DICOM routing mechanism has a transparent application to end-user maintain the standards used by medical imaging devices and repositories.

2 BACKGROUND

2.1 Collaborative Work in Medicine

Currently, most equipment in medical institutes uses the DICOM standard to communicate, store and visualize information. In theory, DICOM standard solved all issues regarding the communication between different collaborators, but it still has some gaps in real environments, mainly in inter-institutional cooperation, which have barriers in "many-to-many" collaboration.

Teleradiology is one of important cooperative areas in medicine and it increased in the last two decades. The medical centres cannot afford specialists from all areas and it is usual to outsource some services, including report of procedures produced inside institutions. There are hospitals and small centres that have technicians and acquisition devices to perform exams. However, in some modalities, i.e. Computer Radiology (CR), they do not have enough specialists to report these exams. In these cases, the remote report is a very common practice. There are also other user cases like, for instance, the telework scenarios, where healthcare professionals need to have remote access to medical repositories and information systems of their institutions.

To summarize, telematics platforms appear as fundamental tools to support medical services and processes. Moreover, these new technologies can be decisive in some scenarios, mainly in regions with difficult communication accesses or with few inhabitants.

2.2 Cloud Computing

Cloud computing is a risen technology that allows enterprises to hold scalable resources without having any IT infrastructure. There are several cloud providers, such as, Amazon AWS, Google and Rackspace that embraces many areas, since storage, databases, signalling and message queue. These providers supply elastic computing power and unlimited storage (Vaquero et al., 2008); (Oliveira et al., 2010) to their customers.

There is a huge amount of interest in the IT industry to migrate services to Internet Cloud platforms (Hajjat et al., 2010). In order to response to their request, many cloud companies have been created to meet their demands. There was a significant effort from Cloud providers to offer new features to clients. For instance, Amazon Web Services has released many services to fulfil their customers' requirements: S3 (S3, 2011), SQS, SimpleDB and many others. In turn, Google AppEngine (Google), Windows Azure (Microsoft) and many others improved their solutions with new APIs to overcome the challenges of their targets.

It is evident that the computing-as-utility is a business model becoming prevalent in the electronic world and numerous institutions are adopting these solutions. Furthermore, the emergence of Cloud computing providers creates a great opportunity to tackle the costs of purchase hardware and software.

The market is changing and there are new paradigms to deploy applications and to store information that are always available on the Internet. We believe that medical solutions will also adopt these new models to improve their business processes. For example, Microsoft Healthvault (Microsoft, 2011) provide a management panel easier to access for the personal health information, always available.

3 ARCHITECTURE

3.1 Description

Cloud computing is largely used to share files over the Internet, and many examples can be pointed out, such as, Dropbox (Dropbox, 2011) and Gmail (Google, 2011a). Moreover, Cloud providers offer high availability and scalability of their services. Our DICOM relay architecture takes advantage of the cloud computing services to exchange information between several locations.

The communication between the components of the digital medical laboratories is mainly used through DICOM. This protocol runs over TCP/IP protocol, but contains its own addressing model through the AETitle that identifies the medical device (DICOM-P7, 2009). Due to network filters (i.e. firewall's), this communication does not work in WAN (Wide Area Network) scenarios. To extend the communication to different institutions, the proposed approach takes advantage of the DICOM addressing mechanism to route the information to the correct location (i.e. AETitle is the DICOM

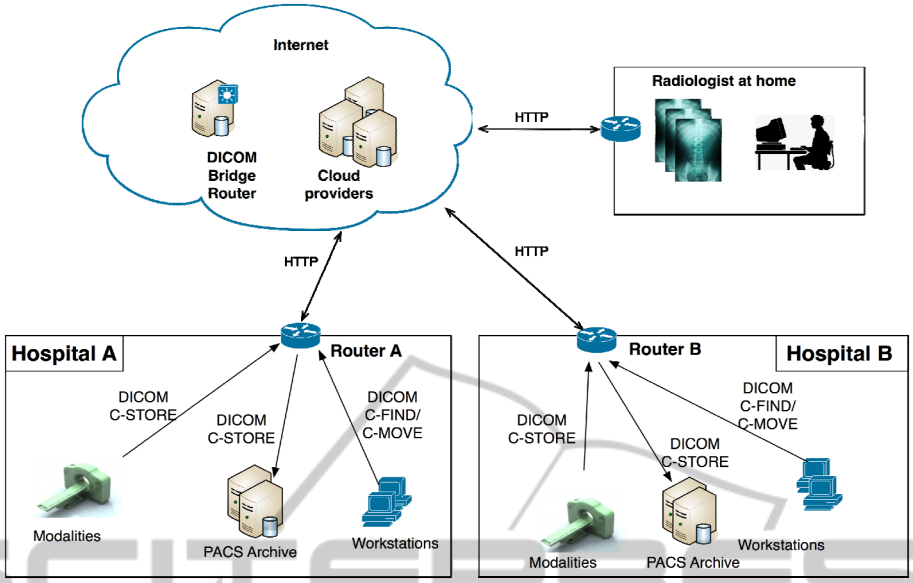

Figure 1: Relay architecture: the boundary Router assures the communications between DICOM devices and the Cloud.

address mechanism). The public cloud infrastructure is used as a communication mechanism to support information forwarding among the involved entities through these routes. Furthermore, additional Cloud provider support is simplified due to a plugin-based system. To create an abstraction over the cloud storage, we have developed a Cloud I/O stream mechanism that allows writing in the cloud storage as a data stream. New cloud providers can be easy supported, by implementing the interfaces supplied by Cloud I/O.

3.2 Components

The proposed DICOM relay service has two main goals: assure the secure/reliable connection between the actors and create a simple solution to access the internal medical repositories "anytime and anywhere". Our architecture (Figure 1) contains two major components: 1) DICOM Bridge Router and 2) DICOM Cloud Router.

3.2.1 DICOM Cloud Router

The DICOM Cloud Router (Router) is a software component that is mainly responsible to handle the DICOM services and forwarding messages to the correct place. To do so, it uses AETitle routing tables, i.e. for each AETitle belonging to the DICOM network domain, it associates the type of services that is providing and the username of the Router, which will allow to reach the correct router to forward the messages. In fact, manual management of those tables are actual practices because the DICOM standard does not provide a mechanism to auto-discovery of the DICOM nodes. Also, for security reasons, only allowed medical devices should be accessed from outside the medical institution and those tables also work as access control list. So, the Router has a graphical interface to setup the IP, port and the services available inside the medical institution.

Real world objects were mapped directly in the DICOM standard. For instance DICOM equipment is represented as a "Device" in the defined concepts of the standard. The Router supports multiple devices (i.e. as many as are online in the WAN DICOM network), each one with a different AETitle and transfer syntaxes (i.e. the data codification supported).

Finally, each medical institution or isolated DICOM network that wants to share services to the WAN DICOM network needs to run a Router inside the private network that will work as a standard DICOM node supporting several services.

3.2.2 DICOM Bridge Router

The DICOM Bridge Router or Bridge, works as a relay mechanism between different DICOM Cloud Routers dispersed over several locations. This component works in a partnership with the cloud providers. The huge amount of information that flows in WAN network needs to be uploaded/downloaded to the cloud providers. DICOM Bridge Router is an important part of the

architecture because it stores residual information about all devices (i.e. AETitles) and corresponding services supported. Moreover, it has accounts from routers and a list of cloud providers that routers can use to store temporary information. It needs to be always available over the Internet because routers need to write information in the Bridge to provide communications. It can be deployed in several places like, for instance, in a private cloud detained by a medical institution or a public cloud provider. Due to privacy concerns, we strongly recommend deployment of this component in a trustable provider or in-house (i.e. medical institutions).

The management of the diverse Routers is supported by a temporary information system located on the Bridge and it is accessible through a RESTful web service. Only registered users have access to the DICOM WAN Network. Moreover, the Bridge is a very important component because it stores the session key used to cipher DICOM messages of an association. Thus, it should be located in a trustable location, to safeguard the architecture.

The Bridge is considered the main component of the architecture because it performs the management of the relay service. It only contains a reduced amount of information, and during the dataflow it just store a minimum amount of data, i.e., the confidential shared key. The remaining information is transmitted through the cloud in a ciphered mode. It is used two different cloud services: blobstore and signalling. The Cloud providers supply, on the one hand, temporary storage of blinded data (encrypted DICOM objects/commands) and, on the other hand, a signalling service that allows establishing communication in real time between the routers.

4 CONCLUSIONS

The presented solution allows DICOM standard communication between medical devices located in distinct institutions. The proposed architecture allows creating a federated DICOM network across distinct medical institutions, with a unique view of all resources.

Our DICOM relay service does not need complex setups to start communicating with external repositories, allowing interoperability with any the DICOM standard device.

With this system, radiologists can work remotely, in the same way that they do in the hospital, without changing their methods.

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