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Integration of Federated Medical Systems for Vendor Neutral Image Access in Teleradiology Applications

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Abstract. This paper proposes a framework designed to interconnect medical imaging facilities and teleradiology service providers on a single access interface. This framework aims to solve the interoperability issues of Picture Archiving and Communication System (PACS), Radiology Information System (RIS) and Hospital Information System (HIS) developed by different vendors and enrich the digital health record delivered to non-local radiologists or physicians with the integrated information from several systems. This is achieved by introducing a "Grid Agent" into the domain of medical software systems, which seamlessly integrates with present systems and forms a network to deliver data between other Grid Agents and the "Grid Manager". Resultant solution decreases the access time of medical images by non-local medical staff and increases the efficiency and durability of the teleradiology service architecture.

Keywords. Grid based teleradiology, information centric network architecture, vendor neutral, federated medical systems.

Introduction

Due to lack of radiologists within the facilities and consultation needs, the business model for radiology practice around the world is formed to include the facility's employing and outsourcing radiology services to non-local radiology groups [1]. PACS and RIS are typically designed to handle local radiology communication and workflow management. However, non-local radiologists that serve several sites need to access medical images with a single interface in order to return medical reports efficiently. In order to accomplish an efficient teleradiology process, previous examinations and health records of patients are also required. This consequently requires the integration of HIS, RIS and PACS independent from the developer vendor. During the evolution of teleradiology studies, non-local access by means of web servers employed in a hospital [2, 3], Hypertext Transfer Protocol (HTTP) to Digital Imaging and Communications in Medicine (DICOM) connectors [4] or Java based web viewer [5] have been proposed. However, these studies usually focus on off-hour access of hospital staff when they are outside the hospital rather than interconnecting hospitals or facilities. Regional PACS [6] solutions provide interconnection of medical archives, but they usually require Virtual Private Network (VPN) structures and single vendor software. Vendor

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dependency causes durability problems in system alteration decisions and high migration costs. Central medical archiving and aged data management solutions [7-9] and PACS based on data grids [10, 11] propose central or co-allocation parallel transfer strategies to improve the non-local access interface and reduce the transfer time for medical images. Integration with heterogeneous resources and systems such as RIS and HIS is also crucial for the quality of the service. This can be achieved by employing agents that support DICOM, Health Level Seven (HL7), HTTP, Cross-Enterprise Document Sharing (XDS) and non-standardized data at regarding sites [12]. In this study, both integration with heterogeneous resources and vendor independent management of federated data are achieved with the proposed framework design. The implemented design employs a Grid Agent that can seamlessly be integrated to the medical facilities at remote sites and a central Grid Manager that can optimize the data flow between sites on a single interface.

1. Methods

Teleradiology data serving and sharing network architecture with an enhanced caching, querying and retrieving mechanism is implemented by seamlessly integrating "Grid Agent" and "Grid Manager" to conventional digital medical systems as illustrated in Figure 1. Grid Agent is deployed on each site and is responsible for rendering medical data and incoming messages or transferring radiology data between PACS, RIS, HIS, Workstations, non-local clients, Grid Manager and other Grid Agents. Grid Manager is responsible for the flow management of images between sites and reporting units or distribution of reports generated by radiologists. It communicates with Grid Agents and performs database, indexing and file operations at the center. A typical data integration and communication scenario example covering most of the interactions is as follows:

- A non-local family doctor requests an MR inspection using the web interface.
- Grid Manager delivers the imaging request as an Extensible Markup Language (XML) message to the Grid Agent at the corresponding medical center.
- The Grid Agent informs the HIS and delivers the Modality Work List request to RIS.
- When the incoming patient is registered in HIS, Grid Agent is informed which gets the index of Grid Agents that have patient's data regarding previous examinations from the Grid Manager.
- Grid Agent pre-fetches the patient's previous medical information and synchronizes PACS and HIS so that the radiologists can access the history of the patient no matter at which hospital, with which vendor's software the data is acquired.
- The radiologist investigating the radiology examination makes a consultation request from a remote radiology group.
- Grid Agent at the reporting unit of the radiology group receives the updated request list from the Grid Manager and fetches the patient's data including previous examination with the Grid Agent Index and synchronizes the data to PACS in the unit.
- The radiologist at the reporting unit retrieves medical images to be reported from several medical centers on a single interface and generates corresponding reports in RIS or using the web interface.

- The report is first delivered to the Grid Manager , then to the Grid Agent at the regarding medical center and finally to HIS.

1.1. The Grid Agent

Grid Agent communicates with PACS, RIS, HIS and workstations using DICOM and HL7 protocols. The communication between Grid Agents and Grid Manager is accomplished using encrypted XML messages using HTTP and Real Time Messaging Protocol (RTMP) protocols. Grid Agent software is developed to run on an open source media server *Red5* which also includes an embedded *Tomcat* servlet container for JEE Web Applications and supports streaming and shared object communication over RTMP. DICOM and HL7 messages are handled by asynchronous java threads using *dcm4che* and *HAPI* java libraries.

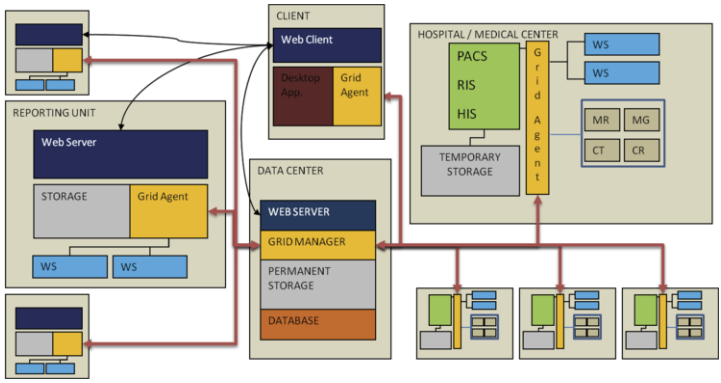

Figure 1. Framework architecture

1.2. The Grid Manager

Grid Manager has the Grid Index which includes the patient examination map cached by Grid Agents. The index is in shared object form so that a change in the index is pushed to all agents with the help of RTMP protocol. The caching mechanism at the agents provides the redundancy of the medical data so that the data archive is distributed and web server maintenance costs are prevented.

Grid Manager is developed to run on *Red5* and is specialized to send and receive encrypted XML and SOAP messages or DICOM files utilizing DICOM, HTTP or RTMP protocols.

1.3. Data Center Architecture

The central server is composed of the Application, Database and File Operation Layers. Grid Manager forms a bridge between these layers as illustrated in Figure 2. The Database layer is implemented with open source *Postgresql* software with 3 virtual servers running in failover. The database instances are implemented in shards to deliver large scale loads. Application layer is implemented with *Red5* media server and 3 virtual servers connected to a load balancer. File Operation layer is implemented with Tomcat Servlet Container with 3 virtual machines connected to a load balancer.

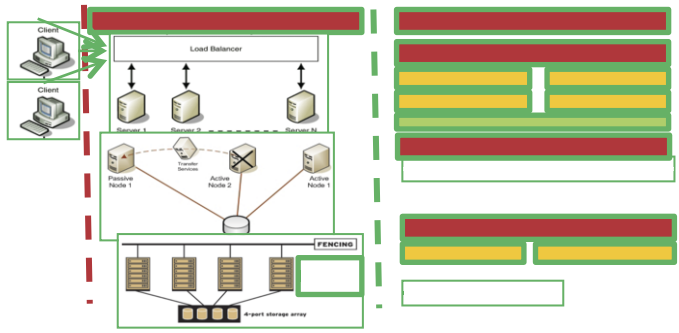

Figure 2. Central Server Hardware and Software Architecture

1.4. Clients

Clients can query and retrieve medical images in parallel from multiple Grid Agents where medical content is cached during the pre-fetching and synchronization processes. For web clients, java based open-source DICOM viewer software, *ImageJ*, is customized to stream image instances in parallel chunks. The DICOM Viewer screen of the web client can be seen in Figure 3. A query that is directed to the grid agent in a hospital by workstations is also directed to other grid proxies. Consequently, the query is performed at every hospital and central web server. Grid Manager provides the Grid Agent and consequently workstations with the result list and the images or data can be retrieved by the help of Grid Manager. Parallel downloading and efficient query algorithms in the Grid Manager enhances the bandwidth usage and time delay.

Figure 3. Web based DICOM Viewer

2. Results and Discussion

The framework implementation is tested by simulating medical facilities and information systems using open source dcm4che2 DICOM Toolkit. Three medical facilities, three reporting units are each represented by a virtual machine on different networks. A set of 100 sample radiology inspections for 10 different patients are generated by the facilities. It is observed that the Grid Agent synchronizes the previous inspections of a patient at the site with the arrival of a new examination. Therefore, there are at least two copies of an inspection preventing single point of failure and eliminating the cost of central disaster recovery solutions. The synchronization also

takes place at the reporting unit with the incoming reporting request. The clients can access the images belonging to different sites on a single interface on the web or using their presently installed DICOM viewer software.

The proposed architecture increases the efficiency of reporting, image query and retrieval processes for teleradiology applications and provides a process centric network structure with an enhanced caching, querying and retrieving mechanism. The Grid Agent and Grid Manager solutions provide integration of several standard compliant medical systems regardless of the developer or manufacturer vendor and accomplished medical data redundancy without the maintenance cost of a single central web solution.

It is planned to test the implemented architecture with a real-world scenario including medical sites with different vendor facilities and reporting groups with non-local radiologists and to evaluate the results in terms of user experience and data access time. The data flow algorithm is aimed to be enhanced in order to increase report quality and turnaround time by delivering medical images that require subspeciality or urgency to the best matching radiologist.

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