A Data Grid Model for Combining Teleradiology and PACS Operations

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Abstract
The use of teleradiology for X-ray image communication and display was introduced as early as 1972 [1] and the PACS concept was conceived in 1982 [2, 3]; after more than twenty years of technological advancement and refinement, both teleradiology and PACS have become indispensable components in today’s healthcare delivery system. Although both teleradiology and PACS share many common technological components and workflow profiles, these two imaging-based systems are operated independently and are not readily integrated. This paper compares the commonalities and differences between these two systems, and suggests a method for their integration in terms of image archival, reporting, and workflow using a Data Grid model.

Key words: PACS, Teleradiology, Data Grid, DICOM, IHE

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1. Introduction
Teleradiology is a subset of telemedicine operations focusing on remote diagnosis of medical images. Teleradiology utilizes computer, display and telecommunication technologies for radiologists at workstations (WSs) to make diagnosis from clinical images generated from remote examination sites. The diagnostic report is sent back to the examination site where a primary physician can provide proper treatments to the patient immediately. Teleradiology operation can be very simple or extremely complex as shown in Table 1. Three factors contribute to the complexity: 1) Historical images are required for comparison; 2) Information from the radiology information system (RIS) is needed; and 3) Image archive is necessary. Teleradiology is relatively simple to operate when neither image and information retrieval, nor archival of images and reports are required. However, when both archival and retrieval are required, the operation becomes extremely complex. In this paper, we try to address the issue “How to combine images and reports from teleradiology with those from an outside archive, like a PACS?” as a means to systematically analyze the “most complex teleradiology operation” model shown in Table 1. We first define the pure teleradiology model, then the combined teleradiology and PACS model. The former model allows us to appreciate the workflow and workload of multiple sites teleradiology operation. The latter model addresses the global issue related to the earlier question.

Table 1 Four modes of teleradiology operation according to their complexity.

<table>
<thead>
<tr>
<th>Historical Images/RIS</th>
<th>Archive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most simplistic</td>
<td>no</td>
</tr>
<tr>
<td>Simplistic</td>
<td>yes</td>
</tr>
<tr>
<td>Complex</td>
<td>no</td>
</tr>
<tr>
<td>Most complex</td>
<td>yes</td>
</tr>
</tbody>
</table>

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2. Materials and methods

1) The pure teleradiology model with multiple sites

Teleradiology can function as a pure teleradiology operation shown in Fig. 1. In this operation, the teleradiology management center serves as the operations manager. It receives images from different imaging centers, 1,…, N, keeps a record but not the images, routes images to radiologists at different expert centers, 1,…, M for reading based on the “Supply and Demand” criterion. Reports come back to the management center, the transactions are recorded, and the reports are forwarded to appropriate imaging centers. The management center is also responsible for the billing and other administrative functions like image distribution and workload balancing.

2) PACS and teleradiology combined model

Teleradiology applications and PACS can be combined together as a unified healthcare enterprise operation with workflow shown in Fig. 2 [3]. Two major components in the combined model are the PACS (upper rectangle), and the pure teleradiology model (lower rectangle).

A. Pure Teleradiology Model: Image center sends images to the expert center for reading as in the pure teleradiology model shown in Fig. 1. The workflow step is depicted as No. 7 in Fig. 2.

B. PACS Radiologists assist Teleradiology Reading: Outside imaging centers (1) send exams to PACS WSs (2) for PACS Radiologists to read. Reports are sent to the database gateway for PACS record (3), and/or to the expert center (4).

C. Expert Center radiologists assist PACS reading: PACS sends exams to expert center radiologists to read (5). The expert center returns report to the PACS database gateway (6).

The combined Teleradiology and PACS model is mostly used in an enterprise level Healthcare system with satellite imaging centers, or in back-up radiology coverage for a hospital by imaging centers. In this model, PACS and each imaging center keep its own images; but the reports can be shared. This model addresses the sharing and archival of reports, but not image archival.

3) A Data Grid for medical imaging applications

Data Grid is a service of the Grid Computing technology [4]. A Data Grid [5-7] specifically designed for clinical image backup and disaster recovery was developed at IPI (Image Processing & Informatics Laboratory) using the Globus Toolkit 4 (GT4) [8]. This Data Grid shown in Fig. 3 was designed to utilize the strengths of grid technology along with PACS (Picture Archiving and Communication Systems)/ DICOM (Digital Imaging and Communi-
cations in Medicine) technology for storing and distributing clinical images. In particular, some PACS/DICOM resources are embedded within the GT4 five layer grid architecture (Fig. 4) developed by IPI. These include Storage service, Query service, and Retrieve service, which are integrated with the DICOM standard protocols in addi-
tion to the use of other Data Grid Services. We use this Data Grid model to discuss the workflow of a combined PACS and Teleradiology Operations at the enterprise level.

3. Results

1) PACS and teleradiology in an enterprise level operation using the Data Grid model

PACS and teleradiology combined model described in Fig. 2 can be extended to the enterprise level PAC systems and teleradiology operation. This model becomes popular in today’s enterprise healthcare delivery system. Data Grid concept can be used to consolidate images/data obtained from both PAC systems and teleradiology operations into one unified image/report archive system for storage and distribution shown in Fig. 5[9]. We use the Data Grid Model to address the global question raised earlier: “How to combine images and reports from teleradiology with those from outside archive?” Several PAC systems would be treated in this context as images and reports from outside archive.

Each PACS in the model has a shared storage contributed to the Data Grid as described in Fig. 3. In addition to P2 partition of the SAN storage in each PACS (See Fig. 3), the Data Grid has a major software module, Teleradiology DICOM, which directs the image and report workflow of teleradiology. Refer to Fig. 5, Teleradiology DICOM has three components: the Manager, Tele Rad Arch, and Tele Rad Backup. One function of the Manager is to determine if images from an Image Center need to be archived in the Tele Rad Arch storage. If this is the case, a backup copy would also been sent to the Data Grid, which would then create two backup copies strategically saved in the Grid (Fig. 3). The Tele Rad Backup architecture and functions are the same as one of the PACS Back-up storages (See P2 in Fig. 3) which becomes a share resource of the Data Grid.

2) Workflow in the enterprise PACS and teleradiology operation

The workflow of images, reports, and radiologist’s readings are similar to that described in Fig. 2 except Item B in Section 2.2 where images from each Imaging Center to be archived would be determined by the Teleradiology DICOM Manager. A copy would also be sent to the Data Grid which creates two backup copies in the Grid (Fig. 5). Two new software packages would be necessary: 1) The Teleradiology DICOM to handle the image archive as well as its backup in the Data Grid, and 2) The Application Layer (Top Layer in Fig. 4) for PACS and Teleradiology operation which would be different from that listed in Fig. 4.

![Fig. 4 Five-layer architecture (Fabric, connectivity, resource, collective, and application) of the Globus Toolkit 4, and contents of the Data Grid, shaded areas are integrated with DICOM services developed at IPI. Application Layer software is designed for clinical image data recovery. See also Fig. 3 caption [6].](image-url)
4. Conclusions

Following the combined PACS and teleradiology model, we design a Data Grid model to handle the integration of the image archive and reports in an enterprise operation. Although the Data Grid model is defined, due to the complexity of its implementation, development of using the Grid Computing technology for Enterprise level PACS and teleradiology combined model is still in its infancy.

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References

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Dr. Huang pioneered in picture archiving and communication system (PACS) research. He developed the PACS at UCLA in 1991, and the hospital-integrated PACS at UCSF in 1995. Dr. Huang has taught at Georgetown University, University of Iowa, UCLA, UC Berkeley and UC San Francisco, the Hong Kong Polytechnic University, and the University of Southern California.

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