Implications of Introducing Grid in Medical Applications

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Introducing Grid technology in health care applications opens up for new possibilities in the medical domain. Grids are much more than distributed super-computers. Grids provide seamless access to diverse resources across enterprise boundaries with a defined service quality. We show examples of services on medical Grids, implications for medical standards when introducing Grids, and show scenarios for the use of multimedia-grids in medical applications. For the benefit of medical applications Grid middleware capable of handling multimedia-requirements must be developed.

INTRODUCTION

Grid technologies are being introduced in many applications, including medical applications. From the viewpoint of information technology, medical applications are of the most demanding multi-media applications with high data volume, high processing demands, the need to transfer these data, very high security demands, and very often hard synchronisation and latency demands.

Grid technologies support many of the specific properties of the medical data, including work-flow, load balancing, service quality, and security policies. When Grid is to be used in medical applications, the Picture Archive and Communication System (PACS) must be adapted to Grid technology, and standards must be adjusted to include Grid. However, the current standards are not suited for the service-oriented Grid architecture.

Since the Grid technology was conceived at institutions with high computing power demands for simulation tasks (e.g., at CERN), Grids are often mistaken for being large, distributed super-computers. However, the stress in Grid technology is on seamless access to resources across organization boundaries, and providing a QoS regime.

New systems can only be introduced in health care when they support the existing work-flow, instead of trying to invent new work-flow regimes, as the experiences from the PACSflow project show [Balasingham et.al. (2006)]. It is important that the data are kept in the system while being processed, rather than being exported and imported again after processing.

While standards like DICOM are based on the practical needs and the technologies available when the standard was designed, Grid technologies are based on a layered service architecture. When introducing Grid into PACS systems these standards must be re-evaluated in order to include more functionality into medical applications.

GRIDS

The name “Grid” comes from the metaphor of “Electrical Grids” and the idea to get access to a resource (e.g., electricity) by using a plug. Likewise, the access to a medical resource should be by giving the clinicians the possibility to enter a case into the Grid system, and get an answer according to a service agreement which includes that policies in health care are followed.

There is no unified definition of the term «Grid» available, and the common definitions often address different application areas, like super-computing. For the medical domain the definition by the NGG Expert Group on European Grid research may give the most suitable definition from an application point of view: «*A Grid provides an abstraction for resource sharing and collaboration across multiple administrative domains ...*». While technicians often refer to the Grid as a «computational Grid» that provides high computational resources in a seamless manner, the general meaning goes much farther: The Grid is an infrastructure that gives seamless access to resources in an application domain. Overviews of Grid technology and applications can be found elsewhere [Leister et.al. (2004)], [Abbas (2004)].

For medical applications this means that the Grid is an infrastructure that provides resources to the medical personnel. These resources may include computational resources, storage, equipment (e.g., scanners, lab), or human resources (specialists). The Grid technology builds an infrastructure to access these resources seamlessly, and following a work flow that follows the necessary policies in health care.

Grids have the following properties:

- The Grid is a distributed system without a central unit available to control the entire system.

- Grids have a layer-based architecture (service stack), which consist of the fabric layer, the connectivity layer, the resource layer, the collective layer, and the application layer.
- The layers in a Grid are based on services that can be accessed by the layer above.

SECOND OPINION APPLICATION USING GRID

As an example we take the procedures for «second opinion» in e.g., cardiology. Transferring cardiology images for the purpose of a second opinion to another hospital requires large bandwidth between the hospitals. Though PACS-to-PACS transfer is implemented there still exists a rather manual work flow, including agreements over the phone, and fax transmission of data from the Electronic Patient Journal (EPJ) before sending the PACS data. See Figure 1 for an example. This procedure is based on manual work flow, which is labour-intensive, and may cause errors during handling.

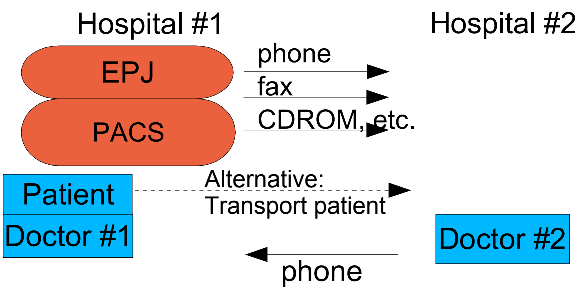

Figure 1 Work flow in traditional technique

At the Rikshospitalet University Hospital the PACSflow system was developed together with the Norwegian Computing Center [Balasingham et.al. (2006)]. The PACSflow is a web-based application for medical personnel to transfer PACS and EPJ data in a one-step procedure. PACSflow is an interoperable and standard-compliant web based application, which gives clinicians a user-friendly interface to transferring medical images and data along with the data from the EPJ, as shown in Figure 2.

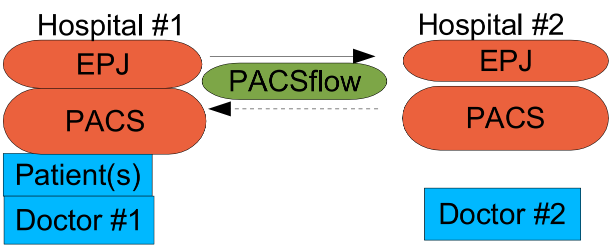

Figure 2 Work flow using PACSflow

The Department of Cardiology at the Rikshospitalet University Hospital in Oslo and the Department of Internal Medicine at the Sørlandet Sykehus in Arendal make clinical use of the system. Tests indicate that the use of PACSflow reduce the time to prepare and transfer data by a factor of 3; most of the improvement comes from reducing manual intervention in the transfer process.

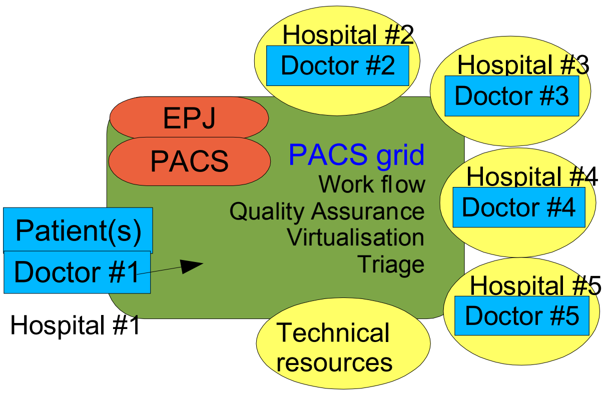

Figure 3 PACS Grid

While the PACSflow improves the transfer of medical images, this solution cannot claim to be a Grid system. Clinicians still need to negotiate with their colleagues, and to know who can perform a second opinion for a certain case. In a Grid system, this issue would be handled automatically, insuring that procedures and policies are followed, e.g., performing certain procedures twice independently, or use CAD[1] methods. See Figure 3.

Note: Policies and legal constraints in health care could make it necessary to move PACS and EPJ outside the grid.

STANDARDS AND MEDICAL GRIDS

For the Grid the standards OGSA and OGSI are used: OGSA describes the architecture, while OGSI describes the infrastructure of a Grid, using a service architecture. The infrastructure is based on open standards, e.g., web services that employ standards like XML, SOAP, UDDI, etc.

Usually applications are built on top of Grid middleware. Typical tasks for this middleware are the packaging of individual application tasks into suitable pieces of single work units, and workflow management.

DICOM, developed by NEMA [DICOM (2006)] is a widely used standard for the interoperability of medical imaging equipments. DICOM addresses the storage and sharing of digital imagery between medical imaging equipment and other systems. Being a standard by an interest organization of manufacturers of equipment, DICOM is developed out of practical considerations. DICOM is linked very closely to other technologies, and includes these explicitly into the standard. Although this approach results in a standard that is well-defined, it lacks flexibility with regard to new technology development. E.g., DICOM includes explicitly the

1 CAD: Computer Aided Diagnosis.

use of the TCP/IP stack, instead of referring to an abstract service layer interface. Therefore, making the DICOM-standard Grid-aware would require changes in the DICOM standard.

When implementing Grids in a PACS environment the DICOM standard can play two roles. Most current Grid projects employ DICOM as part of the Fabric- and Connectivity-Layers, i.e., by using the functionality of a DICOM-compliant PACS system as a building block for the layers above. Projects like eDiamond and MAMMOGRID [Amendolia, et.al. (2004)], are examples for this approach.

The second possibility aims at a Grid-aware version of the DICOM standard, and thus moving DICOM into the resource- and collective layers. This would turn the DICOM standard into the basis of resource-Grids.

SECURITY IN MEDICAL GRIDS

In health care applications the data are usually of a sensitive nature, and must therefore be protected very carefully. While new security regimes could be developed in the medical domain, we recognise that many of the requirements are similar to those in the area of multimedia, where concepts for Digital Rights Management (DRM) [Abie, et.al (2004)] were developed.

One solution that provides a tool box for handling DRM is the MPEG 21 framework (ISO/IEC 21000). MPEG-21 defines digital items that can be identified. Digital Items can be subject to Intellectual Property Management and Protection (IPMP). In the Rights Description Language, rights associated with a resource are issued to a principal, subject to certain conditions. This model can be extended to medical data, and be enforced in the daily procedures when handling medical data of patients. The MPEG-21 framework can help to make Grid systems suitable for handling sensitive patient data.

ADVANCED MEDICAL GRID SCENARIOS

While many medical Grid projects look into the organizational and security issues of making images and documents available to the medical experts, the new multimedia grids support advanced visualisation and other interactive applications with strong requirements to service quality (QoS). The QoS is defined by a service contract and the guarantee of a certain service qualities, e.g., throughput, synchronisation between media, security, etc.

For advanced medical applications the same requirements are valid, since the documents made available by a medical grid contain streams of data consisting of several synchronised media types, with very high QoS requirements. We illustrate these future medical applications in the following scenarios. Note that these applications, like Virtual Endoscopy [Bartz (2005)], cannot be supported in today's grid architectures, and funding for research in these areas are necessary to proceed this important step into the future.

Scenario 1: The first medical scenario describes a situation, where a small medical institution of basic care (SMI) encounters a difficult and complex medical situation that exceeds their medical capacity. Transporting the patient to a specialty hospital could require too much critical time for the patient to be saved. Using a Grid service, expert medical advice through an expert medical institution (EMI, e.g., a university hospital) can be provided through various image- and video-based means in addition with an already available voice stream (previously by phone). Thus, the local physician can be supported in a significant better way while treating the patient in the Operating Room (OR).

Within the Grid-based framework, a tracked video camera is capturing a video stream of the OR-situs of the patient, or of a virtual endoscopy session at the SMI. This video stream is directed to the expert surgeon at the EMI, who sees the same information as the OR camera at the SMI. Critical structures (eg., nerve fibers, blood vessels) are marked and annotation and thus made visible to the local surgeon. Furthermore, the expert surgeon describes the optimal surgical approach via phone or *voice over IP*. Based on locally available 3D image data of the patient, a virtual endoscopy session of the target organ system can be engaged, where the control of the virtual camera can be switched between local and expert surgeon, while the virtual endoscopy video stream is delivered to both surgeons.

Scenario 2: The second medical scenario describes a situation, where an EMI encounters a rare and difficult injury or disease, which requires a specialized care or surgical intervention. Therefore, the physician at the EMI seeks additional advice from a specialized expert medical institution (SEMI). Instead of giving limited support through the SEMI, which increases the probability for serious complications or additional medical remote damages to the patient, in a Grid-based scenario, the physician at the EMI can receive similar support by the SEMI. In contrast to scenario 1, a bi-directional exchange of annotations and navigation commands can be provided to foster discussion between the EMI and the SEMI physician.

Scenario 3: In this scenario, a medical institution (MI) seeks technical expertise for advanced 3D visualization and analysis of the patient data from a technical service provider (TSP). The MI transfers the image data of the patient (e.g., CT, MRI scans) to the TSP, who processes the data and prepares visualization and analysis of the data. Without a multimedia Grid these prepared data are transferred back as either static video or images, which allow no interaction. Alternatively, the image data can be inspected image by image by the physician. Using a Grid-based framework, the TSP provides an interactive grid-based session, and connects the MI with the available computing and rendering resources. The TSP streams the resulting image data to the MI, while the MI sends navigation and other commands to the application at the TSP to which areas of the patient data are visualized. Typical visualization services are virtual endoscopy explorations of patient organs represented by the image data. If a mixed reality representation is chosen, in addition to position and orientation data of an image-based navigation system (which relates patient data and patient location on the OR table) a video stream of the OR-sites must be upstreamed to the TSP.

There is not yet an infrastructure available to build multimedia-aware medical Grids that support the scenarios described above. While applications to support a single of these scenarios exist, there is no solution that provides an infrastructure.

Services related to workflow orchestrate underlying Grid services as required by the target real-time medical applications. Existing workflow engines, e.g., GridAnt, WSFL, XLANG, BPEL, Gridbus Workflow, or GridFlow) could be used for service composition. Here, it is important to choose systems that support the workflow in medical applications. Note also that inter-enterprise medical applications in Grid systems must follow the four basic federation processes, which are generic for business collaboration: Atomic Service Provision (a service provider makes a service available to a customer), Service Encapsulation (a service provider makes use of other services in a way hidden from the consumer), Service Orchestration (a consumer of several services arranges these to interact with each other), and Consumer Federation (a consumer of a service arranges for other users to access this service). Traditional Grid technologies do not support all of these federation processes with all security and service requirements.

CONCLUSIONS

The applications using Grid systems in the medical domain have demanding requirements on the infrastructure that are similar to those in multimedia. The development of the so-called middleware is essential, e.g., the generic infrastructure between the application and the hardware/operating system of a system. While the development and design of the middleware is a task for computer scientists, the requirements must come from the medical practitioners. We see an important synergy between multimedia and medical applications, since the requirements from the applications to a Grid system are similar. Service quality and security are important issues to be handled by a Grid system that can be used in health care enterprises. The development of Grid infrastructures must be enforced, and supported with resources by the health authorities in order to come closer to the vision of a medical Grid, and in order to solve the many technical and organizational challenges.

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