Processing of Medical Images in Virtual Distributed Environment.

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ABSTRACT

The processing of medical images within a PACS system depends on high capacity of communication channels and high performance of computational resources. We introduce pilot project utilizing grid technology to distribute functionality of PACS system to several machines located in distant places which allows economizing utilization of network channels. We also discuss benefits and disadvantages of virtualization techniques allowing to separate physical machine capabilities from the operating system. We compare this pilot project utilizing high speed CESNET 2 network with similar mature projects based mainly on P2P secure connection, centralized system and proprietary protocols.

Categories and Subject Descriptors
J.3 [**Medical information systems**]

General Terms
Management, Design

Keywords
Virtualization, Grid, PACS

1. INTRODUCTION

The Digital Imaging and Communications in Medicine (DICOM) standard is widely used in medical devices and applications. Picture archiving and Communication Systems (PACS) to archive DICOM are currently used in information systems within hospitals and today's effort is focused on connecting the systems among hospitals. The additional security and authorization mechanism must be kept with respect of data privacy and safety as DICOM itself doesn't provide such features [1]. DICOM series represents also usually large amount of data, which has specific requirements of capacity of communication channels.

Dostal et al. [2] introduced the client-server message brokering system with a centrally located server cluster and client application on user computer, the MeDiMed project. It was primarily used in national education network CESNET2; however other clients may connect via public Internet channels too. Client application retrieve DICOM series from the client's local or institutional PACS and send it via proprietary protocol using SSL encryption to server. Client application identifies the receiver and sets some other metadata regarding the message. The receiver must have the same client application and get the DICOM series from the server later. This solution based on the central point of the system architecture may become a bottleneck or single point of failure. There are other commercial solution using SSL encryption and authentication which are based on establishing VPN connection between peer endpoints.

Erberich et al. [3] utilized grid technology and open standards and protocols to process DICOM images securely in distributed environment to prevent some issues coming from VPN and proprietary protocols. They introduced project named Globus MEDICUS which integrates DICOM interface as a service of a grid infrastructure. Montagnat et al. [4] used similar approach in their Medical Data Manager which integrates grid middleware gLite with a DICOM interface providing strong security and encryption mechanism to preserve patient's privacy.

Different systems and technologies have different requirements on hardware and software environment. Virtualization techniques allow providing separation between software and underlying hardware. However virtualization introduces some overhead when translating isolated application instruction to lower level of a system. Current virtualization techniques allow full operating system isolation. Youseff et al. [5] showed that XEN paravirtualization doesn't impose an onerous performance penalty comparing to non-virtualized OS configuration.

We deployed the selected grid middleware and DICOM grid interface service from the Globus MEDICUS project to the virtual machines within the physical servers geographically spread throughout various institutions. We successfully exchanged the DICOM series between the DICOM grid interface and MeDiMed project without any proprietary modification of the systems used.

2. METHODS

The Globus Medicus project [3] provides a DICOM grid interface service (DGIS) able to communicate in DICOM standard, metacatalog service and storage service provider. Each service may run on separated host machine. The DGIS service is a bridge to grid infrastructure and hides the fact that the data are processed

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throughout a grid. The metacatalog service and storage service provider are deployed on the Globus Toolkit.

We modified the DGIS to be able to communicate with the client application of MeDiMed project and accept the DICOM images exchanged in this project.

Because of specific requirements of the services of Globus MEDICUS, we chose to utilize virtualization techniques to fulfill the requirements dynamically. We installed the opensource XEN paravirtualization implementation, which adds a modification to the kernel of a guest system to be able to be executed and monitored by the host machine. Modification of the host system is, however, not required on hardware with virtualization support.

We installed the services of Globus Medicus within the virtual grid nodes on the paravirtualized guest systems Centos 5.2 Linux, kernel version 2.6 which are hosted on 64-bit Intel XEON running XEN 3.0.3.

DICOM standard uses separated direct IP connection to the user's location to send the results of the user's request. Because of that the DGIS service must have direct access to the user's application or DICOM device via IP transport level. So we decided to deploy DGIS service together with other services of Globus Medicus within the same guest system. The DGIS connects to the other local or remote services of the grid infrastructure via HTTP and gridFTP protocol. The communication between nodes and services is secured by asymmetric encryption and x.509 certificates.

3. RESULTS

We deployed nodes of the pilot grid infrastructure into the following pilot location: CESNET association, First Faculty of Medicine of Charles University and Central Military Hospital. All three locations are in Prague and are connected via high speed national educational and research network CESNET2 operated by CESNET association. We plan to use the pilot grid infrastructure also for another purpose and the XEN paravirtualization allows us to deploy and test another isolated projects next to this one.

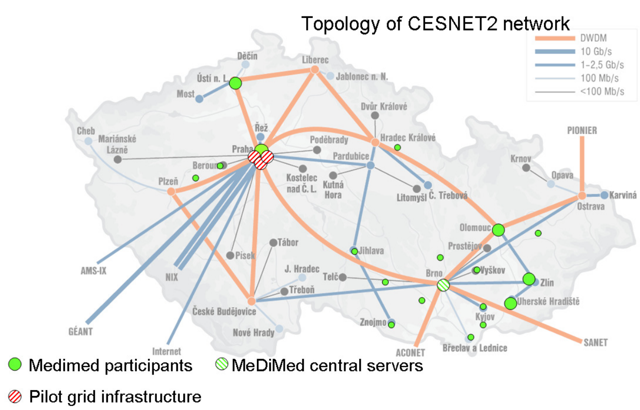

Figure 1. pilot grid infrastructure and MeDiMed project participants

We configured the guest virtual machines to share the same IP connection with the host system with IPv4 address. We configured the transport to virtual machine via network address translation (NAT) and we use Linux ipfiltering "iptables" ruleset to forward incoming connection to the grid services.

Some institutions hosting pilot project servers follow strict security policy, so they require the installation and execution of the grid services in demilitarized zone next to the institutional firewall with restricted access to local resources. With administrators of the institutional firewall we explicitly agreed and configured the firewall exception for the gridFTP protocol as the transport of such protocol uses TCP port number usually restricted by default.

We uploaded initial DICOM studies with about 1300 DICOM images for demonstration purposes. We successfully exchanged and processed the DICOM studies with the desktop application K-PACS.

We demonstrated that connection and DICOM studies exchange is possible between the MeDiMed project and the Globus Medicus. We used the client application of the MeDiMed project to retrieve and send selected DICOM series from the grid Globus MEDICUS to the participant connected in the MeDiMed project successfully and vice versa.

4. CONCLUSION

The grid technology is able to serve medical image processing in secure and reliable way as well as current systems. The only unsecured communication is between DGIS and DICOM compliant client, which is same for other types of solution (MeDiMed or VPN based) and is not usually recognized as security issue if unsecured connections are within trusted local network.

The grid services operate on specific TCP port numbers, the access to them was restricted by default in some institutions and explicit exception had to be implemented on the institutional firewall. Comparing to current production systems to share DICOM images (e.g. the MeDiMed project), they don't need such network configuration or they use VPN. The other problem regarded to network communication is sharing one IP connection among multiple virtual machines on the same host physical server. In such case we set the NAT and IP filtering rules statically on each physical server. Challenge for future development would be dynamic routing to virtual servers.

The DICOM grid service interface behaves as another DICOM compliant device and the whole system with the utilizing grid services may be considered as another PACS system e.g. as a remote backup or an external PACS for exchanging e.g. educational DICOM studies. In contrast the MeDiMed client's application doesn't allow to be controlled via DICOM protocol thus cannot be accessed by institutional application and the proprietary MeDiMed client application must be used to process DICOM studies from MeDiMed project.

The MeDiMed project will have to face problems of scalability and single point of failure. The grid technology and virtualization might be an answer to such problem for future enhancement and development as it can benefit from live network topology and doesn't need to maintain virtual topology established by VPN based solution. The MeDiMed client uses the proprietary protocol to communicate with server in contrast to the pilot grid infrastructure which is based on open standards.

Virtualization techniques allow dynamic allocation and management of physical resources. The pilot physical infrastructure of the servers might be utilized to deploy another virtual application or systems next to the DICOM and PACS services. This benefit is currently considered by the other participated institutions.

5. ACKNOWLEDGMENTS

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