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THE LINUX-BASED PACS PROJECT AT THE GERMAN CANCER RESEARCH CENTER

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This paper describes a PACS project which is based on Intel platforms and the Linux operating system. It describes the goals and requirements of the radiologists, the realized hardware and software architecture and specific features, like fault tolerance, security measures, teleconferencing and extensibility of the system.

1. INTRODUCTION

The PACS project at the German Cancer Research Center (DKFZ) in Heidelberg, Germany, is a continuation of the successful MEDICUS and CHILI® projects. A dedicated teleradiology system has been developed and was in clinical use in the first project [1]. The successor of that system was the general purpose radiology workstation CHILI, which has many advanced teleradiology functions [2]. Important unique features of the CHILI system are vendor independent communications protocols [3], a strong security concept [4], and its extensibility [5][6].

The CHILI system is installed at more than 50 sites in Germany and in the US. The radiology department of the Cancer Center is using the system to exchange radiological images with referring providers and with scientific cooperation partners. Nearly 100,000 images have been distributed and discussed by means of this (tele-) radiology system by the cancer center only.

2. GOALS AND REQUIREMENTS

2.1. Functional Requirements

The radiology department decided in early 1999 to replace the film based image archive by a long term PACS archive. All existing digital modalities (CT, MRI, US, and PET) should be integrated (classical x-ray is not performed).

Image reading should be done at the diagnostic workstations. Additionally, the workstations should be able to support printing, worklist management, and image transfers to external referring providers and other medical partners including synchronized teleconferencing.

2.2. Organisational Requirements

An important requirement was that the PACS should be based on the existing central archive system (ADSM, Tivoli) of the Cancer Center, which is professionally managed by the central data processing division since 1994.

It was planned to start with the implementation of four diagnostic workstations (CT, MRI), two workstations at the CT and MRI consoles and one for the radiation therapy planning group. All workstations should be able to perform teleconferences between each other and with external partners. Furthermore, all PCs on the doctors desks should be able to access the image archive with web technology.

2.3. Data Requirements

An investigation of the generated amount of data has been performed by the radiologists at the end of 1998. The result was that about 0.5 TB of data are produced per year. An image cache (RAID) should hold the images of the last 1 to 2 month on-line.

2.4. Project setup

A Europe-wide request for proposals was necessary as the German Cancer Research Center is a public research organization. The Steinbeis-Transferzentrum Medizinische Informatik was selected as the purveyor with its CHILI-PACS concept and received the contract in december 1999.

3. SYSTEM SPECIFICATION

3.1. Hardware Architecture

The core of the PACS is the existing ADSM backup/archive system hosted on 2 dedicated AIX servers. This is a black box for long term archiving. The system is in production since 1994 and serves currently 360 backup and 130 archive clients. The total storage capacity of 27 TB is provided by 3 tape libraries (ATL Products, StorageTek); storage media is DLT4000 and DLT7000. One library, an ATL 4/52 (4 DLT4000 drives, 52 tapes) with 1 TB storage capacity, is currently used by PACS exclusively.

All other hardware components are based on PC technology running the Linux operating system (SuSE Distribution 6.3).

One central server is providing the disk space for the PACS database and the latest on-line images. The processors of the server are two Intel Pentium III with 500 MHz. The data disks (5 x 36 GB) are organized as a RAID system, running raid level 5. Two redundant system disks (9 GB each) are running raid level 1. A uninterruptible power supply (UPS) can supply enough power for a period of 10 minutes.

All workstations are based on Intel Pentium III 600 MHz processors with a 18 GB disk each. The diagnostic workstations are equipped with two gray scale, high contrast monitors

(SIEMENS 2183L). The systems at the CT and MRI console are equipped with one color flatpanel with a resolution of 1600 by 1024 pixels (SGI 1600SW).

The local area network is a 100 Mbit/sec Ethernet.

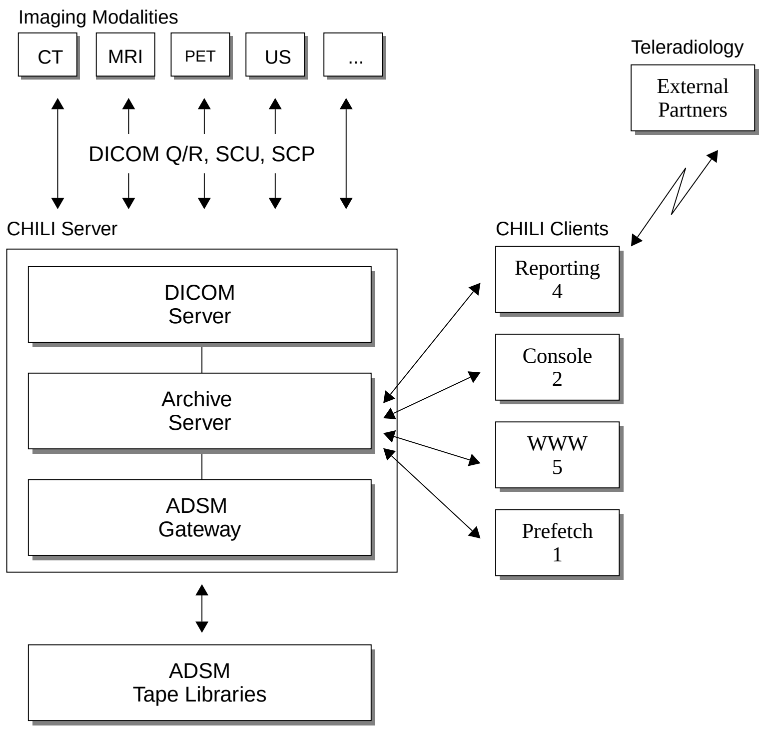

Figure 1. The configuration of the DKFZ PACS

3.2. Software Architecture

The software of all CHILI components is running under the Linux operating system. Important criteria for that choice have been performance, reliability, costs and security.

An expert at the British government's computer security headquarters, CESG (Communications-Electronics Security Group) has endorsed Linux along with the open source model for software development as the most secure computer architecture available. CESG is the sister organization of the GCHQ (Government Communications Headquarters), which is roughly the British equivalent of the American NSA (National Security Agency). There is also a warning against a competing commercial product with hidden source code [7].

The CHILI system is based on a distributed client/server architecture (figure 1). A CHILI archive server is running on the central server computer which is also running the RAID system. The server is configured by the following software components: patient database, DICOM server, send service, receive service, multicaster and the CHILI multiplexer [3]. This server handles both the local data on the RAID and requests to the long term archive (ADSM). An ADSM gateway handles data requests to the archive.

The CHILI clients (such as diagnostic workstations, viewing stations) have their local viewing component but are using the central services of the server for data management, image reception from modalities, teleconferencing and so on. Additionally, all workstations have a disk cache where loaded image data is kept for a definable time period. This speeds up the next access to the same data as long as it is in the cache.

All CHILI clients are able to transmit data to local or remote workstations. They are able to perform teleconferences with internal and external partners using the CHILI protocol.

The CHILI Webserver enables all existing computers in the local network to view the image data of the PACS with any web browser. The web clients are not restricted to use specific browser versions or operating system versions.

The PlugIn mechanism of the CHILI workstations can be used to integrate additional functionality (e.g. 3D visualization, image analysis) into the existing environment [6]. The PlugIns can immediately use the whole IT infrastructure of the CHILI network. The users can stay in their familiar environment [5].

3.3. Fault tolerance

The central server hardware is redundant and fault tolerant. But a backup system has been implemented in case the server is not working. The most important task is that images can still be acquired and read at the diagnostic workstations. Thus, all diagnostic workstations have a local emergency database and a DICOM server which can receive data from the modalities. The modalities are configured with these workstations as DICOM nodes as well.

This ensures that the routine work (image reading) can continue even when the central server is down. The buffered data at the workstations is automatically transmitted to the central server and archived as soon as it is up again.

The data of all workstations and the server disks are protected by a daily incremental backup of the ADSM backup system.

An archive system for PACS has to meet high requirements with regard to availability, reliability, security and lifetime of data. The setup of ADSM at DKFZ fulfills all this. Stability of the server (all important data is mirrored) and automated libraries guarantee permanent access to the archive. A second copy of all data is stored on a separate stream of volumes which are kept in an off-site location for disaster recovery; more on-line copies would be possible. ADSM provides automatic migration of data to new storage media which guarantees the readability of the archive for the required time frame even on new technology.

3.4. Interfaces to the archive

Several interfaces have been implemented to access the archive. The CHILI client is the standard interface to the data. The second is a DICOM query/retrieve interface for other DICOM compliant devices. ADSM is providing an interface for the data curator of the archive and access to the stored DICOM data in disaster cases when all other systems are not working.

3.5. Security measures

The PACS system is based on the CHILI security concept [4] which has been developed according to the European IT security manuals, resp. their German version (IT-Sicherheitshandbuch) of the Bundesamt für Sicherheit in der Informationstechnologie (BSI) [8]. Furthermore, we took into account the German signature law (SigG, IuKDG) and the requirements of the German electrical and electronic manufacturers' association (Zentralverband der Elektrotechnik und Elektronikindustrie ZVEI e.V.) [9][10]. Implemented security measures in the archive system are for example:

- Logging of accesses to the system (user, time)
- Protection against unauthorized access
- Protection against data loss (fault tolerance, redundancy)
- User authentication by accounts and passwords
- Authentication of the data receiver (ADSM)
- Authentication of allowed hosts in the network
- Data integrity in the archive (digital signatures)
- Access restrictions to the archive system (outside viewing station)
- Protected log files of data transmissions.
- Privacy of stored data in the archive (restricted hosts, authorized users)

Additional measures for the teleradiology functions of the system have already been described before [4].

4. RESULTS

The PACS is implemented in phases. The hardware components for the server and the workstations have been installed in January 2000. The CHILI server hardware is running since February and archiving all CT and selected MRI data in the archive. The workstations for CT and radiotherapy planning are currently installed and will be tested and evaluated by the users until mid April. The workstation for MRI will follow after that and will be tested and evaluated in additional 6 weeks. The users will be able to request additional functionality during this phase. Technically feasible and general useful functions will be implemented, tested and evaluated until end of August 2000. The connection of PET and ultrasound devices will follow then.

Up to now we did not encounter any problems with the hardware or operating system. The performance of the whole system is more than satisfactory. Users can not distinguish whether their image data is located on a local system disk or in the raid system of the server which is connected with a 100 Mbit/sec Ethernet.

5. CONCLUSION

The CHILI concept is different to existing commercial PACS implementations in several aspects: An existing archive system has been integrated into the concept. All workstations and the server are based on PC technology, using Intel processors and the Linux operating system. This saves costs but is very powerful and secure at the same time.

Teleconferencing between internal and external workstations is not an option, but a feature of all workstations.

The Client/Server concept is very flexible, adjustable to the user needs and can be exploited to configure a fault tolerant PACS network.

The PlugIn concept allows the integration of additional image analysis modules even by the end users or researchers at the cancer center.

The security concept is integrated into the system. Access to data through different standardized and open interfaces (DICOM, ADSM, CHILI) protect the investments of the customer as vendor dependencies are avoided wherever possible.

The integration with the RIS is an important issue for a successful PACS project. It is planned to replace the current legacy RIS in the near future. The PACS/RIS integration will be the next important step.

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