Chapter 3

MEDIMED Shared Regional PACS Center — Case Study

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Additional information is available at the end of the chapter

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1. Introduction

Today most hospitals use PACS systems locally to store and evaluate picture data produced by various modalities (i.e. x-ray, ultrasound, computer tomography, etc.).

Outsourcing of archiving and communication technology offers a place for cooperation among hospitals and for utilization of the existing multimedia data on patients. This approach changes the thinking of medical specialists and teaches them to cooperate and share data on patients.

Gradually, it changes the thinking of medical specialists and gets them to cooperate and share data about patients in electronic form. It builds a network of medical specialists. The impact of this project is not only in patient care but also in the education of medical specialists. Some data (e.g. typical cases of given disease) stored in the MeDiMed PACS archive can be anonymized (i.e. personal data of patients is replaced by fictitious data) and used for educational purposes.

In the following chapters we briefly recall basic principles of the PACS and introduce the MeDiMed project.

1.1. PACS

The PACS (Picture Archiving and Communications System) is a currently used procedure and methodology for processing medical multimedia data obtained from picture acquisition machines like x-ray, ultrasound or computer tomography. Medicine picture data obtained from these machines (in PACS terminology called modalities) are stored in central PACS server. The PACS server then provides these multimedia data to viewing stations. Viewing stations serve for the radiologists to analyze and evaluate the multimedia data. This approach offers much more capabilities than former film medium. Viewing stations allow image transformation, combination of images from more modalities etc. National Electrical Manufacturers Association (NEMA) has developed a standard for communications between modalities, PACS servers and viewing stations. This standards is DICOM [3]. Currently DICOM version 3.0 is used in mostly all modalities and PACS servers. The structure of PACS is cleanly presented on the Figure 1.

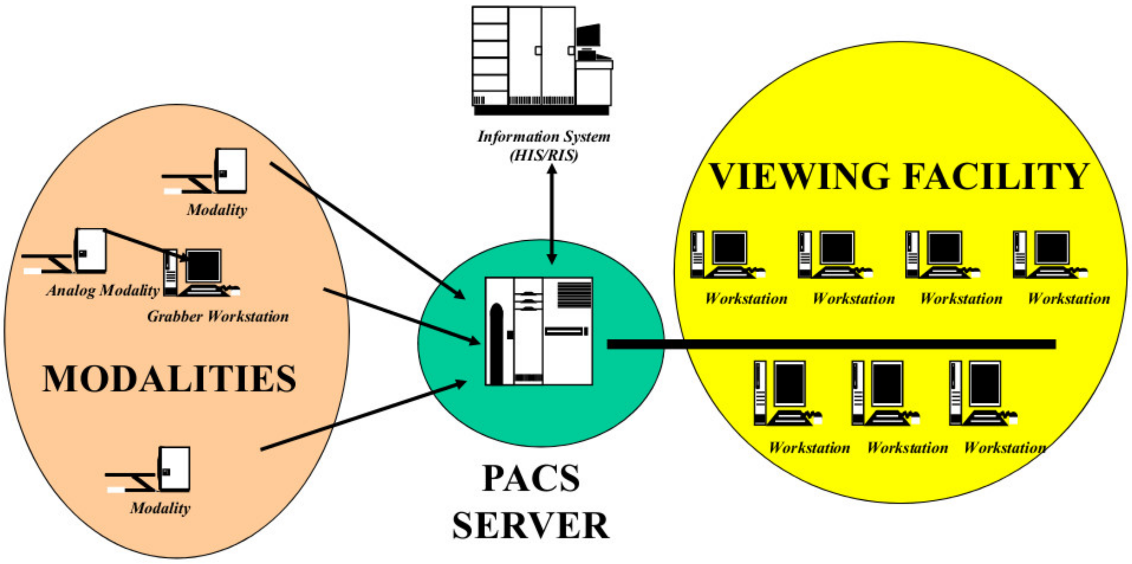

Figure 1. Common structure of PACS system. Modalities serve for acquisition of medicine multimedia data. These data are stored in PACS server and examined and analysed in viewing stations.

The digital processing of medicine multimedia data is very cost effective comparing to the legacy film based approach. A good example is the price comparison between a teleconsultation and a scenario where a doctor has to drive to visit a patient. The advantages of the telemedicine activities compared to the traditional methods are as follows:

- sharing of images among the cooperating institutions and their departments;
- cooperation with foreign medical partners;
- external long-term archiving of image data;
- management of other information associated and processed with image data;
- cost-benefit analysis performed by radiologists on standby duty at home;
- possibilities of functional integration of radiology departments of more healthcare institutions; and,
- integrating medical imaging with the concept of an electronic patient record.

Deep theoretical background of PACS principle and into basic protocol DICOM is discussed in [1] and [2]. Brief technical introduction to the PACS system architecture is in [4,6,8].

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Utilization of computer based medicine image processing brings new capabilities to the healthcare. Picture data can be processed and evaluated remotely in a reasonable time now. This approach allows to quickly ask for opinion of top specialists in case of a rare diseases diagnostics and ask for a second opinion or second reading in case where the radiologist is unsure.

1.2. MeDiMed project

Today most hospitals are using local PACS system serving only to one hospital. The goal of the MEDIMED project [7,10,11] is to initialize collaboration among hospitals as far as archiving and use of medical multimedia data and to provide the necessary technological infrastructure.

The Shared Regional PACS project MeDiMed started as a collaborative effort among Brno hospitals to process medical multimedia data. Masaryk University is the coordinator of this project ensuring that the demands and requirements of radiology departments are met, overseeing the changing legislative standards and the practical limitations of technology. Masaryk University, in cooperation with CESNET Association, also provides the necessary networking infrastructure.

Additionally, the project is to create conditions for general access to medical imaging data. The data exists already but its use is limited both in scope and time. By better utilization of the already existing equipment the project will bring a new quality into the healthcare operative, medical education and medical research as well as the decision-making on the level of local authorities.

The system deals with transmitting, archiving, and sharing medical image data originating from various medical modalities (computer tomography, magnetic resonance, ultrasound, mammography, etc.) from hospitals in the Brno metropolitan area. The Central PACS serves as a metropolitan communications node as well as a long term archive of patient's image studies.

Rather than creating just a computer network, it builds a network of medical specialists. This work not only impacts the healthcare field but also the education of medical specialists. The data stored in the shared archive can be made anonymous (i.e. personal data of patients is replaced by fictious data) and used for educational purposes.

Moreover, the process of making the data anonymous can be done in such a way that the data on a real patient obtained from several hospitals uses the same anonymous identity. That offers the students a more complex view of the evolution of the patient's health.

The realization of the project facilitates fast communication among individual hospitals, allows decision consultations, and brings various other advantages due to direct connections via optic networks. In general the MediMed project is clearly designed to support society-wide healthcare programs in the Czech Republic as well as programs implemented by other countries. The system is also supposed to serve as a learning tool for medical students of the Masaryk University as well as physicians in hospitals.

The gradual development of the joint system for processing and archiving image information is a natural step towards an increasing health care standard in the city of Brno and the whole region. Information on a patient's treatment in his own healthcare center as well as in other centers would be available. Consultations by more specialists will be enabled over the patent's picture, in case that a required specialist is not available in the center in question. Image information evaluation can be carried out in another place, general practitioners in the country will be able to consult specialists in hospitals, etc. Examination results will be available for the doctors in much shorter time than before. The implementation of the project has increased the speed of communication among individual hospitals, allowed decision consultations, and brought various other advantages due to dedicated network connections.

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More detailed description of regional PACS system MeDiMEd and it step-by-step development is available in [4-6,8,12-14].

2. Technology used in MeDiMed

Medical picture data like X-Ray, CT, US, MR, etc. cannot be used without additional information like picture data description or evaluation, diagnosis, possibly a reference to the history of a patient's health, previous treatments and other information relevant to the patient. This complex set of information about a patient represents a very sensitive data.

Therefore high level of security for medical image data maintained by the regional PACS archive has to be provided. We have to secure the data in three stages: data stored on servers of the regional PACS, data transported over the network between this archive and the user, and users' access to these data.

The security of the data stored on the regional PACS servers is achieved by using dedicated hardware for this application and by strict limitation of the access (both physical and network based) to this equipment.

The security of the data transported over the network is provided by using dedicated fibre optics lines when available and by employing strong cryptography (IPSEC with AES-256 encryption algorithm) on all lines which are shared with other data traffic.

The main principle of the hospital-to-MeDiMed connection is the use of two firewalls. One of them is in front of the MeDiMed PACS servers and is under the control of the MeDiMed staff. The second one is the hospital's firewall and is controlled by the hospital staff. It allows us, as administrators of the application, to control the access to central resources and allows the administrators of the hospital's network to control the access to the hospital's network. That way all participants have the access to the network they are responsible for under their control. This principle applies to all types of connections (dedicated fiber optics or IPSEC tunnel) between the MeDiMed servers and the hospital. The structure is easy to see from Figure 2.

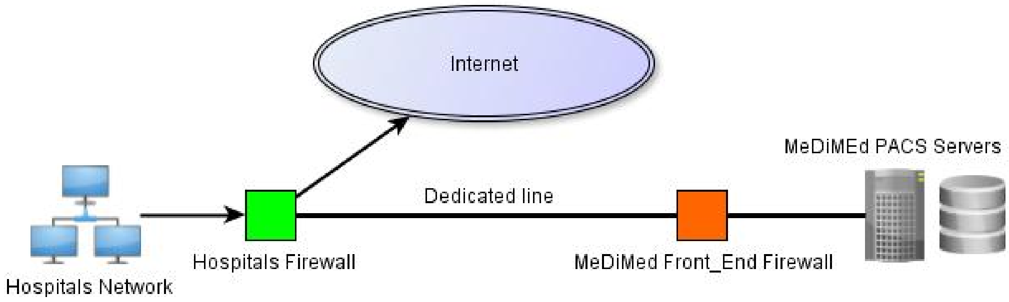

Figure 2. Common principle of the hospital to MeDiMed connection. There are two firewalls on the path form modalities and viewing stations to the PACS server. One of them is controlled by hospital and the second on by university.

Image distribution by specially configured dedicated computer networks plays a key role in the implementation of telemedicine. Every particular component of the whole system is certified so it can be integrated into the hospital information system infrastructure of cooperating healthcare institutions. All software tools are strictly based on the DICOM standard and could be easily incorporated into the already running systems.

The technology and networking solutions used in MeDiMed will be described in the following chapters.

2.1. Connections based on dedicated fibre optics

There is a large fibre optic cable network owned and operated by the universities in the city of Brno. The development of this network started in 1993. The ownership of the physical communication infrastructure is the key point for development and deployment of advanced networking services. MeDiMed is a good example of such a service.

The network is based on a fiber optic cable. Both, terrestrial and above ground, types of cable are used. The optical lines mostly have a ring topology for better reliability. This network interconnects all universities in the city and their faculties spread around whole city, various institutes of the Academy of Science, local government, courts, mostly all hospitals and some other institutions which were "on the road". Currently the network consists of about 150 km of optical cables and more than 90 nodes are using it.

The ownership of the private fiber optic network with enough free optics is mandatory for the implementation of new applications. It offers the freedom to establish private connections dedicated to these applications.

The development of computer networks is very fast as far as both the technology and the needs of network users are concerned. Since the beginnings of the Internet, full of enthusiasm of users and their happiness when the network was running at least sometimes we have moved through decades of manifold bandwidth raising (64 kbps was considered very good 15 years ago, today 100 Mbps is considered substandard) up to current state when a high performance internet connectivity is a standard. The users' demand for reliability has grown at a similar ratio.

In the beginning of the development of our network we used 10 Mbps Ethernet, mostly on a multimode fiber. At that time it was an economically acceptable solution corresponding with the level of technology of that time. In 1995 we started to use ATM because of the need for more bandwidth as well as the need for a dedicated transport channel for special applications. Today ATM is outdated in the area of data communication. However, at the time when FDDI was no longer a perspective technology and Fast Ethernet was not yet standardized, it was a reasonable solution. Both Ethernet and ATM network were built as a common open network of Masaryk University, Brno University of Technology and other academic parties. The ATM technology was the first one offering enough bandwidth and enough privacy to be able to support medicine multimedia data transport.

After the ATM age the networking technology moved to gigabit and ten-gigabit ethernet. This technology offers enough bandwidth and necessary services for a reasonable price. The second main change is the concept of an interconnection of the various institutions inside the metropolitan network. Terms like firewall and network security were not very common in the beginning of the Internet. Mail relays were open for everybody etc. At that time individual nodes of the metropolitan network were interconnected without any regard for the administrative structure. The main criterion was technical and economical availability. With the development of the Internet, the principles of solidarity and academic cooperation have gradually been ignored. The Internet has become an everyday part of our lives and not everybody respects the privacy of the participating institutions. Contemporary networks are built in such a way that every institution makes a compact unit ensuring security from unwanted activity of other Internet users.

The application of medical multimedia data transport was constructed as an isolated and closed network. Only two hospitals with only one type of modality (ultrasound) were interconnected in the first stage via the ATM network. This interconnection was created as an ATM LANE network and a private IP address space was used. Step by step, more hospitals and more types of modalities have been connected. As far as technology is concerned, we have moved from ATM LANE to the private Fast Ethernet based on dedicated fiber optic pairs. A necessary prerequisite for this was the development of private fiber optic network. A dedicated fibre optics line can be dedicated to demanding applications as the private fibre optics cables contain enough free lines.

2.2. Encrypted tunnels

For hospitals along the scope of our fiber optics network we need to use dedicated lines leased from anybody who can offer it (very expensive solution) or public data network. The use of the public data network is more economical but it enforces utilization of strong cryptography for securing the data. IPSEC with AES-256 encryption algorithm is used for this purpose. The basic principle is kept as depicted on Figure 2. Typical interconnection of his type is on Figure 3.

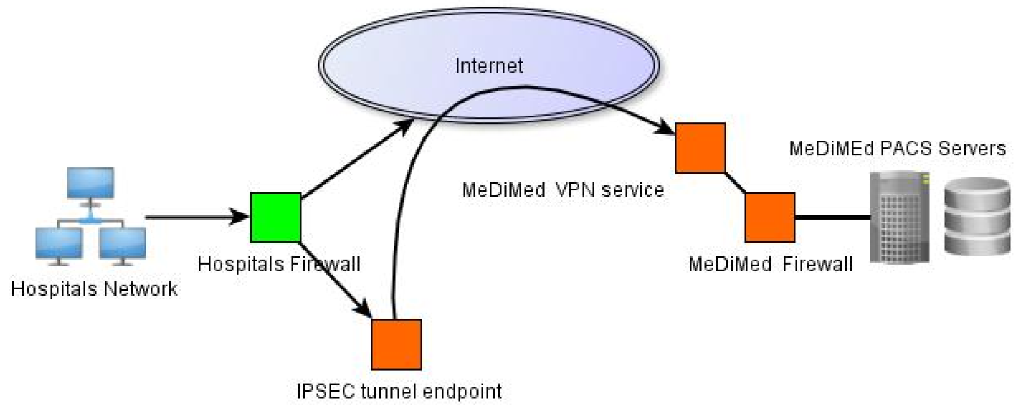

Figure 3. Connecting the hospital via IPSEC tunnel

2.3. Alien wavelength across the cesnet DWDM network

CESNET is an association originated by universities and Academy of science of Czech republic in 1996. Its main goal is to operate and develop academic backbone network of Czech republic. This network has started on lines with bandwidth in hundreds of kbps and step by step has grown to current backbone based on combination of ten-gigabit ethernet an even hundred gigabit etherent. The target speed of the core backbone is 100Gbps for the upcomming two years. The CESNET backbone interconnected all academic cities in republic.

CESNET provides services to education and research community. For research projects the budget is usually limited and the demand for special networks services (high bandwidth, low latency, certain level of privacy etc.) is very high. CESNET is a member of European research organisations like GEANT and is participating in a lot of research project in computer networks.

The CESNET backbone network is based on leased dark fiber lines enlighted by CESNET equipment. This is so called Custommer Empowered Fiber (CEF) approach. Dark fibre provides a lot of advantages and CESNET is using this technology on all backbone lines. DWDM technology is used in the core of the network. DWDM is used to provide data channels going through several backbone nodes. The real length of data channel may be several hundreds of kilometres. More detailed description of the CESNET backbone networks and technology solutions used to operate it is described in [16 – 19].

DWDM transport networks is traditionally used by service providers to offer clear channel services to its customers. Customers signal is typically carried as "gray" signal from customer's equipment to provider's equipment. This signal is inside transponder converted into "coloured" one and transported across DWDM providers network.

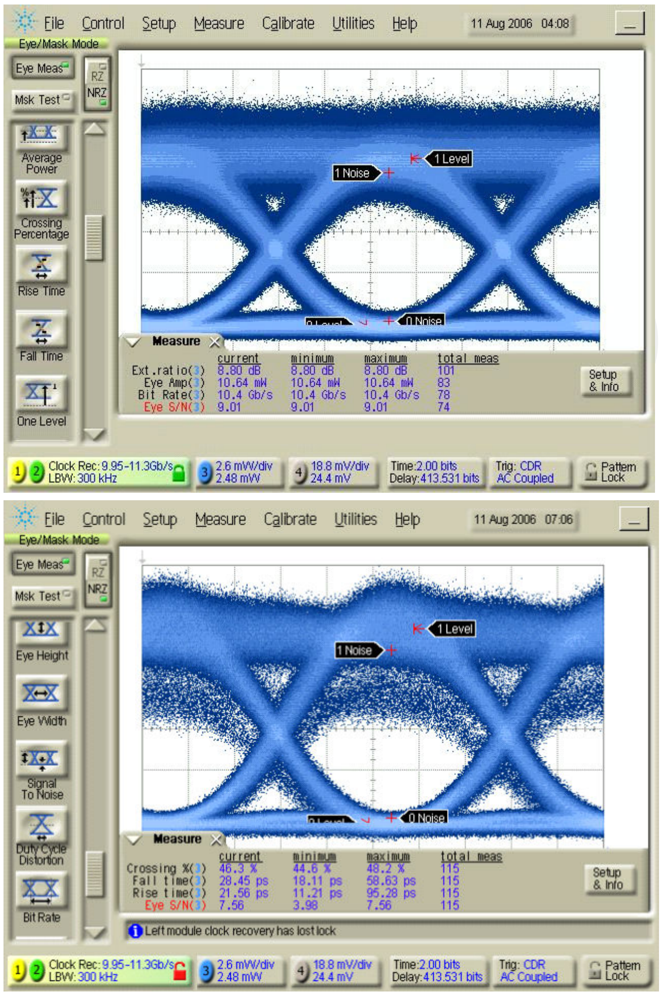

Figure 4. The eye diagram of signal used for testing of DWDM connection for Faculty Thoamyers' Hospital. The signal on the upper figure is clear signal generated by ten-gigabit ethernet pluggable module. The bottom figure is the weakest yet fully usable signal. Pictures are taken from [19].

Price of transponder is a mandatory part of the overall cost of DWDM service we've tried to use DWDM gigabit ethernet pluggable modules instead. The cost of these DWDM pluggables is several times lower than the price of corresponding transponder. The transponder provides more than just "colouring" of customers signal. It also ensures proper signal power. The length of the fiber line from transponder to the DWDM multiplex itself is usually few tens of centimetres. In case of utilisation of "coloured" custommers‘ signal the length of corresponding fiber span is typically several kilometres or tens of kilometres. The fiber optics line between customer and provider will introduce some attenuation of the signal. We have performed a set of lab measurements to learn the minimal input signal level of customer's DWDM signal that can ensure enough OSNR and guarantied BER. The eye diagrams from these testing are presented on Figure 4 just for better overview.

The first application of alien wavelength technology in CESNET was connection of Faculty Thomayers hospital in Prague to the MeDiMed PACS archive in Brno.

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2.4. Wireless and satelite connections

As already mentioned, the backbone system uses optical wires as a transport medium. Nevertheless, only the hospitals in the city and several of the others in the republic are connected by optical wires.

Another transport medium which is being used is the radio connection. It may be utilized for the main connection of the locality, however in that case the bigger hospitals require at least 20-30 Mbit/s speed. We are speaking mainly about sending and storing pictures from MR, CT, and similar modalities where there is a high demand for transport capacity.

Fixed wireless connection is often used as the first mile of the hospital's connection to the public data network. We have optical connections between cities, but the fixed wireless connection is needed to connect the hospitals inside the city. This concerns establishing traffic in the paid band.

One of the biggest groups of the users of the wireless networks are the radiologists. They very frequently use the opportunity to create the descriptions of the pictures at home. That way, they may react to urgent cases immediately. There is no need to go to hospital and start working on a pressing case after a significant delay. Simultaneously, they save their time, because the work on the picture may often take significantly less of it, than the voyage.

Another technology, which we use for the MediMed project, is the satellite. Within the scope of HEALTHWARE project (which is a 6th EU framework program project), there are being installed terminal satellite devices to the places, where any proper connections are not existent. Some facilities, such as medical institutions for patients with tuberculosis, may be found in woodlands, areas without industrial burden. Than, the usage of a satellite system is one of the few ways, we may use for transfer of a medical information. It is therefore used despite its limited data capacity, that is so needed in the cases of urgent demands for transfer and processing of medical image data.

2.5. Mobile users

By scaling PACS outside of single hospital we meet with some limitations of DICOM protocol. DICOM was designed to be used inside one hospital. Inside one hospital where everything is under one common administration there is not necessary to have strong authentication mechanism. DICOM can identify its users only by IP address of the user's viewing station. In collaborative environment spread across more hospitals it may happen that the given medicine specialist needs to use more than one viewing station and vice versa the given viewing station is used by more specialists. Every medicine specialist should have access to different collections of patients picture data.

PACS users authentication in heterogenous environment (like regional PACS archive is) it is rather complicated. Lets recall most common cases of PACS usage.

First kind of PACS users are medicine modalities (X-Rays, CT, MR, etc.). Modalities are producing medicine picture data and storing it into PACS archive. Modalities have got a fixed IP address and a limited set of communication and authentication capabilities. From computer science or networking point of view modalities are particular devices witch special communication requirements and should be served with respect to their natural properties. These devices may be used by authorised personell only and security of data provided by these equipments is guarantied by restricting physical access to these devices for authorised staff only.

Dedicated viewing stations are special working places which serve for evaluation of picture data obtained from modalities. This evaluation is performed by radiologiests or another medicine specialists who are trained and sklilled specially for evaluation of medicine picture data. These specialists should have access to all images obtained from modalities because they are responsible for picture data interpretaion. Picture data description provided by radiologiests is in next step used by other medicine specialists for diagnosis assesment and treatment of patient. Radiologists need a specialised hardware for proper work. From computer perspective this hardware can be identified by its IP address. This type of identification is sufficient to authorise radiologist access to given medicine picture.

Physicians - experts in various branches of medicine - represent the most complicated part of PACS users. Given physician should have access only to data concerning his patients, sometimes patients of his department and in some special cases given patients of other physicians. By special cases we mean first of all consultations asked by personal physician of given patient. Physicians typically can access the PACS system from more than one computer (from working place, from home or some times from other department of hospital). On the other hand given computer may be shared by several physicians especially in case of specialised stations with graphics capabilities customised for viewing images from X-ray or other particular modality. For this group of PACS users we have to provide proper authentication mechanism.

The only authentication mechanism common to all used versions of DICOM is the IP address. In case of modalities and viewing stations used by radiology deparment for medicine pictures evaluation this is appropriate solution. We decided to use IP addresses also for authentication of all other PACS users. Of course general IP address of workstation cannot be used as an user identity. Pretty good solution seems to be utilisation of some properties of IPSEC.

In this case the user is authenticated by his publis RSA key. After successfull authentication an IPSEC tunnel is established between users workstation and dedicated IPSEC server used by regional PACS. IPSEC server then assignes tunnel IP address to the user's station. User authentication in the PACS system is then based on the tunnel IP address.

PACS users identity is based on PKI infrastructure. Each user who needs to use more than one station or who is sharing viewing staions with others will be provided by an USB dongle containing his private RSA key. The key is generated on the dongle and never leaves it. So it's really very difficult for anybody else then the authorised user to use it. The corresponding public key is signed by regional PACS certification authority. A dedicated certification authority is used at this moment. The problem of electronic identity of physicians should be solved globally for the whole healthcase system in the future.

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2.6. Redundancy

The key services of the regional PACS system are running in two distinct locations. The MeDiMed services can provide better reliability and availability this way. MeDiMed is able to survive the failure of any single fibre optics line, server, storage, electricity (though it is backed up via UPS and motor-generator) in one location and even a failure of the PACS system software in one location. The global view on this system is illustrated on Figure 5.

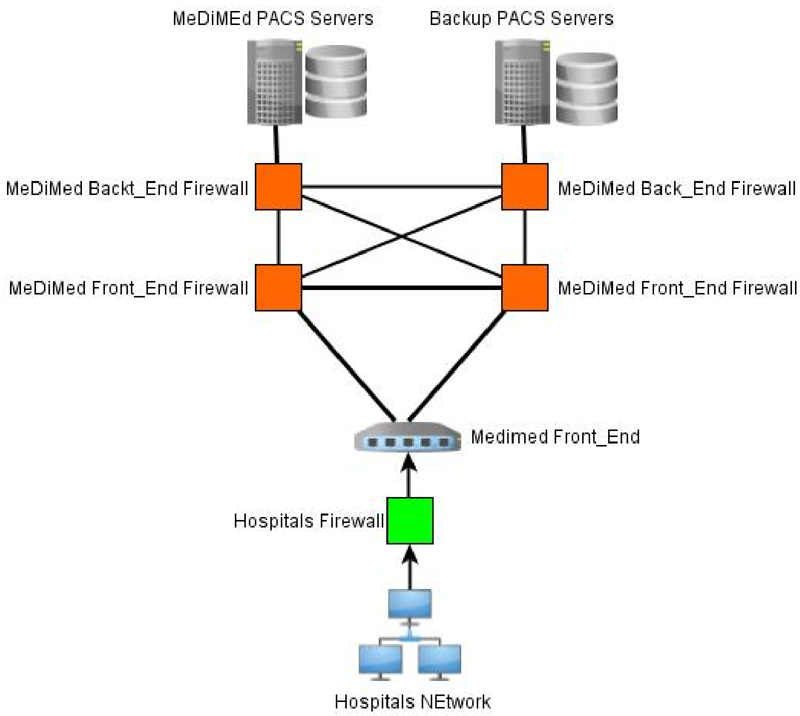

Figure 5. Detail of MeDiMed redundant infrastructure.

Networking infrastructure offers redundant connectivity for both local and remote hospitals. For local hospitals there are two independent fibre optics lines. One line connects the hospital to the primary location and the second one to the backup location. Remote hospitals utilize IPSEC tunnels also connected to both locations. The critical single point of fail for them is the connection to public data network. This connection is usually unprotected.

The MeDiMed project utilises a lot of servers for many different applications. For all applications provided to the MeDiMed users we have to offer a reliable enough service.

There is a set of PACS servers used for a routine storage of medical images. The PACS server for this type of service runs on a dedicated hardware in both university sites used by MeDiMed. Primary and backup PACS servers servicing the given hospital or providing given particular service work as two standalone and mostly independend servers. Data from the primary server are replicated to the backup one via DICOM protocol. One site is a primary site and, until it fails, all images are stored on this location. The second site serves as a backup location and all data are automatically copied from the master servers to the backup servers. The backup servers are available at all times for retrieving of medical images in the read-only mode. This way the overall performance of the system can be improved. If the master site fails we can manually switch the backup site to the read-write mode and the former master site to the read-only mode. In many cases the primary and the backup PACS servers are from different vendors. Even though, bidirectional synchronisation of the PACS servers is more complicated in this case. The manual switching of primary and backup PACS servers provides good enough service with regards to the number of failures. Moreover, modalities have some local cache so that they can keep images for several days. Older images are available for reading on both primary and backup sites.

Another large set of PACS servers are so called communication PACS servers. That means PACS servers used for an interchange of medical images between healthcare institutions. Unlike the PACS servers used for routine storage of medical images, the communication PACS servers have to be switched automatically. Communication PACS retrieves the image from one client and offers it to another one. Clients have to manually switch to backup communication PACS server in case of failure of the primary one.

We have considered a cluster of two hardware servers, preferably located in two different sites of the network. Even though this solution seems to be popular, well known and tested, it is not suitable for PACS servers used in MeDiMed. The utilisation of hardware clusters needs some basic support from applications. Hardware failure may occur at any time and any stage of data processing, especially at any stage of storing the data into the database or simply writing the data into the disk subsystem. The time granularity of copying the raw image from a master to a slave system more or less corresponds to the heartbeat frequency. In the case of the master to slave switching we may lose data processed since the last heartbeat tick to the failure of the master system. The application should assume such situation and enclose the critical operations into transactions to allow recovery from the master hardware failure. Most communication PACS servers used in MeDiMed do not expect to run in a cluster environment.

2.7. InstantPACS system

Small healthcare institutions and private doctor’s offices are being more and more equipped with diagnostics devices like CT X-ray ultrasound etc. The small healthcare institutions demand for medicine picture data processing capabilities and services is coming right now. MeDiMed intends to offer PACS services also to these new perspective medicine users. The specific property of PACS or any ICT services in small healthcare institution is lack of technical staff capable to solve issues on place. For this reason we are developing an ”all-in-one” device which will serve as local PACS server for the healthcare institution and provide backup and communication services. Development and deployment of such a system is coved by the InstantPACS project.

The aim of the InstantPACS project is to develop a maintenance-free PACS system suitable for small and midsized healthcare institutions. This PACS system will offer to the small healthcare institutions a user amenity obvious in hospitals including e.g. automatic backup of medicine data. The most important properties of this system are user friendliness, maintenance free

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operations and pricing acceptable for private doctor's offices. The InstantPACS project is an integral part of the MeDiMed shared regional PACS server overlay project.

InstantPACS is remotely controllable and from point of view of users is not asking for any local maintenance. General user of the InstantPACS will be private doctor's office. A private doctor's office is typically equipped with an ultrasound and one or two more modalities like CT. Modalities in private doctor's office are from point of view of data communication isolated devices. Data from these modalities are usually transported on a USB sticks or processed locally on the modality's console. It is necessary to interconnect modalities and viewing stations in the doctor's office to offer medical picture processing comfort usual in large hospitals. Once the data will be transported from the modality outside it is necessary to provide at least the following services:

- transport data to the viewing station
- backup the data to an external device or PACS system
- long term archive of the data
- prevent any unauthorized access to the data
- allow to share data between authorized users

The InstantPACS server is used in a very similar manner like PACS systems in large hospitals. Of course there are some technology discrepancies given by different server placement possibilities in large hospitals (dedicated computer room with air conditioning enough space etc.) and private doctor's offices (one room shared by treatments and server hosting, room temperature etc). These worst environmental conditions have introduced some InstantPACS server hardening demands. Backup of medicine picture data from Instant PACS server will be performed on two backup PACS servers located at Masaryk University. The data communication will be performed over Internet via two tunnels protected by strong cryptography used as shown on Figure 6.

The key requirement is no or as small as possible regular local maintenance of the system. Users of the InstantPACS are expected to have no or very little experience with management of servers operating systems etc. On the other hand we expect rather large number of users. All critical events and states should be automatically detected and reported. Also some extensions of the installed system like addition of new modality (which is typically performed by trained ICT staff in large hospitals) should be solvable in an intuitive way.

The hardware platform used for InstantPACS is based on off-the-shelf components and was tailored especially to this project. It has dedicated memory for system software and configuration and redundant disk subsystem for storage of medicine picture data. It can contain embedded ethernet switch to connect few modalities in a typical private doctor's office. IPSEC tunnels for backup data encryption are terminated directly in the InstantPACS so no additional equipment is needed.

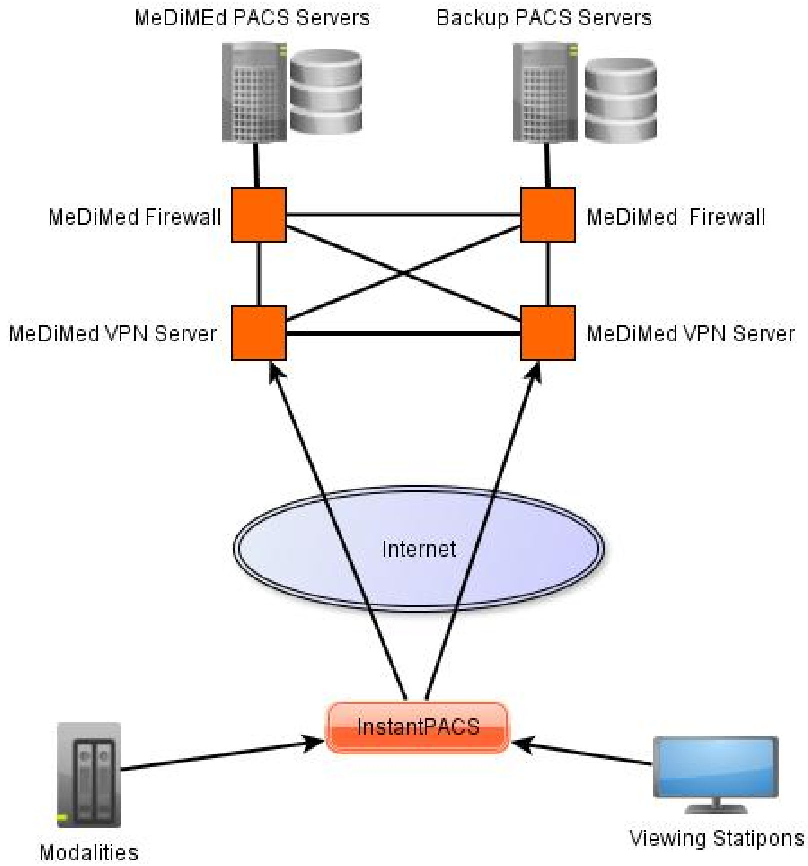

Figure 6. Common principle of InstantPACS communication with the centralized PACS servers.

2.8. Monitoring

The amount of various equipments used in MeDiMed is increasing during MeDiMed development and new functionalities deployment. The amount of used equipment and the increasind demand for reliability and availability of MeDiMed services enforced development of centralised monitoring system. This monitoring system provides all the necessary supplemental services like collecting of traffic statistics, networking devices configuration backup, time synchronisation, network administrators authentication, etc.

Two Linux based servers are used as central management stations. These servers are working independently and are located at both of the MeDiMed centrall locations. The primary management station is located at the Institute of Computer Science of Masaryk University and the second one is located at the Faculty of Medicine. Each management station provides full set of services. Monitoring servers form a redundant solution for all the goals listed above.

Both of the monitoring servers are running Nagios. Nagios is a popular open source software platform. It is widely used to network component status, servers CPU utilisation and number of running processes, disk storage utilization and many others.

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The whole monitoring system is accessible via web interface and provides the current status as well as the history of all equipments and services availability. Critical alarms are propagated via SMS messages distributed via SMS Siemens 35i terminals directly connected over RS232 interface to both management servers.

The monitoring servers are collecting syslog messages as well. Syslog messages are parsed and processed on daily basis. The resulting file provides both statistics of stored medical image studies, DICOM pictures provided by separate modalities and errors encountered by all PACS servers. This summary result is distributed via e-mail daily.

It is very useful to have remote access to console interfaces of both servers and networking devices especially for emergency cases. A set of KVM (Keyboard-Video-Mouse) switches are used in both primary and backup locations for this purpose. KVM switches offer remote access via web interface. Dedicated Cisco routers are used to connect those KVM switches to the data network. These routers also provide access to console interfaces of networking equipment via reverse telnet. Access to KVM switches and other console ports from outside of the dedicated MEDiMEd wolrd is permitted only via IPSEC tunnels ended directly on the above mentioned routers. This approach provides us emergency secure access to management interfaces of all key equipments.

3. Benefit of cooperation in medicine

Many PACS installations are only limited to the scope of a particular radiology department or work as a repository of a single modality. An effective usage of that technology means image distribution at least throughout the whole healthcare institution. However, the most promising approach for exploiting of PACS technology is to use it at the regional or national level and to support the associated medical processes that way.

By effective usage is meant not only basic support of daily routines in radiology departments but also the support of distant consultations, digital long-term archiving and development of shared knowledge databases for research and education.

MeDiMed project brings a new quality into healthcare, medical education and medical research as well as the treatment decision-making.

3.1. Cooperation on the area of medicine picture data processing

The is a set of so called communications PACS servers inside the MeDiMed. Communication PACS server means PACS server used for interchange of medicine images between healthcare institutions. Communications PACS subsystem allows medicine specialist to share the picture data for diagnosis consultations second reading or even load balancing of radiologists.

The MeDiMed platform supports the cooperation it the area of processing of medical image information also in international scale. For example the Healthware (Standard and interoperable satellite solution to deploy health care services over wide areas) project within the sixth framework programme of EU covers many telemedicine activities.

The goal of the Healthware project is developing of healthcare services over the satellite network to increase quality and comfort in European medical practices. The aim is to bridge the medical digital divide in Europe by designing, integrating and validating interoperable telecoms and services platforms to provide existing and future healthcare services. The satellite based platforms can interact with mobile and terrestrial technologies to supply effective and reliable end-to-end healthcare services and boost the deployment of large-scale satellite communications telemedicine services.

Additionally, Healthware will have a beneficial effect on training and education as far as 7 Universities and Research Centres are concerned. For undergraduate, post-graduate and PhD students, the participation in such programs is a unique opportunity to be exposed to team work with regular reporting and evaluation by the partners. The research performed is usually of very high quality due to the number experts involved in the group and the concentration of financial resources. It is also the occasion to be exposed to a multicultural environment and to establish international relationships that are very useful to build and strengthen the European Research Area.

3.2. Medical training support

Teaching has always been one of the most important parts of radiology. The fundamental principle is very simple. Every radiology department participating in teaching of medical students or in research is equipped with specialized diagnostic workstation. This workstation must be primarily connected to their hospital PACS system or other equipment generating image studies in DICOM format.

Images appropriate for teaching and research purposes are made anonymous (i.e. the personal data of the patient and other information that may disclose the patient's identity is replaced by fictitious information) when sending into Educational and Research PACS. One of the basic principles when sending images into the Educational and Research PACS is the coordinated assignment of fictitious patient identity, so it can offer a more complex view of the evolution of the patients health in situations where the patient is being treated in different healthcare facilities. Therefore, the legal barrier preventing access to sensitive and confidential patient data is removed.

The database of anonymized CT images is populated by senior medicine specialists. It is used by medicine students and by novice medicine doctors as well.

The education superstructure consists of Case Study objects. Every Case Study object is hypertext document describing given medical case and referencing relevant anonymized medical image studies. Case Study is accessible via standard www browser and if there is specialized diagnostic viewer installed on this computer then referenced image can be manipulated and processed appropriate way using all possibilities supported by particular viewer. It means that students of medical faculties could access huge amount of interesting systematized medical image information related to their subject from their teaching rooms. Teaching room equipped with appropriate software can also serve as trainer for young

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radiologists. This way they can learn new technologies, compare hardware and software of different diagnostic workstations.

The core of our solution is tailored PACS. That PACS can be used as a "PACS trainer" for students and young radiologists but also forms the basis for additional educational and research applications such as for example the Case Studies describing treatment of real patients. The Case Study is an integrated hypertext document forming didactic unit and consists of short texts, structured clinical data, radiological images of various kinds, images from nuclear medicine modalities, macroscopic and microscopic pathology images or demonstration of the video movies recorded during surgeries.

The Case Study can be accessible via standard web browser and if the users have DICOM diagnostic workstation installed on their computers, then the referenced image study can be manipulated and processed in all ways supported by the particular workstation. It means that medical students can access large amounts of systematized medical cases related to their subject. The labs equipped with appropriate software can also serve as training simulators for those training to be radiologists. The students can learn more practical lessons instead of wasting their time in the library.

Every image study must be annotated with a detailed description in DICOM Structured Report format and every image must also be assigned a set of key words describing all the medical findings and diagnosis for better retrieval of specific cases. Data on the real patient obtained from several hospitals uses the same fictitious identity, thereby offering students a more complex view of the evolution of the patient's health.

Educational and Research PACS solution also supports utilization of sets of key words making a search for specific image studies easier. An automatic evaluation of answers regarding prepared collections of images that are not described, used for medical students' examination purposes, etc. and provide an additional benefit.

4. Conclusion

The MeDiMed project has started a deeper collaboration among hospitals in the area of processing of medical multimedia data and to provide the necessary technological infrastructure for this cooperation. Additionally, the project created conditions for general access to medical imaging data.

The implementation of the MeDiMed project facilitates fast communication among individual hospitals, allows decision consultations, and offers capabilities of today's computer systems and data networks to medical users. Moreover, the system is supposed to serve as a learning tool for medical students as well as physicians in hospitals participating in this project.

The gradual development of the joint system for processing and archiving image information is a positive step towards increasing the healthcare standard in the city of Brno as well as in the whole region.

Information on a patient's treatment in his/her own healthcare center as well as in other centers would be available, review and consultations regarding the patient's data by more specialists will be enabled, image information evaluation can be carried out in another place in case a required specialist is not available in the center in question, general practitioners in the country will be able to consult specialists in hospitals, etc. Examination results will be available for the doctors in much shorter time than before.

The development of the system for processing, archiving and accessing the patients' image information, designed in this way, contributes to a significant improvement of the patients' image information and to significant improvement of the patients' care. It enables consultation with specialists not only within a region but also outside the country. Created data files enable practitioners to carry out evaluation of the treatment as well as administered medication in a large sample of patients.

The new goal for the MeDiMed project is to offer PACS system to small institutions. Small healthcare institutions and private doctor's offices usually have limited data network availability. They are typically located near patients and data communication is not they priority. ICT staff in such institutions is also very limited if it exists at all. For this reason the solution used by large hospitals is not suitable for small institutions. Even though the basic principles used in large hospitals can be preserved also in this case.

Current ICT, as well as existing and developing standards, enable physicians to deliver some services through the computer network. It means that medical specialists from distant specialized departments can consult urgent cases or make decisions. It is a concept of expert centers based on the practices of telemedicine. Image studies of every patient can be referred to a distant expert center for a primary diagnostic or second opinion. This way a much higher quality diagnosis can be assured.

Another important application of the shared regional PACS servers is education. Interesting cases are anonymized and used for both education and research. The shared regional collaborative environment is more than just a set of computer network applications. Gradually, it changes the thinking of medical specialists and enables them to cooperate and share data about patients in electronic form. It builds a network of medical specialists. The implementation of the system has increased the speed of communication among individual hospitals, allowed decision consultations, and brought various other advantages due to dedicated network connections.

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