MeDiMed - regional center for medicine multimedia data exchange

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Abstract: Institute of Computer Science of Masaryk University is working on the field of supporting medicine multimedia data transport archiving and processing more than ten years. Since first steps like transport of ultrasound and CT images across private fiber optics network these activities have grown up to regional PACS archive. This paper describes the technology background of the MeDiMed project.

Key–Words: PACS, DICOM, medicine multimedia data

1 Introduction

Radiologists in the Czech Republic still mostly use film copies. It is difficult and time-consuming to retrieve needed image studies from filled storerooms. The radiology departments, using fully digital technology, usually have still not fully made the transition of old image data to the PACS, but the number of examinations accessible via PACS increased significantly.

PACS is the Picture Archiving and Communications System. It is a general framework used for dealing with medicine multimedia data like X-ray, CT, ultrasound etc. This system consists of so three main components: modalities, PACS servers and viewing stations. Modalities are equipment used for obtaining the patients images like CT, ultrasound, X-ray etc. PACS servers are servers maintaining the databases of such images and viewing stations are typically specialized graphical stations used for examination of patient's images. The overall structure is depicted on figure 1. The DICOM protocol standardized by NEMA organization is used for communication between the above mentioned components of PACS.

Radiologists are limited by the number of high quality workstations in reading rooms equipped with PACS feature display technologies. Also the amount of archive space and bandwidth of hospital computer network is limiting factor. But both the radiologists and the hospital headquarters appreciate all the advantages of digital mode of processing these data. Fiber optic, phone lines, wireless connection or even satellite can be used these days to access such digital information, which was not possible before. The coexistence of both the technologies, film and film-less, is usual in healthcare institutions these days. So they must solve the questions like how to move film based images to and digital ones from PACS, how to annotate them, how to identify the patient, the image study, how to find them, etc.

To be well prepared for this new age of digital imaging also appropriate informatics lectures are necessary, instructions on how to use the PACS and the radiology information system, basic knowledge about storage and archive mechanisms, about displaying of medical images, about DICOM standard, etc.

One of the goals of our solution is also to establish an open, collaborative environment to support coordinated research and education among cooperating healthcare institutions and faculties of medicine by exploiting the large potential of databases of medical image information being processed in hospitals today.

Outsourcing of the hospitals' archiving and communications technology permits cooperation among hospitals and the use of existing patient multimedia data. The Shared Regional PACS is more than just a set of computer network applications. 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 work is not only in patient care but also in the education of medical specialists. 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.

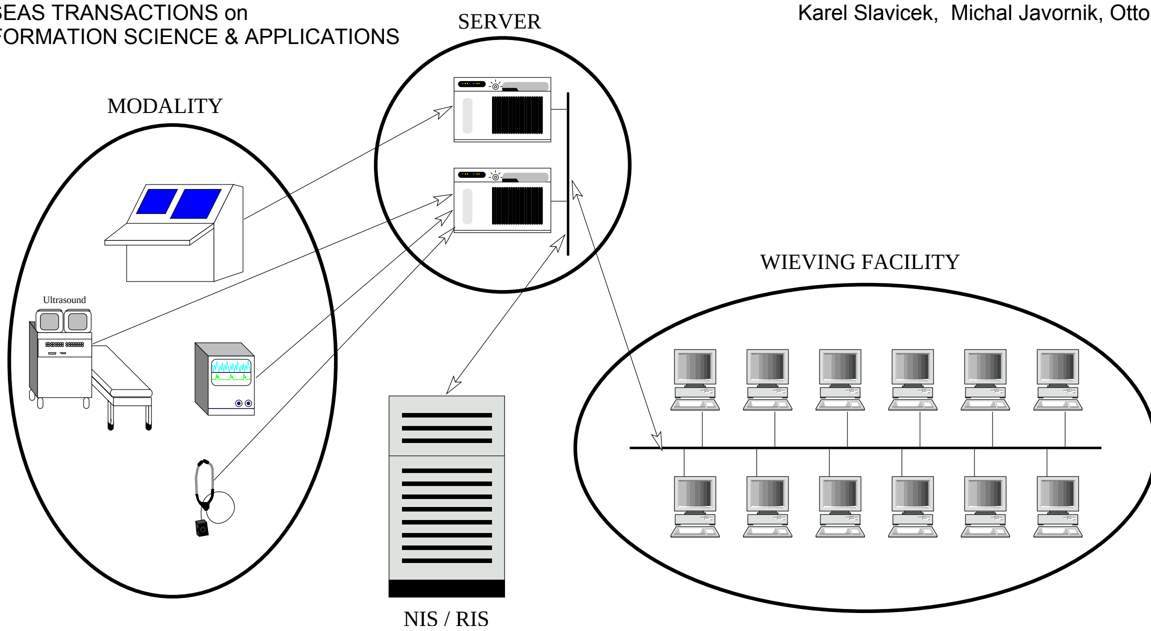

Figure 1: The general structure of PACS system.

2 MeDiMed

Today most hospitals are using local PACS system serving only to one hospital. The goal of the MeDiMed project [5] is to start a collaboration among hospitals with respect to archiving and use of medical multimedia data and to provide the necessary technological infrastructure for the System.

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 programmed 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 patients 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.

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Dissemination of medical knowledge, tools to support and assist in decision making and relevant and accurate sources of information for scientific research all enhance the synergy among the medical community, play a very important role in health care and consequently bring benefits to all people, in particular the community they serve.

This paper describes the solution whose aim is to establish a collaborative platform supporting daily routine in radiology community, to develop a communication channel supporting the exchange of information and special consultations among various medical institutions and also to support medical training for practicing radiologists and medical students. We enable the users from outside the hospitals to have the same access and functionality allowing them to have almost the same working conditions as in the radiology departments of their hospital.

3 Networking technology background

One of the main ideas of our dedicated network topology is the following: the network firewall, which is connected by a dedicated fiber optic pair to the center, is in front of a hospital's router/firewall which connects the hospital to the Internet. It allows us, as administrators of the project, to control access to the central resources, to monitor status of the whole hospital and at the same time allows the administrators of the hospital's network to control access to their network. That way everybody controls access to the part of the network they are responsible for. The structure of hospital-MeDiMed interconnection is easy to see from figure 2.

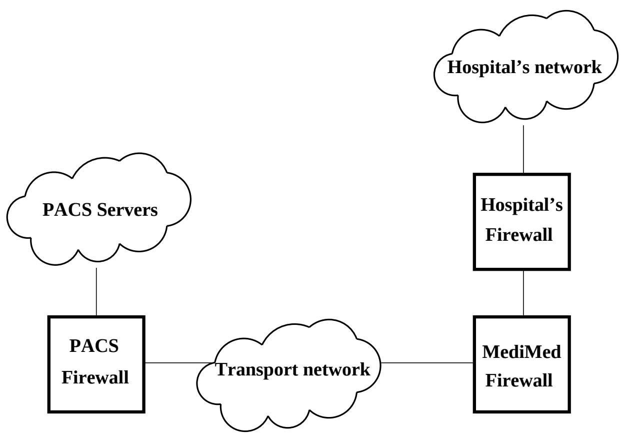

Figure 2: The main security principle of MeDiMed.

3.1 History - the beginning of MeDiMed project

In 1993 the fibre optics network started vith few kilometres of cable containingonly 8 multimode fibres. At that time multimode fibre was choosen mainly for economic reasons. As a networkint technology 10 Mb/s ethernet was used. During the evolution of network we moved from ethernet to ATM and since begining of this millenium we moved to Gigabit ethernet. Of course during the technology evolution we've moved from cables containing only fwe multimode fibres to cablers contaning usually 48 or 96 singlemode fibres.

ATM period of metropolitan network in Brno ment start of developing new applications and especially network usage for medicine multimedia data transport. ATM though now is a little bit obsolete technology in terms of computer networks was the first technology which was able to provide dedicated data channel for speciall applications like medicine. It allowed us to start the MeDiMed project. Of course now ATM is no more used for regional PACS archive. Insted of it dedicated fibre optics pairs are used for connecting hospitals reachable by university metropolitan network. Remote hospitals are connected via IPSEC tunnel builded on public data network.

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.

However ATM is no more used in data networks this technology played a meaningfull role in development of MeDiMed project. It was the first data network technology which offered dedicated layer 2 channels with enough bandwidth.

From the beginning, 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 our private fiber optic network.

3.2 Traditional networking technologies

Since the metropolitan academic network started to use ”thick enough” fiber optics cables, i.e. cables with more fiber optics threads the MeDiMed project was shifted from ATM do dedicated fiber optics lines.

The ownership of fiber optics infrastructure is the enabling technology which allowed us to establish and develop the MeDiMed activities. This allowed fast and cost-effective interconnection of hospitals to centralised PACS servers.

There is a large fiber optic cable network owned and operated by the universities in the city of Brno. The development of this network started in 1993. It is a private network of all Brno universities connected

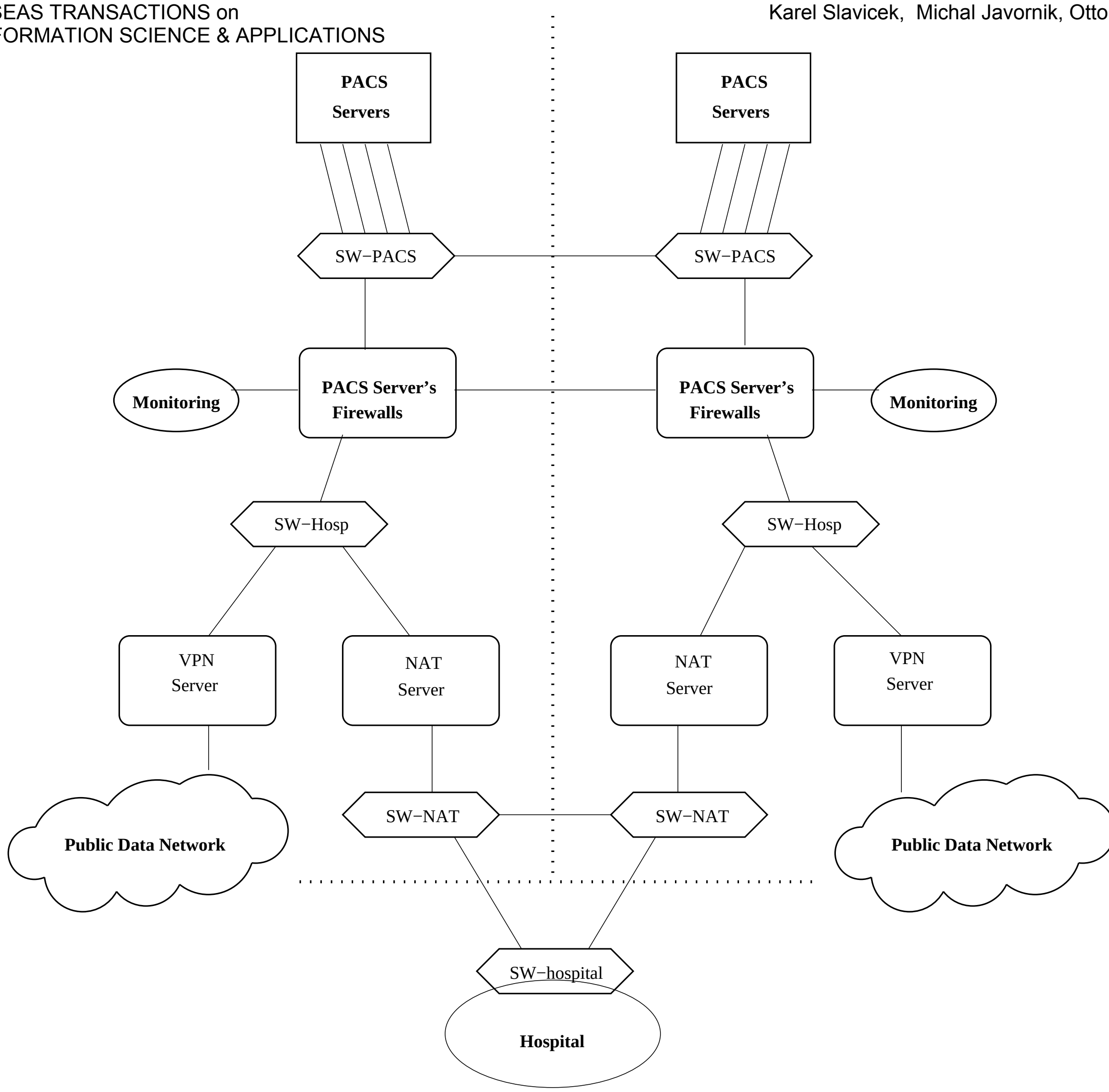

Figure 3: Detailed view of redundant PACS system architecture.

to the National Research and Education Network (NREN), operated by CESNET association, through the Masaryk University computer center. The network connects all universities in the city and their faculties spread around the city, various departments of the Academy of Science, most hospitals and some other institutions. Currently the network consists of about 120km of optic cables and more than 100 nodes are using it. Since the Brno Universities own the fiber optic network, they can ensure that there is sufficient fiber optic cable available to implement new applications and to support new initiatives. The ownership provides the freedom to establish private connections dedicated to these applications.

For hospitals along the scope of our opticable network we need to use our dedicated data network which is rather expensive or public data network. The use of the public data network is more economical but it forces us to use an encryption for securing the data. For this purpose we use IPSEC protocol usually with AES encryption algorithm.

3.3 High availabilility and reliability

For better reliability the key services of Regional PACS system are operated in two distinct locations. On each node PACS system from another vendor is used. By this way the Regional PACS is able to survive failure of any single fibre optics line, server, storage, electricity (though it is backuped via UPS and motorgenerator) in one location or vendor of PACS software.

Networking infrastructure offers redundant connectivity for both local and remote hospitals. For local hospitals there are two as much as possible indepen-

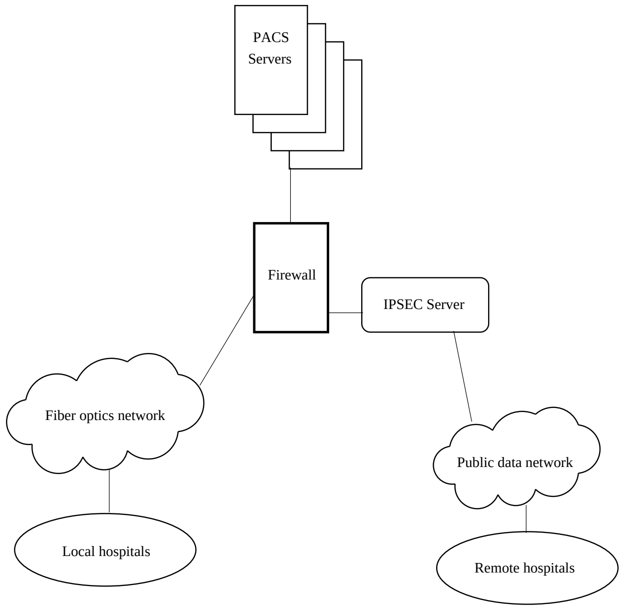

Figure 4: The overall structure of regional shared PACS archive in Brno.

dent fiber optic lines going to both locations. Remote hospitals utilize IPSEC tunnels also connected to both locations. The critical single point of fail for them is their (usually only one) connection to public data network. On solving of this point we are still working. The detailed structure of the redundant PACS servers to hospitals interconnection is illustrated on figure 3.

3.4 DWDM technology

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 ”colored” one and transported across DWDM providers network.

Because price of transponder is a mandatory part of the overall cost of DWDM service we've tried to use DWDM SFPs instead. The cost of these DWDM pluggables is several times lower than the price of corresponding transponder. The transponder provides more than just ”coloring” of customers signal. It also ensures proper signal power. The length of the fiber line from transponder to equalizer in front of DWDM multiplex itself is usually few tens of centimeters. In case of utilization of ”colored” signal the customers signal is carried over fiber optics line that is several kilometers in length. The fiber optics line between customer and provider will introduce some attenuation of the signal. For these reasons lab measurement was performed to learn the minimal input signal level of customer's DWDM signal that can ensure enough OSNR and guarantied BER.

Though we expect to use alien wavelength mainly for gigabit ethernet we've tested alien wavelength on tengigabit ethernet signal. The signal was transmitted from DWDM XENPAK inserted into a router. On the remote site the signal was looped back. On the receiving site there was a splitter inserted in front of the receiver and the signal was observed on sampling oscilloscope with optical probe. We've done BERT test on IXIA protocol analyzer to ensure that the input signal level tuned to optimize the eye-diagram was set up properly. The eye diagram of the worst usable signal is on the figure 5.

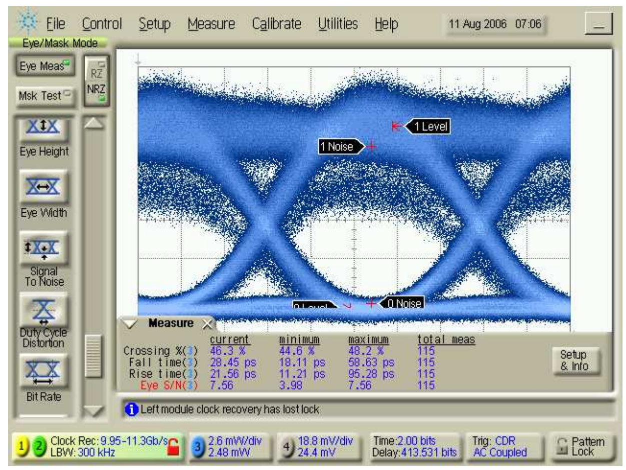

Figure 5: The eye diagram of worst acceptable input signal.

An EDFA amplifier was necessary to use on the line from Faculty Thomayer's hospital to CESNET DWDM transport network to enforce proper input signal level and requested BER. The situation is depicted on figure 6.

3.5 Wireless technology

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.

For deployment of MediMed to some remote locations and especially to residence users (medicine specialists) it was necessary to utilise wireless and microwave technologies. Experiences with usage of wireless technology for delivery of medicine picture data are described in this section.

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 such where there is a high demand for transport capacity.

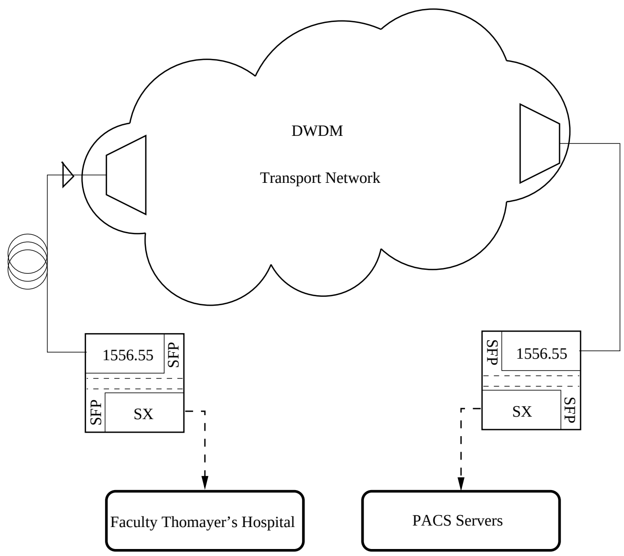

Figure 6: The Faculty Thomayer's hospital utilizes DWDM to connect to MeDiMed.

Radio connection is also being used as the so called last mile. We have optical connections between cities, but the radio connection is needed to connect the hospitals inside the city. This concerns establishing traffic in the paid band. Another large area where we employ radio connection is to provide a backup connection. In that case, the requirements for data capacity are lower than for the main connection, however, they still must be sufficient for the operation of the medical facilities.

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.

There are some issues with the usage of the wireless systems. The performance may drop during bad weather such as heavy snowing and there are sometimes problems in the cities when a new building (or an extension of an old one) emerges in the way of the original signal. Still, it can be said, that their employment accelerates the exploitation of systems for archiving, exchange and processing of data as a whole. The way of usage of these ways to transfer data is different in different medical facilities. One of the possibilities is, that the doctors have radio connections to their houses, so they may describe pictures at home, consult over medical information with a specialist in another medical facility in another city (or even state), etc. Also, the cable television connections are being used for this purpose if the doctors have them.

As for the doctors working outside their workplace, there is a frequent request for a transportable notebook with mobile telephone for a connection to the central system. However, the limited speed available limits the range of modalities to work with.

3.6 Satellite communication

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.

We cooperate 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 program of EU covers many telemedicine activities. The goal of this 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 Centers 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.

3.7 PKI utilisation

By scaling PACS outside of single hospital we meet with some limitations of DICOM protocol. DICOM is standardised by NEMA - National Electrical Manufacturers Association and this protocol is widely used for communication between modalities, PACS archive and viewing stations. Originaly it 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 users viewing station. In collaborative environment spread across more hospitals it may happen that the medicine specialist needs to have possibility to use more than one viewing station and vice versa the given viewing station is used by more specialists wha should have access to different collections of patients picture data.

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 nature. 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. Riadiologists need for proper work specialised hardware. From computer perspective this hardware can be identified by its IP address and identification of radiologist who has evaluated given picture is not necessary for PACS access regulation.

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) and 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.

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. We was searching for any way how we can assign IP address to the staion dependent of legacy authentication of its user. As a 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 performed on the basis of 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 correspondinf public key is signed by regional PACS certification authority. We decided to use a dedicated certification authority at least for the take-off of IPSEC user authentication because we believe that in near future the problem of electronic identity or better cryptography identity of physicians should be solved globally for the whole healthcase system.

Now the project of PKI utilisation for regional PACS is at its beginnig. We are obtaining experiences with production usage of this system and preparing its deployment to larger scale. We have got some feedback from operating this system and have identified some point for improvement of it. First possible improvement we plan to deploy soon is deployment of some kind of emergency PKI keys which will be available for case of emergency (e.g. Physician with access to patients picture data is not available and patient needs urgent surgery for which picture data stored in PACS are necessary.)

We have considered several hardware equipments capable for generating and storing of RSA keys. There are several nature requirements for such and equipment: Such device should be really portable - i.e. it should be of reasonable physical dimensions and weigh because it is expected that physicians will keep this equipment mostly all time. this requirement resulted into two possible types of devices: USB dongle and smart card. PKI key storage device should be easily connectable to mostly any workstation in the hospital. Almost all stations suitable for evaluation of medicine picture data have free USB ports available. Almost none of them are equipped with smart card reader. This fact limits the possible device type to USB dongle. The PKI key storage device should provide appropriate level of security of private key stored inside.

The private RSA key stored in the USB dongle provides cryptographic identity of physician accessing sensitive patients information. Thus we have to strongly consider security of the USB dongle. For examination of various types of USB dongles security level we come from classification of possible breaks in. In general we can devide possible attacks into two branches: key retrieval and spurious key. Key retrieval means obtaining access to private RSA key from existing and used USB dongle. By spurious key we understand atack perfomed during inicialisation of the USB dongle by which a copy of private RSA key may be obtained.

Let's discuss possibilities of unauthorised retrieval of private RSA key from exisiting used USB dongle. We dont consider physical access to the dongle. We assume that each user of such equipment pays attention to physiacal access to the USB dongle like access to his/her credit card, personal identification card or similar items. Private key storen inside the USB dongle is protected by PIN. That means some kind of password information. Now take a look at possibilities of accesing the private RSA key without knowledge of PIN, i.e. how unauthorised person can retrieve the private key from the USB dongle.

All wide deployed USB dongles seemed to be resistant against software attacks. We haven't tested any kind of electronic attack because of lack of necesary hardware equipment. (Similar situation we assume on the side of possible intruder as well, so we don't vary of this kind of attack.) We have checked some references about hardware attack. All described kinds of such attacks can be easilly prevent by more robust hardware construction of the USB dongle and we expect that manufacturers will do so in near future. More over hardware attack is only the first step in the process of acquiring private data from the USB dongle. The next necessary step is electronical analysis of chipset used inside the dongle. This all together makes the hardware attack on USB dongle usable only for technically very good skilled and equipped personels and of course it means that the price of this method of acquisition of private RSA key will be in mostly all cases higher than the value of informations secured by this key.

Much more difficult is defence against spuriou key attack. All crypto USB dongles we was able to obtain for testing have the following security weakness: this equipment was originally designed mainfo for data encryption. For our application we need it only for digital signature. For data encryption appliaction it it very usefull to store a copy of private RSA key in some secure place outside the USB dongle. The reason is clear: if we loose the dongle we were never be able to decrypt our data without the private RSA key. Usually the public/private key pair is generated in trusted server and stored into the USB dongle. For this reason all USB dongles known to our team support this feature. This is the main weakness of this solution. Most of our users are medicine specialist who need some assistance with inicialisation of their USB dongle.

If the IT administrator responsible for distribution of USB dongles and certification of public key used by given USB dongle will not generate the keypair inside the dongle but in his computer, he can keep a copy of both public and private part of the key. The lawful user of the USB dongle will probably not be able to learn it. This problem can be partially solved by administrative precautions but everytime these precautions can't provide technological prevention to abuse or circumvention of these administrative precautions. We are working on some technological solution for improvement of this security weakness. On the other hand this security weakness is not critical. With good administrative precautions it is possible to minimise the security risk.

3.8 Centralized monitoring and management

The amount of various equipments used in this project is increasing during its development and deployment of new functionality. Recently the number of used devices enforced development of centralized management system. This system provides all the necessary supplemental services like collecting of traffic statistics, backup of configurations, time synchronization, authentication of network managers, etc. Two Linux based servers are used as central management stations. These stations form redundant solution for all the goals listed above. 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. All the backup PACS servers are installed at this faculty. Each management station provides full set of services and both stations work independently. The open source solution - Nagios - was selected for network status monitoring. This software is used for monitoring of network component status, CPU utilization number of active users, number of running processes, local disk usage of servers and also monitoring of disk usage of central storage system. 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 terminals Siemens 35i connected via RS232 interface directly to both management servers. The management system is the target for all syslog messages. 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. For this special access to servers KVM switches are used in both primary and backup locations. Used KVM switches offer remote access via web interface. These devices are connected to network via dedicated Cisco routers. Routers serve for more applications. There is firewall securing access to KVM switches and providing access to console interfaces of networking equipment via reverse telnet to its serial interfaces. Access to management routers is permitted only via IPSEC tunnels and ended directly on these devices. This approach provides us emergency secure access to management interfaces of all key equipments. Management servers are used primarily for monitoring of availability of all components of this regional solution. At the same time these servers are used for backup of networking devices configuration, time synchronization and syslog messages processing. The management system is the central point of the whole regional solution and a key element for providing reliable services.

4 Medical training support

Teaching has always been one of the most important parts of radiology. Nurture an excellent radiologists in this technological age involves more resources, new methodologies, reorganization of radiological training.

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.

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 identity of the patient is replaced with fictious information or modified in such a way so as not to lose any relevant information but so as to prevent disclosure of the patient’s identity) 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 patient’s 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 supporting tools for developing of Case Studies utilizes more common standard technologies such as DICOM image viewer, WWW-based, Acrobat-based and Word-based files providing additional options for displaying, printing or copying of its content. The presentation including big amount of image data can be done, depending on network capacity, online or off-line. 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.

The disciplines of oncology, urology and respiratory diseases were selected for pilot Case Studies. However the aim is to put together a comprehensive collection of medical image information covering all medical disciplines. The database of frequent cases as well as the database of singular cases of all major medical areas must also exist.

5 Conclusion

The efficiency and rationalization of technological and human resources must be considered in connection with improvements of the quality of healthcare. Teleradiology in the Czech Republic is crucial because medical experts and specialists can be available in urgent cases permitting qualified external medical experts to be involved in the diagnosis. Regional-level procurements of systems and services are preferred to achieve major savings and improve the quality of healthcare including the learning processes.

The evolution of educational and research services provided by this solution is also influenced by emerging wireless communication technology. This technology permits the appropriate services to be accessible also through the satellite network covering the Europe. The satellite based platforms can interact with mobile and terrestrial technologies.

The whole integrated solution is certified so it can form a part of a hospital information system infrastructure of cooperating healthcare institution. All software tools are strictly based on DICOM standard so they could be easy incorporated into running systems of participating hospitals or other relevant institutions. The specialized and dedicated workstations can also be used for daily diagnostic purposes in the radiology departments.

The supporting computer network infrastructure consisting of dedicated fiber optics or a VPN connection including necessary security equipments enables the medical community all over the world to access the collaborative environment.

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