Extension of the Shared Regional PACS Center MeDiMed to Smaller Healthcare Institutions

Karel Slavicek, Michal Javornik, Otto Dostal
Institute of Computer Science
Masaryk University
Brno, Czech Republic
Email: karel@ics.muni.cz, javor@ics.muni.cz, otto@ics.muni.cz

***Abstract*—Masaryk University in Brno is operating a regional Picture Archiving and Communications System serving to mostly all hospitals in Brno metropolis and a lot of remote healthcare institutions. The system known under name MeDiMed is utilized by most of the regional hospitals. The last MeDiMed enhancements, which open this system for small healthcare institutions and private doctor's offices, is discussed in this paper.**

Keywords*-*PACS; DICOM; shared solution.

I. INTRODUCTION

The PACS - Picture Archiving and Communications System - [1] is a currently used procedure and methodology for processing medical multimedia data obtained from picture acquisition machines like computer tomography, ultrasound, x-ray, etc. Multimedia medicine 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 to radiologists for analyzing 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 - [2] has developed a standard DICOM [3] - Digital Imaging and Communications in Medicine - for communications between modalities, PACS servers and viewing stations. DICOM version 3.0 is the currently used by mostly all modalities and PACS servers. The structure of PACS is presented on the Figure 1. In depth background of PACS principle and DICOM protocol is discussed in [4] and [5].

This paper is organized as follows: The overview of MeDiMed project is presented in Section II. Section III describes describes the underlying networking infrastructure. Sections IV and V discuss the service reliability and data redundancy and the overall impact of the MeDiMed project to the healthcare institutions. Currently, we are improving the MeDiMed system to better support small healthcare institutions and private doctor's offices. This effort is discussed in Section VI. The conclusion and further work is presented in Section VII.

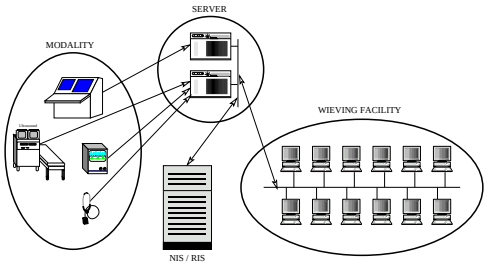

Figure 1. Common structure of PACS system. Modalities serve for acquisition of medicine multimedia data. These data are stored in PACS server and examined and analyzed in viewing stations.

II. MEDIMED

The Shared Regional PACS project MeDiMed started as a collaborative effort among Brno hospitals to process medical multimedia data. Masaryk University is the co-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 (the Czech national research and education network operator), also provides the necessary network infrastructure.

The system serves for transmitting, archiving, and sharing medical image data originating from various medical modalities (computer tomography, magnetic resonance, ultrasound, mammography, etc.) from hospitals. The central PACS serves as a metropolitan communications node as well as a long term archive of patients' image studies. More detailed information about regional PACS archive maintained under the MeDiMed project is described in [6], [7], [8], [9] and [10]. The MeDiMed demand for dedicated communication channels has induced some exploration of backbone optical transport network [11].

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 computer network. Gradually, it changes the thinking of medical specialists and gets them to cooperate and share data about patients in

 ISBN: 978-1-61208-183-0

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 data stored in the shared archive can be converted to anonymous study or survey (i.e., personal data of patients is replaced by fictitious data) and used for educational purposes.

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. The Masaryk Memorial Cancer Institute is an important node in the regional network of hospitals. It specializes, in a complex way, in oncology diagnostics, treatment and prevention as well as respiratory diseases and gynecology [12]. In general, the proposed 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 system works in the context of the existing legislative system and will also reflect its changes, especially in the field of data security. The long-term goal will be to adapt legislative standards to the needs of the medical practice (an obligation to provide information, data security issues, etc.).

Nowadays, some type of modalities are commonly used not only by large hospitals but also by small healthcare institutions or even private doctor's offices. This fact brings a new demand for PACS systems. There are ICT departments in large hospitals with enough staff for servicing PACS systems powerful enough server farms, dedicated computer rooms, etc. In small institutions, there is no ICT department so the PACS system should be more robust and reliable. Development of PACS system tailored for small healthcare institutions and private doctor's offices is goal of our current project.

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 Internet connectivity and data network availability in general. They are typically located near patients and data communication is not their 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. Eventhough the basic principles used in large hospitals can be preserved also in this case.

III. The basic networking principles of MeDiMed

Medicine picture data like X-Ray, CT, US, MR, etc. cannot be used without additional information like picture data description or evaluation, diagnosis, may be reference to history of patients health, previous treatments and other information relevant to patients health. All medicine images have to be equipped with patients identity as well. We are dealing with sensitive information about the patient. The patients privacy must not be compromised.

We have to provide high level of security for medicine picture data maintained by regional PACS archive. We have to protect the data at three stages: data stored on servers of regional PACS, data transported over network between this archive and user, and users access to these data. Security of data stored in regional PACS servers is provided by usage of dedicated hardware for this application and by strict limitation of access (both physical and network based) to this equipment. Security of data transported over network is provided by usage of dedicated fibre optics lines when available and by employing of strong cryptography (IPSEC with AES-256 encryption algorithm) on all lines, which are shared with other data communication traffic.

The main principle of hospital to MeDiMed connection is usage of two firewalls. One of them is in from of MeDiMed PACS servers and is under control of MeDiMed staff. The second one is hospitals firewall and is controlled by 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 everybody has under control access to the network he is responsible for. This principle holds for all types of connections (dedicated fiber optics, IPSEC tunnel, or any other) between MeDiMed and the hospital. The communication infrastructure principle is easy to see from Figure 2.

Since Regional PACS system is used on a regular production basis it should provide users with reliable and safe services. Because we are dealing with very sensitive information, we strongly relay on data storage and transport security. Regional PACS archive is running on dedicated network infrastructure with mostly no interaction with another data networks. In case that it is necessary to use public data networks for servicing remote hospitals, we are using strong cryptography to secure medicine data transport.

IPSEC VPN server is connected to the PACS firewall in the same way like local hospitals connected via dedicate fibre optics pairs. The VPN server provides only secure data transport channel. Users connected via IPSEC tunnel then have to follow the same packet filtering like locally connected users.

IV. Server redundancy

For all applications provided to MeDiMed users, we have to offer reliable enough service. Reliability of a service is a quite complicated thing. MeDiMed uses a client-server model. Clients are modalities and viewing station and servers are PACS servers and other servers used to store and retrieve medical images. Under the term reliable enough service we understand the situation when the client can in a reasonable time store or retrieve the medicine image.

 ISBN: 978-1-61208-183-0

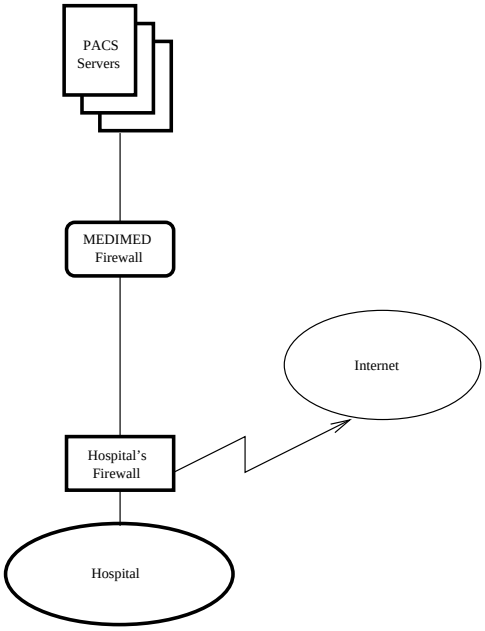

Figure 2. Common principle of hospital to MeDiMed connection. There are two firewalls on the path form modalities and viewing stations to the PACS server. One of them is controlled by hospital and the second on by university.

For better reliability, the key services of Regional PACS system are operated in two distinct locations. PACS systems from different vendors may be used on primary and backup sides if requested. This way, the Regional PACS is able to survive failure of any single fibre optics line, server, storage, electricity (though it is backup-ed via UPS and motor-generator) in one location or even vendor of PACS software.

There is a set of PACS servers used for a routine storage of medicine images. PACS server for this type of service runs on dedicated hardware in both university sites used by MeDiMed. PACS server installations on these sites are standalone and up to some extent independent. One site serves as a primary and until it fails all images are stored into this server. The second site serves as a backup and all data are automatically copied from master to the backup. The backup server is all the time available for retrieving of the medicine images in a 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 read-write mode and the former master site to read-only. In many cases the primary and the backup PACS servers are from different vendors. To keep bidirectional synchronization of PACS servers is more than complicated. This manual switching of primary and backup PACS servers provides good enough service with regards to 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 site.

V. PACS COMMUNICATION SERVERS

A distinct set of PACS servers are so-called communications PACS servers. That means PACS servers 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.

Many PACS installations are only limited to the scope of a particular radiology department. An effective use of that technology means image distribution at least throughout the whole healthcare institution. However, the most promising approach to exploiting the PACS technology is to use it at the regional or national level and to support the associated medical processes this way. That means not only basic support of daily routines in radiology departments but also the support of distant consultations, digital long-term archiving or development of shared knowledge databases for research and teaching in this particular area.

Current ICT, as well as existing and developing standards, enable physicians in the region 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 rid of patients personal data 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.

VI. INSTANTPACS PROJECT

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 Internet connectivity and data network availability in general. They are typically located near patients and data communication is not their 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. Eventhough the basic principles used in large hospitals can be preserved also in this case.

 ISBN: 978-1-61208-183-0

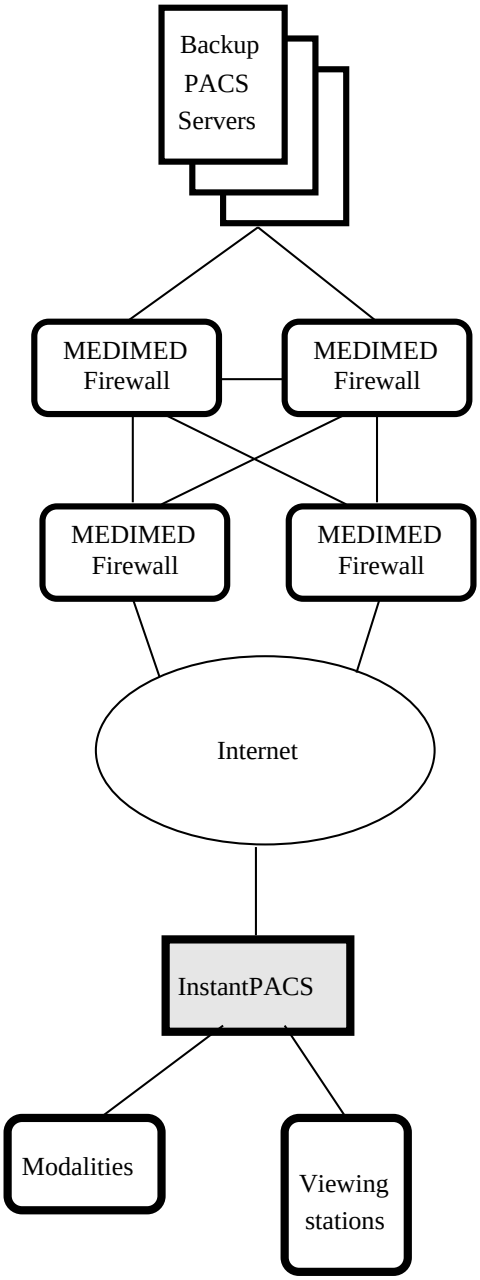

Figure 3. Common principle of InstantPACS communication with the centralized PACS servers.

The aim of the InstantPACS project is to develop a maintenance-free PACS system suitable for small and mid-sized healthcare institutions. This PACS system should offer a user amenity obvious in hospitals including e.g. automatic backup of medicine data. The most important properties are user friendliness, maintenance free operations and pricing acceptable for private doctor's offices. The project is an integral part of the MeDiMed shared regional PACS server overlay project.

As small healthcare institutions and private doctor's offices are being more and more equipped with diagnostics devices, like CT X-ray ultrasound, etc., we expect demand for medicine picture data processing capabilities and services. Our intention is 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. This device will be fully remotely controllable and from point of view of users will not ask for any local maintenance.

Typical user of the InstantPACS will be private doctor's office, which is typically equipped with an ultrasound and one or two more modalities like CT. Currently, modalities in private doctor's office are (from point of view of data communication) isolated devices and data transport is usually performed on USB sticks or the data are processed locally on the modality's console. To offer medical picture processing comfort usual in large hospitals we need to interconnect modalities and viewing stations in the doctor's office. Once the data will be transported from the modality outside we need to provide at least the following services:

- Transport data to the viewing station
- Backup the data on any external device
- Long term archive of the data
- Prevent any unauthorized access to the data while the data are in our device
- Allow to share data between authorized users

The InstantPACS server will be 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 shared room for 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 IPSEC tunnels as shown on Figure 3.

The main properties of the InstantPACS server located at doctor's premises are the following:

- Small dimensions
- General environmental conditions
- No demand for regular local maintenance
- Easy to use
- Expenses corresponding to small size of user's company

The key requirement is no or as small as possible demand for regular local maintenance of the system. Users of the

 ISBN: 978-1-61208-183-0

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. This leads to demand for maintenance performed by systems user. All critical events and states should be automatically detected and reported. Daily routine maintenance of the system should be practicable in an intuitive way. For example, introduction of new modality (which is typically performed by trained ICT staff in large hospitals) should be performed by general InstantPACS user (medicine doctor).

The hardware platform used for InstantPACS is based on off-the-shelf components. However, it is not like a general PC-like station. It has dedicated memory for system software and configuration and redundant disk subsystem for storage of medicine picture data. It contains also embedded ethernet switch for simple connection of few modalities in a typical private doctor's office. Currently there are two versions available with active and passive cooling system. IPSEC tunnels for backup data encryption are terminated directly in the InstantPACS so no additional equipment is needed.

There is yet one important property of the system to discuss: data protection under marginal or special cases like disk replacement in the InstantPACS or even theft of the whole system. PACS systems are typically located in areas with limited and controlled access in large hospitals. This way enough physical protection of the media containing sensitive patients data is enforced. In case of failure of a disk in raid containing patients data the failed disk is usually physically destroyed so that the data can't leak to unauthorized persons. We expect to use more service or implementation companies who will install the system so it is very difficult to enforce data protection in case of disk replacement. We intend to protect sensitive patients data even in the case when unauthorized person can gain physical access to the InstantPACS device. The work on this topics is still in progress.

VII. Conclusion

Medicine modalities are becoming more widely deployed in medicine public and more commonly used even by private doctor's offices. Development and deployment of PACS systems should follow this trend and offer proper services to new smaller users of medicine modalities. This can improve the healthcare and potentially save life of patients. The introduction of PACS system to small healthcare institutions will bring both some comfort and order into processing of medicine picture data necessary for proper medical examination. The InstantPACS project intends to bring PACS environment commonly used in large hospitals to all medicine users.

Acknowledgment

This work is supported by Czech Technology Agency fund project number TA01010268 - "Maintenance-free PACS system for small and mid-sized healthcare institutions".

References

[1] O. Dostal, M. Petrenko, and M. Filka, "Picture archiving and communication systems," in *Telecommunications and Signal Processing - TSP 2000. Brno*. cwVUT Brno, 2000, pp. 25–27.

[2] "Nema homepage," Online, http://www.nema.org, Retrieved November, 2011.

[3] "Dicom 3.0 standard," Online, http://medical.nema.org/standard.html, Retrieved November, 2011.

[4] K.J.Dreyer, D.S.Hirschorn, J.H.Thrall, and A. Mehta, *PACS A Guide to the Digital Revolution*. USA: Springer Science +Business Media, 2006.

[5] H. K. Huang, *PACS and Imaging Informatics: Basic Principles and Applications*. Hoboken, NJ: Wiley, 2004.

[6] O. Dostal, M. Javornik, and K. Slavicek, "Medimed-regional centre for archiving and interhospital exchange of medicine multimedia data,," in *IASTED International Conference on Communications, Internet, and Information Technology, Scottsdale, Arizona, USA, IASTED, 2003*, M. H. Hamza, Ed. IASTED/ACTA Press, 2003, pp. 609–614.

[7] O. Dostal, M. Javornik, K. Slavicek, M. Petrenko, and P. Andres, "Development of regional centre for medical multimedia data processing," in *IASTED International Conference on Communications, Internet, and Information Technology, November 22 - 24, 2004, St. Thomas, US Virgin Islands*, M. H. Hamza, Ed. IASTED/ACTA Press, 2004, pp. 632–636.

[8] O. Dostal, M. Javornik, and K. Slavicek, "PKI utilisation for PACS users authentication," in *ICN/ICONS/MCL*. IEEE Computer Society, 2006, p. 84. [Online]. Available: http://doi.ieeecomputersociety.org/10.1109/ICNICONSMCL.2006.170

[9] O. Dostal and K. Slavicek, "Wireless technology in medicine applications," in *PWC*, ser. IFIP, R. Bestak, B. Simak, and E. Kozlowska, Eds., vol. 245. Springer, 2007, pp. 316–324. [Online]. Available: http://dx.doi.org/10.1007/978-0-387-74159-8_30

[10] O. Dostal, M. Javornik, and K. Slavicek, "Opportunity of current ICT in the processing of medical image information," in *IASTED International Conference on Advances in Computer Science and Technology, January 23-25, 2006, Puerto Vallarta, Mexico*, S. Sahni, Ed. IASTED/ACTA Press, 2006, pp. 193–195.

[11] K. Slavicek and V. Novak, "Introduction of alien wavelength into cesnet dwdm backbone," in *Sixth International Conference on Information, Communications and Signal Processing*. IEEE, 2007, pp. 1–5.

[12] O. Dostal, M. Petrenko, and P. Ventruba, "First application of picture archiving and communication system (pacs) in gynecologic endoscopy," in *ISGE - 6th Regional Meeting*. ISGE, 2002, pp. 53–56.

 ISBN: 978-1-61208-183-0