ISBN 978-981-07-8391-4
Proceedings of 2013 3rd International Conference on Computer Engineering and Bioinformatics (ICCEB 2013)
Bangkok, Thailand, November 23-24, 2013, pp. 26-31

Integration Concept in Regional Medical Imaging

Michal Javornik [1+], Karel Slavicek [1] and Otto Dostal [1]

[1] Institute of Computer Science, Masaryk University, Brno, Czech Republic

Abstract. Sharing of medical knowledge, sharing of accurate sources of information, close cooperation using tools supporting or assisting in decision making, all play a very important role in healthcare, enhance the synergy among the medical community and consequently brings benefits to all people. Secure medical image workflows are currently limited to the private computer networks of individual healthcare institutions. But current requirements in this area are mobility, flexibility of provided medical services and especially global cooperation.
The goal of this article is to present an integration concept how to support regional and national cooperation in the area of processing of medical image data, how to integrate independently provided medical services, how to share an expensive medical facilities or medical specialists, how to make diagnostic process more efficient, etc. This article describes an advanced system developed at the Institute of Computer Science, Masaryk University, Czech Republic.

Keywords: DICOM, PACS, Integration, Medical Imaging.

1. Introduction

Conventional hospital clinical information systems do not support functionalities enabling medical specialists to deliver particular services via the computer network. This concept is known as telemedicine and is based on distant expert centres or specialised medical departments providing services like for instance consultations of urgent cases. Practises of telemedicine bring higher quality as well as higher economic efficiency. For example in the area of medical imaging the image studies can be referred to distant healthcare institution for a diagnostic, second opinion or consultation.

Traditional medical image data processing (so called film-based as well as so called film-less or digital) is mostly organised within the scope of one healthcare institution. Integration concept presented in this article allows full communication among relevant applications and individuals from remote institutions.

2. Medical Digital Imaging Background

International standard DICOM (Digital Image Communication in Medicine) above all enables interoperability between medical devices and applications of the different manufacturers in the area of medical imaging. DICOM communication protocol works over TCP/IP layer. In its client/server architecture there are Service Class Providers (SCP) and Service Class Users (SCU). From DICOM protocol point of view every DICOM compatible device can have role of SCP, role of SCU or both roles. There are two basic components of DICOM protocol: service classes and information object classes. Information object classes specify the relationships and content of images. Service classes define all operations we can do with information objects.

The term PACS (Picture Archiving and Communication System) means a system for streamlining distribution of image studies throughout the healthcare enterprises. It enables delivering of images,

[+] Corresponding author. Tel.: + 420 549493348.
E-mail address: javor@ics.muni.cz

delivering of structured reports describing the medical findings as well as other relevant information. To be easy integrated into hospital information system all of the PACS communication interfaces must be fully compatible with DICOM standard.

Radiology departments often use PACS systems only as a local storage of their local equipment like ultrasound, CT or x-ray. But effective usage of PACS technology means distribution of image studies and related information at the scope of at least the whole healthcare enterprise. The best way how to exploit all of the advantages of PACS technology is its implementation at the regional or national level. To support associated workflows at this level the whole implementation must be based on DICOM communication.

There are two broadly used terms in this interdisciplinary area covering medicine, bioinformatics and medical informatics: eHealth and telemedicine. More general term eHealth covers usage of information and communication technologies in the area of health related activities and in administering health related data and information. Telemedicine means delivering health related services among distant hospitals and other cooperating institutions.

The trend in medical informatics is formalization of structures and processes. The best way how to achieve this goal is adoption of IHE (Integrating the Healthcare Enterprise) profiles and usage of HL7 and DICOM international standards. IHE as an initiative of healthcare industry and healthcare professionals tries to improve sharing of information among applications and systems.

Concept of electronic patient record, defined as a systematic collection of electronic health information about patient, brings quite new quality. It means that healthcare professionals are able to retrieve and update all the necessary information about their patients originating from a variety of hospital information systems. There are difficult legal and organizational barriers when implementing this concept. One of the ways towards the electronic patient record is medical digital imaging in regional level.

3. Methods

3.1. Dedicated Computer Network

The universities in the city of Brno (the second largest city in the Czech Republic) own and operate large-scale fibre optic cable network. The network interconnects all the major healthcare institutions in the city. The advanced applications like transmission of wide image data sets can have their dedicated connections. Following is one of the ideas of our network topology. The network firewall located in front of a hospital's firewall (connecting this institution to the Internet) and the central resources are interconnected via dedicated fibre optic pair. This way the administrators who are responsible for hospital's network can monitor and control access to the resources they are responsible for as well as administrators of our system are allowed to control access to central resources of the network and monitor the status of the whole hospital. The central resources are located at the two geographically distant locations at the Institute of Computer Science of Masaryk University. The schema of the dedicated computer network is described at Fig. 1.

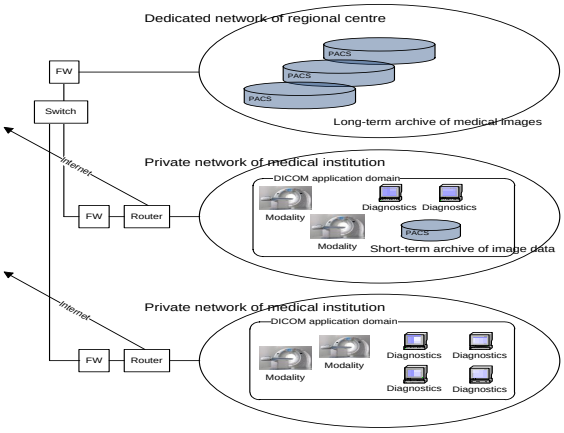

Fig.1. Schema of the dedicated computer network

There are reliable long-term image archives located in the centre where the image studies are being sent from the individual hospital PACS systems. So the image data are partly distributed in short-term archives of incorporated healthcare institutions as well as they are safely stored in long-term archive in the centre.

The central image archive is broadly accessible for physicians from cooperating hospitals. Its content can be retrieved according to the strongly defined rules and access rights. There is group of experts governing and administering all the core components, shared resources as well as delivering related technical support. As all the strategic services must be always achievable there are primary and secondary instances of key components installed in the geographically distant localities. All the content (patient image data, structured reports, parameters of connected modalities from hospitals, etc.) of the distant installations is permanently synchronized.

The question of user authentication and authorization in the scope of set of DICOM applications in one medical institution is simple and can be solved many ways. But the communication standard DICOM does not support this issue in the range of network covering several hospitals. Utilisation of IPSEC technology, the use of Public Key Infrastructure and authorisation based on IP address of the requesting computer from particular hospital network could solve this problem even at regional level.

3.2. PKI Utilization

There are many limitations of DICOM protocol when scaling PACS outside of single healthcare institution. This protocol was designed to be used inside of one hospital where everything is under one common administration. In the environment of many hospitals we need strong authentication mechanism. DICOM can for instance identify its users by IP address of their diagnostic workstations. In the collaborative environment covering many hospitals medical specialists need to have possibility to use more than one viewing/diagnostic workstation and also some workstations could be shared by more specialists.

Modalities (ultrasound, computed tomography, endoscopy, etc.) produce medical image studies and store them into PACS archives. These modalities use fixed IP addresses and are equipped with only limited set of authentication capabilities. Modalities are devices of special communication requirements, should be served with respect to their nature, may be used by authorized staff only, etc. Security of the data provided by them can be for instance guaranteed by restricting physical access only for authorized personal.

Viewing and diagnostic workstations are identified by its IP addresses. Identification and access regulation of radiologists from inside the healthcare institution is an easy task. On the other side experts in various branches of medicine from distant hospitals represent much more complicated group of regional PACS users. They should have limited access only to data concerning their patients or sometimes patients of special treatment. General physicians need access to the PACS system from more computers (from home, from other departments of their hospital, from distant hospitals, etc.). They often share specialized diagnostic workstations.

Our idea is to use IP addresses as alternative authentication mechanism of regional PACS users. General IP address of workstation cannot be taken as user identity. But some properties of IPSEC protocol could be very interesting solution. The user can be authenticated by his/her public RSA key. Regional PACS uses dedicated IPSEC server. IPSEC tunnel between user's workstation and dedicated IPSEC server is established after successful authentication. Tunnel IP address is then assigned to the user's workstation. So the tunnel's IP address then enables user authentication in the regional PACS system. Regional PACS user identity is performed on the basis of PKI infrastructure.

PACS users who need access to more workstations or who need sharing workstations with others are provided with USB dongle containing their private RSA key. As these keys are generated on the dongle and never leave it, it is really very complicated for anybody else to misuse them. Corresponding public keys are signed by regional certification authority. The issue of electronic identity of physicians should be solved globally for the whole national healthcare as well as the regional certification authority should be replaced by national one.

3.3. DICOM Proxy Concept

The concept is designed to protect past and future investment while opening the space for effective global cooperation in this field. DICOM Proxy allows full communication among DICOM application entities of the remote healthcare institutions without any need of modification on the side of existing applications. It does not require any new skills on the user side. It does not require any changes of the existing DICOM equipment. Individual healthcare institutions can simultaneously play the role of resource provider as well as resource consumer. The following terms are used in this concept.

DICOM Application Entity. An application equipped with an interface for communication according to the rules of DICOM protocol. It can be CT acquisition station automatically sending the image data to a particular diagnostic station, it can be archiving system, regional register of image examinations, the database of reference image studies for research or teaching purposes, diagnostic/viewing workstation, DICOM printer, DICOM application for examination planning, etc.

DICOM Application Domain. A group of interoperable DICOM application entities, usually within a closed computer network of healthcare institution. Each application entity must have assigned a fixed IP address, communication port and its value of DICOM Application Entity Title. This trinity within the particular application domain must be unique for each DICOM application entity.

Every authorized user, usually radiologist, communicates via appropriate DICOM application entity, usually diagnostic workstation. DICOM application entity as well as its authorized user is, if needed on the remote DICOM application domain, represented by DICOM Proxy Client.

DICOM Proxy Client. The client represents DICOM application entity or its authorized user outside of their primary DICOM application domain. Proxy client must be accessible for the required application entity within the remote application domain. DICOM Communication port as well as AE Title of the interface of a particular DICOM Proxy Client must be configured in accordance with the rules of remote DICOM application domain.

Proxy Client simulates the availability of remote DICOM application entity inside of the local DICOM application domain. In other words it represents the gateway to the services provided by the remote hospital or other institution dealing with some kind of processing of medical image data.

Proxy Client representing the remote application entity outside of its primary DICOM application domain has two communication interfaces. One interface is used for communication with the local applications, the second interface communicates with the central communication node of the DICOM Proxy. Communication between DICOM Proxy Client and central communication node is generally supposed to go over an insecure computer network.

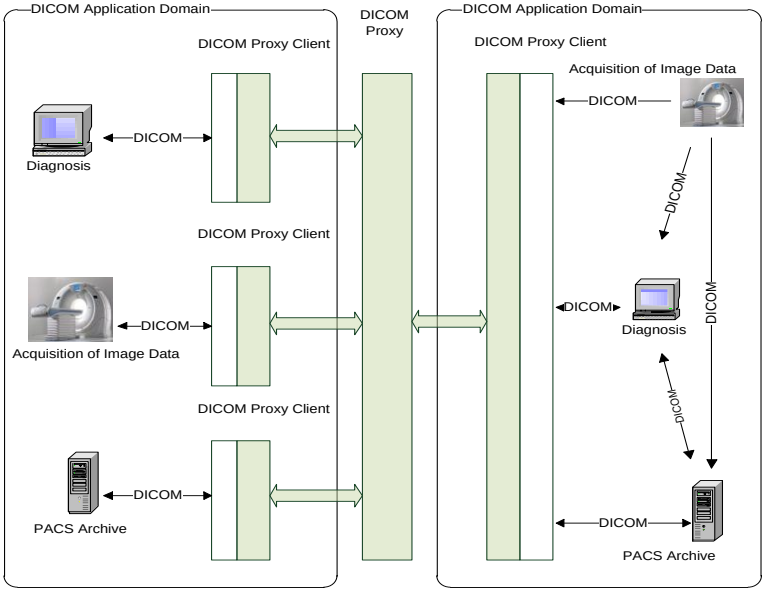

Fig.2. Concept of DICOM Proxy

As authentication mechanism of remote application entities (represented by DICOM Proxy Client) you can employ public key certificates signed by some respected certificate authority. Authorization of remote application entity may be based on the attributes of used digital certificate. The scope and level of access rights must be in accordance with the Act on Personal Data Protection and other applicable legal standards. Those functionalities are outside the range of the DICOM standard and are specific for particular manufacturer of given application.

In accordance with the DICOM standard you can encrypt the whole information object or selected attributes of this object. Similarly you can also digitally sign selected attributes of DICOM information object, group of attributes or the whole information object. Digital signature and encryption of attributes can be implemented at the level of DICOM application as well as at the level of DICOM Proxy.

4. Results

4.1. Radiological Communication System ReDiMed

Radiological Communication System ReDiMed creates the opportunity to transfer highly sensitive patient image data between various DICOM compatible medical devices from inside the medical institution and DICOM compatible medical devices located in another institution via open Internet. System ReDiMed consists of central servers located at the Masaryk University and specialized components (Proxy Clients) deployed inside private networks of involved medical institutions. These components are equipped with DICOM communication interface and represent standard DICOM nodes within DICOM application domain of the institution. As the external communication runs over the open Internet all the transfers are protected by asymmetric encryption. This system supports simple workflows as well as quite complex solutions like distribution of medical images through the region. Now it enables secure communication of more than 300 healthcare institutions and medical specialists mostly from the Czech and Slovak Republic.

4.2. Knowledge Management

For radiological training (to become an excellent radiologist) it is necessary to have access to large knowledge databases of case studies. A case study as a basic didactic unit consists of structured information about real patient: image data of many types (radiological images, pathology images, video recordings, demonstrations from surgeries, data from nuclear medicine, etc.), clinical information and also links into other relevant data sources. Personal data of all involved image studies as well as of all other related files are modified, patients are made anonymous. As the patient can be treated in many different healthcare institutions the coordinated modification of his/her identity (replacement with fictitious one) is necessary. We need to prevent disclosure of his/her identity as well as not to lose complex view of patient's treatment. Even if the patient is being treated in different hospitals fictitious identity of all of his/her recordings in knowledge databases is the same. The principle of fictitious identity removes the legal barriers preventing usage of confidential and highly sensitive patient data in the area of research and for education in medical faculties.

5. Conclusion

The system described in this paper is much more than just a specially configured dedicated computer network and its applications. Much more important is network of radiologists and other medical specialists which is being build. As they use our secure network and secure applications they change their traditional thinking, cooperate in the regional level, share data and information about their patients, etc.

Radiological Communication System enables secure communication of more than 300 healthcare institutions. The capacity of fast accessible long term medical archive located at the Masaryk University is more than 200TB of image studies. Shared knowledge database of described case studies serves not only for education of medical students and young radiologists but also enables more effective decision making in cooperating hospitals.

6. Acknowledgements

These activities are supported by the Masaryk University, Czech Republic, project TACR TA01010268 - Instant PACS and project Eureka OE10014 - Mobilized Lifestyle with Wearables.

7. References

[1] H. K. Huang, DSc. *PACS and Imaging Informatics: Basic Principles and Applications*. Hoboken, NJ: Wiley, 2004 ISBN 0-471-25123-2.

[2] DICOM Standard.

[3] O. Dostal, M. Javornik, K. Slavicek. Integration of Telemedicine Activities in the Czech Republic. In: *Proceedings of the 4th International Conference on Innovations in Information Technology*. Dubai, United Arab Emirates: College of Information Technology, UAE University, 2007. ISBN 978-1-4244-1841-1.

[4] K. J. Dreyer, D. S. Hirschorn, J. H. Thrall, A. Mehta. *PACS A Guide to the Digital Revolution*. 2006, Springer Science +Business Media, Inc., USA, ISBN 978-0387-26010-5.

[5] D. A. Clunie. *DICOM Structured Reporting.* Bangor, Pennsylvania, PixelMed Publishing, 2000.

[6] O. Dostal, M. Schmidt, M. Javornik. MEDIMED - Regional PACS Centre in Brno, Czech Republic. *Proceedings of the 22th International Conference of EuroPACS & MIR (Management in Radiology) Conference*. September, 2001, Trieste, Italy.

[7] Health Level Seven Standard, HL7. Health Level Seven, Inc.

[8] E. Bellon, M. Feron et al. Incorporating novel image processing methods in a hospital-wide PACS. *The 19th International Conference of CARS 2005*. Berlin, CARS, 2005.

[9] International Classification of Diseases, ICD.

[10] Integrating the Healthcare Enterprise, IHE.

[11] International Medical Informatics Association, IMIA.

[12] Logical Observation Identifiers Names and Codes, LOINC Standard.

[13] Medical Imaging Resource Center, MIRC.

[14] H. Munch, U. Engelmann et al. A secure software architecture for collecting and processing medical image data in centers of excellence. *The19th International Conference of CARS 2005.* Berlin, CARS, 2005.

[15] Lexicon for Uniform Indexing and Retrieval of Radiology Information Resources, RadLex.

[16] Systematized Nomenclature of Medicine, SNOMED Standard.

[17] Telemedicine Alliance, *Towards Interoperable eHealth for Europe: Telemedicine Alliance Strategy*, Noordwijk: ESA Publications, 2005.