Udating DICOM Network Architecture for its Integration at International Level

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***Abstract*—this article describes functionalities and specific features of the "DICOM Network" informational system that provides possibility to collect, process, archive, distribute and visualize data in DICOM format. Article represents all technical and architecture details and proves the benefits for end users to use the system for secure access to DICOM investigations. Provided information about approaches of the system development and implementation at national and international levels. This system can be interesting for medical institutions and their patients, for specialists that are developing and integrating medical imagistic in complex informational systems. In the paper demonstrated how the system can save time and money for beneficiary institutions and increasing the quality of provided services.**

Keywords—DICOM; VI-SEEM; RENAM; Distributed System; HPC; Processing Alghoritms;

I. INTRODUCTION INTO DICOM NETWORK

Progress in telecommunications technologies has ensured Internet infrastructure penetration and generated the emergence of Information Society development. The level of knowledge and human capacity for assimilation and development of modern information technologies determine technological and social prosperity. A special importance has implementing these technologies and knowledge in various areas of medicine to advance the quality of medical investigations. In Moldova is actively promoting the development of information technologies and e-health components as part of National strategy of sustainable development. Over 90% of medical institutions (hospitals, clinics and research institutions) connected to the Internet and widely purchases medical equipment compatible with modern computing facilities. Many of these medical devices produce results of medical investigations in DICOM format – de-facto a standard in medicine [1].

As the result of the project "Distributed information system 'DICOM Network' (SID "DICOM Network")" supported by the Agency for Innovation and Technology Transfer of Moldova were created innovative informational systems for providing modern e-health services in cooperation with other informational systems existing in the beneficiary medical institutions (like IBS Hippocrates). The system represents an ensemble uniting people – users and maintaining personnel, equipment, software, stored data and processes for producing decision-making services for providing information necessary to develop solutions of problems faced in front of professionals in medicine [2].

Informational system is a complex of structured elements, which are interdependent and interconnected and forming a complex operating unit in a given environment in order to achieve specific objectives.

The main purpose of the project was implementation of integrated information system to provide automated services of information exchange in DICOM format, using distributed computing technology. Main objectives of "DICOM Network" are increasing the quality of services and simultaneously decreasing prime cost. Ensuring security and data integrity according the legislation in force is a very important objective for the system implementation. For this purpose were developed and implemented measures to ensure the necessary level of security to access the system and stored resources.

The current and future trends in Internet segment development in Moldova focused on broadband communication implementation provide the basis for formation of conditions that will allow to store, processing and distribution of medical investigations in DICOM format. "DICOM Network" allows also offering remote consultations by specialist from national central clinics and abroad.

Potential beneficiaries of the system are medical institutions that produce and collect various imagistic investigations like tomography, Roentgen, ultrasound,

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angiography, etc. Familiarization and working experience accumulation by medical specialists in using such systems offer obvious advantages in imagistic investigations and forming treatment decisions, allow appealing for support from the best local and foreign specialists who have extensive experience in the field. This will facilitate in establishing collaborative partnerships among national, regional and international specialists, increasing access to and participation of local physicians in international research and innovation programs.

As a scientific, technological and socio-economic impact of the "DICOM Network" we can consider raising healthcare quality of services and creating the necessary conditions for national human resources development and advancement of preparedness of local specialists in the use of advanced information technologies.

II. DICOM FORMAT OVERVIEW

A. Digital Imaging and Communications in Medicine

DICOM is based on the OSI ISO-standard, which is supported by the main producers of medical equipment and medical software. [1].

DICOM Standard (Digital Imaging and Communications in Medicine), developed by National Electrical Manufacturers Association, allows you to create, store, send and print single image, a series of images, patient information, research, equipment, facilities, medical personnel providing inspection, etc... [3].

DICOM Standard defines two informational levels: File Level - DICOM File object is a file with tags that contain information about the organization for the representation of the image frame (or series of frames) and accompanying / control information (in the form of DICOM tags);

Network (Communication) Level — DICOM Network Protocols — to transfer DICOM files, DICOM and control commands across networks with TCP / IP support.

B. File level — DICOM File. Presentation of images in medicine

To imagine how to build a 3D-model, for example, the brain of 2D DICOM-files, you need to understand how images are represented in medicine. Let's start with the fact that all modern imaging (MRI, CT, PET) do not produce final images. Instead, the image is formed in a special DICOM format, which contains information about the patient, study, as well as information to render the image. In fact, each image is slice of any part of the body, in any plane, usually horizontal. So each of these DICOM-files contains information about the intensity or density of the tissue in a specific slice on the basis of which is building a final image. In fact, the intensity and density - are different concepts. Computer tomography saves X-ray density in files, which depends on the tissue physical density. The bones have a higher physical density, lower blood etc. A magnetic resonance imaging saves the return signal intensity. We shall use the term density, thereby generalizing the concept described above.

Information about density in DICOM file can be represented in the form of a normal image, which has a resolution, pixel size, format, and other data. Only in the pixel stored information about tissue density instead of the color.

Diagnostic station produces not a single file, but several with information on tissue density for a single study. These files have a logical structure. The files are combined in series and are a set of successive sections of one organ. Series are combined in the stage. Stage defines the one whole research. The sequence is determined by a series of stages in the study protocol.

C. Network Level — DICOM Network Protocols.

Let us consider of PACS system for understanding of its role in the common diagnostic center. Every diagnostic center has diagnostic equipment like MRI, CT scanners, ultrasound or ECG-station apparatus (any one of these devices in terms of the DICOM protocol is called Modality) and software for support of making diagnostics. After receiving the image from the MRI scanner, you must send them to the diagnostic station. Obviously, this requires a certain integrating element, which collects images from scanners, ultrasound stations, ECG machines, etc., is able to search and find devices, retrieve images and send images over the network. The role of this integrating element is executing PACS server as it shown in Fig.1.

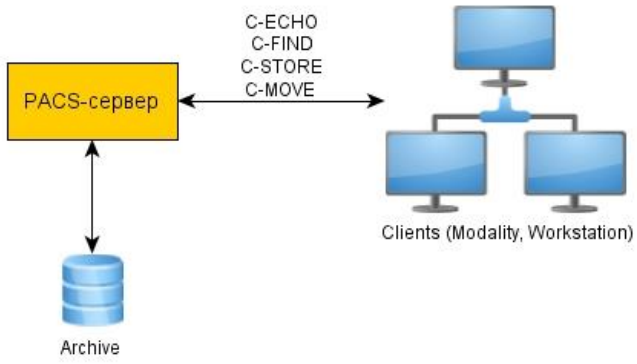

Fig. 1. PACS system implementation scheme

For interaction of different-quality medical equipment is requiring a single protocol. As the unique protocol is used DICOM protocol, which has been seriously improved over the last 20 years, enabling easy integration of medical equipment in a common information system. Almost all medical equipment manufacturers follow this protocol. Therefore support of DICOM protocol is a natural requirement for any PACS server.

D. Main functions of PACS-system.

Let us consider briefly the main functionalities (services) of standard PACS-system [4]. All interactions of workstations with PACS server are client-server type and thus all operations are implemented in two variants - at client and server levels (see Fig 2).

The prefix 'C-' for operations is meaning the “Composite”, which implies that the operation is an integrated and self-sufficient, and is performed without reference to the other operations. There are more types of operations with the prefix 'N -' (N-CREATE, N-SET, N-GET, etc.), which are carried out within the framework of some more general operation (set the status and inform about the beginning of the study, and others). These operations are not relevant to description of the system functioning and are not considering in this paper.

C-ECHO – command that allows the client to know the availability of the network. Similar to the Ping command in Windows and other operating systems. The implementation of the command is very simple - just send a response with the status STATUS_Success: DIMSE_sendEchoResponse (assoc, presID, request, STATUS_Success, NULL), where assoc - the connection established by the client, request - the incoming request.

C-STORE — command allows you to save images to the PACS-server in DCM format.

C-MOVE — command that allows to transfer images from the PACS to diagnostic client workstation. The command is transferring by the calling workstation (source) to PACS and it indicates to what workstation (destination) you want to download the image. In the particular case when source = destination, it is simply downloads image.

C-MOVE command is more universal than C-GET command that is allowing only downloading images. C-MOVE can download images not only to its own, but also to any other workstation. The command indicates AETitle station to which you want to load images. AETitle - is the client's name, usually in capital letters (e.g., CLIENT_SCU). The client's name is set-up when you start the DICOM-listener’s server.

That means that client that initializes the C-MOVE command in the PACS server should run a mini-PACS at its workstation that is allowing accept only C-STORE command. The PACS server in turn should to establish a new connection with the client after receiving C-MOVE command, to retrieve the image from the database and perform for each of the specified clients the client version of C-STORE command to send the image back to the client. Only C-MOVE command can transfer as compressed images (JPEG), as uncompressed images due to ability of establishing of a new connection.

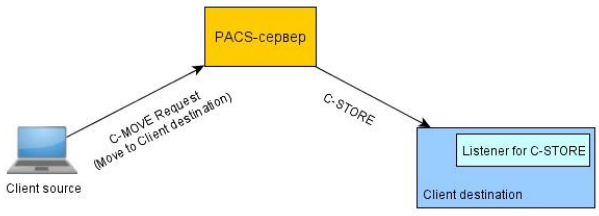

Fig. 2. Basic functionality of the stadard PACS system

Command C-GET, however, is able to download images without establishing a new connection and, therefore, without the need to activate the mini-PACS server on the client side. In this case, the PACS system also performs the client version of the C-STORE command, but only through connection established by C-GET command.

C-FIND — command allows you to search for images at different levels. In fact, there are four types of C-FIND command: C-FIND commands at the level of PATIENT, at the level of STUDY, at the level of SERIES and at the level of individual IMAGE.

III. SYSTEM ARCHITECTURE

Implementation of “DICOM Network” based on the elaborated complex architecture that is comply with distributed system requirements and is flexible enough to cover all beneficiary requirements [5].

The system Data Storage and Data Processing components distributed between different processing units and storages, which could be customized using specific interfaces. The general architecture of the “DICOM Network” system presented in the Fig.3. The system structure comprises the following data servers and modules:

- Data from equipment are collecting at the “DICOM Server” modules that can be installed in the same location with the used medical equipment or can be distributed through other institutions and even countries.
- All the investigations (DICOM Images) are archiving on DICOM Servers, but the information about investigation is stored in DICOM Portal (like www.dicom.md) database. Many DICOM Services can be connected to one DICOM Portal.
- DICOM Portal stores all data like user’s info, access info, system settings, DICOM Server settings and some other, but not DICOM images it salves. Each Institution can deploy DICOM Portal internally on own server.
- DICOM DATA Interface collects information about users and investigations from all DICOM Portals and provides functionality for data exchange and unification.

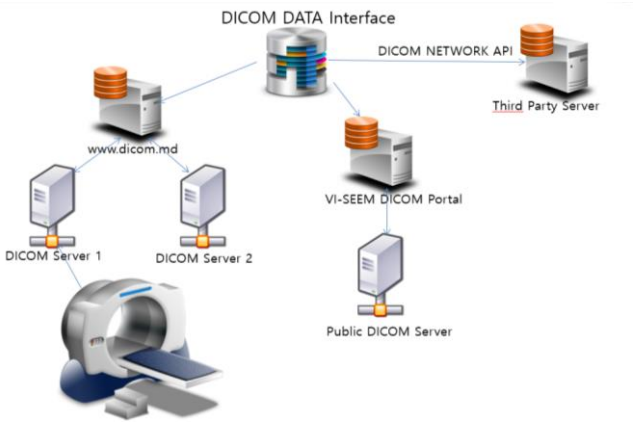

Fig. 3. General scheme of DICOM Network architecture

This architectural approach provides a flexible information exchange that can be adjusted by requirements of individual customer or specific institution.

Scheme in Fig.4 shows the process of collecting and processing DICOM investigations within one institution that is using one DICOM Portal and a number of DICOM Servers.

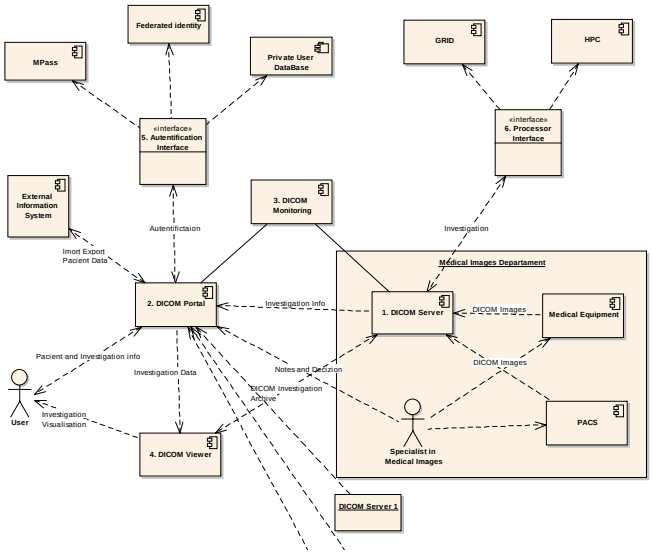

Fig. 4. The realization of the sytem with one DICOM Portal and a number of DICOM Servers

The dataflow represented in Fig. 4 sows ability of DICOM Network to store data at DICOM Portal and visualize data using DICOM Viewer that loads images from DICOM Server. DICOM Networks provides interfaces for Integration of HPC resources and SSO authentication that offers integration of the system with existing software installed in the medical institutions.

A. System Modules Decription

"DICOM Network" is a modular system. Below described the basic modules: «DICOM Data», «DICOM Server», «DICOM Portal», «DICOM Monitoring», «DICOM Server», «DICOM Viewer», «DICOM AUTH», «DICOM Processor» and «DICOM Audit».

DICOM Portal - Front End User interface. Web portal provides end-user access to the system through Web interface. Portal offers workspace for following users' roles:

- Patients who have access only to their investigations based on individual identity (IDNP).
- Doctors who have access only to their patients investigations.
- Doctors - radiology and imagistic specialists who are working in 24/7 regime.
- Users with limited time access, to get temporary access to specific investigations. This is necessary to ensure access to foreign experts, the legacy organizations, etc.
- System Administrator that performs monitoring and configuration of the system.

"DICOM Portal" regulates the level of access in the system for other users. For System Administrators developed management console available online.

DICOM Server - Equipment integration and data storage. This module provides a service of collecting data from the equipment, saving the archive of images and transmission of information on the server in the «DICOM Portal».

This service is designed for various interfaces of import / export of data, depending on the beneficiary's equipment. «DICOM Server» can also be used as a PACS and provides all the necessary commands for realization of the DICOM protocol. This module is ensuring adherence interactions with the specialized data visualization system. This component is also responsible for the transfer of investigation data to «DICOM Viewer» based on the appropriate user's access level.

«DICOM Server» component allows scalable extension, can be installed in different locations and in different organizations, allowing you to store distributed image archive without affecting or overloading the informational infrastructure of certain organization.

DICOM Viewer - Medical images visualization module. The module provides all the necessary operations on medical images:

- DICOM images display. User-friendly interface.
- Regular operations with DICOM images: Line, Circle, Rectangle, Curve line.
- Selection of area for calculation and dimensions: Line, Angle, diameter, S circle, S rectangle, Zoom +/-, Zoom area, Move.
- File operations: Save, Print, Bulk Print.
- Image visualization: table n*n images, negative view.
- Different projections: "Skull", " Lung", " Abdomen", " Mediastinum", "Bone", "Spine", "Postmyelo", "Felsenbein", " Cerebral", "Standard".
- 3D modeling.

DICOM Monitoring - Equipment and services monitoring.

Monitoring performance of the system – analyzing of «DICOM Server» configuration. This module allows determining the failure or unavailability of equipment connection, which, as a result, allows resolving technical problems earlier that increases the resiliency of the entire system.

DICOM Audit - Securing personal data and medical investigations access:

- Each investigation is linked to a patient with its personal data.
- For each investigation there is possibility to set up individual access.

- Each request to data access is logging and investigations workflow is tracked.

B. *Security*

As far as system stores and distributes the patients' personal data the level of data access security and data confidentiality should be respectively high. To ensure these requirements were implemented a sub-system of secure access providing that is centralized in the „System Management Interface" of the "DICOM Network" system. This functionality is realized by different modules and can be enhanced on demand:

- Access to investigations and respective dataflow is monitored and managing by Dataflow audit module that means that all events are logged and all the access requests are captured and controlled by system administrators.
- System does not allow any anonymous access to data. Each investigation has access levels that configured for predetermined users with necessary permissions.
- SSO and Federated Identity could be integrated and configured for each „DICOM Portal" individually. That allows gaining access for institutions' staff by integration and use of their users' databases (institutions members' identity information).

IV. THE EPERINCE OF THE SYSTEM APPLICATION

«DICOM Network» informational system was developed for medical treatment and diagnostics institutions for collection, processing and visualization of medical images.

This system covers all necessary workflows for processing and documentation of medical investigations - from collecting images directly from equipment to archiving investigation in the patient medical record. «DICOM Network» offers extended functionality for enhancing quality of medical management and secured access to investigations. This helps doctors, specialists and penitents to gain access to structured database of medical images, allows documenting images that are collecting from various medical apparatus. At institutional level, the system helps to reduce costs of investigation, rise the quality of services.

The system initially was deployed at the National Centre of Ambulance of Moldova and during the first six months of functioning has shown it attractiveness for personnel and effectiveness that is resulting in:

- **7** Medical equipment's were connected to the "DICOM Network".
- **16** Doctors from radiology section are using "DICOM Network" system in 24/7 regime.
- **200** Investigations average per day are collected by the system now.
- **400** Investigations per day are expected by the end of the year when all equipment will be connected to the system.
- Over **500** doctors have access to their patients investigations from their working place
- 2 193 investigations were searched and downloaded by doctors and imagistic specialists last 2 months.

A. *Benefist for medical organisations*

- The investigations prime cost reducing:
  - No need for Investigation Print consumables
  - No need for CD/DVD archive
  - No need for third party software support
- Increase Quality of Service:
  - Online investigations access by specialists, doctors, patients
  - Allow investigations exchange between institutions.
  - Online consultations that is reducing paper documents, etc.
- Statistics enhancement:
  - Quality statistics' services available 24/7
- Advanced reporting:
  - Ability to realize any sophisticated reporting system
- Archiving and convenient data retrieving:
  - Secure and reliable archive for investigations.

V. CONCLUSIONS

At present, the level of development, penetration and use of information technologies in medical institutions of the Republic of Moldova is insufficient. This is due to the lack of qualified professionals and limited experience of working with large-scale information systems. Most of information systems are purchased or obtained from foreign suppliers, have restricted abilities for local adaptation that often leads to the fact that final product does not match requirements and expectations.

Unlike closed solutions described above, "DICOM Network" system was developed domestically, in contact with the local medical constituency; it very well adsorbs needs of medical institutions, has necessary level of openness and can be effectively adjusted to local requirements. The elaborated system uses of the latest advances in information technologies, favorable from economical point of view, can be interesting for practical utilization to medical staff of institutions in the Republic of Moldova and abroad.

A. *Future research, activities and innovations*

Although the system is now in production stage, functionality of the "DICOM Network" is permanently enhancing. During the process of the system implementation beneficiaries specified their necessities for providing additional features and services. We plan to realize some new functionality in the near future, such as:

- Integration with MPASS (national medical insurance system) and legalization of the patient's access to his investigations.
- Integration with new sets of medical equipment.
- Mobile version of the «DICOM Viewer»
- Enhancing connectivity to the regional VI-SEEM Platform and cooperation with other international projects and platforms [6].

In addition, as the long-term plan are developing and integrating more ambitious functions:

- Studying and realization of new methods for optimization of data transfer and archiving.
- Image preprocessing and detection of anomalies.
- Incorporation of expert systems to help making diagnoses for doctors.
- Development of open APIs for "Dicom Network" to collect, archive, access and process medical images at international level.

B. Integration into VI-SEEM platform

"DICOM Network" system was selected as pilot application for integration into distributed regional platform that is deploying by the European Commission project "Virtual Research Environment for regional Interdisciplinary communities in Southeast Europe and the Eastern Mediterranean". It is presumed that the regional platform should provide necessary resources for installation of "DICOM Portal" and "DICOM Server" instances.

VI-SEEM project deploys and offering user-friendly integrated e-Infrastructure platform for Scientific Communities in Climatology, Life Sciences, and Cultural Heritage for the SEEM region by linking compute, data, and visualization resources, as well as generalized services, software and tools. The regional infrastructure deployment concept is presented in Fig. 5.

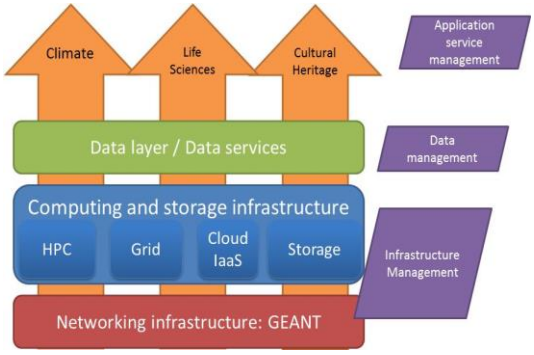

Fig. 5. VI-SEEM Technology context

This platform will offer possibility to install and configure public available DOCOM Portal that can be used by any interested institutions to store, access and share medical images. Setting up public DICOM Portal instance will increase the level of access to DICOM investigations and will help to promote DICOM Network for medical research and practicing community.

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