A Web PACS Architecture Based on WADO Service of DICOM Standard

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Abstract: - All users of informatics applications need rapid and reliable access to the kind of information they are interested in. Web technology provides such capabilities. Thus, the evolution of medical systems and especially PACS that is the issue of this paper comes through World Wide Web. DICOM Standard committees attended these trends. They developed WADO (Web Access to DICOM Object) Service in order that system interaction inside PACS takes place through Web, in a standardized way, allowing interoperability and proper information management. The authors have recently began a project of a WADO based Web PACS development, according to the Standard specifications. In this paper a PACS Server, providing through a Web portal platform all DICOM Services to Internet users, is presented. Java technology is used to satisfy design considerations and dynamic data exchanges.

Key-Words: - PACS, DICOM, WADO, Web Portal, Three-tier Architecture, Application Server

1 Introduction

Today, almost every bioinformatics engineer, doctor or physician is willing to recognize the improvement of the medical care and medical data administration through proper entrance of computer and network systems inside hospital. The use of PACS (Picture Archiving and Communication System) in a filmless radiology department of a hospital has become conscience inside the community of the biomedical informatics engineers and the medical stuff. It is already adoptable that such systems can improve healthcare delivery and decrease the demanded service cost and time. The development of DICOM (Digital Imaging and Communication in Medicine), that is the dominant medical standard protocol, promoted functionality and interoperability inside PACS and between different PACS [1].

During last few years the Web evolution shows the way of services integration. Web portals are the platforms, which can provide all kinds of data exchanges. Anymore, medical information services should be implemented over these platforms. PACS needs the support of Web pages in order to be uploaded to the Internet world and be a tool, not only inside the hospital, but everywhere a doctor or a patient exists. Additionally, each one of them should have access in medical data without the need of a special computer system and software, but only using simple applications and a Web browser [2].

The PACS Web service was not supported by a standard protocol until 2004. Then the Web Access to DICOM Object (WADO) Service was developed and included in DICOM standard, Part 18 [3].

Based on the specifications of WADO, our team has recently began the development of Web PACS applications, using essentially open source tools, in order to provide DICOM services over Web in a "full" DICOM way.

The application was developed in three different stages. On the first stage, the implementation of the PACS Server [4] was completed, using architecture compatible in the whole with the DICOM standard. On the later stage, we began the development of a Web portal platform [5] that was intended to support medical applications. In a further development (third stage), we exploited the portal platform by extending the services of PACS Server over Web, taking into account the WADO specifications. Thus, we designed and implemented a real DICOM Web PACS based on the recent (2004) standard. In this paper we present the architecture of the above system.

2   PACS Network Architecture

PACS, inside radiology departments of hospitals, provides: (a) picture viewing at diagnostic, reporting, consultation and remote workstations, (b) archiving on magnetic or optical media using short or long-term storage devices, (c) communications using local or wide area networks or public communications services, and (d) systems that include modality interfaces and gateways to healthcare facility and departmental information systems offering one integrated system to the user.

The American College of Radiology (ACR) and the National Electrical Manufacturers' Association (NEMA) formed a joint committee to develop the dominant protocol for modelling the whole system, which is DICOM. The DICOM Standard is a set of rules that allow medical images to be exchanged between instruments, computers, and hospitals. It establishes a common language, which guarantees that a medical image produced on one vendor's machine will be displayable on another vendor's workstation [3]. Following the DICOM Standard we developed a PACS, which consists a "full DICOM" system, that is our PACS can support all services Nema's Standard describes.

Service has a fundamental meaning inside PACS. It is the union of a specific set of message elements and a data abstraction of similar real-world objects, which completely define a precise context for communication. Additionally, the message elements of the services have particular Application Service Elements (ASE), which can interact with peer ASE of remote application users. These ASE are ECHO, STORE, FIND, MOVE, GET. Below we concisely describe these services.

Verification: It is used for the tests. It allows knowing if the machines "get along" mutually. This class is not associated with an DICOM object; it returns information in the form of an echo (ECHO).

Storage (& Media Storage): It allows the transfer and the backup of the images between two DICOM entities (STORE). There is an alternative: Media Storage Class Service, which specifies the exchanges between two machines by the intermediary of a media (CD, diskettes, etc.).

Query/Retrieve: It implements standard commands: FIND, MOVE, and GET. FIND requires a list of images. MOVE and GET initiate a transfer, which will be carried out via the class "Storage Service Class".

Study Content Notification: It is used to notify the arrival of a new image or series of images. It can be used to initiate a transfer or to check if the transfer of a series of images is complete.

Patient Management: It allows the machine to interface with hospital network PACS or HIS/RIS (Hospital Information Service / Radiological Information Service). It additionally allows management of the data of the patients, demography, admission and output of the patients.

Study Management: It is used for creation, management of appointment and follow-up of the examinations.

Print: It allows the connection with a reprographer and it specifies the type of image (colours, levels of grey etc.).

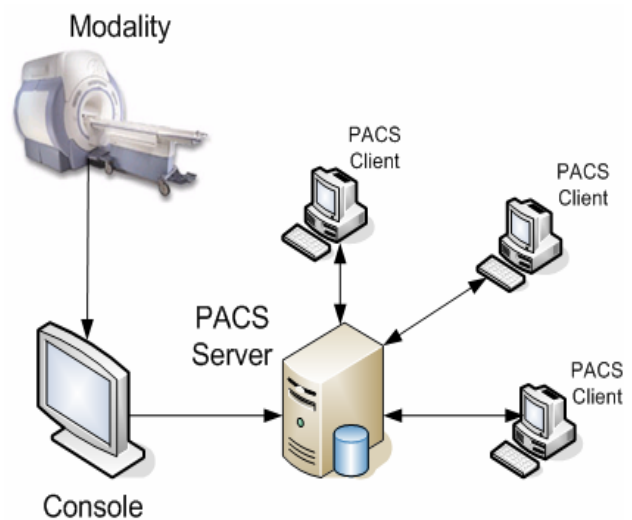Results Reporting: It allows the management of the results of the examinations.

Fig.1 - PACS Network Architecture

Our PACS [4], shown in figure 1, has a network architecture consisting of three basic elements, the Modalities, the PACS Server and the PACS Clients.

The **Modalities** (MRI, CT, CR, Ultrasound etc.) are the producers of digital medical images. They are connected to the PACS Server. A Modality can only send images or studies. Some Modalities (e.g. CR, MRI) have independent user console for a first processing of images and reports before their store in the PACS Server. Console may have a small database, only for storing the recent exams.

The **PACS Server** accepts images or studies (including or not report) from the modality or from the clients and has the role of the DICOM Service Provider. The PACS Server has three different databases in order to serve all requests following the specifications of the protocol:

- Control DB is the database, which has the responsibility to perform the communication between the server and the clients in a formal and efficient way. This database is a

look up table for the communication and furthermore records all the information about the identity of servers and clients.

- Image DB is the database, where DICOM files can be stored in an efficient way. In DICOM files the information is structured in five different levels. Each one of the levels represents a DICOM Entity. These are Patient, Study, Series, Image, and Instance. Patient entity consists of one or more Studies, which can belong to one or more kind of exams. Study entity consists of one or more Series, which can belong to one or more kinds of exams. Series entity consists of one or more Images, which can belong to one kind of exams, only. One Image corresponds to one and only one Instance, which is the representation of the Image entity into the physical medium.

- Report DB is the database, where DICOM Structured Reports are stored. Additionally, all information is essential for the association between the report and the proper study, is preserved there.

The **PACS Clients**, which have the role of the terminal users of all DICOM services, can accept/send images, studies (including report) from/to the server. They can also send a study to another Client via the server (Query/Retrieve). They have a local database that is used to keep the retrieved from the Server information in order to be processed locally. PACS Clients can belong to different clinics or laboratories [6].

3 WADO Service

Users of medical information systems require rapid and reliable access to reports and images. Within computerized environments such access is increasingly based on Web technologies. Clinicians need to have access either in native DICOM format for advanced use or into a generic format (e.g. jpeg, txt) that can be presented without the requirement of specific medical applications. WADO specifies a Web-based service for accessing and presenting "DICOM persistent" objects such as images and medical reports. This is intended for distribution of medical information to healthcare professionals. It provides a simple mechanism for accessing a "DICOM persistent" object. This new standard will allow a physician to use the Web browser on his office or home PC to obtain and review any medical information, (that he is authorized to view or to process), which is stored in the computer systems of

hospitals, clinics, or archiving centers anywhere in the world.

WADO is a joint effort of DICOM (WG10) and ISO (TC215/WG2) and therefore, published by both organizations (NEMA04a, ISO04c). It is not a new medical communication protocol, but a "Web View" in DICOM. Scope of this Standard is a new Web-based Service for accessing and presenting of "DICOM persistent" objects and a simple mechanism for viewing and processing of them from HTML pages or XML documents, through HTTP/HTTPS protocol, using the DICOM UIDs (Unique IDentifiers for a study, a series, an image - instance).

Part 18 of DICOM standard is referred, in the whole, in WADO Service specifications. Below are defined the fundamental terms of this new Service and the interaction between the communication entities of the protocol in the Web environment.

DICOM Persistent Object is an instance of a data object that has been allocated a unique identifier in the format specified for SOP (Service Object Pair) Instance UID and has been chosen as an object to be saved securely for some period of time. Within the DICOM Standard, a DICOM Persistent Object is referred to as a Composite SOP Instance.

Web Client System is a system using Internet technologies (Web, e-mail…) in retrieving DICOM Persistent Objects from a Web Enabled DICOM Server, through HTTP/HTTPs protocol.

Web Enabled DICOM Server is a system archiving and managing DICOM Persistent Objects and able to transmit them on request to the Web Client System.

Web Access to DICOM Persistent Objects is the Service enabling Web Client System to retrieve DICOM Persistent Objects managed by Web Enabled DICOM Server. HTTP/HTTPs protocol is used for this communication [3].
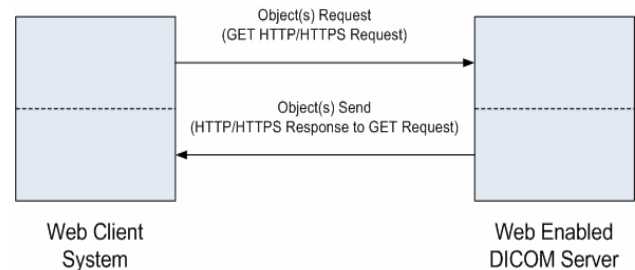

Fig.2 - WADO Interaction Diagram

The figure 2 shows the Interaction Diagram for the communication between the Web Enabled DICOM Server and a Web Client System. The parameters of the query are sent to the Server

through the http GET and the server will respond sending one or more objects in a proper MIME (Multipurpose Internet Mail Extension) type. The MIME types, corresponding to each persistent object, which should be supported in the WADO Server response, are presented in the Table 1.

applications	DICOM
images	jpeg, gif, png, jp2
video (for multi-frame images)	mpeg
text	plain, html, xml, rtf, CDA

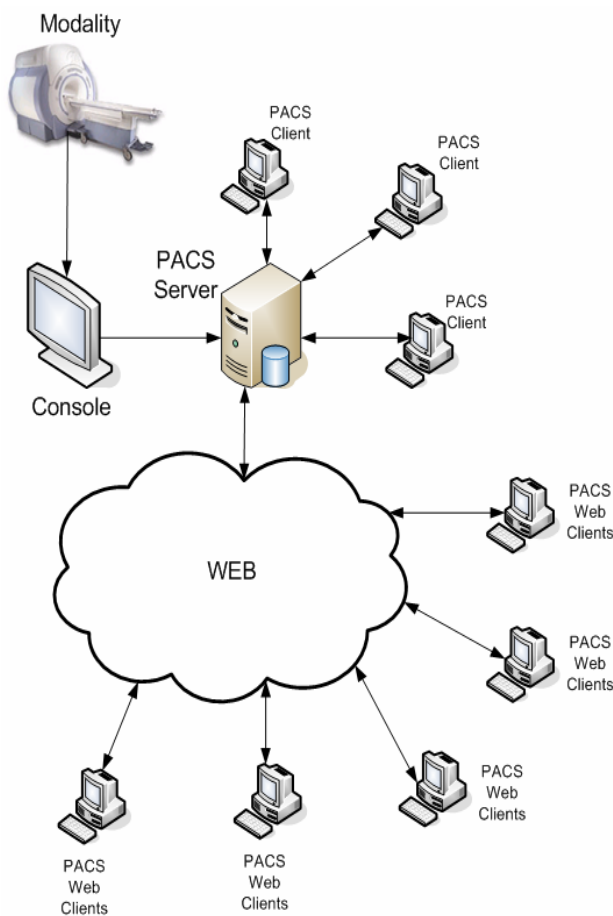*Table 1 - MIME Types of WADO Server Response*

Fig.3 - Web PACS Network Architecture

In this communication architecture the Web Client System becomes very flexible. The WADO functionality supports access to "native" DICOM data and common data format (e.g. JPEG image, TXT reports). So, in PACS including WADO (figure 3), client design can be either complex, providing advanced functionalities by taking "raw" DICOM data to be applied, or simple, relying on basic features of the Web browser. All functions (viewing processing and others) are typically

provided as controls within the server applications. These may be downloaded to the workstation as Java applets, so that the only necessary software on the workstations is a Web browser and Java application supporting platforms (thin software, easy to download and to install). There is no special client application.
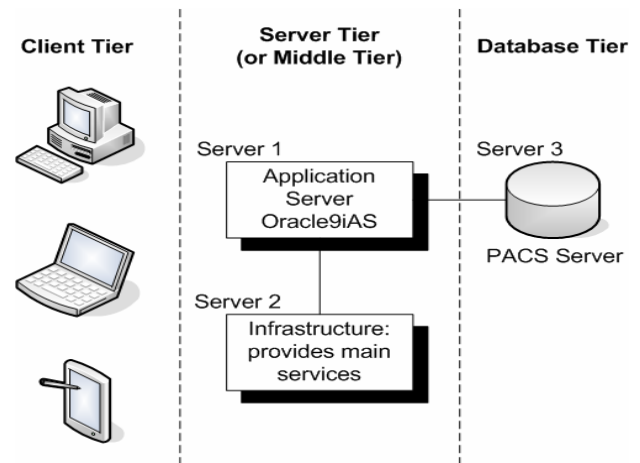

Fig.4 - Three-Tier Architecture

4 Web PACS Architecture

The implementation of the Web PACS architecture is based on Oracle Web based services and applications platform, called Oracle 9i Application Server and is implemented based on a three-tier architecture (figure 4).

The database tier comprises of databases that include data, metadata and enterprise management rules. In our system this tier includes all databases concerning the DICOM information. The user is not in direct contact with the data storage level. Every user has to retrieve the required data through the middle tier. This method is used to preserve data security and integrity. The end-user has no knowledge of the underlining processes cooperating in order to render data to him.

The server tier (or the middle tier) includes the solutions of the Application Server Oracle9iAS that concern formalized application and Web services. The server processes the service requests coming from the client tier. The service of a client tier request may demand access or change of the database tier data. The middle tier is the most important and complicated tier of this architecture. It provides the technology for Web application development. The middle tier of Oracle9iAS consists of Application Server and Infrastructure Server.

The client tier comprises the different kind of clients and it includes Web browsers, Web services

and back-office applications. The clients request services on the server tier using different networks and telecommunication protocols. The front-end interface of the applications appears on this tier, providing the end-user with all necessary information to fulfill the desired tasks [7].

The Application Server creates an expandable, secure and embedded platform middle tier, which it allows Web content provision, Web application support and communication with back-office applications. It improves the performance, scalability, and availability of frequently used Web sites that run on the Oracle9i platform. By storing frequently accessed URLs in memory, Oracle9iAS Web Cache eliminates the need of repeatedly process requests for those URLs on the Web server. Furthermore, HTTP server (part of Application Server), based on Apache Web technology, handles the http requests [8]. The Application Server uses the J2EE platform offering various advantages, because it supports: (a) JSP (Java Server Page), (b) Java servlets, (c) Enterprise JavaBeans (JVB) [9].

The existence of the Infrastructure Server is prerequisite for many of the Oracle9iAS Application Server Layer parts. There is a database inside the Infrastructure Server, which contains the whole of data and metadata that support all the individual parts of Oracle9iAS [5].

7 Conclusion

Real world activities demand Web services in a shared environment of information distribution. Medical images and reports should follow the World Wide Web way in applications development. In our Web PACS we have designed a system able to serve all the participants in digital radiology and to offer them all the facilities in order to manage the medical data, even if they are away of their workstations in the hospital.

DICOM, the dominant protocol in medical imaging communication, already provides the standard for Web development applications that is WADO. So, using Java technology in different modes (JSP, servlets, JavaBeans) and the Oracle portal development technology, we achieved to apply over Web the services that DICOM Server can provide.

The whole project results in providing "full" DICOM services through Internet in a real efficient way, overcoming the "wall" of a hospital intranet. Moreover, the portal platform can be further developed to provide more services than those, which PACS supports, offering Web functionality in other fields of medical information. More modules can be easily added, such as telemedicine facilities, teleconferences, etc. [5].

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