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# A service based approach for medical image distribution in healthcare Intranets

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ABSTRACT

The Digital Imaging and Communications in Medicine (DICOM) protocol is currently the ubiquitous standard for the communication of medical images and related data within the radiology department. However, seamless image distribution within the healthcare enterprise and especially with research and educational information systems is still hard to achieve, as software developers of such third-party applications have to go through the rather cumbersome task of adapting the DICOM communication model and implementing the DICOM protocol. This paper gives a brief outline of current trends in medical image distribution in the healthcare enterprise, and proposes a new technological approach for distributing DICOM images and related data through commonplace Internet technologies, based on the emerging web services software paradigm. In particular, the paper describes the DICOM Image Management (DIM) web service which acts as a façade for conventional DICOM sources allowing DICOM image data and related information, to be transformed into XML documents encapsulated in SOAP messages, enabling integration at the application level through general purpose standardized web technologies. Implementation issues are discussed and a demonstration of engaging the DIM web service is included.



## 1. Introduction

The Digital Imaging and Communications in Medicine (DICOM) protocol [1] has become the predominant standard for the communication of medical images and related data within the radiology Intranet. DICOM is continuously being enhanced to support new imaging and other diagnostic modalities (e.g. ultrasonography and visible light imaging) and relevant medical procedures (e.g. radiotherapy), while new storage media and advanced security issues are also addressed. Recently, the standard has been augmented with the DICOM Structured Reporting (SR) extension, a powerful and expressive mechanism for representing hierarchically structured clinical findings including links to the source diagnostic data, e.g. images, waveforms, etc. [2], thus extending the impact of the standard from the management of raw medical data to the more complex and broad tasks of diagnosis and patient management.

At present, as far as medical imaging is concerned, adherence to DICOM is practically always assumed, and efficient image distribution among different imaging modalities and information systems within the radiology department is realized via the DICOM communication protocol. However, seamless image distribution within the healthcare enterprise and especially to research and educational information systems is still hard to achieve, as software developers of such third-party applications have to go through the rather cumbersome task of adapting the DICOM communication model, implementing

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the DICOM protocol and keeping up with new changes in the standard.

Recently, the ubiquitous adoption of Internet and related technologies has made a considerable impact on extending medical imaging services outside the radiology department. Initially, web-based applications have enabled users to access DICOM image servers through a common web browser. Additionally, eXtensible Markup Language (XML) [3] technologies have been used to represent DICOM data in a generic standard way to promote data interchange amongst disparate healthcare systems.

The following paragraphs give a brief outline of current trends in medical image distribution in the healthcare enterprise, and propose a new technological approach for distributing DICOM images and related data through commonplace Internet technologies, based on the emerging web services software paradigm. In particular, this paper presents the DICOM Image Management (DIM) web service which acts as a façade for conventional DICOM sources allowing DICOM image data and related information, such as structured reports, to be transformed into XML documents encapsulated in SOAP messages, enabling integration at the application level through general purpose standardized web technologies. Implementation issues are discussed and a demonstration of engaging the DIM web service is included.

## 2. Medical Image Distribution in the Healthcare Enterprise

Today, medical image distribution is no longer limited to the radiology department, but it is also required in various hospital clinics and other parts of the extended healthcare enterprise [4]. Towards this end, the Integrating the Healthcare Enterprise (IHE) initiative [5] proposes a framework for tight functional integration of radiology and related information systems using pre-set workflow (integration) profiles that are implemented by well-defined transactions based on existing standards, such as DICOM and Health Level Seven (HL7) [6], as well as Internet technologies.

However, seamless image distribution within the healthcare enterprise and especially with research and educational information systems is still hard to achieve. During the past years, the Internet and related technologies have been widely introduced in the radiology department (and healthcare enterprise in general) to provide an easy and commonplace way of accessing clinical data and to support various healthcare processes. In the case of medical imaging, respective work addresses both aspects of image management as supported by the DICOM standard, namely data representation and data communication.

### 2.1. *Medical Image Access via Web-Browsers*

In terms of medical image communication and distribution, nowadays most Picture Archiving and Communication Systems (PACS) manufacturers provide a web browser access to medical images, tightly coupled to their PACS implementation. Various architectural approaches and systems have been proposed for the development of wed-based PACS (for some examples and overview of the field see [7,8]), while efforts have been made to implement generic DICOM web servers to access seamlessly disparate DICOM archives [9]. Common to all approaches is the fact that DICOM images that originate from dedicated medical imaging repositories and archiving systems can be accessed by individual users via a commonly available web browser, without any need for special software or hardware. Although an easy and efficient solution for simple image distribution services to individual users, web browser access to DICOM images has some drawbacks: (1) initial DICOM data are usually transformed into a web compatible format (usually Joint Photographic Experts Group (JPEG) for image data), so that information is not entirely preserved, e.g. related information included in the header file, or even image quality; (2) since the web browser is a thin client, it is not always easy to develop advanced functionality for processing, rendering, manipulation, and overall management of images and related information; (3) access to DICOM images and related information is limited to human users, while other software applications cannot take advantage of this web-based communication.

It should be noted that the need for software applications to independently access DICOM data through standard Internet technologies has been realized early by researchers in the field. Thus, the DICOM and ISO TC215/SC2 working groups have joined efforts to create standard guidelines for accessing and presenting DICOM images and related data over the Web. In this direction, the Web Access to DICOM Persistent Objects (WADO) supplement to DICOM standard [10] has been developed and is currently under ballot. WADO specifies a simple mechanism for accessing a DICOM persistent object (image, waveform, structured report, etc) from web pages or other software applications (e.g. an e-mail system), through the HTTP communication protocol. However, WADO does not support any other conventional DICOM services (e.g. find or store), and assumes that the unique identifiers required for retrieving an object from a DICOM archive are known by other means.

### 2.2. *XML and Medical Image Distribution*

In terms of data representation, the widespread adoption of XML technologies [3] has made a notable step towards easier integration of clinical data in healthcare information systems. Transforming DICOM objects in XML format mainly aims to enhance exchange of medical image data across the healthcare enterprise [11,12], especially as other clinical information systems and relevant standardization bodies begin to adopt XML technologies. For example, HL7, the prevailing standardization body for exchange of clinical and administrative data in healthcare, is currently promoting the use of XML for message syntax in the forthcoming versions of the standard [13], while it is developing the Clinical Document Architecture (CDA) for exchange of healthcare documents specifically based on XML technologies [14].

Special interest is drawn to DICOM structured reports, as it is usually one of the most important pieces of information that needs to be retrieved and communicated among DICOM servers and other healthcare information systems. Currently, several research efforts address the transformation of DICOM structured reports to XML and vice-versa, e.g.

[15,16,17], although XML has also been used to transfer DICOM header information between disparate clinical databases [18]. Representing DICOM structured reports and related information in XML mainly aims to:

- enable easy and efficient exchange of radiology reports and related data across the healthcare enterprise, especially as other clinical information systems are currently adopting XML technologies;
- make radiology reports and related data at the same time machine processable, human readable and web compatible;
- support data integration with general purpose research and academic tools (e.g. to create easily searchable clinical data repositories that support research, teaching and data mining for administrative and clinical protocol planning, budget control, etc).

So far, attempts to transform DICOM data into XML format address only the representation of data itself but do not support mechanisms to query DICOM servers and/or retrieve the image data and other DICOM objects. Although XML addresses the problem of data integration, it does not support control integration among disparate information systems.

### 2.3. *Service Oriented Architectures and the Web Service Paradigm*

Recently, the XML/SOAP web services programming paradigm [19] has been a catalyst for achieving both data and control integration among applications through commonplace Internet technologies. Initially developed by a group of software companies and now handled by the World Wide Web Consortium (W3C), web services are loosely defined as self-contained, self-describing, modular applications that can be located and invoked over the Internet. Web services are based on open Internet standards: built on the HyperText Transfer Protocol (HTTP), they use XML for data presentation while messaging is described in an XML-based messaging protocol, Simple Object Access Protocol (SOAP). Web services describe themselves through a standardized Web Service Description Language (WSDL) document, and can be published to one or more Intranet or Internet repositories for potential users to locate through a standard Universal Description, Discovery and Integration (UDDI) registry. A whole suite of additional standards are currently being developed to formally address issues such as security, reliability, transactions, etc.

In essence, web services are a middleware technology for developing service-oriented architectures (SOAs). A SOA refers to a collection of interconnected software entities (services) that provide some capability through exchange of messages, and can be described, discovered and invoked over a network. Although web services are a relatively recent development, the concepts underlying service-oriented systems are common to standard distributed middleware computing. Examples of earlier implementations of SOAs include the Common Object Request Broker (CORBA, Object Management Group Inc. Needham MA, USA), the Java Remote Method Invocation (RMI, Sun Microsystems Inc., Santa Clara CA, USA) and the Distributed Component Object Model (DCOM, Microsoft Co., Redmond WA, USA). However, the widespread adoption of Internet and related technologies, as well as the focus on concurrent communication and collaboration among people and applications, currently make web services the middleware technology of choice for the implementation of service-oriented systems.

Web services technology is a way for applications to expose software services using standard interoperability protocols, regardless of the platform on which they are implemented. Furthermore, third party applications that invoke web services do not need to know any of the web service implementation details; they only need to be able to send and receive XML/SOAP messages. Initially, it is expected that web services are mainly used as wrappers of existing applications serving to interconnect legacy systems without altering their code, as well as to decompose their usually complex functionality and offer it as separate, well-defined targeted services.

The web services paradigm has already gained broad industry support. In the healthcare sector, it has recently been identified as an especially important technology for the future of healthcare delivery and administration [20,21], and the first implementations are currently emerging. For example, preliminary forms of XML services (though not XML/SOAP web services as described above) have been successfully used as a middleware solution for integrating disease specific information systems into a single clinical workstation [22], and for supporting a web-based virtual patient record architecture [23]. The emergent XML/SOAP web services technology has been employed to enable integration of biology sequence data banks over the web [24], as well as to support a core infrastructure of components and services for the management of data from diverse sources in cancer informatics [25]. Moreover, web services are expected to play a key role in integrating the healthcare enterprise as they are currently being adopted by relevant standardization bodies. For example, HL7 is promoting web services for message exchange in the forthcoming versions of the standard [13], while IHE is already employing web services for the implementation of certain transactions of its integration profiles [5].

The following paragraphs describe a novel DICOM Image Management (DIM) web service that acts as a wrapper to any conventional DICOM image server, and exposes the principal DICOM services of query, retrieve, and store to any other software application over the Internet, using standard XML documents communicated via SOAP messages. This approach combines the advantages of using XML for DICOM data representation with the benefits of employing open ubiquitous web technologies for messaging and communication. Thus, DICOM image data and related information can be discovered, retrieved and maintained in a third party non-DICOM application in its fullness, and through open, standard messaging. The proposed web service interface was primarily developed to seamlessly integrate radiological data into a generic web-based e-learning environment that will support undergraduate medical education in the Democritus University of Thrace, Greece. However, it can also support integration of conventional DICOM sources with other web-service enabled applications such as authoring tools, general purpose image processing environments, and clinical web servers.

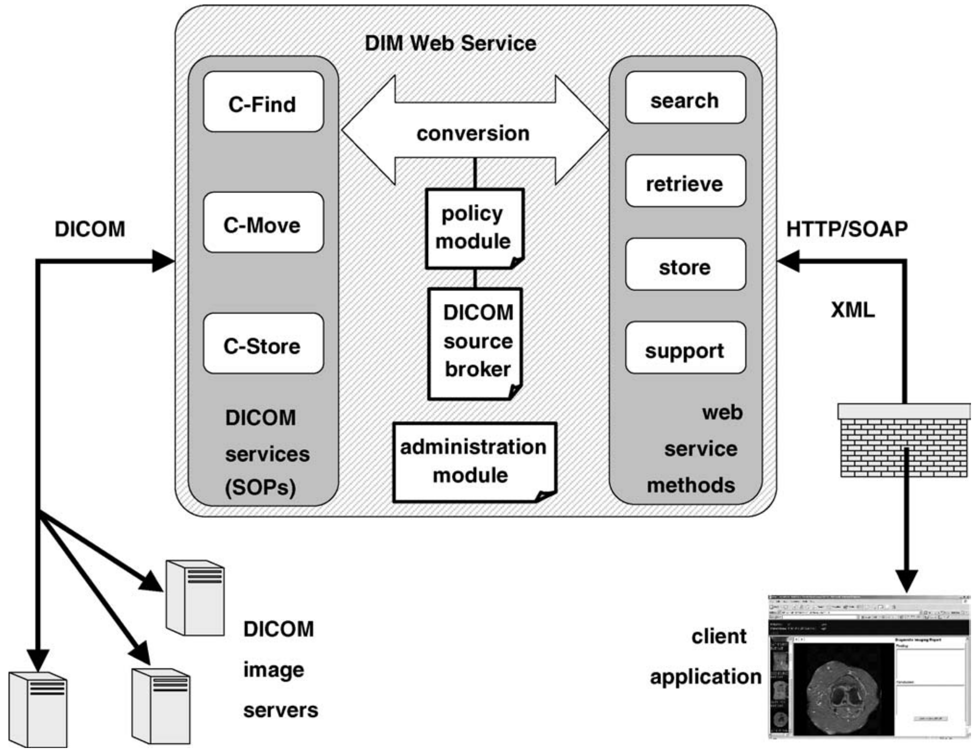


**Fig. 1 – The DIM web service architecture overview.**

## 3. DIM Web Service Description

The DICOM Image Management (DIM) web service transforms DICOM messages and related data into standard Internet communication for consumption by third party applications. In essence, it acts as a web façade for conventional DICOM sources, concealing the DICOM communication model and protocol specifics from the end application that requires access to the DICOM source.

### 3.1. *The DIM Web Service Architecture Overview*

The process of engaging the DIM web service as well as a schematic overview of its architecture is given in Fig. 1. The web service accepts queries from a client application about a DICOM server in SOAP/XML form, transforms them into the equivalent DICOM protocol services, communicates with the DICOM image server using the DICOM protocol, and transforms the results back into XML documents, encapsulated in SOAP messages. Any conventional DICOM source can use the proposed web service to expose the principal DICOM operations of query, retrieve, and store over the Internet, using XML documents communicated via SOAP messages. The web service can be invoked by any web-service enabled client application, regardless of its implementation specifics and the platform it runs on (this includes both thin web-based clients and conventional software applications).

Functional and information organization in the DIM web service is based on the DICOM information model. This model organizes information related to a medical image using a logical structure of information entities and their relationship. Basically, the standard specifies the entities involved in radiological operations, such as patients, visits, studies, images, reports, and other data objects. Each entity is characterized by a collection of attributes, which carry all information related to the particular entity. Every instance of study, series and data object in DICOM is assigned a unique number as an identifier (UID).

The DIM web service assumes the DICOM information model and implements the basic functionalities supported by the DICOM protocol for searching a DICOM image server and retrieving images, structured reports and other data objects, as well as storing in a DICOM archive. Different access privileges are supported via a policy module which takes into account administrative information about the user (either client application or end-user of the client application) and the target DICOM server.

The following section gives some details about the particular methods exposed by the DIM web service in order to implement the query, retrieve, and store, processes and general administrative facilities. Common to all methods exposed are certain input options that address security, privacy and management issues. In this respect, every method call requires inclusion of username (client application or end user specific) and password. Additionally, an optional list of target DICOM servers might be included. Finally, data anonymization can either be requested at method call, or be imposed by the web service itself following preset policies that take into account several factors such as the target DICOM server, the DIM web service client application, the end user of the client application, etc.

Currently, the DIM web service is using a proprietary XML schema for representing DICOM tags. This schema was created with simplicity in mind, to be used by developers not familiar with the DICOM standard. Given a third-party XML schema for DICOM data representation, an eXtensible Stylesheet Language Transformation (XSLT) [26] can be constructed to convert from one XML schema to another, either within the DIM web service or at the side of the client application.

### 3.2. Methods Exposed by the DIM Web Service

The web service exposes several methods that support searching at various levels of the DICOM information model. All search methods implement the C-Find Service Object Pair (SOP) of the DICOM protocol [1]. Therefore, in order to formulate a query for any level of the information model, the unique identifier (UID) for that level as defined in DICOM must be known. The starting point for searching can be either the patient or the study level. The result of each search at any level is a list of information entity instances included in this level (and their UIDs where appropriate), information related with the listed object instances, as well as information about the DICOM server where the listed object was found.

The functionality of the various search methods exposed by the DIM web service is briefly described below:

- *FindPatients*: searches for patients and retrieves patient-related data from a DICOM server.
- *FindStudies*: searches and retrieves studies and related data.
- *FindSeries*: retrieves series information, within a particular study.
- *FindObjects*: retrieves information about images or other objects within a given series (objects can be various types of images, waveforms, structured reports, and a number of other information objects generated and stored as part of the DICOM object file).

The web service also exposes a generic retrieve method for all types of DICOM data objects and related meta-information. Additionally, emphasis is placed on the retrieval of image data and structured reports which are especially handled by dedicated retrieve methods. The internal implementation of the methods that realize this facility is based on the C-MOVE SOP of the DICOM protocol. Each DIM retrieve method formulates its input parameters according to the WADO supplement to DICOM standard [10], although the communication mechanism is SOAP messaging and not the HTTP call as required by WADO. The functionality of the various retrieve methods exposed by the DIM web service is briefly described below:

- *RetrieveObject:* retrieves a generic DICOM data object from a DICOM repository.
- *RetrieveImage:* retrieves an image object – the result of the method can be the requested data stream and/or a URL link to the requested image file.
- *RetrieveSRDocument*: retrieves a DICOM structured report as an XML document.

Image and related data can be stored in a DICOM archive using the Store Facility of the DIM web service. Methods of this facility internally implement the C-STORE SOP of the DICOM protocol. Their functionality is briefly described below:

- *StoreDicomFile*: uploads a DICOM file into a DICOM repository.
- *StoreImage*: combines a non-DICOM image, e.g. bitmaps (BMP), Joint Photographic Experts Group (JPEG), and Tagged Image File Format (TIFF), and related attributes to create a DICOM file and stores it into a DICOM repository.
- *StoreSRDocument*: combines structured report document in XML format as well as related information needed to construct the DICOM file and stores it in a DICOM repository.

Finally, administrative information about the web service itself can be retrieved by the *GetServiceParameters* method. This method informs the client application about the list of DICOM servers supported by the web service and their attributes (e.g. application entity title, type and description of the DICOM server, SOP supported, etc).

### 3.3. Engaging the DIM Web Service

The DIM web service methods presented in the previous section are formally described in the corresponding WSDL document. The complete DIM web service WSDL document, as well as detailed documentation and other related information, can be retrieved from: http://iris.med.duth.gr. Using this document, software developers of third party applications can build the appropriate SOAP messages to invoke and consume the web service. A portion of the WSDL document for the *RetrieveImage* method is displayed in Fig. 2. One can clearly see the structure of the *RetrieveImage* method, the input arguments (queryImage, retrieveOptions, imageOptions), as well as the expected response. Due to space limitations, the detailed info for each argument is skipped.

A software developer of a client application can engage the particular *RetrieveImage* method as described in the above part of the WDSL document as simply as presented in the code sample (written in C#) shown in Fig. 3. It should be noted, that most current Integrated Development Environments (IDE) can generate automatically the required SOAP messages out of the WSDL document. This source code as illustrated in Fig. 3, once executed, generates a SOAP request message to the DIM web service. The generated SOAP request message and the SOAP response from the DIM web service are illustrated in Fig. 4.

## 4. Implementation Issues

The DIM web service has been developed in C# using the MS .Net Framework 1.1 (Microsoft, Redmond WA, USA) and uses the DICOM library DicomObjects 4.1 (Medical Connections, Reynoldston, UK). System requirements at runtime include the MS Internet Information Server >5.x, and MS .Net Framework 1.1, (Microsoft, Redmond WA, USA).

In practice, DICOM servers can be rather slow to respond in search and retrieve requests mainly due to the size of the data involved, and this can considerably compromise com-

```
<?xml version="1.0" encoding="utf-8"?>
<!--(the part that follows is edited from the DIM Web Service WSDL document)-->
<definitions xmlns:s="http://www.w3.org/2001/XMLSchema" xmlns:s1="http://..."  . . . >
<types>
    <s:schema elementFormDefault="qualified" targetNamespace="http://iris.med.durh/DIM/">
        <s:import namespace="http://iris.med.duth.gr/DIM/WSInformationModel.xsd"/>
            <s:element name="RetrieveImage">
                <s:complexType>
                    <s:sequence>
                        <s:element minOccurs="0" maxOccurs="1" ref="s1:queryImage"/>
                        <s:element minOccurs="0" maxOccurs="1" ref="s1:retrieveOptions"/>
                        <s:element minOccurs="0" maxOccurs="1" ref="s1:imageOptions"/>
                    </s:sequence>
                </s:complexType>
            </s:element>
        <s:element name="RetrieveImageResponse">
            <s:complexType>
                <s:sequence>
                    <s:element minOccurs="0" maxOccurs="1" ref="s1:RetrieveImageResult"/>
                </s:sequence>
            </s:complexType>
        </s:element>
    </s:schema>
</types>
. . . . . . .
. . . . . . .
<message name="RetrieveImageSoapIn">
       <part name="parameters" element="s0:RetrieveImage"/>
</message>
<message name="RetrieveImageSoapOut">
       <part name="parameters" element="s0:RetrieveImageResponse"/>
</message>
<portType name="DicomImageManagementSoap">
    <operation name="RetrieveImage">
        <input message="s0:RetrieveImageSoapIn"/>
        <output message="s0:RetrieveImageSoapOut"/>
    </operation>
</portType>
```

**Fig. 2 – A fraction of the DIM web service WSDL document that formally describes (part of) the *RetrieveImage* method. Due to space limitations, the detailed info for each argument is skipped.**

munication and system performance. Related scalability and reliability issues in the DIM web service are addressed by employing an asynchronous communication pattern. Thus, for methods that may correspond to long running transactions with a DICOM server (e.g. *FindPatient*, *RetrieveObject*, etc.) an alternative implementation is also provided. The original method is split in two parts. The first part includes a request of the appropriate operation (e.g. find patients) and its DIM web service response is a token. Subsequently, the client application invokes the second part of the method inquiring for results (if ready) of the previously submitted request, as identified by the relevant token. This communication pattern results in a better performance and simpler implementation for the client application whenever long running DICOM server operations are involved. It might involve some extra delay, since multiple messages are required to get the desired result (until the original request is completed), but it nevertheless supports efficiently long running transactions.

```
DIM.DicomImageManagement dim = new DIM.DicomImageManagement();
DIM.ImageOptions imageOptions = new DIM.ImageOptions();

DIM.RetrieveOptions retrieveOptions = new DIM.RetrieveOptions();
retrieveOptions.AE = "Server1";
retrieveOptions.user = "demo";
retrieveOptions.password = "password";

DIM.QueryImage queryImage = new DIM.QueryImage();
queryImage.studyUID  = "1.2.840.113619.2.3.281.9032.2003.3.30.1120";
queryImage.seriesUID = "1.2.840.113619.2.3.281.9032.2003.3.30.1120.2";
queryImage.objectUID = "1.2.840.113619.2.3.281.9032.2003.3.30.1120.2.1.1";
queryImage.enableURL = true;
queryImage.type = DIM.QueryImageType.JPEG;
DIM.ResultImage result = dim.RetrieveImage(queryImage, retrieveOptions, imageOptions);
```

**Fig. 3 – A sample code (in C#) that demonstrates the *RetrieveImage* DIM web service method call, as performed from a client application.**

**REQUEST MESSAGE**

```
<?xml version="1.0" encoding="utf-8"?>
<soap:Envelope xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
               xmlns:xsd="http://www.w3.org/2001/XMLSchema"
               xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"
               xmlns="http://iris.med.duth.gr/DIM/WSInformationModel.xsd">
  <soap:Body>
    <RetrieveImage xmlns="http://iris.med.duth.gr/DIM/">
      <queryImage
               objectUID="1.2.840.113619.2.3.281.9032.2003.3.30.1120.2.1.1"
               seriesUID="1.2.840.113619.2.3.281.9032.2003.3.30.1120.2"
               studyUID="1.2.840.113619.2.3.281.9032.2003.3.30.1120"
               type="JPEG" enableURL="true"  />
      <retrieveOptions user="demo" password="password" AE="Server1" />
      <imageOptions imageQuality="90" frameNumber="1" annotation="Patient"
       charset="UTF-8" />
    </RetrieveImage>
  </soap:Body>
```

**RESPONSE MESSAGE**

```
<?xml version="1.0" encoding="utf-8"?>
<soap:Envelope xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
               xmlns:xsd="http://www.w3.org/2001/XMLSchema"
               xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"
               xmlns="http://iris.med.duth.gr/DIM/WSInformationModel.xsd">
  <soap:Body>
    <RetrieveImageResponse xmlns="http://iris.med.duth.gr/DIM/">
      <RetrieveImageResult
               ImageURL="http://iris.med.duth.gr/Wado/RetrieveImage.aspx?
               requestType=WADO&
               studyUID=1.2.840.113619.2.3.281.9032.2003.3.30.1120&
               seriesUID=1.2.840.113619.2.3.281.9032.2003.3.30.1120.2&
               objectUID=1.2.840.113619.2.3.281.9032.2003.3.30.1120.2.1.1" >
        <ImageData>
               FF D8 FF 00 10 4A 46 49 46 00 01 00
               00 00 00 00 10 00 01 02 02 00 01 01
               00 00 01 00 10 00 00 00 00 00 01 01
               ...
       </ImageData>
       <errorMessage errorText="success" errorCode="0" success="true" />
     </RetrieveImageResult>
    </RetrieveImageResponse>
  </soap:Body>
</soap:Envelope>
```

**Fig. 4 – SOAP messages (request and response) exchanged between a client application and the DIM web service during the call and response of the *RetrieveImage* method.**

This may prove especially valuable in cases of wireless connections (e.g. handhelds), allowing the client to move seamlessly across various network cells (or on and off the network) while engaging in a request that needs considerable time for completion.

Basic security is achieved through the Secure Sockets Layer (SSL) encryption mechanism for data transmission and this is enhanced by a user authorization process. The DIM web service is currently being augmented to use additional web services security specifications in order to provide end-to-end integrity and confidentially. In particular, the WS-Security specification [27] is considered for message integrity, message confidentiality and proof of identity, while the XML-Encryption [28] and XML-Signature [29] specifications are employed to enforce confidentiality and ensure that messages are transmitted without modifications.

For demonstration purposes, a fellow software developer not acquainted with the DICOM standard was asked to build a web-based application that retrieves, displays and stores DICOM images and related information from various DICOM servers solely by employing the DIM web service as this is published and described in the respective web site: http://iris.med.duth.gr/. This demo application was developed in C# using the ASP.NET platform (Microsoft, Redmond WA, USA) for the MS Internet Information Server >5.x (Microsoft, Redmond WA, USA). The development process was reported to be simple and uncomplicated and a demo application prototype was completed in about 5 working days.

The demo application is not itself DICOM aware. However, it employs the various methods of the DIM web service to access various DICOM servers in order to search and retrieve DICOM images and related data, which are then displayed to the user's web browser. Fig. 5 displays two representative web pages showing the results of a query for patient and/or study, and the Patient Manager, which allows the user to browse and view studies, series and images for a particular patient. In

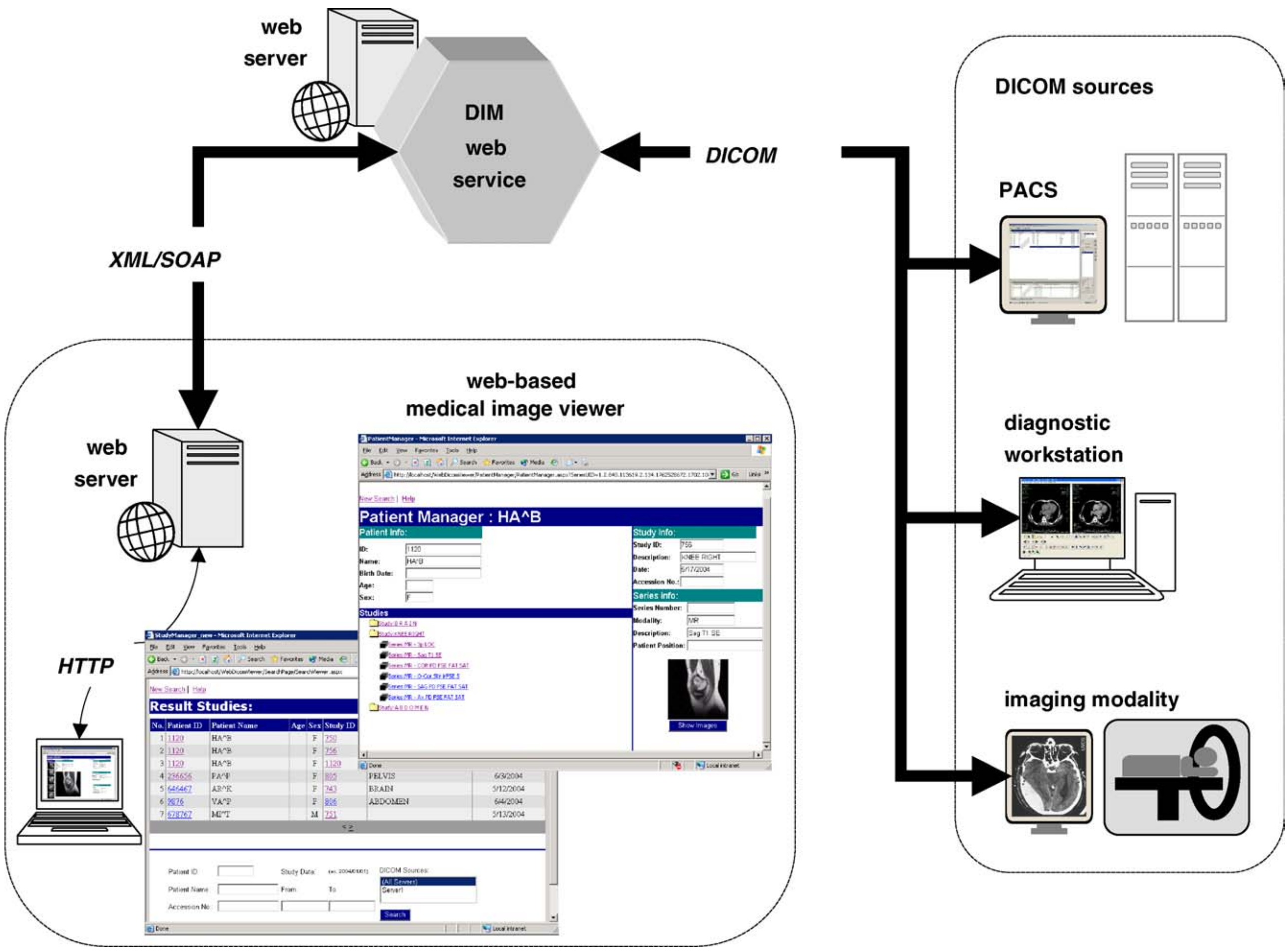


**Fig. 5 – Example of a demo application engaging the DIM web service in order to access three different DICOM servers within a hospital LAN.**

essence this demo application can be regarded as a generic web-based front end for disparate DICOM sources.

The demonstration of engaging the DIM web service via the web-based demo application included retrieving DICOM images from three different DICOM sources within a hospital 100 MB/s LAN, as shown in Fig. 5. The DIM web service and the demo web-based application were installed on a computer with Intel Pentium 4 processor at 2.8 GHz, 1GB RAM, running MS Windows Server 2003 operating system and the MS Internet Information Server 6.0 (Microsoft, Redmond WA, USA). The DICOM sources used in the demonstration included (1) a PACS workstation, Centricity RA 600 v6.1 (GE Medical Systems, Giles, UK), installed on a HP workstation XW8000, with an Intel Xeon processor at 2.66 GHz and 1 GB RAM; (2) a 1.0T MR Signa Scanner (GE Healthcare, Giles, UK), workstation software version 9.1.0311b, installed on a SUN workstation with a IP30 processor at 225 MHz and 512 MB RAM; and (3) an eFilm workstation v1.5.3 (Merge eFilm, Milwaukee, WI, USA), installed on a workstation with a Pentium 4 processor at 2.66 GHz, and 512 MB RAM. The demo web-based application is currently available for demonstration over the Web at http://iris.med.duth.gr/.

The primary goal of proposed web service approach is to hide the complexity of the DICOM protocol from the software developer of third party applications mainly in the educational and research application field; therefore performance itself is not the central issue of our work. The DIM web service creates essentially an extra wrapper layer to conventional DICOM servers, thus adding extra communication load and the corresponding processing load of transforming DICOM data to XML. Therefore, in the general case the use of DIM web service is expected to result in increased overall communication times. Although a thorough performance test is outside the scope of this paper, in order to get an estimate of this expected increase in communication time we performed indicative time measurements using the experimental set-up shown in Fig. 6. The DICOM server involved was an eFilm workstation v1.5.3 (Merge eFilm, Milwaukee, WI, USA) installed on a computer with Intel Pentium 4 processor at 2.8 GHz, 1GB RAM (unit C1 in Fig. 6). The DICOM aware application (using the same DICOM library as the web service), the DIM web service and the DIM web service aware application were installed on different workstations, each with an Intel Pentium 4 processor at 2.8 GHz, and 512 MB RAM (units C2-C4 in Fig. 6). Testing involved the DICOM C-MOVE operation (i.e. retrieval of an identified object from a DICOM server) performed for 1200 different DICOM objects in a hospital 100 MB/s LAN. In test scenario (A), measured mean times for the 1200 random C-MOVE operations were found to be: $T_1 = 625 \pm 41$ ms, $T_2 = 626 \pm 42$ ms, $T_3 = 27 \pm 11$ ms

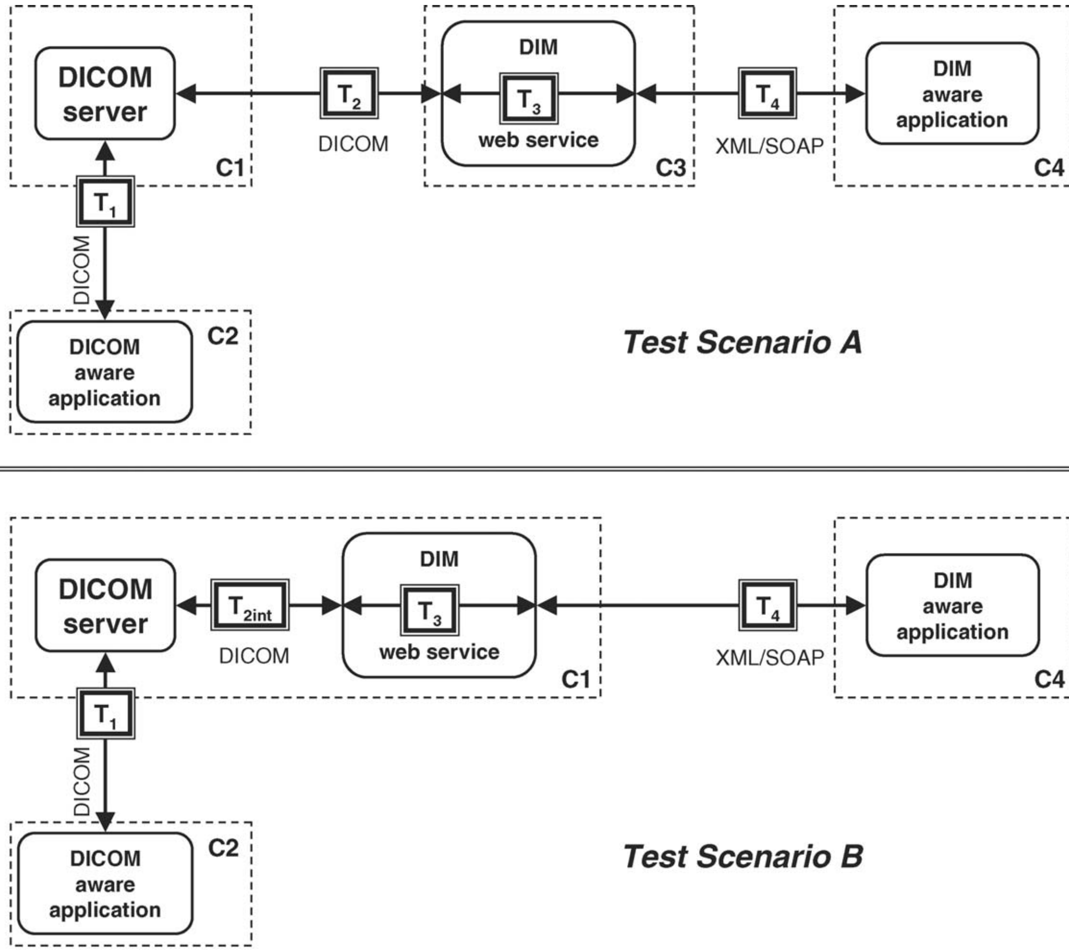


**Fig. 6 – Experimental setup configuration for comparing the performance of web service based image transmission with that of direct DICOM transmission.**

and $T_4 = 134 \pm 66$ ms. This indicates that when the DIM web service wrapper is involved there is an 26% increase in overall communication time for the C-MOVE DICOM operation for this particular set-up, while DICOM-to-XML transformation time (time interval T3) is about 4% of the overall communication time when DIM web service is involved. In test scenario (B), the DIM web service was installed on the same machine as the DICOM server, and in this case measured mean times for the same set of 1200 C-MOVE operations were found to be: $T_1$=$625 \pm 41$ ms, $T_{2int} = 121 \pm 21$ ms, $T_3 = 28 \pm 12$ ms and $T_4 = 132 \pm 65$ ms. It should be noted that when the DICOM server and its DIM web service wrapper are on the same machine, there is a notable 55% decrease in the overall communication time for the C-MOVE operation when the DIM web service is involved. This improvement in overall performance is mainly due to the rather complex association negotiation of the DICOM protocol [30,31] which considerably increases the overall communication time when performed over the network. When the DIM wrapper is on the same machine with the DICOM server, this communication is limited within the same computer and only the stateless SOAP/HTTP communication is performed over the network, thus resulting in a notable overall decreased communication time.

## 5. Discussion

The proposed DIM web service aims to support communication and integration of DICOM image sources with other applications using internet standards, thus enabling the seamless distribution of DICOM images and structured reports using commonplace Internet technologies. Examples of such applications, that do not necessarily implement DICOM, could include Internet based medical e-learning environments, medical research support tools, medical expert systems and other clinical information systems.

As already mentioned, closely related to this work is the WADO supplement to DICOM standard, which specifies a simple mechanism for accessing a DICOM persistent object from Web pages or XML documents, through the HTTP communication protocol, using already known DICOM UIDs. However, WADO does not define a way for searching DICOM sources. In contrast, the DIM web service supports searching DICOM archives over the Web, as well as storing and retrieving DICOM data objects. It should be noted, that although the retrieval process is based on the HTTP protocol, the DIM web service employs second generation web service technologies, namely XML/SOAP messaging and all related metadata technologies (e.g. WSDL, UDDI), thus supporting a much broader range of services related to the overall management of DICOM images than the ones addressed by the WADO standard. Therefore, although the logic and the conceptual requirements set forth in the WADO standard apply to the retrieval facility of the DIM web service, the implementation particulars differ.

The DIM web service is a first step towards developing a cluster of collaborating web services for advanced radiology services over the Internet. Short term goals address the development of added-value web services that use the DIM web service to access medical image data from various sources in order to perform more complex tasks, such as composite queries and mining of DICOM repositories for epidemiology, research, teaching, and administration purposes. In particular, this work is part of our efforts to seamlessly integrate clinical data into a generic Internet based e-learning environment that will support undergraduate medical education in Democritus University of Thrace, Greece [32]. The project involves the use of open source technologies and off-the-shelve components to deploy an integrated e-learning environment, based on a conventional e-learning platform to support pre-clinical teaching, tightly integrated with teleconferencing technology for the real-time and/or on-demand transmission from an examination room or the operating theatre to the lecture room, to enhance clinical apprenticeship and provide extended real-world experience. At the core of the project is the effort to develop web service façades for legacy healthcare information systems, in order to extract and communicate educational information using common web standards (as opposed to standards proprietary to the medical environment). In this respect, the DIM web service is intended to be engaged in order to provide clinical data for a radiology teaching files authoring tool, as well as directly through the integrated e-learning environment for dynamic clinical data retrieval during the instructional process, e.g. to explain how a diagnostic imaging data set is manipulated and reviewed in order to reach diagnosis and construct the final report.

We strongly believe that this current implementation only scratches the surface of the potential capabilities web services might have for radiology and other healthcare information systems. Adopting an XML/SOAP web service oriented architecture for medical image management and distribution in healthcare Intranets and even Extranets may have many advantages when compared to traditional system integration and/or simple web-based application interfaces. These include the ability to give compound structure to queries and results, handle complex tasks that require coordination of a number of disparate applications, and implement store and forward techniques. Using a web service façade, traditional DICOM image servers can communicate seamlessly with general purpose research and academic tools (e.g. to create easily searchable clinical data repositories that can support research, teaching and data mining for administrative and clinical protocol planning, budget control, etc). Moreover, providing image data and related information in an XML format supports essentially the ongoing effort to create multimedia patient records and display them easily in various clinical workstations and devices with different display capabilities (from diagnostic workstations, to operating room displays and even handheld devices in wireless networks).

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