Leveraging Internet Technologies with DICOM WADO

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Published online: 13 March 2012
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Abstract The digital imaging and communications in medicine (DICOM) 3.0 standard was first officially ratified by the national electrical manufacturers association in 1993. The success of the DICOM open standard cannot be overstated in its ability to enable an explosion of innovation in the best of breed picture archiving and communication systems (PACS) industry. At the heart of the success of allowing interoperability between disparate systems have been three fundamental DICOM operations: C-MOVE, C-FIND, and C-STORE. DICOM C-MOVE oversees the transfer of DICOM Objects between two systems using C-STORE. DICOM C-FIND negotiates the ability to discover DICOM objects on another node. This paper will discuss the efforts within the DICOM standard to adapt this core functionality to Internet standards. These newer DICOM standards look to address the next generation of PACS challenges including highly distributed mobile acquisition systems and viewing platforms.

Keywords Web technology · Wide area network (WAN) · Systems integration · PACS integration · Image distribution · Integrating healthcare enterprise (IHE) · Internet technology · Enterprise PACS · Digital imaging and communications in medicine (DICOM)

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Background

The digital imaging and communications in medicine (DICOM) standard is not a static document. Each year, new objects are defined to support new imaging modalities, new ways of representing data, and new ways to communicate that data among multiple systems. The DICOM standard committees are composed of over 750 experts from vendors, professional societies, government agencies, and general interest members. There have been 155 supplements to the DICOM standard between 1993 and 2011.

The DICOM standards committee has taken several steps in developing standards that enable delivery of DICOM objects and metadata over hypertext transfer protocol (HTTP). In 2004, DICOM Part 18, web access to DICOM persistent objects (WADO), was ratified by DICOM working group 27 [1]. The standard was further advanced in 2011 with the final text addition of DICOM Part 18, Supplement 148 WADO by means of web services [2]. These DICOM standards are directly related to delivering medical imaging solutions over the Internet using HTTP.

This paper outlines the developmental progress of these standards and how they apply to the basic functions of a web-based imaging application. It will also provide an overview of the integrating the healthcare enterprise® (IHE) [3] integration profiles that use these standards.

Background of Internet Technologies

The success of the World Wide Web can partly be attributed to the adoption of open standards on how data will be accessed, transmitted, and secured. This provides an infrastructure that can be extended into the field of medical imaging.

Access

The Internet engineering task force (IETF) and the World Wide Web Consortium (W3C) coordinated the standards development of HTTP version 1.0 in 1996 [4, 5]. HTTP is the foundation for the World Wide Web and is a networking protocol for distributed information systems. HTTP standard follows the client–server computing model—a web browser is a client that submits a *request* message to a server. An application hosted on a web site is considered the server that *serves* the requested data to the client.

Uniform resource locators (URLs) follow HTTP schemes to define and locate the HTTP resources on a network. URLs are sequences of strings that identify a specific response and define the standard to be used in the request. For example, the URL <http://medical.nema.org> means the HTTP standard should be used to request the resource found at address *medical.nema.org*.

Like DICOM, FTP, and SMTP, HTTP is an application layer protocol of the transmission control protocol (TCP) over Ethernet. TCP over Ethernet manages the physical communication of devices on a network and the transport of data packets. HTTP delivers resources, such as HTML data, over a TCP connection to a browser application.

Consumption

Hypertext markup language (HTML) is the standard markup language for web pages, maintained by the W3C. An HTML page, or resource, consists of nested HTML elements, which are tags and tag pairs that define the content following or in between tags. This content can be text, tags, comments, or other text-based content.

A web browser does not directly display HTML content to users; instead, it parses the HTML document via the HTML tags to make meaningful use and representation of the encoded data and construct a viewable web page. HTML webpages can embed scripts from languages such as JavaScript. The W3C became the governing body for HTML standard with the introduction of version 3.2 [6].

As of 2011, HTML 4.0.1 is considered the accepted standard, and the majority of web users have browsers that fully support it. Major updates to HTML 3.2 included introduction of improved tags, cascading style sheets (CSS), focus on internationalization and standardizing interpretation of HTML code and character encoding by browsers. CSS is a style sheet language used to separate document presentation from document content. Internationalization was mostly achieved through introduction of document type declaration and specification of character encoding.

Although backward compatible, HTML5 is a major overhaul of HTML 4.0.1. New parsing rules, inline scalable vector graphics, and global attributes are some of the

various changes introduced by HTML5. The evolutionary effort of HTML5 comes from its introduction of markup and application programming interfaces for complex web applications. These technologies are proposed to provide the functionality to carry out complex and expensive threads and applications within a browser (e.g., hardware-accelerated 3D rendering by WebGL [7]). These technologies reduce the need for thick client software applications and move various applications onto the web and the web browser.

Security

IETF defined the standards protocol transport layer security (TLS) and its predecessor secure socket layer (SSL). The TLS protocol defines methodologies to enforce encryption and authentication on a client–server connection. HTTP secure (HTTPS) combines HTTP and TLS/SSL to allow encrypted communication over HTTP. Unlike HTTP, HTTPS is a stateful protocol that uses handshaking procedures to define the connection's security between a client and a server. TLS uses cryptography methods for privacy and randomly generated, encrypted session keys to generate a secure connection. The server provides a digital certificate, which includes the server name, the trusted certificate authority, and the server's public encryption key for identification purposes. There are two advantages of TLS. The first is the on-demand nature of encryption, which removes the necessity to encrypt original data on server-side storage. The second is that the encrypted data are protected from potential eavesdropping during transmission. TLS enforces encryption only during transmission; data are received decrypted by the client.

Web Services

Web services are a means of interchanging information models between disparate systems. The W3C defines a web service as a software system designed to support interoperable machine-to-machine interaction over a network. A web service permits communication between multiple systems, where the transmitted data are not intended for consumption by web browsers. WS defines an interface language, known as web services description language. Systems interact with a web service using simple object access protocol (SOAP) messages. These messages are generally extensible markup language (XML) messages that are communicated through HTTP. There are three common uses for web services: remote procedure calls (RPC), service-oriented architecture (SOA), and representational state transfer (REST). An RPC is a message initiated by a client to execute a specified procedure on a known remote server. SOA is a methodology to develop and maintain software as services, and web services can be used to define

communication between services as messages (compared to operations). REST defines protocols to well-known operations, such as HTTP GET, POST, PUT, etc. REST does not interact with messages or operations but rather with stateful resources.

Web services have gained popularity by providing flexible ways of integrating multiple systems with much lower cost of interoperability than traditional DICOM and health level seven (HL7) version 2. Increased adoption drove web services to become standard components of many software development kits, integrated development environments, and other modern developer tools.

Overview of DICOM and IHE Web Service Coverage

In order to provide functional web-based imaging study delivery, a set of basic services are desired. Content discovery services provide a query and/or notification interface to discover available imaging studies. Metadata retrieval services provide the information required to deliver study data and images in the correct context. Object retrieval services deliver imaging objects such as an image or report to the object consumer. Renditions allow for the content consumer to view objects in non-DICOM format. Transformation services apply manipulations to the imaging objects such that they may be retrieved and viewed in the desired presentation format. These services are currently provided through the existing non-web-based DICOM standard using the service-object pair class model of DICOM, where information object definitions are paired with services like DICOM C-MOVE and C-FIND to provide the necessary transactions. Refer to Table 1 below for an outline of the DICOM web standards and IHE frameworks including coverage of basic services desired for imaging applications. IHE cross-enterprise document sharing for imaging (XDS-I) [8] and cross-community access for imaging (XCA-I) [9] integration profiles include components common to the WADO standard.

In a typical picture archiving and communication systems (PACS) environment, these high-level services are provided using DICOM methods that may not easily lend themselves to web integrations. As medical image data access is desired beyond PACS workstations, it is more expensive to move all

original DICOM objects in a study to the display application, especially when it is not needed for the use case. The ubiquitous platform for providing enterprise access to data today is through the web. The typical web browser can place constraints on the type of data that may be provided and may require additional services such as renditions in order to display images within the native browsing interface as noted in Table 2 below.

1. Content discovery

Sample discovery queries:

- What exams are available for this patient?
- Who has had an imaging exam performed today?

The DICOM standard provides a single method for discovery of patient and studies using a service named C-FIND. The DICOM C-FIND service is not easily integrated to web standards without creating middleware services. Internet standards could be applied to replicate C-FIND functionality in a browser environment. Today, in common web-based consumer image sharing applications, albums, people, and images can be discovered through a simple URL call. The DICOM standard committees have not yet defined a web standard to address direct imaging content discovery. There are other methods often used when discovering studies to be displayed in the browser; a patient centric application such as an electronic medical record (EMR) or personal health record may already have been updated with a list of imaging patients/studies through a pushed HL7 message, or may also have implemented an XDS-I or XCA-I registry for content discovery.

2. Metadata retrieval

Sample metadata requests:

- What is the size of the target image?
- How many images are in this series?
- How many series are there in this study?
- Are there any Key Image Note (IHE:KIN), DICOM Greyscale Softcopy Presentation State, or IHE Consistent Presentation of Images objects?

DICOM provides important structural, descriptive, and technical data (metadata) with each individual object header within a study. In order to discover this metadata, an object must be retrieved and parsed. Performing this step in

Table 1 An overview of basic web image service coverage by current DICOM standards and IHE profiles

Framework	Content discovery	Metadata retrieval	Object retrieval	Transformations	Renditions
WADO			Yes	Optional	Yes
WADO via WS		Yes	Yes	Optional	Yes
XDS-I	Yes	Limited	Yes	Optional	Optional
XCA-I	Yes		Yes	Optional	

Table 2 DICOM standards for web and non-web basic image service delivery

Framework	Content Discovery	Metadata Retrieve	Object Retrieval	Transformations	Renditions
Web-based DICOM standards	–	WADO via WS	WADO, WADO via WS	WADO, WADO via WS	WADO, WADO via WS
Non-Web DICOM standards	C-FIND	C-FIND	C-MOVE C-GET	–	–

compliance to traditional DICOM standards requires an entire DICOM object to be transferred to the target application. This transfer becomes a significant burden to web-based applications, due to the need to retrieve the entire object with all structural data for the simple purpose of retrieving metadata. As of August 2011, DICOM has provided a standard method for accessing metadata; WADO via web services (DICOM Part 18, Supp. 148)[1]. This standard allows metadata to be retrieved for multiple DICOM objects over SOAP web services without the need to transfer the entire DICOM structural data.

3. Object retrieval

Sample object retrieval requests:

- Request for a DICOM object.
- Request for a HTML based structured report.
- Request for a series of images.
- Request for single frame from within a multi-frame object.

When an object identity is discovered, it can then be requested from the image source. This action traditionally is performed via DICOM C-MOVE, implemented using a TCP/IP protocol which is not easily implemented over the public Internet using HTTP. DICOM WADO provides a URL-based request model for retrieving single objects. The DICOM WADO via web services supplement also provides a multi-object request and retrieval interface within a single transaction over HTTP(S).

4. Renditions

Sample rendition requests:

- Request for a JPEG, or portable network graphic rendition of an image or set of images for display within a web browser.
- Requesting a text/html representation of a DICOM structured report.

Renditions are traditionally performed within the context of the DICOM object itself, and are not available to web-based applications without interpreting the DICOM object itself in the middleware layer. The DICOM WADO standard provides a framework and a requirement for WADO service providers to deliver these renditions directly to the web-based application over HTTP(S).

5. Transformations

Sample transformation requests:

- Request for a rendered image 200 pixels in width as a thumbnail.
- Requesting a sub-region of a rendered image at the specified window level.
- Requesting an image with a presentation state applied. When an object is returned, often the professional that is reviewing the study wishes to have markup, brightness and contrast (window/level) adjustments, and other manipulations applied to the image. Traditionally, these actions are the responsibility of the imaging client and are often managed through proprietary implementations. DICOM WADO and WADO via web services provide an optional framework for delivering these manipulations over the web via a URL or web service call.

Overview of the Base DICOM WADO Standard (DICOM Part 18)

DICOM WADO provides the capability to return DICOM content identified through URL interface over HTTP(S). To access DICOM content, the integrator needs only to provide a simple URL. The WADO standard defines services for object retrieval, transformations, and renditions. Some portions of these services are optional, and are thus not guaranteed with all WADO service providers (Fig. 1).

Minimum required service:

- Retrieval of a single DICOM object, lossy JPEG, or text object per HTTP request

Recommended (optional) services:

Transformations:

- Flip, rotate, scale, region (cropping)
- Application of DICOM image presentation states
- Anonymization of image renditions
- Annotations

Renditions:

- Variable image quality factor for JPEG compression

Fig. 1 DICOM WADO interaction [1]

- Single frame rendered image from multi-frame objects.
- Non-JPEG renditions
- PDF, XML, and HL7 clinical document architecture support
- DICOM transfer syntax support

Excluded basic image services:

- Metadata retrieval
- Reconstructions
- Object discovery (query and notification)

Recommended services are implemented at the discretion of the implementer. Each of the services listed as

recommended should be evaluated prior to choosing an implementation.

Example request formats:

An example WADO URL call to retrieve an object for display: <http://server.hospital.com/wado?requestType=WADO&studyUID=1.2.12&seriesUID=1.2.40&objectUID=1.2.40> (Fig. 2)

An example WADO URL used to retrieve the same object with transformations: <http://server.hospital.com/wado?requestType=WADO&studyUID=1.2.3&seriesUID=1.3.1&objectUID=1.3.2&windowWidth=2000&windowCenter=500®ion=0,0,1,0.5&rows=200&columns=200> (Fig. 3)

Fig. 2 Unmodified JPEG returned through WADO

Fig. 3 Transformed JPEG returned through WADO

Overview of DICOM WADO by Means of Web Services (Supplement 148)

DICOM WADO via web services was finalized in August of 2011. This supplement is designed to extend the URL-based WADO standard. This supplement provides the ability to enrich the existing WADO service with SOAP and message transmission optimization mechanism with XML-binary optimized packaging (MTOM/XOP) services. These services can provide the necessary information about the objects known within a study to display a rendition without the need to pull the DICOM objects themselves. The services also allow for large binary DICOM objects to be encoded within a SOAP message for rapid transport (Fig. 4).

Minimum required services added to WADO:

- Provide one or more objects upon request to a client using MTOM/XOP
- Provide an XML encoded metadata element for all retrieved objects using XPath
- Error handling framework
- Application entity specification

Discussion

DICOM WADO exists today and is a platform of growth for future DICOM communications. WADO and WADO via web services provide value and advance the delivery of image

enabling applications. Organizations can provide key images to be displayed in reports, deliver series of images for review, and provide web-based PACS applications [10]. The WADO standard has been adopted by IHE within the XDS-I and XCA-I integration profiles as the foundation of cross-enterprise and cross-community access of imaging data over HTTP(S). XDS-I, as defined, is a study-level DICOM object retrieve when using WADO. By default, an IHE XDS-I Imaging Document Consumer will request and retrieve all study objects, as the XDS Registry and manifest does not provide enough metadata for the Imaging Document Consumer to choose individual objects.

There are still important next steps for DICOM WADO and WADO via web services standards. As shown in Table 2, the most notable absence is the ability to discover imaging content through a web-based query. This would provide content discovery functionality over HTTP. WADO via web services could be extended to include metadata queries within the existing SOAP based protocol. Adding this functionality would allow integrators to query for a patient's imaging studies through on-demand HTTP(S) requests. Study discovery for many applications, such as an EMR, require integrators to implement a cache to store and synchronize pushed HL7 ORM messages. There have been published efforts to propose extensions to WADO such as the web access to DICOM archives (WADA) service [11]. The WADA service was proposed as a query and reporting extension to WADO with the application of access controls to allow for PACS level functionality. DICOM working group 27 has also approved the creation of work items to

Fig. 4 WADO web services application flow [2]

provide query based on ID for DICOM object(s) (QIDO), as well as notification of availability DICOM object(s) (NADO) [12]. Both NADO and QIDO are designed to provide content discovery to image enabling applications, further extending the power of DICOM on the WEB. These work items have yet to be produced as a formal draft.

Advanced visualization and 3D image processing services could potentially benefit from a standardized web service similar to WADO and WADO via web services. This could allow unified user interfaces for any advanced visualization system [13]. Delivering advanced visualization renditions via a standard interface such as HTTP may also provide advantages in modularization of server based rendering components [13].

The standardization of web-based DICOM services provides common interfaces for web applications to integrate medical imaging. Web-based applications may also be currently integrating existing DICOM imaging interfaces and protocols in the absence of web-based standards. It is important that the DICOM working groups provide standards for services that pair the semantics of the existing standards with the semantics of new web services. This pairing of semantics may help to lower the technical barrier for implementing the web services as a proxy service to the existing standard and encourage integrators to adopt the standards.

Summary

Web-based applications are being adopted by healthcare organizations as health information systems evolve. DICOM WADO and WADO via web services are two important stepping-stones to ensure that medical images will be easily accessible within these web-based applications through an open standard. The DICOM WADO standard and the WADO for web services supplement do not define all of the necessary services for access to medical imaging data. Regardless of these limitations, the capabilities provided by these standards will allow integrators to include images within the patient record securely and without the need to implement high bandwidth connections to end users. The goal is to be able

to provide all medical imaging services through the web using open standards to ensure interoperability and innovation.

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