WHITE PAPER

Standard-Compliant Streaming of Images in Electronic Health Records

Combining JPIP streaming and WADO within the XDS-I framework

AWARE

COMBINING JPIP STREAMING AND WADO WITHIN THE XDS-I FRAMEWORK

The Obama administration has identified the adoption of interoperable electronic health records (EHR) as a key means to substantially reduce healthcare costs. Given that medical imaging is known to be a significant source of cost in the healthcare industry, an EHR solution must address medical imagery to take full advantage of its full cost-saving potential. But the size and growth of medical image data, as well as the preponderance of proprietary imaging systems, makes the incorporation of imagery in a truly open EHR platform a particularly daunting challenge. Establishing interoperability is the key to the success of an EHR platform in achieving the cost savings that the US Government will ultimately demand.

There are existing standards and technologies that help address this interoperability challenge; they are designed to establish connectivity between disparate systems and enable instantaneous display of imagery over the low-bandwidth networks that connect them. This paper 1) describes the standards and technologies that enable medical images to be cost-effectively incorporated into an EHR solution, and 2) demonstrates the considerable performance benefits that are achievable through use of standards-based image streaming, viewing, storing, and transport technologies.

EHRs with diagnostic images reduces healthcare costs and improves quality of patient care and safety

An electronic health record is incomplete without diagnostic images. Imagery from prior exams provides historic and baseline information that is valuable to radiologists in formulating a diagnosis. When they do not have access to prior scans, they often order rescans. This redundancy wastes money and resources, and can exposure patients to radiation unnecessarily.

An image-enabled EHR system also enables simultaneous viewing of data and real-time collaboration between clinicians, radiologists, cardiologists, orthopedists and other specialists. It can help improve efficiency by enabling the distribution of the workload among radiologists in remote locations. Patients with access to their records, such as in a personal health record (PHR), can also provide images to other clinicians for consultations or follow-on care.

Fast, ubiquitous access to medical images through an EHR system can also aid diagnosis and treatment in remote locations or under emergency conditions by enabling use of mobile devices such as laptops and cell phones to access imagery.

Image streaming speeds workflow

The primary challenge in sharing medical imagery is that medical images are large; image files are very high in resolution and color bit depth, and CT and MR image stacks are dense. Sharing images in an EHR requires transporting them over wide area networks, which typically offer far less bandwidth than on local Ethernet networks. To make the network bottleneck more transparent—that is, to make the images in a shared system appear to be local—image "streaming" is employed. The intent of streaming is to efficiently provide the viewer only that portion of the image or study that is being viewed at any given time. "Progressive viewing" gives users a lower resolution version of their requested image as quickly as possible. This is useful for the clinician to navigate an image or study before it has been completely downloaded.

Without streaming and progressive viewing, an entire image or dataset must be transported prior to viewing; this can be extremely time consuming, depending on the volumes of data and network bandwidth. Streaming technology speeds workflow by providing simultaneous data transfer and image rendering. Regions of images, sub-resolutions of images, or sections of studies can be viewed quickly while the remainder is streamed to the clinician or radiologist as a background process.

Standards-based image streaming enables interoperability

Interoperability is a fundamental requirement of EHRs. The way to ensure interoperability and reduce the proliferation of proprietary systems is through adoption of technology standards. As more countries and regions deploy image enabled EHRs, and as more patients begin to use PHRs such as Google Health and Microsoft's HealthVault, the adoption of the standards highlighted in this paper will reduce the overall costs associated with the technology, provide for future migration paths, and ensure efficient data interchange across networks, systems, and vendors. The following sections identify and describe existing standards for image data sharing in the healthcare industry.

Key standards and profiles enabling image streaming

Standards and profiles have been developed and specified by the industry to help enable image streaming such as in an EHR system. These include JPIP, WADO and the IHE XDS-I Framework. Together they advance EHR as a way to access images over the WAN with unprecedented speed in an interoperable fashion, while leveraging the ubiquitous security environment of HTTPS. This enables clinicians, radiologists, cardiologists, orthopedists and other specialists with a standards-based method to access patient data across multiple PACS, using clients and servers from different vendors. The following describes standards and profiles specified by the healthcare industry to help enable standard-compliant interoperable image streaming.

INTEGRATING THE HEALTHCARE ENTERPRISE (IHE)

Integrating the Healthcare Enterprise (IHE) is a global initiative founded in 1999 to develop a framework for medical data interchange through use of open standards. It does not create new standards, but rather publishes implementation guides (profiles) that drive the use of existing standards, such as DICOM (imaging data) and HL7 (non-imaging data). In doing so, IHE helps solve data sharing issues not addressed by those standards on their own. IHE is sponsored by a number or organizations including the Radiological Society of North American (RSNA), the Healthcare Information and Management Systems Society (HIMSS), and the American College of Cardiology (ACC).

IHE XDS

Cross-Enterprise Document Sharing (XDS) is a family of IHE profiles that support document sharing between enterprises in different care settings and organizations. The XDS "publish and subscribe" paradigm starts when a persistent DICOM object is created, such as an image, report, or other medical document. The document is published to the "Repository" and registered in an index ("Registry"). "Consumers" can query the Registry to "discover" the documents and their location. Consumers can then retrieve the documents "on-demand" from the repository.

IHE XDS-I

XDS-I is the IHE profile that extends XDS to the exchange of imaging documents, and can be used within an EHR paradigm for publication, discovery, and retrieval of patient diagnostic imaging history across multiple enterprises. It has emerged as the prevailing EHR interoperability architecture, and some countries such as Canada already promote compliance with XDS-I. For a complete description of XDS and XDS-I, refer to IHE Technical Frameworks for Radiology and IT Infrastructure, http://www.ihe.net/Technical_Framework/

Figure 1: IHE profiles define the use of standards to share medical image data

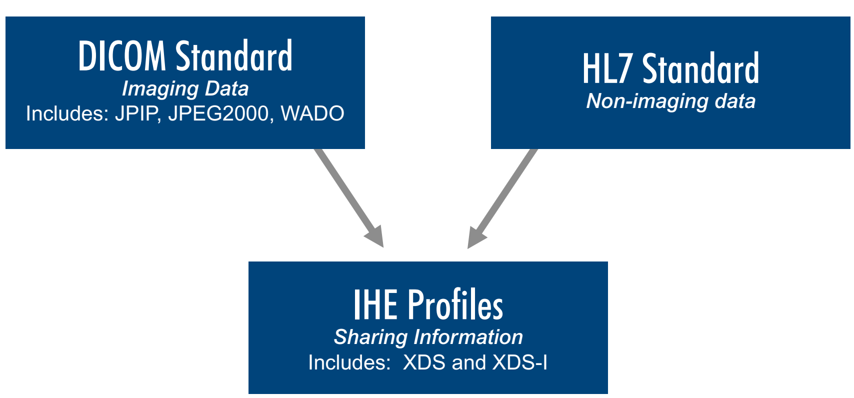
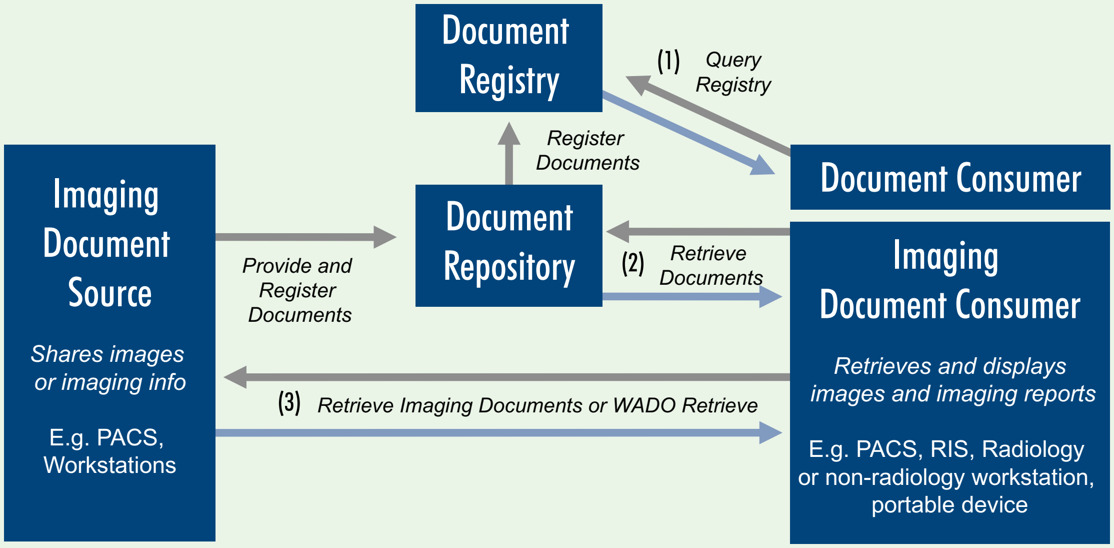


Figure 2: How an XDS-I enabled system works



The Imaging Document Source constructs a "Manifest" to reference the DICOM instances to be published. The Manifest Document as an instance of a DICOM Key Object Selection SOP Class that describes and collects a set of DICOM SOP Instances that are intended for sharing. The manifest is submitted along with metadata to the Document Repository.

The Imaging Document Consumer can query the registry and retrieve available images, presentation states, reports, key image notes and evidence documents. The Imaging Document Consumer also has the ability to retrieve DICOM SOP Instances using a web-based method, WADO.

WADO

Web Access to DICOM Persistent Objects (WADO) is a part of the DICOM standard (PS 3.18) that defines a web-based method of access to DICOM persistent objects, (e.g. images, medical imaging reports). Consumers (e.g. radiologists or clinicians) can query the Document Registry to "discover" documents indexed in the registry. WADO enables the Consumer to then retrieve images via HTTP or HTTPS (a secure version of HTTP). DICOM image access without WADO requires full DICOM protocol support and is slow because complete images and studies must be transmitted.

JPIP

JPIP (JPEG2000 Interactive Protocol) is the only DICOM-approved standard-compliant image streaming protocol. JPIP provides efficient transmission and streaming of JPEG2000 images over varying bandwidth networks, enabling any viewing client to access imaging data from any JPIP-compliant server. For a complete definition of JPIP, see JPEG2000 Part 9 ISO/IEC 15444-9:2004 (http://www.jpeg.org/jpeg2000/j2kpart9.html), ITU-T Rec. T.808 and DICOM Supplement 106.

JPIP provides a highly efficient method of image dissemination and viewing, particularly over bandwidth-constrained networks, by presenting only the portion of the image data that is requested by the viewer. This selective presentation is possible because the JPEG2000 code stream is partitioned into blocks, which can be assembled, disassembled, and moved around a network as independent data objects. The blocks can be of any size and the image data can be arranged by resolution, quality, and region of interest. The result is a richer, more efficient image viewing experience made possible either by 1) processing only the data that the user has requested, or 2) by progressively improving the quality of an image as more of the blocks arrive at the viewing station. JPIP also allows random access to individual frames of large, enhanced muliframe objects.

JPIP streaming enables progressive display, which significantly reduces the time a radiologist or clinician must wait to view an image on their workstation. The user can quickly zoom into areas of interest in large images for region of interest viewing. Performance is further enhanced by the use of client-side caching of select portions of the image data in a multi-image study.

A practical example of the utility of JPIP is for stack navigation of a large CT study, in which JPIP allows low-resolution preview with full-fidelity imagery on demand. Initially only a low-resolution version of all images is transferred from the server to the client. When navigating a large single image, JPIP enables pan and zoom of a region of interest of an image at the display resolution, so that only the region of the image that fits the monitor resolution is transferred from the server to the client. Navigation through the stack can be enabled through a thumbnail representation of a study.

JPIP is particularly advantageous over constrained networks. For example, a 16 bit per pixel, 2040 x 2570 (10 Mbytes uncompressed) computed radiographic (CR) image transmitted through a 2 Mbps network at 50% network capacity would take 80 seconds to view because the image is not compressed and is not natively available in a multi-resolution format. This contrasts with the time-to-start-viewing of 2.2 seconds for the same image by employing JPEG2000 compression and JPIP streaming (see **Table 1** and **Figure 3**).

This data shows that a full-resolution image encoded losslessly with JPEG2000 and streamed through the JPIP protocol can be rendered in approximately 32 seconds, compared to approximately 80 seconds for the raw formatted image, yielding a 60% improvement in efficiency. These standard-compliant technologies allow a clinician or radiologist to experience greatly reduced click-to-view times and to greatly improve the performance of systems designed to access and view large medical images, especially over constrained networks.

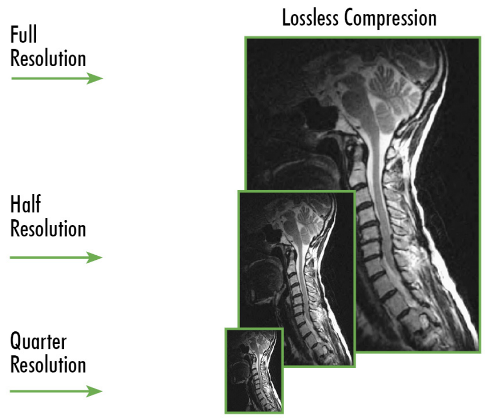
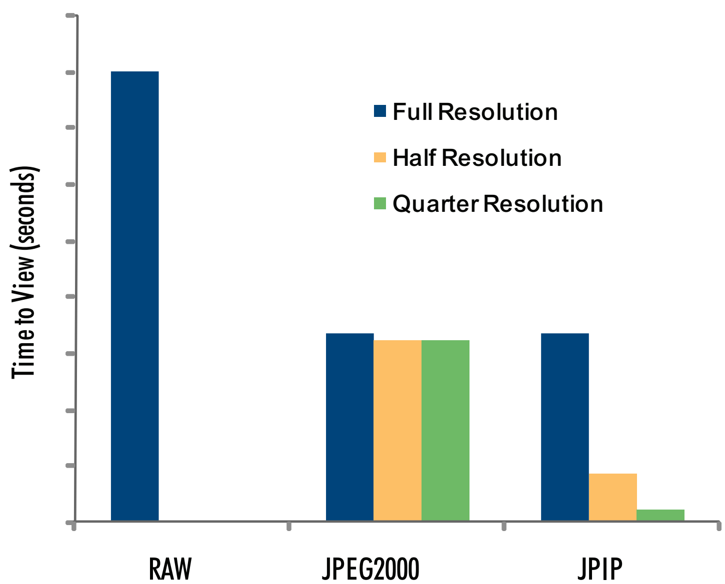


Table 1: Data comparing the performance of viewing a raw image to a losslessly compressed image, employing JPEG2000, JPIP, and progressive viewing.

Time to View (seconds)

Resolution	RAW	JPEG2000	JPIP
Full	80	33.2	33.2
Half		32.3	8.4
Quarter		32.1	2.2

Figure 3: Data comparing the performance of viewing a raw image to a losslessly compressed image, employing JPEG2000, JPIP, and progressive viewing.



AccuRad Stream™ software products for standard-compliant image streaming and viewing

AccuRad Stream™ is a standards-based enterprise medical image distribution and viewing solution that enables standards-compliant image streaming between multiple data sources and viewing clients. The AccuRad Stream Server incorporates JPIP streaming functionality with PACS. The AccuRad Stream Viewer connects with the JPIP enabled PACS to retrieve and stream images via JPIP. It avoids problems related with the proprietary nature of many similar systems in use today, in part by converting images to JPEG 2000 format so they can be streamed to viewers using the DICOM JPIP protocol.

AccuRad Stream includes several components in addition to Stream Server and Stream Client:

1. **AccuRad J2KSuite, a JPEG2000 Software Development Kit (SDK)**
2. **AccuRad JPIPStream, an SDK for building JPIP-based client/ server solution**
3. **AccuRad DICOMView, a lightweight ActiveX control for streaming, viewing, and manipulation of medical images. DICOMView includes a scriptable API for rapid application development of viewing clients.**

THE ACCURAD STREAM SERVER

The AccuRad Stream Server is a middleware application server that receives and prepares medical image data for streaming to remote clinical and diagnostic locations. The AccuRad Stream Server consists of a number of Acquisition Services and an Application Server.

Acquisition Services are mechanisms for importing medical image data from one or more disparate PACS or image sources into the AccuRad Stream Server for processing. In the application server, data is compressed (if necessary) and a cache of images is built based on a variety of criteria related to criticality, access patterns, and aging.

The Application Server builds an image manifest which includes information about the location of the images. Once the viewing client calls for a study, the manifest is retrieved by the viewer.

A session is established via the manifest and then images are requested by the client via JPIP. The Application Server receives the request, locates the image and/or region of an image requested, determines if the image or region has already been delivered, and responds accordingly with JPIP image data or notifications.

ACCURAD STREAM CLIENT

AccuRad Stream Client is a reference application provided with AccuRad Stream to demonstrate a fully functional medical imaging client. The Stream Client is built around AccuRad DICOMView as a Web browser application. DICOMView may also be hosted in any client container that can make use of ActiveX.

The application exposes many of the functions image reviewers rely on to perform their reads. Multiple image layouts are supported. Thumbnail navigation is also presented and studies are broken apart into their constituent series for multi-series review. Context-based predictive image loading is also included to optimize the reading experience as reviewers move through a stack of images. The Client and DICOMView are highly customizable and functionality can be accessed and abstracted via scripting methods.

DICOMView functionality is also very robust and mature, exposing the tools radiologists need to manipulate and work with images. Window-level, zoom, pan, scroll, scoutlines, linking, annotations, overlays, measurements, and cine-loop controls are just some of the functions available.

About Aware

Aware, Inc. was the first commercial organization to provide a wavelet based image compression algorithm for use in medical systems. Aware's active development and commercialization efforts have helped promote the adoption of wavelet based compression and streaming by the healthcare industry standards organizations. Aware continues to serve on both DICOM WG4 (Compression) and the JPEG2000 standards body ISO/IEC JTC 1/SC 29/WG 1. Aware also serves as the official liaison between the two standards groups.

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