Research Review Paper ■

Technology Solutions and Standards for Teleradiology Information Systems

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Abstract. Since teleradiology processes are complex to manage, a tailored and robust information system is required to deal with them efficiently. The market offers a lot of solutions but these are mostly "closed systems". This means that the integration and interoperability among different information systems and upgrades with new functionalities are complex and expensive. Possible solutions to overcome these obstacles are presented. Based on our own teleradiology systems development practice, we present the standards and recommendations that should be implemented. A good practice example from Piedmont, Italy, is briefly described.

Tehnološke rešitve in standardi za teleradiološke informacijske sisteme

Izvleček. Upravljanje teleradioloških procesov je zahtevna in kompleksna naloga, ki jo lahko učinkovito izvedemo samo z robustnimi namenskimi informacijskimi sistemi. Na tržišču so prisotne številne komercialne rešitve, s katerimi pa je zelo težko in tudi drago izvesti integracijo in interoperabilnost z zalednimi informacijskimi sistemi. Še posebej težko je komercialne sisteme nadgraditi z novimi in posebnimi funkcionalnostmi. V članku predstavljamo rešitve za odpravo teh ovir. Iz lastnih izkušenj v razvoju teleradioloških sistemov predstavljamo standarde in priporočila za njihovo implementacijo v praksi. Opisujemo tudi primer dobre prakse iz regije Piemont v Italiji.

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Introduction

From the practical point of view, the term e-health is often confused with the simple digitalization of documents and partial data. In fact, in the years 2008 and 2009 we witnessed very rapid growth of stand-alone systems for management of partial e-health information. This has resulted in "islands" of information that cannot share data and communicate efficiently. Addressing this fragmented approach is the first and simplest step in the process of moving to e-health. The more complex steps are related to the meaning of "sharing": the information should be accessible not only inside those islands but also from all systems around them. This is a critical challenge for health care in our time and also for the e-health development in Europe. For this reason, the most important and also the most common terms in today's e-health technology are integration and interoperability.

- **Integration** means having the capabilities to communicate and share data with other systems, typically using standard protocols and interfaces.

- **Interoperability** is a wider term than integration and extends its meaning. For systems, it means not only to communicate but to cooperate together in the most efficient way.

In this paper, we present solutions, standards and recommendations that provide integration and interoperability in the field of teleradiology.

Teleradiology

Teleradiology is the electronic transmission of diagnostic imaging studies from one location to another for the purposes of interpretation and/or consultation.[1] This definition includes PACS (Picture Archiving and Communication System) networks inside hospitals as well as solutions for remote areas.

It is important to underline that teleradiology is a solution that should support the normal inward radiological activity. An onsite supervising qualified radiologist provides the optimum clinical environment for the patients and the referring physician by providing daily interaction, input and consultation. Only where there is difficulty in fulfilling manpower needs, teleradiology will provide support for 24/7 reporting activity and for interpretation of complex cases.

Teleradiology will also allow timelier and efficient interpretation of radiological images, give better access to secondary consultations and improve ongoing education. It is mandatory that teleradiology should never compromise the radiologist's responsibility to provide quality professional services, but it should be a quality centered and patient focused method of improving services.[2,3]

Standards for teleradiology

Since teleradiology deals with radiological images, the first aspect to consider is the standard that should be used for image communication. For this purpose the choice can be only one and it is the DICOM (Digital Image Communication in Medicine) protocol.[4] There are no other de facto standards for treating digital radiological images.

Once the protocol for image management has been identified, strengths should be focused on how to use it in the best way, considering that in teleradiology environments networks must be secure, stable and fast.

Two interesting aspects of the DICOM protocol are to be described. They regard Web Access to DICOM Objects (WADO) and image streaming over the network.

WADO

This standard[5] specifies a web-based service for accessing and presenting DICOM (Digital Imaging and Communications in Medicine) persistent objects (e.g. images, medical imaging reports). This is intended for distribution of results and images to healthcare professionals. It provides a simple mechanism to access a DICOM persistent object from HTML pages or XML documents, through HTTP/HTTPs protocol, using DICOM UIDs (Unique Identifiers). Data may be retrieved in either a presentation-ready form as specified by the requester (e.g. JPEG or GIF) or a native DICOM format. This standard relates only to DICOM persistent objects, not to other DICOM objects or to non-DICOM objects. Access control beyond the security mechanisms generally available to web applications is outside the scope of this standard. In addition, WADO does not deal with providing facilities for web searching DICOM images.

Streaming

New developments in DICOM involve image streaming through JPIP (JPEG2000 Interactive Protocol),[6,7,8] which is the only DICOM-approved image streaming protocol. JPIP provides efficient transmission and streaming of DICOM images over various bandwidth networks, enabling any viewing client to access imaging data from any JPIP-compliant server. A simple example of how this standard works is shown in Figure 1.

JPIP presents only the portion of the image 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.

It is even possible to view an image by progressively improving its quality as more blocks arrive at the viewing station. If the image is multiframe, JPIP allows random access to individual frames. The architecture of a streaming solution is quite simple (Figure 2).

Figure 1 Image streaming through JPIP.

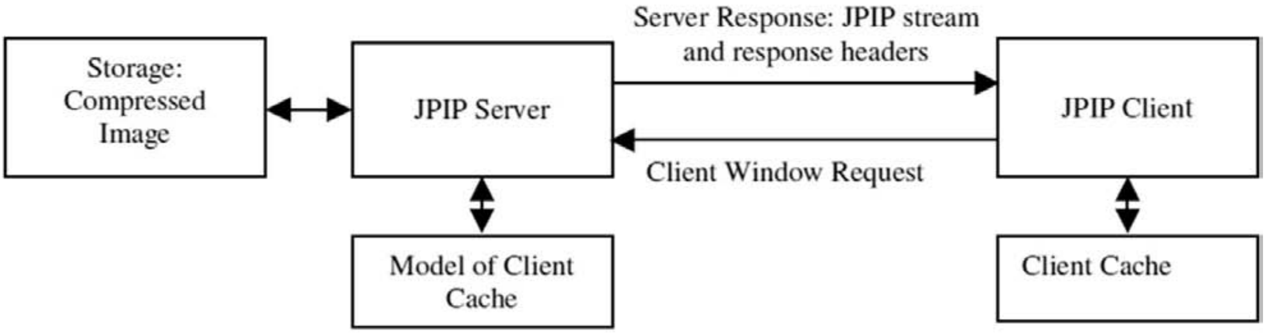

Figure 2 Architecture of a JPIP streaming.

JPIP reduces the time a radiologist/clinician must wait to view an image on the workstation. If a user just needs to view a particular region of a large image, he/she can quickly zoom directly into the area of interest. Performance is further increased by the use of client-side caching of selected portions of image data in a multi-image study.

A practical example of the utility of JPIP can be seen in the stack navigation of a large CT study, where JPIP allows low-resolution previews, allowing the full-quality version to be sent on demand. Initially, only a low-resolution version of all images is transferred from the server to the client. When browsing a large single image, JPIP enables panning and zooming into 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.

Recommendations

Sticking to the technological level without entering the clinical one, once standards are chosen, there are other issues to be resolved before starting a teleradiology project. One should think about interoperability, especially related to the workflow.

In general, one should start thinking about how to organize a teleradiology service. Fortunately, there are some initiatives that can help defining system roles and behavior. The most important one is IHE (Integrating the Healthcare Enterprise),[9] an initiative that was born in 1998 in the USA. Its main purpose is to foster the adoption of standards and interoperability solutions in the clinical practice, starting from radiology and extending the solution to other specialties. Many of the solutions proposed by IHE, which are called profiles, are easily portable and usable in the teleradiology field. Here, only the most interesting and powerful ones are described.

XDS and XDS-I

It is widely recognized that electronic information systems could lead to better patient care. Many solutions are available for specific clinical areas such as General Practice, laboratory results and radiological reports, but little real-life progress has been made in wider clinical practice. This is largely due to the lack of agreement on how such clinical data should be stored and transmitted.

IHE Cross Enterprise Document Sharing (XDS) differentiates from previous approaches in the way that it aims to overcome implementation problems by separating logically indexing information (the meta-data) from the actual content. This allows XDS to support a wide range of documents, though presenting a simple and consistent method to store, index, locate and retrieve them for clinical use. This logical separation also permits adding XDS export functions to existing systems in a rather simple way, since it allows using existing output formats such as CDA, PDF and even simple text documents, as well as DICOM and JPEG Images.

XDS uses existing "open" IT standards (HTTP and ebXML – an OASIS and ISO standard) to share stored electronic documents, and therefore enable development of wide-area electronic healthcare records. XDS is an excellent tool in addressing the interoperability problems, which are inherent to sharing electronic healthcare records between different IT systems. Hence, it is rapidly being adopted around the world with ongoing national programs in Italy, the USA, Austria, Canada, France and also several regional projects. Figure 3 shows that an XDS system is composed of four main components:

- **Document Source**: The system which publishes the clinical document. It produces the document and its metadata, then sends both to a repository. It is an easy system to implement, since it performs just the basic task described above, unless it needs to modify the data it had already sent.

- **Document Repository**: This is where documents are stored. The overall system can have multiple repositories. The repository forwards information to the registry, but this information is limited to the documents' metadata, together with a pointer to where it has stored the document.
- **Document Registry**: This is where metadata is stored and searches are performed. Registries can be linked together to provide different levels of integration, from a simple cross-project to an international one. An XDS project needs just one registry, but others can be added to provide additional features.
- **Document Consumer**: This is a user system which needs to retrieve documents stored in one or more repositories. It queries the registry for documents meeting certain criteria, e.g., records of a particular type for a particular patient. After the pointer to the documents has been returned, it can retrieve the original documents from the repositories.

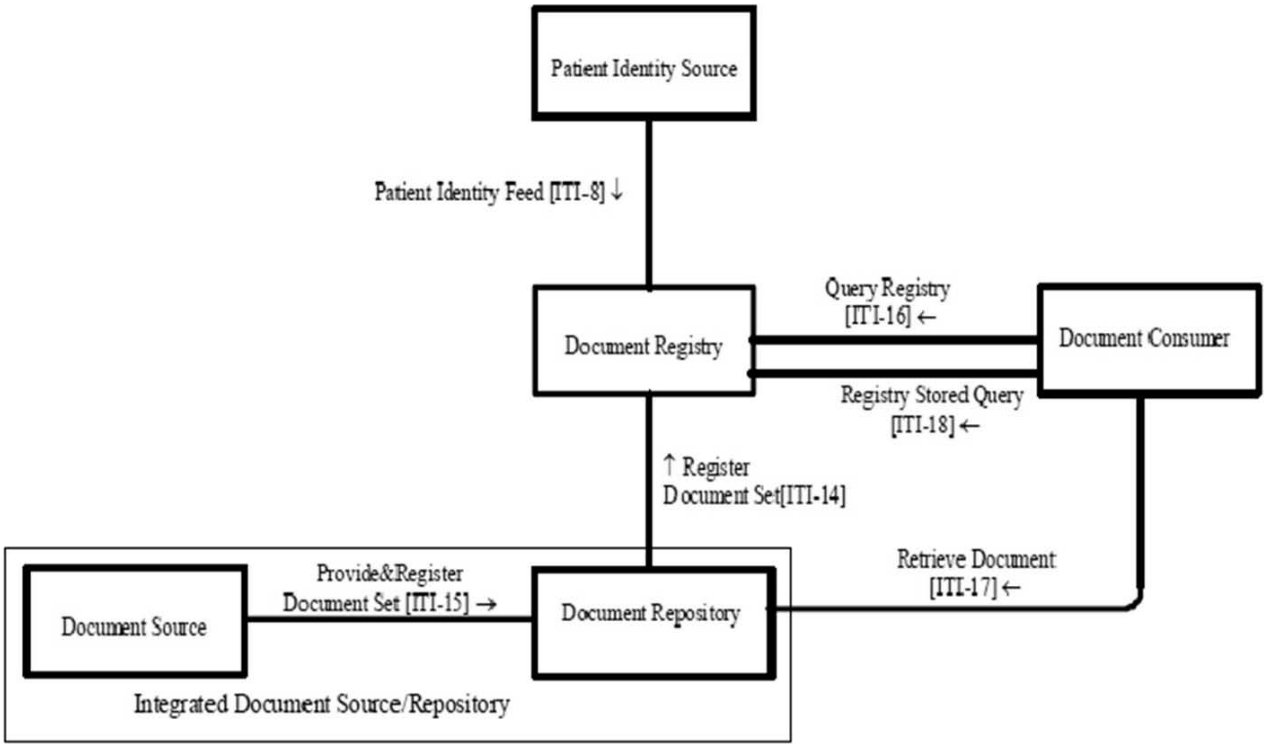

Figure 3 Components of an XDS system.

Repositories and the registry use only standard web services, whereby usage of ebXML enables use of standard off-the-shelf or even open source solutions. As far as the registry and repositories are concerned, documents are simple data blobs and their interpretation is delegated to the consumer. HTTP or (more conveniently for clinical scenarios) HTTPs is the protocol used for all transactions.

The fact that XDS documents are stored in multiple repositories is an important difference from other systems. Decentralization of data storage, where repositories relate to single organizational units or health authorities, is of major help in addressing security and data ownership issues.

The XDS model has evolved through time to support specific document types. This brought to

XDS-I for DICOM images, XDS-MS to deal with HL7 CDA medical summaries, or XDS-Lab to address laboratory structured reports. All these models merely extend the basic XDS profile, the only difference being that particular constraints are placed on stored documents to increase support for specific functions. In particular, XDS-I is perhaps the only significant extension. Its purpose is to avoid storage costs, permitting to store the original data on the original PACS and defining the document stored in the repository as a simple list of DICOM objects (a small "Key Object Selection Document") instead of the actual documents. This lets the consumer retrieve the original documents from the PACS.

ATNA

The Audit Trail and Node Authentication (ATNA) Integration Profile establishes security measures which, together with the Security Policy and Procedures, provide patient information confidentiality, data integrity and user accountability. This environment is considered as the Security Domain and can scale from a department to the whole enterprise or affinity domain. The overall outlook of this kind of profile is summarized in Figure 4.

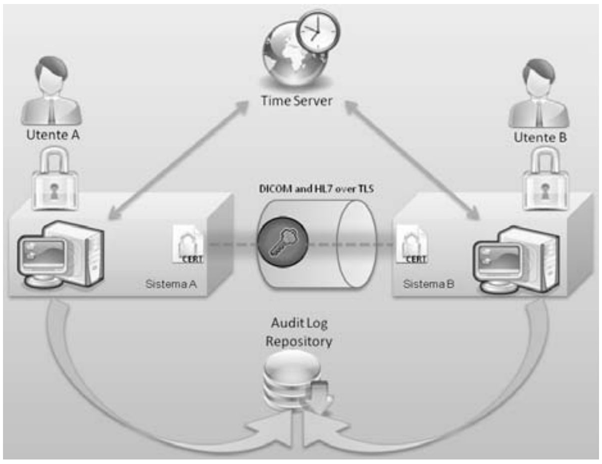

Figure 4 ATNA profile.

The ATNA Integration Profile contributes to access control by limiting network access between nodes and limiting access to each node to authorized users. Network communications between secure nodes in a secure domain are restricted to only other secure nodes in that domain. Secure nodes limit access to authorized users as specified by the local authentication and access control policy.

- **User Authentication**: The ATNA Integration Profile requires only local user authentication. The profile allows each secure node to use the access control technology of its choice to authenticate users. The use of Enterprise User Authentication is one such choice, but it is not necessary to use this profile.
- **Connection Authentication**: The ATNA Integration Profile requires the use of bi-directional certificate-based node authentication for connections to and from each node. The DICOM, HL7, and HTTP protocols all have certificate-based authentication mechanisms defined. These authenticate the nodes, rather than the user. Connections to machines that are not bi-directionally node-authenticated shall either be prohibited, or be designed and verified to prevent access to Protected Health Information (PHI).
- **Audit Trails**: User Accountability is provided through Audit Trail. The Audit Trail needs to allow a security officer in an institution to audit activities, to assess compliance with a secure domain's policies, to detect instances of non-compliant behavior, and to facilitate detection of improper creation, access, modification and deletion of PHI.

Reporting workflow

Teleradiology procedures usually encounter difficulties integrating with the radiology information system (RIS), so it is difficult to organize the reporting activity. IHE offers a very smart and secure way to organize the entire task related to the reporting procedure. This solution is the Reporting Workflow Profile, which provides the means to organize and schedule reporting tasks and monitors their progress and completion. It provides the capabilities to sustain and optimize several tasks typically required for image interpretation (reporting). It specifies transactions to support a seamless flow of information for typical reporting tasks, such as:

- Interpretation,
- Dictation,
- Transcription,
- Verification,
- Review.

The Reporting Workflow Integration Profile addresses the following functions and systems interactions:

- **Planning** – a report management and scheduling system (RIS) assembles and prepares the data needed to perform certain reporting tasks.
- **Provide Worklists** – a reporting workstation (PACS Workstation) queries the scheduling system for worklists (lists of reporting tasks to be performed) and presents the information to the user.
- **Interpretation** – the workstation user selects (claims) a certain task to work on, retrieves the images pertinent to the selected task, evaluates the image information and generates results (a dictated or transcribed report, quantifying data on findings, possibly additional processed images or other evidences) to be stored. The correlation of patient, procedure, images and results information can be properly maintained.
- **Status Tracking** – the workstation keeps the scheduling system informed about the status of the procedure: claimed, in progress, completed.

Once a reporting procedure has been completed, it can be removed from the schedule, another pending work item can be taken on, and so forth.

Open Source Teleradiology project – a good practice example

An example from the Piedmont Region in Italy is presented here for the first time. O3 Enterprise[12] with the partner ITAL TBS has won the tender for the project in 2010. The contract was signed in June 2010, the pilot is being launched in December 2010, and the system will be implemented online for the users in the first half of 2011.

The CSI Piemonte – Consortium for IT development of the Public Administration of the Piedmont Region has devised a project for central management of all the images produced within the ASL Torino 1 and ASL Torino 2 health bodies. The main characteristic of the project is the complete usage of Open Source software and open protocols in order to assure extensibility, scalability and easy integration with other systems. All the potential benefits of Open Source approach in teleradiology are elaborated in a related paper.[11]

Scenario

The ASL Torino 1 and ASL Torino 2 health bodies are located in the central area of Turin, serving together around one million inhabitants. The overall number of GPs is around 1500, uniformly split between the two ASLs.

ASL Torino 1 includes 3 hospitals: Martini, Valdese and Oftalmico. The first hospital has a PACS system from Carestream Health Italia s.r.l., while the second and the third one have two Micromedica PACS. Both PACS systems are already running. The RIS system is unified across the three hospitals; it has been developed by Engineering Ingegneria Informatica S.p.A.

ASL Torino 2 includes other two hospitals: Maria Vittoria and S. Giovanni Bosco. The first one uses a PACS system from Agfa-Gevaert S.p.A., while the second one uses a PACS system from

Carestream Health Italia s.r.l. Like Torino 1, the RIS is the same for both hospital; it comes from Elco 3b.

Service model

The teleradiology service model is the following:

- Image and reports are produced locally inside ASL TO1 and ASL TO2 following their own internal workflow.
- Once a day, all the images and reports are properly anonymized, except for the patient ID, and they are sent to the central archive in standard format, namely DICOM for images and HL7 for reports.
- The central archive stores and manages them in a secure way providing long-term archive on different types of media. Images are saved in a PACS systems, while reports are saved in a document management system.
- All radiologists from the two health bodies can access images and reports during their reporting activity. They can view previous images related to a patient and compare them to the new ones. Visualization and comparison are performed by a reporting workstation provided to them.
- Radiologists can issue a tele-consulting or second opinion request linking them to some images. They can send those requests to a single specialist or a group of them picked from a regional list provided to them electronically. The request can be protected by a password, thus avoiding inappropriate views from radiologists outside the target group.
- General practitioners can have access to the central system in order to view images and reports of their patients.

Technical Solution

The technical solution has been designed following two basic principles:

- All the communication should be done following standard protocols.
- There should be a strong adherence to interoperability initiatives, such as the IHE.

These two principles guarantee that the central system can be easily expanded to other health bodies or to add new functionalities. Integration with external systems as regional patients database and/or regional employees database is assured.

Following the two principles, the technical solution proposed for the teleradiology service is presented in Figure 5. In the model, one can distinguish:

- A larger central system (lower ellipse) that contains all the modules related to the teleradiology service;
- Two smaller satellite areas (upper ellipses) that represent the two health bodies. They both have their own PACSs and RISs as explained above.

Since the central system has to manage reports and images, which are two completely different types of data, at the same time, a lot of effort has been put in finding the right solution for storing them safely in a unique way. It has been found out that a system that satisfies all the needs is a Cross-Enterprise Document Sharing Profile (XDS), proposed by the IHE initiative. This profile gives a way of sharing document and images (XDS-I, extension for images) between different health enterprises.

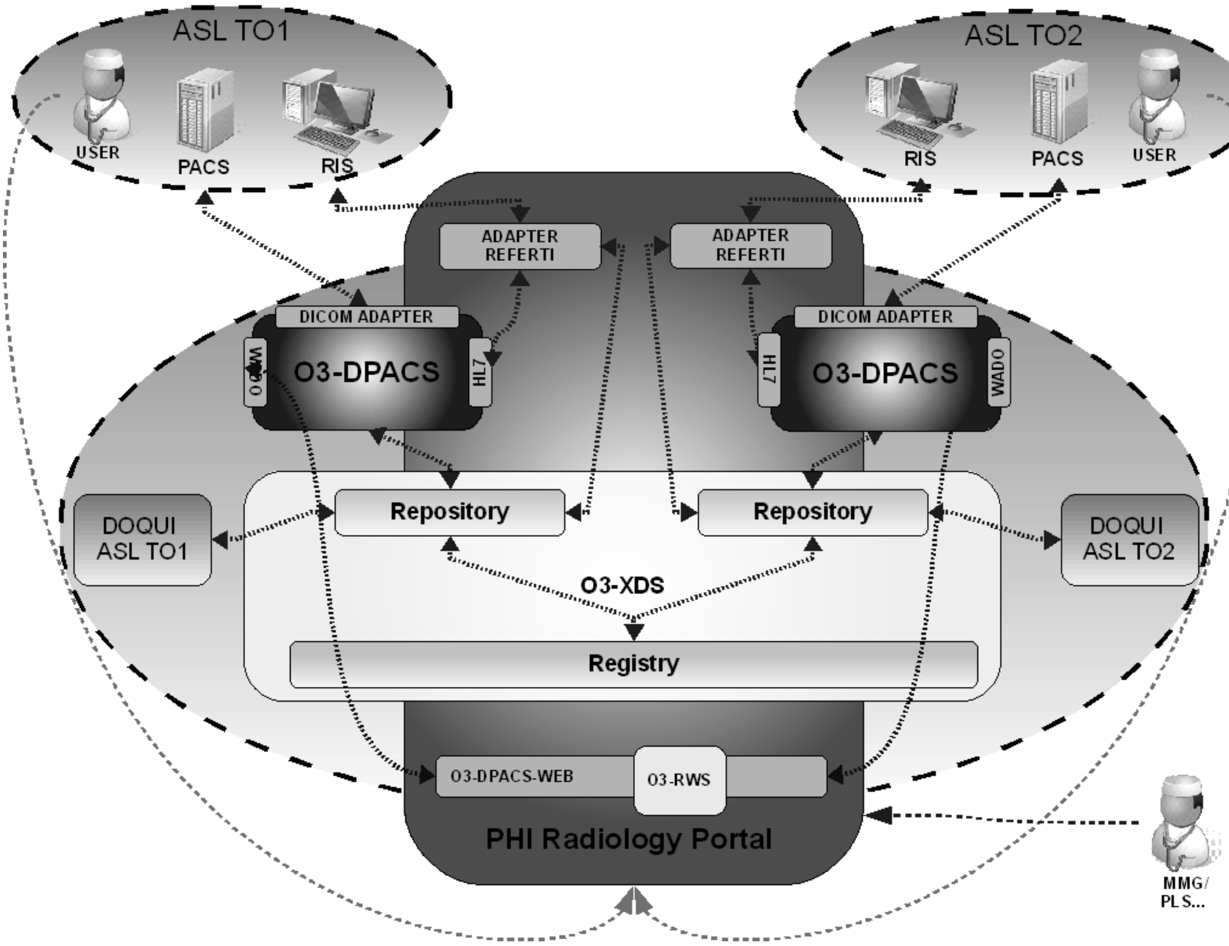

Figure 5 The teleradiology technical model.

There are four basic nodes involved in the XDS profile. Figure 3 shows these nodes and the transaction between them. As already explained, the nodes are:

- Document Source, which is the system that publishes the clinical document.
- Document Repository, which is the system where documents are stored.
- Document Registry, which is the system where metadata are stored and searches are performed.
- Document Consumer, which is the user system that retrieves the documents stored in one or more repositories.

Modules that compose the central system

The central system is composed of several modules; all of them are Open Source. The three most important ones are:

- **O3-DPACS** is an Open Source PACS developed by the O3 Consortium initiative. Its role is to store and manage the images that are sent from the PACSs of the external health bodies. In this particular architecture, there are two central O3-DPACS modules, one for each health body. It is even possible to merge them into one or move them onto the health enterprise side in order not to move information from the source.

- **O3-XDS** is an Open Source XDS system developed by the O3 Consortium initiative. Its role is to save and register the documents, both reports and pointers, to the images (following XDS-I extension). Following the XDS schema (Figure 3), there are two sub-modules: one registry for registering the documents and two repositories, one for each health enterprise. Similar to O3-DPACS, two repositories are provided, which can be merged or moved onto the health enterprise side.
- **PHI Radiology Portal** provides web access to the information stored in the central system. It is based on PHI-Technology, an Open Source framework developed and maintained by TBS Group S.p.a. The web interface allows the radiologists to review the images and the reports. It provides the capability to create second opinion and teleradiology requests.

Conclusion

Practical implementation of e-health in general, and especially of teleradiology systems, faces many obstacles. The applications are fragmented, with little cross-border or even cross-institutional coordination and data exchange. The key technology challenges to be met are integration and interoperability. In order to meet them, it is recommended to use standard communication protocols and IHE recommendations. A properly managed Open Source approach in the development of ICT applications in teleradiology can resolve these challenges very efficiently.

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