Building Continents of Knowledge in Oceans of Data: The Future of Co-Created eHealth
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Shared Medical Imaging Repositories

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Abstract. This article describes the implementation of a solution for the integration of ownership concept and access control over medical imaging resources, making possible the centralization of multiple instances of repositories. The proposed architecture allows the association of permissions to repository resources and delegation of rights to third entities. It includes a programmatic interface for management of proposed services, made available through web services, with the ability to create, read, update and remove all components resulting from the architecture. The resulting work is a role-based access control mechanism that was integrated with Dicoogle Open-Source Project. The solution has several application scenarios like, for instance, collaborative platforms for research and tele-radiology services deployed at Cloud.

Keywords. Medical Imaging, DICOM, Shared Repositories, RBAC

1. Introduction

In the last decades, digital medical imaging systems has seen its presence strengthened in the healthcare industry, as they provide great support to medical staff in terms of clinical diagnosis and support to therapeutic processes. The interoperability between equipment and information of digital medical imaging laboratories is ensured by the DICOM standard. It defines the reference information model, how data is encoded and communicated. Data is agglutinated in DICOM object structures, which contain metadata related to the procedure, patient, acquisition, modality and institution, besides pixel data.

Picture Archiving and Communication System (PACS) refers to the set of software and hardware units responsible for the acquisition, storage, distribution and visualization of medical imaging studies. The core component is the storage server (i.e. the archive) that receives images from modalities, store them in a structured way, supports content discovery and retrieval. They are fundamental to ensure a fully digital and distributed workflow where the intervenient can be anywhere, including the departmental intranet or at home.

In a traditional PACS environment, an archive serves a same organizational domain where authorized users have access to all repository. So, accounting mechanisms are not required. However, more recent usage scenarios brought new necessities like the coexistence of distinct ownership domains in the same server instance. For instance, academic PACS and Tele-radiology PACS deployed at Cloud as a service need to support access control associated with resources. Several use cases may be identified in

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those scenarios. For instance, a student may have a private working area and share some resources with the professor. Or else, an institution outsourced the repository and wants to share examinations with a group of external professionals for reporting purposes.

This article proposes and describes the implementation of a Role-Based Access Control (RBAC) mechanism in an open-source PACS archive, i.e. Dicoogle[2]. The challenge was to study an architectural solution to support the multi-archive and multi-user paradigm, without impact in regular digital workflows supported by DICOM.

The work began by studying and analyzing the existing access control mechanisms and permissions management systems, in order to understand how state of the art solutions could be adapted to solve the challenge. It was concluded that no existing solution satisfied the project requirements and a new system was designed, implemented and validated.

2. Background

Historically, healthcare institutions are obligated to make great investments in IT infrastructure to support medical imaging laboratories, including installation and maintenance costs. However, this traditional model is obsolete and the world is assisting to a shift towards archiving medical images on the Cloud. Nowadays, we are at an early stage transition of the medical imaging market to the Cloud. Logistically, having the resources centralized and always available opens new and more convenient ways to access, work, distribute and collaborate with all stakeholders.

The volume of data generated by some modalities can be very high like, for instance, in XA, US, multi-slice CT and digital mammography with tomosynthesis [1]. So, to manage these data, it is primordial to create robust and efficient storage and communication infrastructures to ensure full availability [2,3], even without requiring major upgrades and overhauls that increase the cost over time [2].

PACS are fundamental to support digital medical imaging workflows, being composed of a set of hardware and software units that process, store, distribute and visually consumes medical imaging studies and associated data [1,4]. They support intra and inter-institutional processes. PACS workflow has the following major steps: acquisition, distribution and displaying [5]. By stating these processes, we can infer that PACS turn the workflow easier in medical imaging environments, allowing clinics, physicians and technicians to access the data quickly.

Digital Imaging Communications in Medicine (DICOM) is the *de facto* standard in the medical imaging area [6,7]. It is universally used and supports systems interoperability in the last two decades and a half. It specifies a non-proprietary medical data interchanging protocol, data format and file structure for medical images and its associated metadata [8]. Over the years, the proliferation of DICOM compliant equipment enabled the exchange of data between medical imaging devices and triggered the implementation of PACS.

PACS typically implement a set of DICOM services, including storage, query and retrieve services for Intranet operation (i.e. C-STORE, C-FIND and C-MOVE) and its Internet version compliant with HTTP communications (i.e. STOW-RS, QIDO-RS and WADO-RS).

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[2] http://www.dicoogle.com

2.1. Dicoogle

Dicoogle is an open-source PACS [9] mainly developed by the UA.PT Bioinformatics research group and the BMD Software company. It can be used to support three distinct usage scenarios: production, research and teaching. It has a modular concept given that it provides a software development kit (SDK) that allows developers and researchers to quickly develop a new functionality.

The platform replaces the traditional relational database with a more agile process of indexing and retrieval mechanism [10]. Dicoogle was designed to extract, index and store all the metadata presented in DICOM files of receipt studies, including private tags, without any engineering or configuration process [9,11].

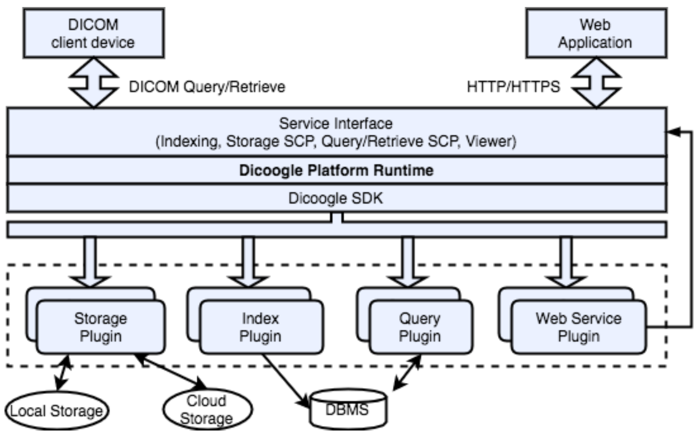

Figure 1. Dicoogle general architecture. Adapted from [10].

Dicoogle SDK was created in order to simplify the development of new features [6] by third parties and assure compatibility with core functionalities. To develop a new functional module, programmers need to implement the available interfaces and move the built package to Dicoogle Plugins directory. After this process, Dicoogle will automatically load the new modules on startup. Dicoogle SDK makes immediately available all operations related to storage, querying and indexation via its internal API [10].

3. Proposed Architecture

This article proposes an accounting architecture for PACS-DICOM archives, allowing that one same server instance to serve multiple organizations, installations, users and permissions. It implements a role-based access control (RBAC) approach in a standard DICOM structured repository to restricting system resources access to authorized users. It provides mechanisms to manage entities, resources and roles.

The architecture is an abstraction of a real-work medical imaging laboratory environment. In figure 2, is shown a representative scheme of the real-world. On top of the hierarchy, there are Organizations, which contains multiple Facilities and Users associated with it. On this point, the focus starts to be on User. A User from a Facility must have access rights to the Resources that belong to that one Facility. Although, there are permissions on the system that users must have to access Resources. For instance, a User must have Permission with the tuple (Read, Resource) to access a Resource.

Resource entity can be an Organization, Facility, User, or even Permission, but can be also a DICOM object. The RBAC information model also follows the DICOM model where the Resource Patient can have one or more Studies. One Study contains one or more Series. This one has one or more Instance objects (e.g. image files). This model allows the attribution of unique permissions of single or group of Resources to different users.

Besides the direct Permissions assigned, a User may belong to a group of users, which in turn will contain multiple Permissions. In the example shown in Figure 2, there is User 1 who belongs to Facility 1 of Organization 1 and, at the same time, belongs to Facility 2 of Organization 2. Additionally, User 1 is inserted in the group Role 2.

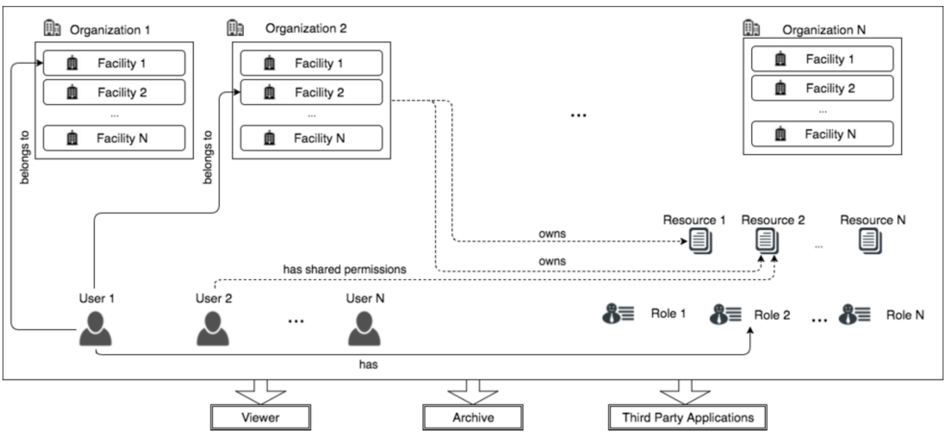

Figure 2. Real-world representation of the *Role Based Access-Control* model.

As expressed, the proposal was instantiated and validated as an extension of Dicoogle Open Source PACS that already provides several features to extract metadata and maintain DICOM archives. We used the Dicoogle SDK layer to develop and integrate the RBAC module with Dicoogle core functionality. Other Dicoogle modules can consume the new security services provided by the RBAC module.

The development of described accounting mechanism was mainly motivated by the necessity of offering those security services in standard DICOM Web provided by Dicoogle platform. In this scope, the WADO-RS, STOW-RS and QIDO-RS services were also refactored to consume the new RBAC module, as an option. So, a third platform may consume Dicoogle services (storage, query and retrieve) with access to resource filtered according with RBAC policies applied to the user that is provided in the HTTP authentication layer.

Finally, a web portal was developed to support for end-user management of proposed architecture, consuming the services available through Rest API.

4. Conclusion

There are several contributions of the work described in this article. First, an accounting mechanisms for medical imaging repositories; secondly, the integration and evolution of an open source platform, i.e. the Dicoogle PACS; thirdly, the development of a Web API of services for management of proposed architecture and transparent integration with third applications; and finally, developed services were integrated with most recent DICOM Web standard, supporting the STOW-RS, QIDO-RS and WADO services.

The proposed architecture was validated through exhaustive functional tests that mime real-world use cases. The implementation of a multi-user medical imaging archive integrated with personal cloud storage services like, for instance, Dropbox or Google Drive is being developed.

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