A Scalable Parametric-RBAC Architecture for the Propagation of a Multi-modality, Multi-resource Informatics System

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Abstract. We present a scalable architecture called X-MIMI for the propagation of MIMI (Multi-modality, Multi-resource, Informatics Infrastructure System) to the biomedical research community. MIMI is a web-based system for managing the latest instruments and resources used by clinical and translational investigators. To deploy MIMI broadly, X-MIMI utilizes a parametric Role-Based Access Control model to decentralize the management of user-role assignment, facilitating the deployment and system administration in a flexible manner that minimizes operational overhead. We use Formal Concept Analysis to specify the semantics of roles according to their permissions, resulting in a lattice hierarchy that dictates the cascades of RBAC authority. Additional components of the architecture are based on the Model-View-Controller pattern, implemented in Ruby-on-Rails. The X-MIMI architecture provides a uniform setup interface for centers and facilities, as well as a set of seamlessly integrated scientific and administrative functionalities in a Web 2.0 environment.

Keywords: Role-based access control, Scalable information system, Web 2.0.

1 Introduction

A significant challenge encountered by biomedical research facilities today is the efficient management of costly instrumentation, staff time, as well as the storage and archiving of large volumes of complex experimental data and results. According to [2], this challenge is both widespread and acute, and can only become more magnified as facilities grow and new tools and techniques become available, a trend recognized by the NIH Roadmap [3].

There are no off-the-shelf software packages which combat these challenges adequately. To address this research informatics infrastructure issue, we have developed a comprehensive web-based information management system called MIMI (Multi-Modality, Multi-Resource Informatics Infrastructure) that seamlessly integrates administrative support and scientific support in a single system. Separate instances of MIMI have been deployed over the past two years, in three different kinds of facilities: Imaging [14], Proteomics, and Flow-Cytometry. With the deployment of more instances of

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MIMI, we realize that scalability and usability are essential properties of a web application in the biomedical research infrastructure domain. Here scalability refers to a system architecture’s ability in setting up and managing a large set of administrative workflows and roles in a secure manner in a complex organization without direct, centralized control. Usability refers to strengthened user interface design in order to account for large discrepancies in computer experience among the users of such a system. Web 2.0 allows us to address the usability issue in a way such that a web application such as MIMI compromises neither features nor responsiveness compared to a typical stand-alone desktop application.

This paper presents a scalable architecture called X-MIMI, to provide a streamlined process to propagate MIMI instances to centers and facilities. A key component of X-MIMI is a setup framework that allows a facility to both setup and manage its available services, users, and supporting staff, under the organizational structure of a center. Centers such as NCI designated Comprehensive Cancer Centers [7] play a critical role in translational research, with both pre-clinical and clinical facilities under a common administrative infrastructure to facilitate the translation of discoveries from “Bench to Bedside” [3]. A facility in the X-MIMI architecture is composed of five main entities: people, equipment/service/workflow, input sample, output/raw data, and administration. These entities can be further categorized into different subtypes if necessary.

Access to the setup framework and other content areas of X-MIMI is mediated by a parametric RBAC (Role-Based Access Control [9]) model, PRBAC. Our extension combines both ARBAC - Administrative RBAC [10] and User-to-User Delegation [13] to provide maximal administrative autonomy and flexibility without compromising information security. ARBAC allows the management of RBAC itself as an explicit permission. User-to-user delegation allows for some of the permissions of a user to be routinely exercised by other users, such as sharing data, generating reports, and managing the scheduling of resources. We also employ user-to-user delegation extensively in user interface testing. In order to ease the complexity of applying the PRBAC model in X-MIMI, we use Formal Concept Analysis [5] as a novel semantic framework for PRBAC, allowing the role-hierarchy to be derived from the Role-Permission table automatically to minimize potential inconsistencies between the role-hierarchy and the intended authority of a role.

Another feature of X-MIMI system is using WYDIWYS (What You Do Is What You See [4]) as the guideline in designing an effective user interface. This feature, together with parametric ARBAC, requires a thorough analysis of user privileges and system functionalities to ensure that navigational links and actions are not displayed when users are not authorized to perform. If it is not done systematically, for data and feature rich systems such as X-MIMI, it may result in a poorly organized system that is hard to extend and maintain.

X-MIMI has the following set of features:

- it provides an integrated solution for managing all informatics aspects of centers and their facilities in a single system, from resource scheduling, operations management, user management, project and data management to billing and report generation;
- it is scalable for deployment by using a decentralized setup framework supported by a parametric RBAC model;