Development of a Grid-based Learning Management System

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Abstract: - Using Grid technologies for enhance e-learning systems represents an attractive, but a laborious solution if we consider not only the benefits, but also the difficulties that must to be overcome. This paper presents our research for development of a Learning Management System (LMS) that integrates Grid capabilities in an efficient and flexible e-learning solution. Certain independence was desired and obtained for the Grid infrastructure and LMS, so that these sub-systems of the e-learning system could evolve according to next developments of tools (Grid toolkits, portal tools, learning tools) and learning standards. The Grid-based LMS manages learning content as aggregates of learning objects that integrates Grid Services, which are developed and deployed in the Grid infrastructure of the e-learning system.

Key-Words: - Web-based education, e-learning systems, Grid computing, learning management systems

1 Introduction

Most of the academic institutions are now offering some forms of e-learning systems for their students in order to enhance the educational process, providing a better interaction between the learners and the learning activities and a better availability of learning experience (i.e. the learning can happen anytime and anyplace).

The main rolls in these systems are the learners, the authors and the administrators. The authors create learning content by means of an Authority System (AS); the learning content is managed and delivered to the learners by a Learning Management System (LMS) controlled by an administrator. The LMS constitutes the most important and complex part of an e-learning platform that manages delivering learning content to learners and monitors progress and performances as the learner moves through the learning content [1].

Learning content are commonly organized in independent units as *learning objects*, which represent reusable granules that can be accessed dynamically and possible remotely, e.g. over the Web. Compatibility and reusability of learning content for different e-learning systems can be accomplished using different standards that were adopted, such as: IEEE Learning Object Metadata (LOM) that enables the search for content [2], IMS Content Packaging that specifies the exchange of content objects between authoring tools, IMS SS (Simple Sequencing) which defines the sequencing mode of the learning objects [3]. These standards are integrated under a reference model developed by the Advanced Distributed Learning (ADL) Initiative, named Sharable Content Object Reference Model (SCORM), which is a collection of specifications adapted from multiple sources to provide a comprehensive suite of e-learning capabilities that enable interoperability, accessibility and reusability of Web-based learning content [4].

Web-based e-learning systems have many advantages, but they also have some drawbacks (such as poor scalability and collaborative interactions) that can be avoided using Grid technologies [5]. E-learning systems can take advantage of Grid technologies that offers robust, distributed collaborated and ubiquitous computing environment as the infrastructure, and secure mechanisms for resources sharing and integration as Virtual Organizations (VOs).

For the development of our Grid-based e-learning system we used open source Globus Toolkit Version 4 (GT4) that implements Web Services Resource Framework (WSRF) specifications, which define a WS-Resource as a composition of a Web Service and a stateful resource [6].

This paper presents a Grid-based Learning Management System and is organized as follows: Section 2 presents a general architecture of the Grid-based e-learning system; Section 3 discusses the organization of learning content and the architecture of the LMS; Section 4 presents the structure of Grid-enabled learning objects; Section 5 describes the course management and progress monitor functions of the LMS; Section 6 presents conclusions.

2 General architecture of the Grid-based e-learning platform

The general architecture of the Grid-based e-learning platform (presented in Fig. 1) is structured into three parts: (a) Grid Infrastructure, (b) Run-Time System, and (c) User System.

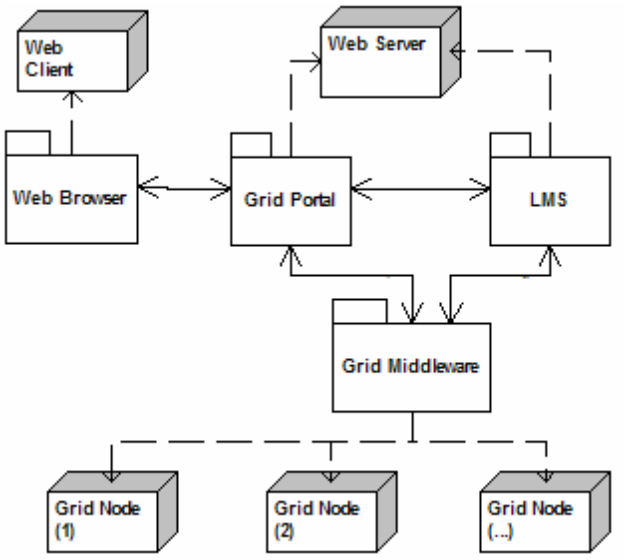

Fig. 1. The architecture of the e-learning platform.

(a) *The Grid Infrastructure* consists of Grid Middleware components deployed in different nodes of the network. For the development of our Grid-based e-learning system we used open source Globus Toolkit 4 (GT4), which implements Open Grid Services Architecture (OGSA). Each GT4 node consists of Java containers, libraries, services and different other components for publish-discovery of services, scheduling, authentication etc.

(b) *Run-Time System* consists of a Grid Portal and Learning Management System (LMS) that are components deployed in a Web server (Tomcat Server) developed in Java technologies (JavaServer Pages, servlets, JavaBean).

A Grid Portal is a specialized web portal that provides an entry point both to the LMS and Grid resources, services and data [7]. The Grid Portal manages the identity of all users (learners, authors and administrators) and offers web interfaces for displaying resource information, job scheduling and file/data management.

LMS coordinates all learning-related activities: stores and manages learning content, administrates courses and tests and keeps tracks of users' individual behavior. The LMS offers both content which makes use of Grid, as well as content that does not need Grid functionality.

(c) The User System provides a browser-based interface for accessing e-learning platform through the Grid Portal.

This architecture combines Grid facilities with web portal capabilities, hiding Grid complexities from user clients, that don't need to download or install any specialized software or worry about Grid details, networks and ports.

3 Organization of the LMS and learning content

In our project, Learning Management System (LMS) is developed as a Web server environment that manages delivering learning content to students and tracks progress and performance as the learner moves through the learning content. It is a flexible framework that support the most important principles established by actual e-learning standards (IMS, SCORM) regarding the format of learning content and real-time interactions.

The organization of the Learning Management System and its functions are presented in Fig. 2.

Learning content is provided composed from relatively small, reusable learning objects, which have no specific context. A learning object can be composed, at its turn, by several smaller entities (resources) packaged together as an auto-established unit.. A package representing a learning object is a unit of learning and contains two major components:

- A special XML document describing the content structure and associated resources of the package called the manifest file.
- The physical files making up the content (image and audio files, JavaScript functions, Flash objects, HTML files, etc.).

A *learning object* may be a part of a course that has instructional relevance outside of a course organization and can be delivered independently, as a portion of a course, an entire course or as a collection of courses. A package must be able to stand alone; that is, it must contain all the information needed to use the packaged contents for learning (resources).

A *learning activity* (such as course learning, module learning, and an assignment) is defined by an activity map that specifies an aggregation of different learning objects. The activity maps provide the execution context and sequence/navigate rules for learning objects, and these rules are interpreted by the LMS.

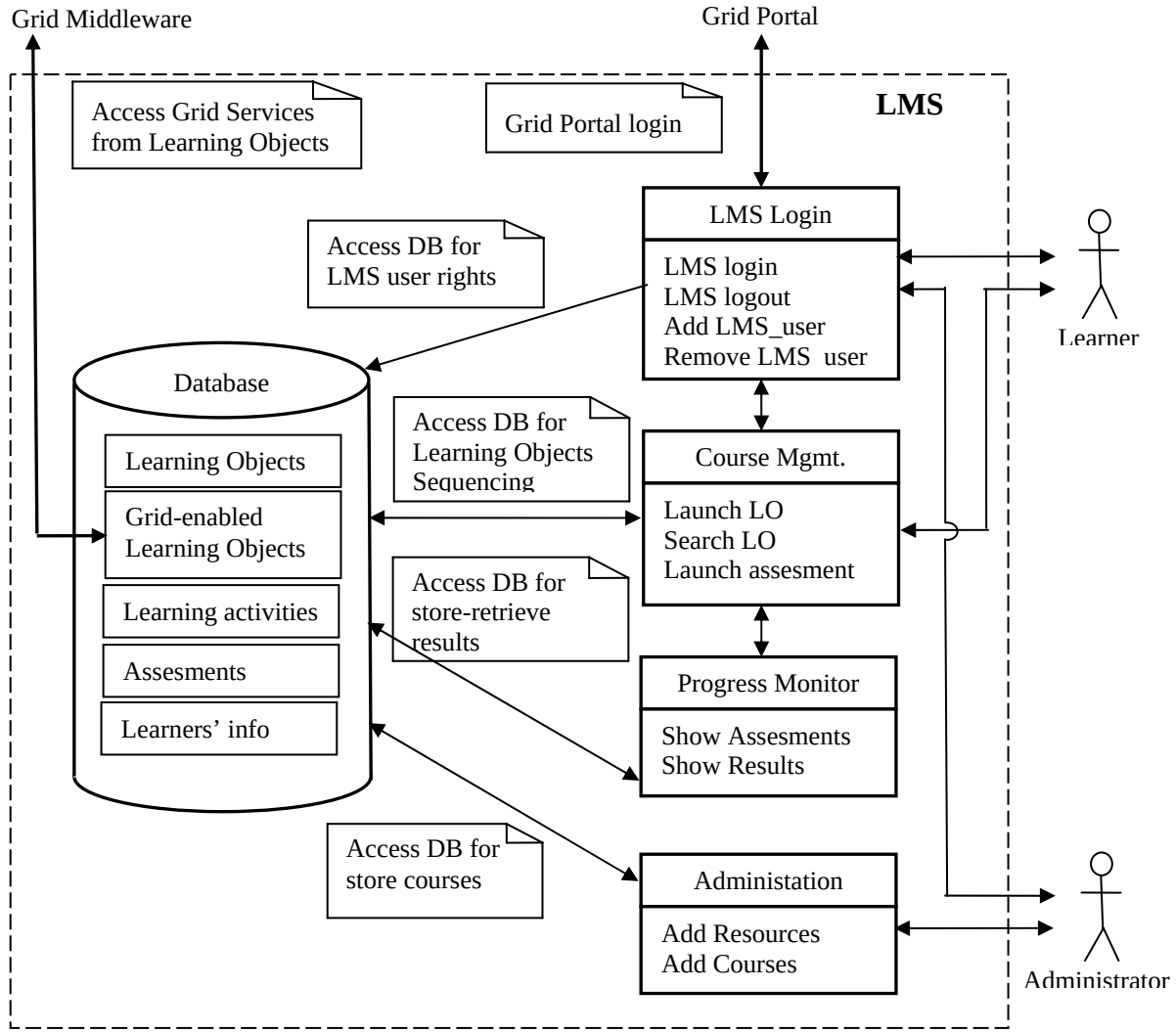

Fig. 2. Organization of the LMS.

This means that learning objects do not contain themselves rules for sequence/navigate through an aggregation representing a learning activity and thus learning objects can be designed for reuse in multiple contexts (as sharable content objects – SCOs in SCORM model [4]).

Learning content can be created using different authoring tools (with the condition that the content structure defined at the design to be correctly interpreted by the LMS) or using some functions of the LMS itself.

In our project the development of learning content is accomplished by a separated off-line tool that defines learning objects and aggregation rules for learning activities. The learning content is registered in the e-learning platform through an administration function of the LMS that stores all information (learning objects information, learning activities rules) in different tables of a database. The DBMS can be implemented with mySQL, PostgreSQL, Oracle or other systems; we used PostgreSQL, which is integrated with Globus Toolkit GT-4.

User login is accomplished through Grid Portal sub-system. Grid Portal offers an integrated authentication infrastructure that combines username and password authentication of users (stored in the database) with Grid credential delegation using a MyProxy repository. In this way, the users (learners and administrators) don't need to re-authenticate while access Grid and e-learning resources frorn any host in the network and passwords used for proxy credentials generation and retrieval by the portal are never stored and travel the internet via a secure https connection. [8].

4 Grid-enabled learning objects

In our Grid-based e-learning platform learning objects can be a simple collection of resources, with an organization specified in the manifest file, or can include one ore more Grid services, which are invoked by learning objects to solve computing-intensive tasks during learning activities (Grid-enabled learning object).

Like any Grid service of the Grid Infrastructure of the system, a Grid services used by LMS through learning objects is published in the Index Service of the system when it is deployed in the Grid [9].

The client of a LMS-used Grid service is developed as a context-independent client, which calls Grid service instance and returns some value, without a specific utilization or graphic interface.

Such a client is invoked in a learning object with a JavaBean that uses the name of the service for discover its address in the *Index Service* of the Grid organization. Alternatively, the administrator of the LMS can select a particular instance of the Grid service registered in the Index Service (as can be seen in Fig. 3(a)). This option allows an independent development of learning content and Grid services, and adaptive run-time connection between them.

5 Course management and progress monitor

Course Management and Progress Monitor is the most dynamic part of the LMS. All elements of this section are dynamic generated by the LMS based on activities maps stored in the database.

The starting page of this section offers a list all all available learning activities (courses, in general). For every logged and authenticated learner, a course new page, dynamic generated from the information stored in database, is sent to the client (browser) and displayed. As can be seen as an example presented in Fig 3 (b), such a page contains the learning objects that compose the learning activity (course) and possible some assignments.

For every learning object ("element") LMS can display the type of the object ("prezentare" – means presentation in Romanian; "test" means an assessment object) and the particular situation ("nota" – grade in Romanian) of the learner (in this example: Vlad Nae). If the learning object is of type presentation, the learner is considered admitted ("adm"); if the object is of type test, the maximum possible grade is displayed (in this example, 10.0).

Fig. 3 (a) LMS administration example: selecting a published Grid service for a learning object. (b) LMS execution example: course presentation (learning objects and assessments).

During a learning activity, LMS uses the activity map (loaded from the database) for sequencing through learning objects and assessments, until all activities are accomplished or the learner abandons the course. During this execution, LMS monitors and stores progress information for those learner.

After the learning activity is terminated (or at a learner request), LMS displays the track of component activities and results of the learner for those learning activity.

Every learning object is indivisible from the LMS point of view: LMS can launch a learning object starting with the starting point stored in the database and loads a special page (sequencing page) when the learning object is terminated. The sequencing page includes JavaBeans components that access the sequencing table in the database and redirects the execution to the next learning object.

This execution can be observed in the fragment from the sequencing JSP page (*sequencing.jsp*) presented below:

```
// Fragm. /ePortal/jsp/sequencing.jsp
<%@ page language="java"
session="true" %>
// Include a JavaBean for DB access
<jsp:useBeanid="DBBean"
class="org.globus.dbBeans.EPortalBean"
scope="session"/>
// Get parameters
String s_idcurs =
   request.getParameter("idcurs");
String s_index =
   request.getParameter("index");
// READ NEXT LO START POINT
ResultSet nextElement =
   DBBean.getElement(idcurs,index);
// Re-direct parameters
<jsp:forward page="<%= uri %>">
   <jsp:param name = "idcurs"
   value="<%= idcurs %>"/>
   <jsp:param name = "index"
   value="<%= index %>"/>
</jsp:forward>
```

Even from the LMS point of view the learning objects are indivisible, the learning object can be composed by many resources (stored as separated files) and Grid services clients (included in a resource file of the object – typically a JSP page), all of them described in the manifest. The condition that component resources of a learning object must fulfill is that the transition between them to be controlled by the learning object itself. After the last resource is terminated, LMS uses its sequencing page for navigate to the next learning object.

6 Conclusion

In this paper we described our design and implementation of a Grid-based Learning Management System (LMS) that allows using Grid Services in context of learning objects during learning activities. LMS recognizes and interprets the structure of learning content, which is composed of many independent, reusable, self-contained learning objects, aggregated in learning activities through aggregation rules stored as activity maps. Learning objects integrates Grid Services, which are developed and deployed in the Grid infrastructure of the system. A possible development of this e-learning platform includes support for SCORM model and integration of different available tools (such as GridPort, Sakai [10]) and this is our intention for the next phases.

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