

The Grid for Learning

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Abstract. Grid technologies are rising as the next generation of Internet by defining a powerful computing paradigm by analogy with the electric Power Grid. A Grid user is able to use his private workplace to invoke any application from a remote system, use the system best suited for executing that application, access data securely and consistently from remote sites, exploit multiple systems to complete economically complex tasks or to solve large problems that exceed the capacity of a single system. Grid could be used as a technology “glue” providing users with a uniform way to access resources by means of several devices. These technologies can provide, in a natural way, a support for Technology Enhanced Learning (TEL) by enabling new learning environments based on collaboration, social interaction, experience, realism, personalisation, ubiquity, accessibility and contextualisation. Nevertheless, to be effectively used in TEL, Grid must be complemented with other elements like semantics and educational modelling so bringing to the concept of “Grid for Learning” whose description is the object of this paper.

Keywords: distributed computing, grid, learning design, ontologies, semantics.

1 Introduction

Over the last few years, Technology Enhanced Learning (TEL) needs have been changing in accordance with ever more complex pedagogical models as well as with technological evolution, resulting in environments with very dynamic teaching and learning requirements. Such important requirements include, according to [5]:

- wide geographical distribution of learners and tutors who can potentially belong to many different educational institutions;
- access from anywhere, on any learners’ computer platform and any software;
- support for a growing load of learning resources and users who access these resources;
- transparent share of an huge variety of both software and hardware learning resources;
- transparent access to shared, heterogeneous learning resources in very dynamic environments;

- multiple administrations from different organisations with specific educational policies;
- inherent dynamism of learners and tutors needs and changing learning resources;
- constant provision of user awareness and feedback so as to keep learners and tutors informed about what is happening in the learning environment resulting in an enhancement of cognitive, social and emotional support to on-line learning groups;
- flexibility to reuse pieces of learning resources of different granularity according to specific needs (e.g. customise a curriculum by reusing specific learning activities with different input data);
- facility to personalise, update, and meet learning resources by instructors and learners without technology skills.

These requirements represent a great challenge for traditional software platforms and tools but may be solved by relying on distributed paradigms like Service Orientation or Grid.

Grid technologies have started to be very popular in education due to the advantages that they offer being based on a secure, flexible and coordinated way of sharing resources in the Internet as well as on its enormous capability of information processing. In addition to the mentioned set of requirements, the Grid approach represents an ideal context for supporting and producing further benefits for TEL including [20]:

- adaptability at runtime to highly dynamic conditions in learning settings;
- interoperability by providing support to the great variety of learners' and tutors' computer platforms and software;
- scalability to a large number of single/group learners and tutors who can be distributed in very different locations;
- availability of an increasing number of heterogeneous and changing learning resources;
- integration of new and existing learning resources and tools as well as other legacy systems from their own or other educational organisations;
- support for notifications to learning participants about what is happening in their environment;
- high level of abstraction that allows all the actors involved in the learning process to easily perform their ideas by services.

In addition, within the TEL domain, Grid promotes collaborative development among all community participants, enhances coordination in the research community, enables sharing of best practices, improves the understanding of the virtual educational needs, etc. As a result Grid appears to be a good choice to support the development of the most pervasive and challenging TEL environments but must be complemented with other technologies in order to be fully effective.

Following this trend, a Special Interest Group of the European-wide Network of Excellence "Kaleidoscope" [17] have been dedicated to the establishment of an observatory on Grid applications to TEL in order to survey the field and to foster

discussion among research groups spread in Europe. One of the results of this discussion is the definition of the “Grid for Learning” concept here presented.

After having introduced some research work related to the Grid and TEL in par. 2, the concept of Grid for Learning is presented in par. 3. Then some challenging scenario exploiting the defined concept is described in par. 4 while par. 5 presents concluding remarks.

2 Related Work

Before starting to introduce the concept of “Grid for Learning” it is useful to outline, according to [7], the most recent and significant works that contributed to the definition of the concept and to the development of technologies that make it possible.

The Grid Service Based Portal for Virtual Learning Campus [26] developed an environment which makes use of the Grid capabilities so that to make possible the dynamic sharing and coordination of heterogeneous resources which are found dispersed in the network. The project focuses on the development of a video digital library based on Grid for a Virtual Campus that allows an easy access and implementation of several services. In spite of being a project that aimed to take advantage of the capabilities that Grid technology provides, it is limited on a unique type of educative resources, like video, which a structure of services is developed for.

In [19] it is described a TEL platform based on Grid service technologies. In this platform the supply of virtual learning services designated for students, instructors and course suppliers is based on the resource administration for group collaboration based on Grid, allowing ubiquitous access to information and taking advantage of the potentiality of the computer systems. On the one hand, the advantage of this proposal is that it is the first one that elaborates on the use of Grid resources and their description through Grid technologies, in particular WSDL. On the other hand, it dictates the need for the development of a semantic model description that enables a more complete description of learning resources.

ULabGrid, an Infrastructure to Develop Distant Laboratories for Undergrad Students over a Grid, [2] proposes a new architecture that allows the educators to design remote collaborative laboratories for university students using the Grid infrastructure. This project is one of the first in its type in trying to combine the facilities that Grid provides in a practical scenario in order to achieve resource sharing and motivate collaborative work. In this sense the design of Grid-based collaborative learning scenarios should be supported by semantic descriptions that allow the best tracking of resources available in the network.

A further work proposes an Agent-Based Robust Collaborative Virtual Environment for TEL in the Service Grid [15]. In this virtual environment, all Web resources and services are accessed via service encapsulation, which may result in a more scalable and robust collaborative learning architecture. A very remarkable aspect of this work is the way it uses to implement complex services from more basic ones, though no use of semantic description is made to allow the automatic composition of complex services from lower level ones.

KGTutor, a Knowledge Grid Based Intelligent Tutoring System [29], proposes a model for the construction of intelligent tutoring in a more pleasant and effective way. The KGTutor is designed to provide better support to student centred distributed learning. Students' characteristics, such as previous knowledge and learning styles, are used to choose, organize, and deliver the learning materials to individual students. During learning progress, the system can also provide objective evaluations and customized suggestions for each student according to their learning performance. This system provides a very important work as far as student centred learning concerns, though it could be further strengthened through the use of aspects of semantic description of learning services.

In [25], a Grid Service Framework for Metadata Management in Self-e-Learning Networks focuses on how the use of metadata can be critical for Grid systems. More specifically, the semantic description constitutes a very beneficial extension of Grid environments. The Self e-Learning Network (SeLeNe) is used as a test application while a set of services is proposed which are implemented with OGSA. The project focuses on providing services that use learning objects metadata, based on a sufficiently generic approach so that they can be used by other Grid-based systems which need to make use of semantic descriptions.

ELeGI (European Learning Grid Infrastructure) [23] was aimed at providing an advance in the current practices of learning through the definition and implementation of a software architecture that achieves to unify the semantic Grid and information technologies in order to promote and give support to the definition and adoption of learning paradigms for the construction of knowledge that combines customized and ubiquitous techniques based on experiential, collaborative and contextualized learning. In this line, [13] presents a work about ontology based user modelling for personalization of Grid learning services. This work describes how the learning services of the Grid should support a user-centred, customized, contextualized, experiential and ubiquitous based learning approach.

The SELF project [1] proposes a learning environment that results from the integration of several technologies, specially the semantic Web, Grid technology, collaborative tools as well as customized tools and knowledge management techniques. SELF provides a mechanism for the intelligent search of services making use of semantic description tools. This project presents an important reference of the use of different technologies for the development of Grid-based learning scenarios, even though it is not based on semantic description models for the definition of its tools.

OntoEdu [14] is a flexible platform for online learning which is based on diverse technologies like ubiquitous computing, ontology engineering, Web semantics and computational Grid. It is compound of five parts: user adaptation, automatic composition, educative ontologies, a module of services and a module of contents; among these parts the educative ontology is the main one. The main objectives of OntoEdu are to obtain reusability of concepts, adaptability for users and devices, automatic composition, as well as scalability in functionality and performance.

The work developed in [18] presents a workflow framework for pervasive learning objects composition by employing a Grid services flow language. Learning objects

are distributed in heterogeneous environments which have been used in order to allow effective collaboration and the reuse of learning objects; this fact can help users to learn with no limitations of time and space. This work shows the great opportunities that exist in those research groups which make use of Grid technology to develop innovative, pervasive and ubiquitous learning scenarios.

Finally, in the work referenced as “Semantic Search of Learning Services in a Grid-Based Collaborative System” [27], the authors have constructed an ontological description for collaborative work tools that allow one to make a manual search of the diverse resources that these tools provide within a Grid environment with the minimum of technical knowledge. This work proposes a Grid-based tool called Gridcole, which can serve as a basis to implement different conceptual approaches of Grid-based semantic description of learning services, thus extending and endowing it with an innovative, pervasive and ubiquitous projection.

3 The Grid for Learning Concept

In the beginning, **Grid** was synonym of meta-computing and according to this first vision, Kesselman and Foster attempted a first definition of the Grid as “... a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities” [10]. Research has brought to a new vision of Grid that became synonym of infrastructure to manage “coordinate resource sharing and problem solving in dynamic, multi-institutional virtual organizations” [10] where the focus is on the concept of Virtual Organization (VO).

Currently, the evolution of Grid is marked by the adoption of a service oriented approach in designing Grid architectures. The Open Grid Services Architecture (OGSA) integrates key Grid technologies with Web Services mechanisms to create a distributed system framework for integrating, virtualizing and managing resources and services within distributed, heterogeneous and dynamic VO [11]. In addition, by adopting the Web Services Resource Framework (WSRF) [9] it is possible to define a Grid resource as a “stateless service acting upon a stateful resource” so applying a service model of an intermediate complexity between pure stateless services and pure conversational ones, thus allowing a simple way to compose services without losing the advantages of state management.

Upon the OGSA model, different kinds of Grids have been raised like Computation, Data or Information Grid. Apart from the specific term, the key features of all these Grids are virtualization in term of services and dynamic policy-based provision of what is virtualized. Some of them deal with well known issues, like Computational Grid that provides the access to a large virtual computer and Information Grid permitting the access to a large virtual information source.

Among them a key role for TEL is played by the **Semantic Grid** that was defined by De Roure and other researchers as: “an extension of the current Grid in which information and services are given well-defined meaning, better enabling computers and people to work in cooperation” [8]. In other words a Semantic Grid is a Grid improved through standards and technologies of the Semantic Web [3] community, to make explicit and machine understandable the knowledge about resources and services as well as communities and individuals of communities.

A Semantic Grid relies on specifications like OWL-S [22] and WSMO [28] in order to semantically enriches resources virtualised through a service to let software agents compare the requirements of a service against its description to find the service that best satisfy the requirements. In this way it supports the automatic negotiation, discovery and composition of services.

For this reason the Semantic Grid is a good enabling infrastructure for TEL, able to fulfil many of the requirements listed in the first paragraph. It also supports personalization and knowledge creation, acquisition and evolution and can provide a wide and heterogeneous set of services and didactical resources for active experiences. It also supports the autonomous and dynamic creation of communities through the VO paradigm.

Nevertheless, in order to be fully exploited in the TEL domain the Semantic Grid should be enriched with **Educational Modelling** capabilities through the integration of feasible Education Modelling Languages (EMLs) and the provisioning of services discovery and composition capabilities driven by such languages. An EML can be defined as a semantic notation for units of learning to be used in TEL to support the reuse of pedagogical entities like learning designs, objectives, activities, etc. EMLs involves the description of learning processes and methods from a pedagogical and instructional rather than content-driven perspective.

IMS Learning Design (IMS-LD) [16] is currently the widest diffused EML and, according to [4], the one more feasible to be used as the basis in a Learning Grid environment. Through IMS-LD it is possible to describe a wide variety of pedagogical models, including group work and collaborative learning. It does not define individual pedagogical models but provides an high-level language that can describe many different models. The language describes how people perform activities using resources and services, and how to coordinate them into a learning flow.

Nevertheless IMS-LD is currently hardly exploitable in Semantic Grid environments due to several limitations coming from design-time resource binding. This imply a lacks of dynamicity i.e. services must be bind at design time rather that at execution time so hindering to fully exploit dynamic discovery and composition of learning services. To solve this problem [6] proposes semantic extensions to IMS-LD.

The integration of the above mentioned technologies bring us to the following definition of the **Grid for Learning**:

A Grid for Learning is an enabling architecture based on three pillars: Grid, Semantics and Educational Modelling allowing the definition and the execution of learning experiences obtained as cooperation and composition of distributed heterogeneous actors, resources and services.

This definition, coming from the Learning Grid Special Interest Group of Kaleidoscope can be seen as a generalisation of the “Semantic Grid for Human Learning” defined by Gaeta et al. in [12] where the focus was on complex learning experiences based on experiential-based conversational processes.

As shown in figure 1, if we refer to the well known two axis diagram that places the Semantic Grid in a two dimensional spaces (the scale of interoperability and the scale of data/computation), the Grid for Learning can be seen as a projection of the Semantic Grid on a third axis measuring the supported scale of pedagogies.

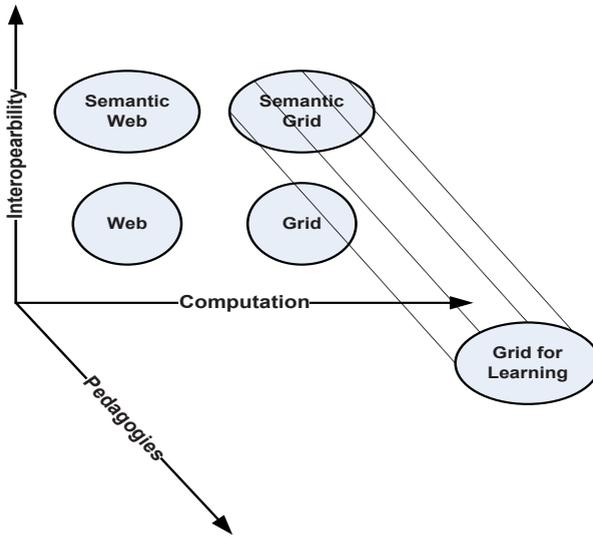


Fig. 1. The Grid for Learning with respect to Grid and Semantic Grid

4 Scenarios for a Grid for Learning

Several challenging scenarios related to the concept of Grid for Learning, as defined in the previous paragraph, and able to exploit available innovative features have been proposed in [21]. A selection of such scenarios is described below.

Enhanced Virtual laboratory. Students can access a virtual remote chemistry laboratory using different terminals (PDA, laptop, PC etc.). Students are identified by the system and a status of their work is stored at their user profile. Such information makes it possible to break and resume experiments that may require distributed simulation or aggregation of distributed information. Supercomputer facilities allow specifying and testing complex analysis, typically performed by groups of three students. Output of experiments may be numerical or graphical and adapted dynamically to the devices used by students. From time to time a synchronization period allows for comparing results between groups and getting partial marks.

Distance Programming Course based on Practice. This scenario is based on an existing TEL programming course where students are learning by doing more than by reading learning material. They are provided with programming exercises that are automatically corrected. Moreover, all attempts are stored so that students can consult their history. Compilation and program execution are implemented as services, students do not need to worry about downloading any programming environment. Grid technology, allows distributed code compilation and execution as well as a distributed storage of students' answers. Semantics allows for better personalization and flexible course composition.

Immersive Virtual Reality. A student is learning water and aquifer behaviour by using a TEL system. She can access introductory books to gain initial knowledge on the topic. She can also use a dynamically generated set of services that, according to her user profile and current PC capabilities create an immersive virtual reality. The service also informs the student about immersion requiring special equipment like gloves and glasses and about the nearest locations where such immersions are possible. Such immersions allow her to go deeper on the aquifer behaviour and on the characteristics of water. In these virtual sites, she also meets other students and interact with them. Learning occurs naturally as a result of experiments and interactions with other students.

The Field Trip. Students, equipped with PDAs, go on a field trip. While performing their activities, they store information under the form of photos, videos, text notes, audio comments, etc. Students can also access digital libraries and documents necessary for their work. The PDA, using user profile and context dependent information, automatically indexes these contents using appropriate metadata. All the contents stored by all students are sent, via an appropriate network to the Field Trip (FT) service created beforehand by the teacher. The FT service uses external services like high performance computing services to provide 3D reconstructions of photos, or to orchestrate speech to text and for text interpretation. Using an ontology based knowledge representation, the FT service can compare students' work with learning objectives and prepare a summary for the teacher in terms of progress and weakness. Using semantic based service searching and location capabilities, the FT service makes also possible for students to contact other students with similar interests or other students who are geographically near (Figure 2).

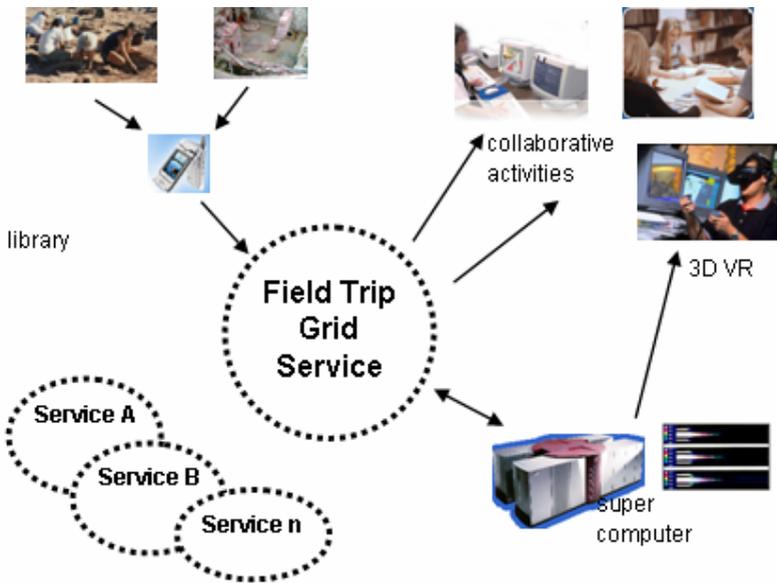


Fig. 2. The Field Trip Scenario

5 Conclusions

This paper described the concept of Grid for Learning as defined in the Learning Grid Special Interest Group of Kaleidoscope and contextualised it with respect to the relevant literature on the field. Some challenging scenario that may be implemented by relying on a Grid for Learning were also outlined. Further examples of systems based on the Grid for Learning concept as well as more details on enabling technologies and pedagogical implications of such concept can be found in [24].

It is important to note that the vision here proposed is strongly connected with the **Knowledge Society** perspective providing an effective mean for lifelong learning and knowledge spreading, leveraging on cooperation among distributed peers and capable of overcoming time and place barriers.

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