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Enabling Enhanced Learning in an Open University Environment: a Grid-aware architecture

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Abstract: *Open and Distance learning has been extensively researched in the past few years, yet the focus was more in its technological dimension. The plethora of advanced tools supporting e-learning and the difficulties in their adoption in real situations has only demonstrated that the primary need is a paradigm shift in the educational model. In this work, we argue that this paradigm shift can be efficiently supported by a new computing model: the Grid. Grid computing facilitates knowledge construction and reuse in highly dynamic, distributed e-learning environments. An initial design of an e-learning Grid is presented for an Open University environment where new e-learning models, such as constructivism, can be efficiently supported.*

Keywords: E-learning, Grid, Architectural features, Internet Technologies.

INTRODUCTION

Current teaching and learning practices are based on the information transfer paradigm: information is transferred from the teacher to the student. This enforces the student to consume information without being able to build knowledge. This static model of learning is supported by most state-of-the-art e-learning tools in the market today. Although the information transfer model is popular, because it is easily supported by Internet technologies, its educational effectiveness is seriously questioned (Xenos, 2002; 2003).

Many researchers propose a shift in the distance education paradigm focused on knowledge construction which will enhance, not replace, the information transfer paradigm (Vrasidas, 2004, Carchiolo et al., 2007). Social learning, a major enabler of the knowledge construction paradigm is based on active collaboration among human peers and especially enhanced presence. In such a context, human learning is a social process where sharing and reusing knowledge and executing tasks in order to reach a common goal. In this paper we argue that this new paradigm can be efficiently supported by a new computing concept: the Grid.

Grid Computing, or simply the Grid, is a new computing paradigm that enables access to distributed and heterogeneous computational resources (CPU cycles, storage, services, sensors, data) in a transparent, simple and on-demand way (Foster & Kesselman, 2004; Wells, 2008). The vision of the Grid resembles that of the Electric Grid where resources (electric power) are offered to the users: transparently (the user is not concerned on how and where the resources where produced or how they are distributed), simply (the user just needs to plug-in and use the resources) and on-demand (electric power is always available and enough and the user is charged on a pay-as-you-use basis). Thus, the vision of the Gird is to enable the provision of computational resources as commodities (Commodity Computing) (Stockinger, 2007). To enable this vision, several technologies have already been made available: coordination and virtualization of resources, management of heterogeneous resources, security, autonomy and lately, Grid services.

Recent advances in Grid frameworks enable its application to many areas, especially enterprise computing, e-Commerce and e-learning (Goyal & Lawande, 2007). The Grid is already emerging as a major enabler for networked organizations (Vanderhaeghen, 2007; Canavesio & Martinez, 2007). Although some of the enabling technologies are at a cusp in their development, the Grid has matured to its third generation of development adopting a service-oriented approach. A more holistic view of information infrastructures is supported and services are metadata enabled and ontologically principled (Singh & Huhms, 2005; Chen 2008). The next generation of Grid solutions facilitates the transformation of information into knowledge, by humans as well as – progressively – by software agents, providing the electronic underpinning for a global society in business, government, research, science and education. The Grid can be a major enabling technology for social learning, which in turn is a basic characteristic of the knowledge construction paradigm: active collaboration among human peers is supported by using different kinds of collaboration technologies and especially enhanced presence. Human learning is a social process using sharing and executing tasks in order to reach a common goal. In this context, it is hoped that next generation Grids will enable collaboration and effective knowledge sharing in large and highly dynamic e-learning environments. Several such examples have already begun to appear in the literature (Apon et al., 2004; Truong, 2004; Holliday et el., 2005; Meng et al., 2007; Gleeson & Pahl, 2007; Ho et al., 2004;). Some efforts worth noting are those of Shih et al. (2006) that use Grid services for distributed information retrieval of SCORM objects, Amoretti et al. (2005) use similar technology for multimedia streaming while Luo et al. (2006) provide on demand e-learning services.

This paper presents the experience gained from the application of distance education technologies to the Hellenic Open University (HOU) and the effect of these technologies to the learning process, the learners and the tutors. Throughout the rest of the paper the term 'Learner' will be used for anyone that learns something, formally or informally, either under a well-organized framework (i.e. school, university), or occasionally (i.e. in-house, while waiting for the bus, etc.). The term 'Tutor' is used to define the notion of tutoring in general and not a specific person (i.e. teacher, professor); in this context a tutor may also be a student offering an explanation to a fellow student. In addition to the presentation of the HOU experience, this work also discusses the problems created by the adoption of distance education technologies that lead the HOU to the possible adoption of Grid technologies. Furthermore, it discusses future educational scenarios based on Grid technologies and presents in detail the HOU Grid-based learning scenario.

The rest of the paper is structured as follows: Following this brief introduction to the paper's contribution, the second section discusses the new potential that the utilization of Grid technologies creates in education and makes a prediction about the way in which Grid technologies may affect the future of education. The third section briefly presents the HOU case and the distance education technologies and tools currently used, as well as an assessment of the distance methods used in the HOU. The fourth section presents Grid technologies to the reader and describes the HOU Grid scenario. Finally the conclusions of the paper are drawn.

DISTANCE EDUCATION IN THE NEAR FUTURE

Evolving education

Currently available communication and information technologies have turned traditional location based education into location independent. Few will deny that location (i.e. school, university) has a strong social impact on the learner, which may still learn and study in a number of 'non-educational' locations. Of course, location based education is still required in certain cases such as laboratories, complex experiments conduction, etc.

Learning includes searching for sources and selecting the appropriate source to study from, while the role of teachers and professors is becoming more and more that of a consultant (tutor) rather than that of the traditional knowledge communicator (Pentland, 2004). This holds mostly because the plethora of sources available on the Internet makes the selection of the appropriate source a rather difficult task, which is why the role of the tutor is important. Despite the wide availability of online sources, important elements of the learning procedure such as practicing and collaborating have not been enabled yet by current technologies and existing infrastructures. The same applies in the case of complex experiments conduction and data processing, as learners today need to actively participate in numerous experiments that allow them to practice on what they study. Such experiments may not be available everywhere, or may require computing power that is not available to every learner. Learners also need to access large volumes of data, most times distributed in many locations.

Most of all, today's learners need a variety of services available on demand that can be accessed and used from their environment. It must also be noted that in applied sciences, experimentation has a central role in teaching. There is, thus a need to use visual content in order to enhance the learning experience of the students and supplement methods such as textbooks, on-line content, synchronous and asynchronous collaboration.

The user problem in modern education can be summarized as follows: learners need a service that improves efficiency in the cognitive and social domains: improve learning capacity and academic performance and increase group and individual self-confidence. There is a need to adopt experience–based e-learning services as an additional medium for engaging the students into actively taking part in distance learning. Furthermore, there is an important consideration that affects the design of any future service in Open Universities: the user population (students) can be measured in thousands. This means that any new service should be able to meet peak processing loads that may vary greatly over time. All of the above can be enabled by the utilization of Grid technologies.

Potential future learning scenarios

Hereinafter we present two potential scenarios that could be fully realized in the near future. These two scenarios are hypothetical, the technology and the infrastructure for their realization could be based on Grid technologies.

In the first scenario, a learner on an early Sunday morning is watching a documentary on television. The topic of the documentary is the solar planet system and the learner finds this quite interesting, so she desires to learn some more. A little later, while traveling on the back seat of her parents' car during a typical Sunday journey, she uses her palmtop to connect to a portal to use the Grid infrastructure and from there to NASA database to view some photos. These photos are actually located in a number of storage devices and in various physical locations, but the student views them as a unified collection available on the Grid. After viewing some photos of Mars, she decides to create a simulation of the relative positions of Mars and Earth in our solar system. So she demands the appropriate service for this on the Grid and starts the simulation. While the student is watching the simulation on her palmtop, the computers from a number of laboratories (closed on Sundays) –all connected to the Grid– share their CPU power to allow her to create all the data required for this service.

In the latter scenario, a learner (a postgraduate student in Computer Science in this case) needs to complete an assignment on digital video watermarking. It is late on Sunday night and he needs to finish the assignment before Monday morning. So he uses his home computer and connects to the university portal to collect from the Grid a number of videos he could use for his assignment, without needing to worry about the actual location of all these videos. Then, he builds his own watermarking service by requiring from the Grid a number of available services (i.e. video coding, compression, etc.). In order to test his service, he starts applying his watermarking method on the videos. This time, utilizing the Grid infrastructure, the videos he processes are tiled in small pieces and processed by a number of computers connected to the Grid that are in idle position during this time period. The entire process takes a reasonable amount of time instead of hours. A similar scenario for using Grid technologies for digital images watermarking (Vassiliadis et al., 2004) has already been proposed.

These are just two possible scenarios that illustrate in a comprehensible way the utilization of Grid technologies in the everyday learning procedure. Numerous other scenarios are realizable with the use of a learning Grid.

CASE PRESENTATION

Brief introduction of the HOU

The Hellenic Open University supports a diverse population of students that register to undergraduate studies. Moreover, it provides postgraduate curricula to graduates who wish to extend or upgrade their studies to subjects related to their profession. Therefore, the HOU curricula correspond to various certificates, Bachelor or Master's degrees. A Bachelor degree may be comprised of several research directions.

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Courses at HOU are designed according to the distance learning methodology: students study from distance using text books and digital educational material, participate in a number of tutorials (usually 5 per year for each module they attend to) taking place in 8 towns, communicate with the corresponding tutor by telephone, fax, email and letters, prepare a number of written assignments (usually 4 to 6 for each module) and finally participate into a final examination at the end of each module. This examination takes place simultaneously in all major towns and students are examined using the same examination sheets.

Each student belongs to one student – group, called class. A class is located in one major Greek city in which class sessions take place. A tutor is allocated for each class of a maximum capacity of 32 students who inhabit in a specific geographical region. The academic personnel of the HOU includes a small number of permanent personnel as well as a large number of tutors. The permanent personnel undertakes, besides tutoring, the coordination of all classes and the overall academic responsibility for a specific course. Tutors cooperate with the HOU on an annual basis. They, in many cases, belong to the permanent staff of other Greek Universities.

HOU allows admission of students without an entry examination. Although it is a public University, students pay fees for the cost of their studies. However, some students are supported by scholarships.

HOU experience in distance education technologies

Beginning from the academic year 2004-2005, HOU provides a total of 6 courses leading to a Bachelor Diploma and 18 courses leading to a Masters Diploma. Approximately 20,000 students are currently attending the HOU courses. Most of the technologies and tools used for distance education presented in this paper were initially introduced in the Computer Science course of the School of Sciences and Technology.

The Computer Science degree is a 4-year course that is comprised of 12 modules and leads to a Bachelor Diploma in Computer Science. Each student may register in one up to three modules per year. Each module is equivalent to 3 conventional University-level lessons. This Computer Science course has a high dropout rate of about 40% (Xenos et al., 2002), which is expected in distance education studies especially in the first academic year. The particularities and the nature of distance studies in the field of computer science, combined with the use of digital material in each course, provided good conditions for the introduction of distance education technologies and tools. In the following subsections, we present the most significant. (The steps taken by the HOU to implement and use these technologies are further analyzed in (Xenos et al., 2004)). Services include a portal for accessing static information, video lectures (also known as web casts), normally 5 to 15 minutes that combine a series of slides with narration and simple video (Hadzilacos et al., 2003) and fora used mostly for non-public communication. In the past two years, virtual classrooms are used to emulate real classroom lectures. In such virtual classrooms students log on to the system and attend a lecture, while interacting with the tutor and with each other. It must be noted the use of virtual classrooms led to a major increase (up to 46%) in the participation of remote students in meetings, but also causes some problems, as virtual classrooms could not fully replace actual classrooms and the students’ ‘feeling of participation’ in them. On the other hand, it proved that it is definitely better to participate in a virtual classroom than to not participate at all, when actual meeting locations are out of reach. Another problem reported is that virtual meetings cannot follow a traditional meeting schedule. It is better to hold shorter but more frequent virtual classroom meetings than few long ones, as in the case of face-to-face meetings. A number of prototype tools have also been tested in a small scale. The most noteworthy is a tool that facilitates problem solving activities. Groups of students work collaboratively from a distance in order to design the solution to a given problem.

Assessment of the ODL methods used at HOU

HOU, as an Open University, serves a diverse population of students. A typical HOU student is rather of a mature age, part time student. Many students are also professionals and have different cultural backgrounds and career goals. They are also geographically dispersed all around Greece. HOU has repeatedly evaluated the procedure of delivering e-learning to its students. The following table describes the main drawbacks of the existing learning methodology:

Drawback	**Description**
Low participation in e-learning sessions:	the participation of students in e-learning sessions and the use of collaboration tools is lower than expected (about 20% of tha total class population). Two reasons have been identified for this drawback. The first is the low connection speed between users and the central server located at HOU. This largely depends on the communication system infrastructure in Greece which is upgraded slowly but steadily. It is expected that this problem will be solved within 2009. The second reason concerns the lack of interest shown by the users for the e-learning system itself. Although basic functionality such as videoconferencing and collaborative support are provided, the system seems to lack the interactivity and the efficiency needed for broad acceptance.
Interactivity:	visualizations or simulations are not supported. Such interactive sessions attract the interest of the user and greatly increase the efficiency of the learning process. For technological courses in particular, simulations or on-line experiments are deemed important in the learning process but it is difficult to support them with the existing tools since many of them require significant CPU recourses. There is no integration of technologies that support the various aspects of the learning process.
Efficiency:	students at HOU have significant time constraints as far as the learning process is concerned. Most of them are professionals and as such, are part-time students. The parameter of time is critical. Learning content should be highly specified and not too general. The e-learning system should provide the means to cut down the costs of learning through adaptation, effective task assignment, execution duration control and monitoring.
Flexibility:	there is a need for a more flexible e-learning system. The target group of learners is highly heterogeneous. Students have different goals. The pace of learning may differ significantly even among students of the same class. Students also differ in the amount of time they spend for attending e-classes or studying.
Progress Monitoring and	although HOU has an good ratio of teaching staff per student (1:30), assessment is often difficult. There is also limited coordination between the

Assessment:	study material and time management of the students. There is also a great difficulty to assess the learning procedure as a whole without the use of the proper tools. Furthermore, links between the learning process, student behavior and categorization, content and time schedules are hard to mine. This kind of metadata could significantly improve the way that e-learning is delivered by the University.
Task oriented system:	the current methodology is task-oriented rather than process-oriented. This means that only individual learning tasks are supported rather than the whole learning process. This fact may lead to poor student performance through the partitioning of the learning process (acquisition of fragmented/ tightly coupled knowledge).
New roles for students are not supported:	new learning models encourage new roles for the students including that of the researcher, creator or even some times the author of content. The current system is somewhat monolithic and lacks the flexibility for supporting new roles.
Costs:	inclusion of new tools or services to the existing system is a too costly process. It is also difficult to manage the integration of internal and external resources since aspects such as security, heterogeneity and copyright are not dealt with.
Number of students is large:	the number of students that needs to be supported by distance learning applications at HOU is quite large. It has already been mentioned that 20000 students are registered. Their number will be increased in the next few years. Normally, this is not a problem if static, web applications are used for delivering content. A simple web server is adequate. Nevertheless, in the case of more complex services such as virtual laboratory experiments, there is a problem on how to cope with tens or even hundreds of experiments running at the same time by remote users. Furthermore, according to HOU rules, there can be no strict rules on when students may access a service or not. Access to services is quite random in terms of number of users, time of access and time of use. HOU's policy to improve the quality and capacity of the e-learning services (number of user supported), requires a solution that can handle possibly thousands of users at the same time in the near future.

Table 1. Major drawbacks identified in the current ODL methodology

These drawbacks are more common in the case of Natural Sciences and Technology courses. Extending the discussion of section 2.1, the user problem in HOU can be summarized as follows:

Users need a service that improves efficiency in the cognitive and social domains: improve learning capacity and academic performance and increase group and individual self-confidence.

As already mentioned, there is also the important consideration of the large (and ever-increasing) population of students that affects the design of any future service. This means that any new service should be able to meet peak processing loads that may vary greatly over time. Business parameters are important as well. Although HOU is a state University, about 80% of its funding comes from students' fees. This means that the University has to adopt a flexible and sustainable business model in order to minimize costs. This business model is closely linked to the quality of the educational services that are provided to the students. Apart from classic problems of distance education which are common for all European Institutions, HOU has to take into account the fact that e-learning has not gained such a wide acceptance in Greece as in other countries. Although very important steps have been made in this field in the past few years, this fact remains a serious concern for HOU policy makers. The University's business policy is greatly influencing the design of any new service. Thus, the business problem in HOU can be summarized as follows:

There is a need to provide new services while keeping costs to a minimum and maximizing return on investment.

From the discussion above, it is obvious that a paradigm shift should be made both in terms of the educational model used and to the underlying technology that supports it. The main goal of this mixed solution is to improve efficiency of current HOU e-learning practices by promoting a collaborative/social learning model. Furthermore, to use the new services as reinforcements to the foundations laid by the linear structured text books and the on-line and off-line lectures. The goal is not to solve all the problems mentioned previously, as this would not be cost-effective at this time, but rather to integrate a new learning methodology that will work as a supplement to existing practices. We have decided that it would be best to concentrate, initially, in the increase of:

- student motivation to participate in on-line sessions,
- student confidence and satisfaction,
- efficiency of the learning process.

In order to maximize the impact of the solution, we focused on three distinctive, yet complementary, sub-goals that have to be accomplished:

1. Provide added value services in the form of virtual scientific experiments (VSE) and basic virtual communities support.

   - provide advanced, media rich services in the form of multi-step, cooperative experiments/ simulations for Natural Science courses,
   - facilitate social learning and collaboration through knowledge sharing and reuse between groups and individuals.

2. Support thousands of users while preserving adequate Quality of Service.

   - provide the services to a diverse and very large student population,
   - provide a single access point with a homogeneous interface,
   - preserve quality of service (fault tolerance, response time) at any time.

3. Evaluate the didactical approach and the technology infrastructure by contacting a real, large scale experiment in the courses at HOU.

   - provide / configure metrics for measuring performance in terms of scalability, quality of service and security,
   - test the infrastructure in a real situation,
   - assess the results and provide feedback.

In order to achieve our goals, a truly innovative educational model has been chosen: the knowledge-construction, human-centric model. This model is a shift in the distance education paradigm focused on knowledge construction which will enhance, not replace, the classic information transfer paradigm used so far. The underlying technology that was chosen to support this innovative educational model is the Grid. It is our opinion that the above mentioned educational and business requirements can best be addressed by building on the open distributed service model that has evolved as part of the Grid.

GRID-ENABLED E-LEARNING

Next Generation Grids

Traditionally, Grid computing has addressed the needs of long-running scientific computations submitted as batch jobs. Long-running batch jobs were distributed across several nodes in a Grid and executed in parallel, resulting in shorter execution times. One of the first applications of the Grid was e-Science: several supercomputing facilities were brought together in order to solve difficult scientific problems. For example, the Large Hadron Collider of CERN when fully operational, will produce more than 10 Petabytes of data each year. Processing this huge amount of data requires a computing power of 200 TFlops. The most important aspect is that more than 2000 scientists from 200 institutions all over the world also need to cooperate for analyzing these data. A special Grid for this e-Science application will support this huge process. In this view, the Supercomputing paradigm (also referred to as meta-computing) was the first generation of Grids.

One of the most representative Grids of the third generation is the Semantic (or Knowledge) GRID: an infrastructure where all resources, including services, are adequately described in a form that is machine-processable, i.e. knowledge is explicit – in other words, the infrastructure provided by the technologies of the Semantic Web. This type of Grid may support a paradigm shift in pedagogy to advance effective learning in large heterogeneous learning environments such as Open Universities (Tian & Chen, 2006). The Grid has already been proposed as a VO enabler due to its highly dynamic nature (Page et al., 2005). In this model, Grid technology is used for coordination, sharing and reuse of services, knowledge and data across the geographically dispersed nodes of the VO. VO nodes are mapped onto the physical Grid nodes (computers or clusters of computers) and predefined workflows are used for service execution and data management.

Conceptually, third generation Grids can be thought of in terms of three layers: the computational/data Grid, the information Grid and the knowledge Grid. The bottom layer is the computational and data grid: the computer hardware and data networks upon which the work will be conducted. Above this lies the 'information grid': the databases of information to be accessed by the hardware, and systems for data manipulation. On top lies the 'knowledge grid', where high-level applications mine the data for the knowledge that forms the basis of semantic understanding and intelligent decision-making.

The Learning scenario

The introduction of Grid technologies in the HOU infrastructure must enable a leverage of the University's course administrative operations, providing new ways for communicating and introducing the use of improved teaching methodologies. However, this is not an easy task since it has to overcome the traditional ways of administration, information sharing, and teaching. Moreover, it needs an effective student-centred implementation and support mechanism in order to assure its widest acceptance and use by the academic community. It will integrate existing tools and databases that are already in use and possibly extend their capabilities. Another goal is

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to improve collaboration between students by using Grid technologies. This will be accomplished through cooperative experiments. Students share resources (data sets, results, opinions etc.) to perform a complex, multi-step process.

Figure 1 presents a general overview of the learning scenario. The Simulation/ Experimentation services (VSE services) are the core of this scenario, providing:

- visualization interfaces for contacting individual and/or cooperative experiments
- perform experiment (visualization of data sets and output)
- access supporting educational material
- perform on-line test/essay

Virtual Communities (VC) services provide basic support for the geographically distributed, diverse and numerous HOU communities through a personalized user workspace providing:

- forums, news alert,
- ontologically principled search engines
- private/public repository for sharing results/ knowledge

Synchronous/asynchronous communication (even during an experiment) is supported both by external tools and advanced communication services. A portal is used as a single access point, for integrating new and existing tools and for providing transparent access.

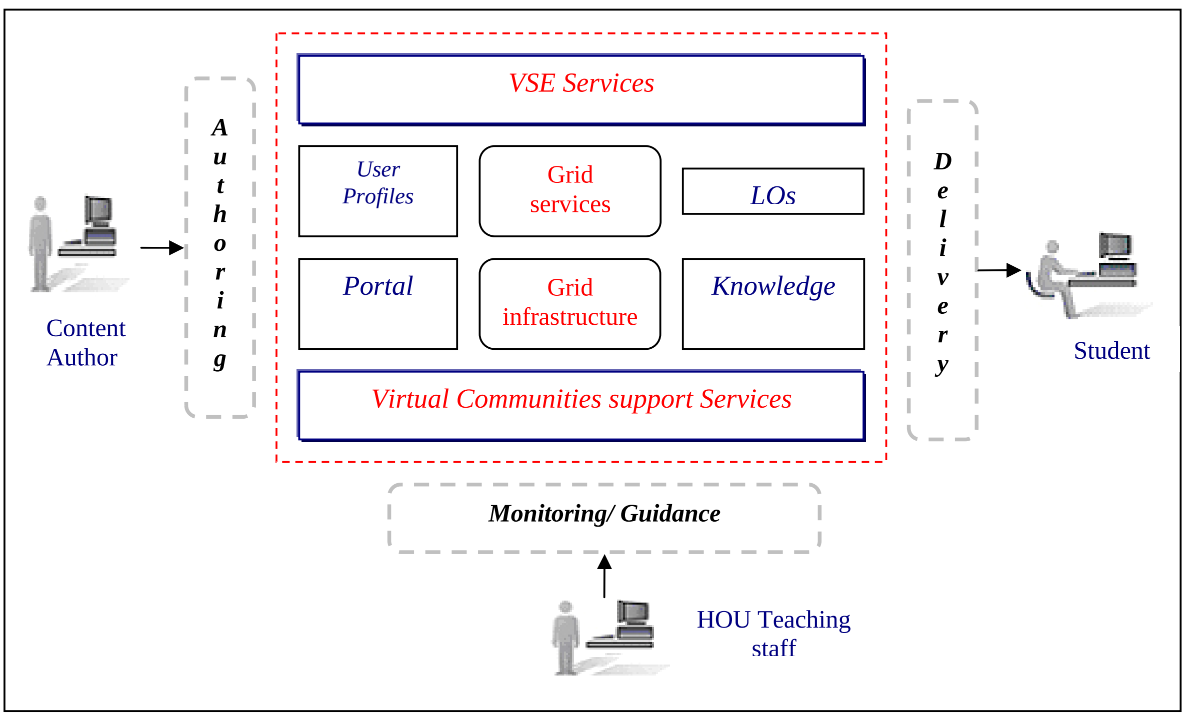

Figure 1. Overview of the Grid-learning scenario organization

A minimum integration of existing tools to the portal is anticipated. Existing tools and services include:

- Centra, a synchronous collaboration tool, which will be used for advanced collaboration/ sharing of knowledge and resources related to the experiments, and virtual class management.
- HOU Web sites and fora, used for asynchronous delivery of educational material and for off-line collaboration.
- Tools and Web browsers are used to access and manipulate information objects (e.g. Internet Explorer/ Mozilla for Web browsing, Word for creating documents, PowerPoint for creating, organizing, and illustrating presentations, WordPad for plain text editing).

In addition to the above mentioned tools, integration methods should allow the use of most kinds of applications or tools that associated with specific file types defined in the Windows environment. Data include:

- Educational material organized in LOs (Learning Objects). This material shall be derived from HOU text books. For this scenario, only a small part of this material will be transformed in LOs.
- User profiles. This information is derived from existing student information and other monitoring tools (e.g. log analyzers, report generators).
- Supporting material especially designed for assisting students in performing the experiments. Authoring of supporting material shall be limited and shall take the form of Web pages with few lines of text and graphics. Links to internal and external sources shall be provided by Content Authors or the HOU teaching staff.
- Other metadata.

Grid services shall be used for resource allocation and service delivery.

In this scenario, simulation shall be designed based on concrete educational objectives that need to be achieved by the student. Feedback is used to make the learning experience more efficient. A simulation has three levels of complexity: easy, medium and hard. Complexity is closely linked to the learning objectives. If the learning objectives include the need for collaboration between students, the complexity increases significantly.

The simulations will be comprised of several steps, thus letting students choose different paths using multiple choice questions. Additional supporting material will be presented when needed including supporting LOs, references to the HOU web site or the text books. After each step, the intermediate results are presented and feedback is provided. It is possible that VSEs will include live data provided by sensors. For example, in the case of signal processing of image data, pictures or video captured in real time by cameras may be used in order to increase user interest. Feedback shall be provided in the following ways:

- on-line and during the experiment, with the collaboration of a Tutor who oversees its completion. Using synchronous tools, the Tutor assess the choices that the student makes and provides feedback when necessary.

- debriefing after the end of the simulation. This can take place through asynchronous communication methods (e.g. email) or during the regular face to face meeting of the classes.
- automatic feedback. Assessment methods that are build-in in the service. Feedback loops in the simulation/experiment narrative, offer hints or additional information on how to improve results.

Simulations will have a finite number of outcomes in order to control their complexity. The challenge in creating the simulations/experiments is to reach a consensus between the stimulation for student participation and the need to reach the learning objectives.

Services should be accessible using standard PCs. The software should include Web browsers with the least possible number of plug-ins. If possible, there should not be a need to install expensive software (e.g. MatLab plug-ins) in the user machine in order to access or use the services. In this scenario, the computational resources of the users are not considered resources of the Grid (i.e. the CPU power of the computer of a user is not used in the Grid).

Students may access the service from anyplace in Greece through a portal. The HOU portal, therefore, will act as a unified access point through which users will share explicit information and exploit online collaboration tools with appropriate functionality (through the use of portal components) for the specific role of each user. This portal will support four different types of services (see figure 2):

1) collaboration and communication: using synchronous and asynchronous tools,
2) delivery: delivery of learning content,
3) operation: special tools used to generate material/communicate (e.g. MS Office tools),
4) experimentation: services for contacting experiments.

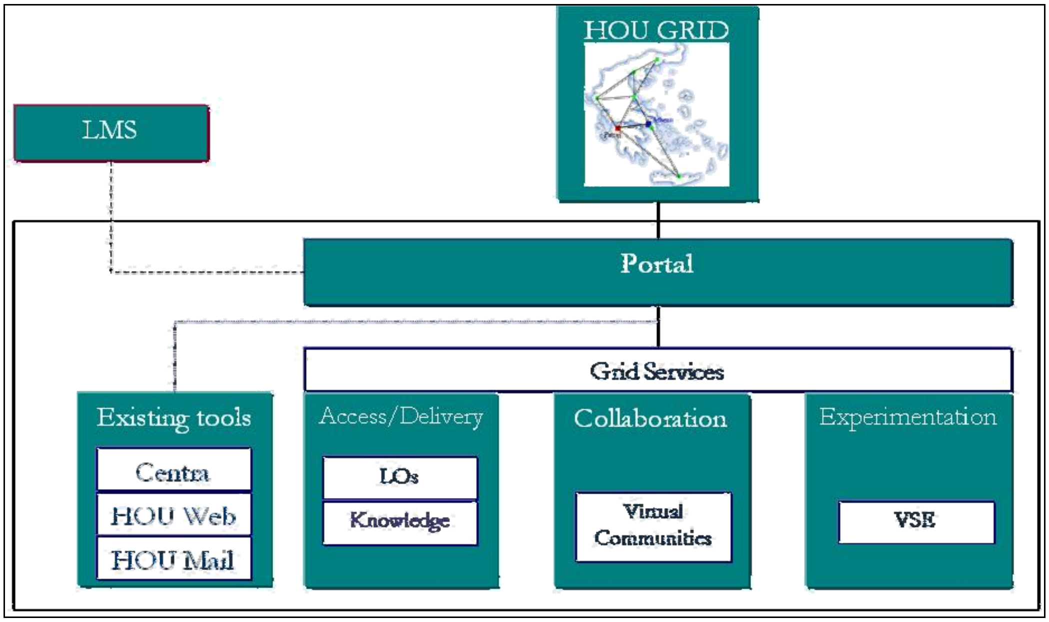

Figure 2. The HOU portal using Grid services

There are, at most, 8 points supporting the portal, called nodes which are used for sharing resources and servicing users. Nodes are geographically dispersed and they are based in major Greek cities where HOU classes are making their regular sessions (figure 3).

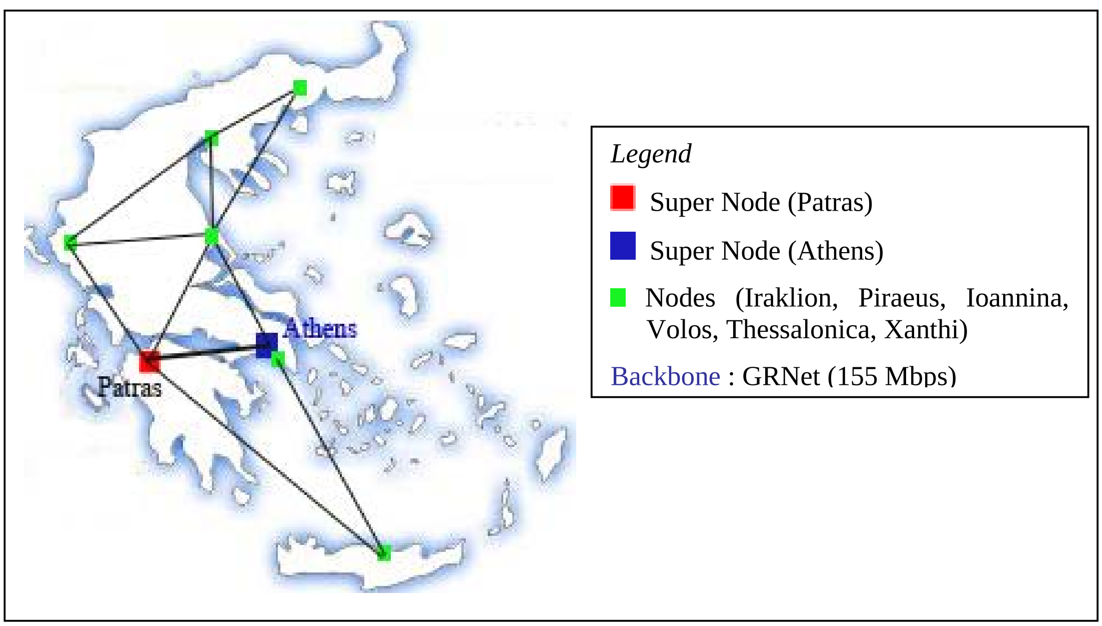

Figure 3. Node distribution of the envisaged HOU Grid

Each node is covering a specific region and supports mainly the students that are living in the vicinity. The backbone that is used by the nodes for transferring data is the GRNet (Greek Universities Network), a high speed network infrastructure that links all Greek higher education organizations. The speed of GRNet is currently at

155Mbps. The goal of the scenario is to transform and extend the actual city-class model to a Grid model. Each node plays the role of an electronic regional support center, offering basic services such as direct and personalized attention towards students: virtual meetings with teachers and other students, seminars and round tables. There are two super nodes that are coordinating the smaller ones. Super nodes are used to handle large CPU loads, store intermediate results from simulation runs and backup data.

CONCLUSIONS

The use of Information Technology and Telecommunication Networks have revolutionized learning, giving birth to new models and enabling new potentials. Advances in Learning Sciences however were not backed up by the appropriate tools. E-learning research is moving beyond the traditional information transfer model to a more cooperative, knowledge construction paradigm. Although this paradigm has been researched extensively from an educational point of view, conventional technologies were not able to support it efficiently. The need for knowledge sharing and reuse, pooling of knowledge, search and management of expertise demands new flexible technological solutions. Requirements are stronger in a highly distributed and pedagogically heterogeneous environment such as an Open University, which can be considered as a Virtual Organization. This type of organization is comprised of collaboration teams (students) that work towards common educational goals. The dynamicity and heterogeneity of such a case resembles, in many respects, actual commercial Virtual Organizations. The question is how to manage such a diverse and dynamic model without compromising flexibility, usability and transparency. Other factors such as expansion policy and operation costs pose significant constraints and should also be taken into account.

Next generation Grid technologies besides being a strong service oriented computing paradigm are a Virtual Organization enabler and as such, a potential technology for enhanced learning. The latter, is a novel educational model which relies on constructivism, social learning and most of all active collaboration: dynamic collections of individuals share computational resources to achieve certain educational goals. Currently, most of the applications driving the development of the Grid are mainly scientific collaborations. Nevertheless, the first examples of using this technology for higher education have already started to appear. We expect that they will become increasingly important in large scale and open environments in the next few years.

This paper discussed the potential created by Grid technologies in education and the way in which Grid technologies may affect the future of education. Still, unless education eventually moves towards other directions, it is almost certain that the current and future technological solutions will more and more turn traditional classroom-based education into 'everywhere available' education. In such a learning paradigm, Grid technologies and learning Grids may play a very significant role. Of course, one needs to admit that, many times, technological breakthroughs surpass future estimations. With a social constructivism approach of education we promote the co-construction of knowledge and a better articulation between the experimental learning activities and the other's one such as lecturing, self-paced learning or group problem-solving and collective projects.

The case of the Hellenic Open University (HOU) presented in this paper is an actual case. The currently used educational technologies and tools were described and a scenario for the utilization of Grid technologies at HOU was presented. This scenario is already in the design phase and will be implemented in the near future.

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