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Efficient web-based open and distance learning services

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Abstract

In this paper, we present data management issues faced during the design and development of an open distance learning system for the University of Patras, Greece. In order to handle data efficiently, as required in a web tele-training application, for each type of information maintained, different strategies must be deployed according to their behaviour and structure. The diversity and complexity of data, the network aspect of the application and web deficiencies impose an architecture design incorporating a plethora of technologies and tools that must be integrated in such a fashion that they efficiently organise these data preserving their relationships. This presents a software engineering challenge requiring coherence of solutions at all levels: structures, consistency, security, models, and protocols. The paper presents the data components of an open and distance learning (ODL) system that access the information stored in a database and the file system, their underlying technology, their interaction with the network services, and features regarding the ways they address issues faced in an open vendor-independent distance learning environment and outlines the system's overall architecture. In addition, this paper presents the architecture, the design and the services of a network-based information system that supports open and distance learning activities. The open and distance learning information system (ODLIS) offers synchronous and asynchronous distance learning and management of information system (MIS) services to support the educational procedure. The ODLIS is a web-based application, which runs over the Internet using real time protocols.

Keywords: Web; ODL; ODL system; CSCW/L

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1. Introduction

An open distance learning information system (ODLIS) can be used in order to provide virtual lectures, virtual conferences, collaborative work on projects which are shared among institutions, exchange of useful material, experiences among teachers, research results and conclusions as well as versatile and more attractive presentations of the subjects taught. In addition, such a system should manage the educational material and its users as well as the information that is useful for the educational procedure. The above requirements create two problems for the system: The first problem is the management of data in web-based applications, which have different characteristics and complexity. The management of information has many limitations of the file-oriented hypertext protocol. The second problem is the integration of different technologies and tools that support educational activities.

In our approach, all application's sensitive information is stored in a relational database management system that provides the mechanisms for the efficient indexing and ensures their consistency. More static data are stored directly on the file system, while the database maintains annotation about them and pointers to their location.

In this paper, we present some tele-training tools as well as the architecture and the components of an ODLIS and particularly the data access components and the business logic regarding the manipulation of information. In addition, we catalogue the functional characteristics based on the user requirements, describe the network that supports the transport of information. Furthermore, we explain the types of data in our system, relationships between data, the issues of consistency, manageability, scalability, security, partitioning, transparency and we describe the characteristics of the mechanisms that are used for the reliable storing. Finally, we present the services provided by the system and our case study.

2. Motivation

Open and distance learning (ODL) could be regarded as the process of learning with the use of Telematics that is the combination of telecommunication, information and multimedia technology and its services (Bouras et al., 1998). In such a scenario:

- All the interactions among trainees, trainers and instructional material, which are essential for the instructional process, can be implemented.
- The information and the knowledge, which are essential for the instructional process are accessible and readable.
- The place, time and the pace of learning are flexible.

The ODL has the following main goals:

- The development of learning environments and methods suitable for the use of information technology to different learning environments.
- The improvement of the organisation environment, in which these new methods are applied, and the quality and manageability of the multimedia applications and the real-time services.
- The encouragement achieved is recognising the quality characteristics obtained through teaching with the use of new ODL technologies and services.
- The encouragement of the recognition of the quality characteristics which are gained from learning with the use of new ODL technologies and services.

The target of the ODL is the development and promotion of special methods and techniques for the increase of the quality, the effectiveness and the suppleness of the learning. The ODL has two main results:

1. *The educational*. The improvement of the existing learning methods and the development of new learning methods.
2. *The technological*. The provision with new distance learning methods with the use of information and communication technologies (ICT).

An ODL environment combines various instructional scenarios such as collaborative learning and education with or without the live presentation of the professor. The integrated distributed learning environments provide a common environment for the implementation of all the above scenarios and the way to success in specific educational targets such as:

- The renewal of the pedagogical methods and environments in the educational institutes.
- The incentives for the diffusion of information among the educational institutes in the world.
- The encouragement for the collaboration.
- The motivation of the trainees with the use of effective and modern equipment for the lesson.
- The effective transmission and distribution of the instructional material to the trainees.

The tool that presented has the following goals:

- To meet the communication needs of a group, such as e-mail, discussion lists, chat and videoconference.
- To fulfill the educational and instructional needs of the University of Patras, such as synchronous and asynchronous multimedia (audio, video, text and graphics) lessons.
- To provide a common and familiar user interface via common World Wide Web browsers, such as Netscape and Internet Explorer.

We use the above-described principles during the implementation of the Open and Distance Learning Center of University of Patras (Bouras et al., 1999).

3. Survey of open distance learning systems

The subject of distance learning and collaboration has engaged researches all over the world. Many solutions have been proposed for distant learning and collaboration over the Internet. Indicative commercial tools for collaboration over the Internet are Microsoft NetMeeting and WhitePine Enhanced CU-SeeMe (WhitePine, http://www.wpine.com). Various methods have been proposed for synchronous learning (Eschelbeck, 1995; Paquette et al., 1995; Boegh et al., 1998), asynchronous learning (Smeaton and Crimmins, 1997; Wolf, 1995), or asynchronous learning with an on-line facilitator (Wang and Karmouch) (Eckert et al., 1997; Mc Daid et al., 1999). Various models for collaborative environments that come to cover the communicational needs of collaborative work in a learning environment either synchronous (Faro et al., 1997; Ponta et al., 1996), or asynchronous (Tsoi and Rahman) have also been proposed. In the next and other paragraphs, we present some integrated distance learning environments (Mcgreal, 1998), which are available:

- FORUM [1] was developed by the Texas A&M University of Laredo. FORUM is a web-based application and its services are available through common web browsers. The FORUM server needs a Novell network server and runs over the Microsoft Windows Platform. FORUM offers the following capabilities: Group authoring and documents processing, file server service, online text-based chat, multiple sessions, predefined lesson structure for the students.
- Virtual-U [2] offers capabilities for design, creates and transmits educational material over the web. It is based on the results of human and computer interactions during network-based distance learning. It offers capabilities for videoconference, creation of educational material and administration of students grades.
- Symposium [3] is a web-based application, which offers both synchronous and asynchronous distance learning. Someone can access the service of the Symposium through common web browsers. It offers capabilities for delivery of educational material through the web, collaboration between virtual teams, asynchronous distance learning, synchronous communication between the participants and creation of educational material.
- Web-CT [4] was developed by the Computer Science department of British Columbia University of Canada. It is a web-based application, which offers enhanced capabilities for creation of educational material and management of the education procedure.
- First Class. [5] The first version of First Class was a client–server application that offers capabilities for e-mail exchange, threaded discussion and remote access. The

[1] http://www.foruminc.com.
[2] http://vitual-u.cs.sfu.ca.
[3] http://www.centra.com.
[4] http://homebrew1.cs.ubc.ca/webCT.
[5] http://www.softrc.com.

last version of First Class is a web-based application. It was used by the Open University in United Kingdom for ODL. It offers capabilities for asynchronous learning, creation of educational material and administration of educational procedure.

Table 1 compares the ODLIS with other integrated distance learning environments. As someone can see in Table 1 the most prominent feature of ODLIS that makes it better among the above-mentioned existing implementations is its fully integrated environment, which offers a compete set of services and it is flexible and adaptive to many possible requirements. In other words, our proposal aims at covering a wide range of related applications instead of limiting its capabilities to a specific operation, which is the case with other existing tools. For instance, the model that we propose can be used for virtual lectures, virtual conferences, collaborative work on projects shared among institutions, exchange of useful material and

Table 1
Comparison of the ODLIS with other Integrate Distance Learning Programs

Tools/features	ODLIS	Forum	Virtual-U	Symposium	Web-CT	First Class
Discussion forums	Yes	–	Yes	Yes	Yes	Yes
Chat	Yes	Yes	Yes	Yes	Yes	Yes
Application sharing	Yes (T.120)	Yes	–	Yes	ver whiteboard tool	Yes
Audio/Video communication	Yes (H.323)	–	–	Only audio communication	Third-party applications can be integrated	–
Asynchronous learning	Yes	Yes	Yes	Yes	Yes	Yes
Sychronous learning	Yes	Yes	–	Yes	–	–
Collaborative learning	Yes	Yes	Yes	Yes	Yes	Yes
Search	Yes	–	–	–	Integrated search mechanism	–
Languages	Greek (soon in English)	English	English, French, German	English	students (English, Dutch, Finish, French, Spanish); lecturers (English, French, Spanish)	English, French, Spanish, Danish, Swedish, Norwegian
Administration of users	Yes	Yes	Yes	Yes	Yes	Yes
Administarion of lessons	Yes	Yes	Yes	Yes	Yes	Yes

experiences among teachers, circulation of research results and conclusions as well as versatile and more attractive presentations of the subjects taught. Our proposal is based on the needs of an educational network as they are described in the previous section.

Generally, the status of tools that offer ODL services, changes rapidly, because new tools are implemented and proposed. All the tele-training tools have their advantages and disadvantages. We have noticed that there are no tools that offer a Greek user interface and this is a reason to implement such a tool. Furthermore, we try to integrate our tool with all the advantages of the above and other tools as well as to reduce all their limitations in a manner that would be helpful and adapted to the need of each user or group of users.

In order to implement our tool, we have followed some basic concepts, which are presented in the next section together with the general architecture.

4. General architecture of the ODLIS

The ODLIS is based on the following concepts:

- An integrated communication environment that covers the communicational needs of a group of participants.
- A client–server model. We propose a model that consists of one server and multiple participant clients.
- An open platform architecture in order to support different operating platforms.
- Internationally accepted standards.
- Access through web pages.
- Object-oriented design and implementation.
- Modular for scalability.

The architecture of the ODLIS is based on the three-tier architecture model. The ODLIS consists of the following components: The database (first layer – data access component), which is responsible for providing the first-born information. The server (second layer – business component), which is responsible for processing this information and the user interface (third layer – presentation component), which is responsible for the presentation of the results and the interaction with the users (Fig. 1).

The environment of the ODLIS consists of three modules that supply various functionalities. These modules are the following:

- The module for the administration of the ODLIS environment offers two basic functions. The first is the administration of the users of the ODLIS and the second is the administration of the lessons of the ODLIS. This module provides capabilities to create, delete or modify a lesson, the educational material of a lesson and the characteristics of a user. In addition this module offers the capability to search the database of the ODLIS.

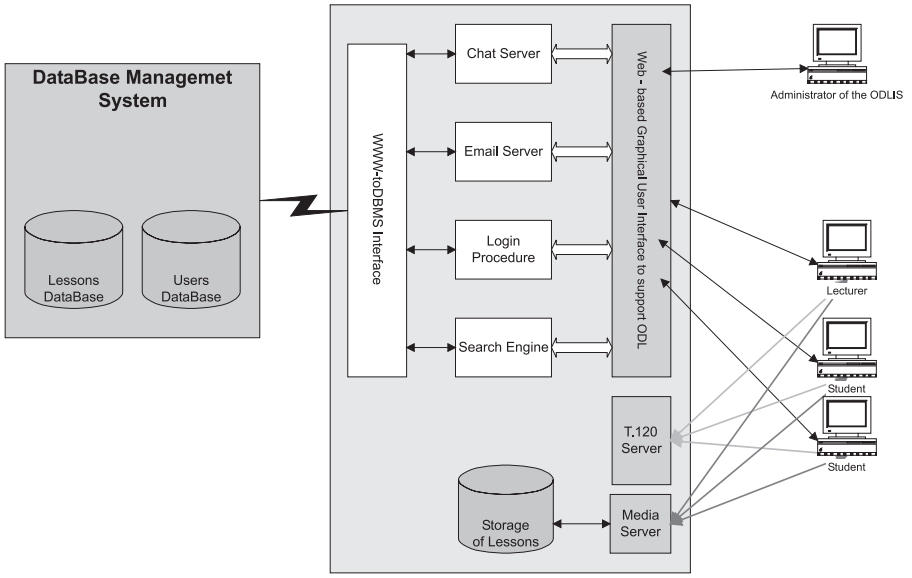

Fig. 1. General architecture of the ODLIS.

- The module for the administration of the educational procedure. This module is responsible for the interaction between the students and the teachers, which are based on a discussion list with thread capabilities, web-based shared workspace and e-mail. This module is also responsible for the submission of exercises to the students by the teacher and the observation of a file with the grades of each student.
- The module which is responsible for providing the synchronous and asynchronous lectures over the network. This module is responsible for the interaction between the students and the teachers during a synchronous lesson. This interaction is based on video communication, sharing whiteboard, chat and "ask floor" capability and for the attendance of the asynchronous lessons by the students.

5. Functional specifications and requirements

Due to various kinds of communication in a classic situation of learning or collaboration, different mechanisms must be established for sufficing the needs of an educational community over the Internet by our tool (Goirizelaia et al., 2000). Our tool will attempt to broaden the horizons of learning and collaboration. Thereby, optimised integration with simple operation mechanisms is an essential necessity. In

order to create a complete learning system, which is able to satisfy the needs of an educational network, our tool is designed as a simulation of a real situation (Bhattacharya, 1999; Chou et al., 2000).

The relation between the services for the integration of the distributed learning environment is shown in Fig. 2.

In the following paragraphs, we present the problems that we have to cope with in order to offer the above services and to implement their interactions.

5.1. The open distant learning in asynchronous mode problem

Asynchronous mode issues have been thought to be quite complex because they usually are fundamental for the correct educational and functional procedure. They involve both programming and installation techniques that demand extreme customisation during development according to the projects special requirements. The reader has to keep in mind that educational matters are extremely delicate and that makes database structure rather complicated at first place. The services that are offered contained quite a few troubling issues in the database management and data transfer level.

- All asynchronous discussions are stored in a special database that keeps log for all participants and their statements. The database structure required careful design and implementation to hold with integrity the raw information of the participants (trainers and trainees) offline behaviour. The database had to keep track of users as objects and be able to categorise their statements both in users' personal data and in discussion data during the whole process of the discussion. The process of log keeping is incredibly expensive both in system CPU resources and naturally in space and network throughput bandwidth consumption. The specific system

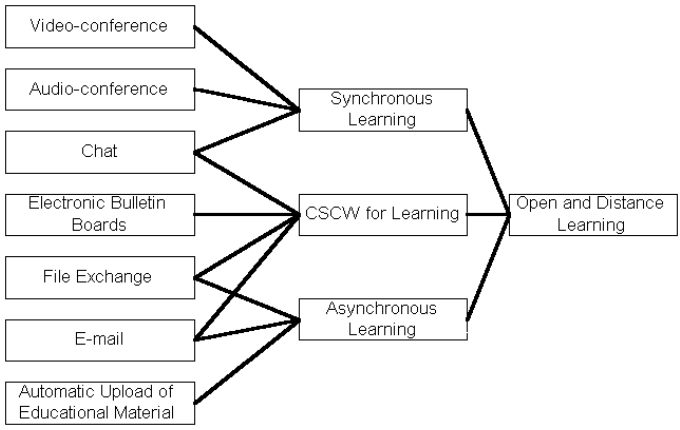

Fig. 2. Services of the ODL.

platform that is used for this application includes a powerful storage system that boosts the whole procedure nevertheless, the implementation and installation that had to take into serious consideration the CPU scheduling and the network resource usage. The database logging process was rescheduled to take a less primary role on the ODLIS project caring, however, for not tampering the security of the whole management system.

- Workspace sharing application had to be able to accept answers to the projects and furthermore keeping track of questions and remarks given by students. The workspace system component contains a variety of different information stores that need care in terms of data integrity, security and organisation. The project faced troubles concerning the user list synchronisation between the authentication level and workspace database users, especially when the power users (such as "instructor") created new workspace without the intervention of the administrator. Policy imposed an "open" schema, in terms of advanced privileges, for the workspace data management. Therefore, several precautions and cross-user authentication procedures were implemented to ensure that data flow and storage are performed according to specifications and the academic community's needs.
- Announcement database issues majored in the indexing and organisation of the data (announcements with advance searching tool). The specific system component is a web-based threaded posting system. This component had to involve typical newsgroup feature through the workspace schema in terms of subject categorising. Announcements are a high level tool mainly used during the offline distant learning, which meant that database structure should maintain a clear and distinct way of keeping and distributing information. Searching procedures are a commonly used tool for information retrieval. There is a tendency of the user to forget specific places where information is stored and for that reason data retrieval procedure ends down to simple searching. Effective searching with instant response was needed and the indexing policy had to be handled with care in order to offer a reliable search mechanism. The system included a cache table for the most popular queries transparent to the user the – latter just enabled the privilege of better response time performance. The cache system scheme was created because in educational environments, users tend to access systems at a short time span usually before academically critical milestones (project deadlines for example).

5.2. The open distant learning in synchronous mode problem

In the synchronous part of the project, issues in totally different perspective had to be dealt with. The components of the system were coherently stuck together and troubling issues were focused in logging and scheduling features. Synchronous component data accounting is centralised mainly to recording different states of file and discussion sessions and not the data exchanged. In this mode of the system, data

flow has a longer time span and duration cycle. Things tend to be simpler but in no way less delicate than the previously described procedures and problems.

- Logging for file transfer and chat-like communication had to be provided. The logs had to be explicit especially whatever concerned the members involved in the communication. Special care had to be taken for the detailed view and archive recording of the system file exchange. They had to be written down explicitly also the chat requests just for the record.
- Scheduling of the meeting had to be available. The meeting-time database had to update the announcements and the calendar of the instructor. Fundamental feature for the correct workflow of the meetings and conferences is an appropriate calendaring system. Therefore, the data system logging has to keep track of system and user time in order to give information and to announce the rendezvous for the synchronous meeting so that all members would be in time updated.

5.3. The user and lesson database issues

The user and lesson database issues had also an important role and needed special attention especially as far as the educational part is concerned. The database system had to take into consideration all the educational aspects that were imposed by the academic view of the project. The bureaucratic process had to pass into an electronic system of invitations, submission forms and responds that the database system had to keep track of. The elements of user registration requests had to be handled with an open-minded way because they involved comparisons and logging of two language words and phrases. Transformations had to be made in a formalised way so that everybody has an ASCII-based login name for the web access better compatibility. User database had to keep wait state status when registering a student for the cross-certification with the secretariat of the department involved.

Moreover, the database had to be ready for annual rebuilding – re-utilisation prepared for the next academic year. That means exhaustive packing and disengaging of all data of the past year from the main database. At that time all outdated data had to be moved to the back up database keeping in mind all issues that may be needed in the following year for better indexing and quicker access and retrieval. In the new academic year, everything has to be ready to accept all the new data recording without, though, losing the capabilities to search and link to older elements especially records of grades, statistics and answers to sets of tests and exercises. The system had to be designed to keep alive the most educationally significant parts of data – the academic partners of the project insisted on that – so that would be easy to access them in the following years for several reasons. It is important that the database system provided easy and consistent access to every annual database because it is consisted of both scientific and other educationally vital information for the better designing and organising of the academic year to come.

5.4. The administration of the ODLIS environment

In this paragraph, we describe the functionalities for the administration of the ODLIS environment module. These functionalities include adding new users and new courses.

When a user wants to access the services of the ODLIS, he must pass the entrance procedure. During that procedure the ODLIS system makes an authentication control in order to recognise each user. If the authentication control fails, then the users will not have access to ODLIS services. The authentication control is based on the authentication control mechanism of the Apache web server and using the login/password logic. During the entrance procedure, the system recognises each user and gives him the appropriate authorities depending on if he is student, teacher or administrator.

Adding new user functionality is available only to the administrator of the ODLIS. The candidate users must complete a form in the web in order to be added to the users of the ODLIS. The user's information will be transmitted to the administrator, and the administrator adds the candidate user to the users list of the ODLIS. The ODLIS follows the following policy for the nomenclature of the users' logins: Each user's login must be related to the user's last name.

Adding new course functionality is available only to the administrator of the ODLIS. If one user of the ODLIS wants to add a new course, then he must complete a form which is available only to the users with teacher attribute. The information about the new course will be transmitted to the administrator, by the ODLIS system, and the administrator will add the new course to the course list of the ODLIS.

Courses, for uniformity reasons and for easy administration, follow a hierarchical model. As a result all the educational material for a course is stored under a directory in the web server. This directory has the following structure:

- A directory with the name "offline". In this directory, the educational material of the asynchronous lectures is stored. A directory with the name "online". In this directory the educational material of the synchronous lectures is stored.
- A directory with the name "wwwboard". In this directory, the information of the course's sharing board is stored.
- A directory with the name "exercise". In this directory, the exercises of the course are stored.

Fig. 3 shows the hierarchical structure of the courses.

5.5. The administration of the educational procedure

The teacher has the capability to answer to questions of the students. The students can submit their questions through e-mail and the teacher will answer the question through e-mail. If the question is interesting and concerns many students, then the

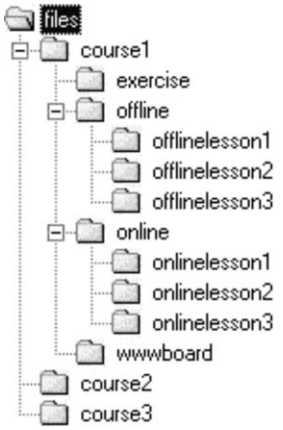

Fig. 3. Hierarchical structure of the courses.

teacher sends the answer to the mailing list of the course. In addition, the participant has the ability to communicate through the shared announcements. The teacher has the ability to post an announcement into the shared board and the students have the ability to post a question to the shared board. The ODLIS offers to the participants the capability to exchange files through a web-based shared workspace. Moreover, the participant of a course has the capability to exchange ideas in real time through the online chat capability. All the above-described capabilities of the ODLIS implement a system with computer support collaboration work for learning (CSCW/L) characteristics.

The teacher has the capability to announce exercises related to the course that he lectures. The exercises will be placed to the shared workspace of the course in a particular format (for example, .pdf format or .doc format). The students will read the exercises and will send their answers to the teacher through e-mail in order for the teacher to evaluate each answer. In addition to the above-described exercises, the ODLIS will offer a multiple-choice test for each lecture of the courses. This test will have a self-evaluation characteristic for the students. Both the results of the exercises and the tests for each student will be stored to the student's record. Each student will have the capability to check only his record.

6. Network

The ODLIS is a web-based system; the network communication between the users and the ODLIS server is based on TCP/IP protocols suite. More particularly, the data are transmitted using TCP or UDP connections depending to the data characteristics. For example, voice or video data are transmitted with the use of UDP

connections because for this type of data, the transmission speed is more important of the reliability. Regarding data types (such as text or images) that reliability is critical the ODLIS uses TCP connections. For the ODL activities, ODLIS uses protocols that support real-time transmission of data and gives to its services quality of service characteristics. For the asynchronous lecture, the ODLIS uses the real-time streaming protocol (RTSP) protocol, which offers enhanced streaming characteristics. For the synchronous lecture, the ODLIS uses the real-time transport protocol/real-time transport control protocol (RTP/RTCP) protocols, which offer end-to-end transmission of multimedia data with real-time characteristics. If the number of participants on a synchronous lecture is too high, then the IP multicasting technique is used (in co-operation with RTP/RTCP) in order to reduce network load.

As we have already stated, the ODLIS offers two kinds of lecture: The synchronous lecture and the asynchronous lecture. These two kinds of lecture, because of their different characteristics, need different handling for the transmission of their multimedia data. Fig. 4 displays the protocols stack of the ODLIS.

We use the real server platform (RealNetworks, http://www.real.com) for the transmission of multimedia data over the network during an asynchronous lecture. The transmission of multimedia data (mainly audio and video) over the network during an asynchronous lecture is controlled by the RTSP. RTSP is a client–server multimedia presentation control protocol, designed to address the needs for efficient delivery of streamed multimedia over IP networks. The RTSP specification contains a section on the use of RTP with RTSP. RTP is a transport protocol for the delivery of real-time data, including streaming audio and video. RTCP is a part of RTP and helps with lip synchronisation and QoS management, among others. With the combination of the RTSP, RTP and RTCP, we can implement a QoS scheme for our application. The client is adaptive and could change the buffering time and the

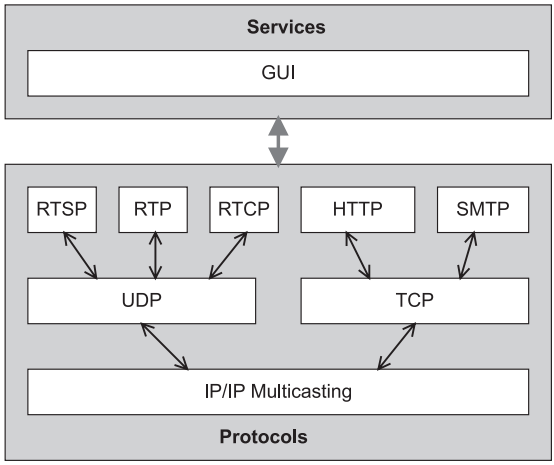

Fig. 4. Protocols stack.

capacity of its buffer accordingly the condition of the network and the bandwidth requirements of the multimedia stream.

With this approach for any participant who wants to attend an asynchronous lecture, a different "tunnel" of RTP packets is created between the server and the participant's computer. As a result the participant can attend the asynchronous lecture with his different pace and can also have video playback, repeat and forward capabilities.

We use the WhitePine MeetingPoint H.323 Multipoint Conference Unit for the transmission of the multimedia data during a synchronous lecture. When the number of the participants into a synchronous lecture is large the transmission of the multimedia data (mainly audio and video) is based on the technique of IP multicasting. IP multicast-based routing facilitates distributed applications to achieve time-critical real-time communications over wide area IP networks through a lightweight, multithreaded model of communication. The IP multicast routers take the responsibility of distributing and replicating the multicast data stream to their destinations as opposed to individual IP hosts. The IP multicasting topology of IP multicast routers is designed in such a manner that it facilitates efficient distribution of packets without congesting any node inappropriately. With this approach, we deal with the quality of the services and the network traffic in the best manner.

When a participant wants (and has the authority) to join one synchronous lecture the participant client tries to join the multicasting session. If the participant is unable to accept multicasting data for various reasons (for example the router from which the participant accesses the Internet does not support multicasting), then the server tries to transmit the multimedia data with the User Datagram Protocol (UDP). Finally, if the transmission with the use of UDP is not reliable, then the server opens one Transmission Control Protocol (TCP) connection with the participant client and transmits the multimedia data. With this approach, we ensure that all participants, regardless of their network equipment, will have the opportunity to join one session.

Since, on a synchronous lecture all participants attend the lecture at the same time, we can use IP multicasting in order to reduce the network traffic.

7. Data manipulation issues

The data access components providing the interface to the information stored reside mainly on the web server and the database server. They access information that is stored on the file system or the relational database management system.

7.1. Interface to web

The web server's data access components take the form of server-side scripts while those of the database server comprise the stored procedures used for the management of the information stored in the database. The technology used for the server-

side scripts is PHP. PHP is a server-side cross-platform HTML embedded scripting language. The majority of the HTML document responses of the application's user interface are produced 'on the fly' according to user's access level, information accessed and user's request so the need for such a mechanism like PHP was essential. [6]

The PHP offers mechanisms for the manipulation of files and folders as well as access to most of the available RDBMSs, so the use of such interface between the web server and the database is necessary. Moreover, PHP has a variety of mathematical, date and string functions. This capability gives the possibility to a developer to deploy easily interactive customised web applications. It also provides mechanisms for maintaining session information. Session information is stored in session variables that contain information during the user's visit. The session variables are used mainly for caching data that are stored in the database or the file system and are accessed frequently during a session.

Currently, the three most popular web servers Apache, Microsoft's IIS, and Netscape Enterprise offer server-side scripting capabilities, executing scripts and components on the server, without the performance limitations and development difficulties of CGI. HTML and HTTP by themselves do not provide a way to access databases or carry information about users from page to page. Server-side scripting accesses programs on the server that provide this necessary functionality behind the scenes to deliver web applications and customised HTML for each user. Web server scripting, also, separates the content from the presentation for easier design and data management allowing the use of templates for creating HTML documents on the fly.

The contents of a page can come from anywhere – databases, plain text files, searches, calculations – and be dynamically inserted before it is sent to the user. Information can be managed in the most appropriate manner, and does not have to be stored in HTML pages that must be changed manually whenever the data changes.

7.2. Types of information

As an educational system, the designing of ODLIS has to deal with two major groups of information. The first group, which contains the training material is mostly media data files and HTML pages. The second group has information for the system. All information about curriculum, courses, lectures and users belong here.

The system is based on a mixed model of storing, so it can efficiently manage these two different groups of information. All data comprising the lectures' content are stored on the file system, while all other kind of data are stored in the database. The reasons for following that model have to do with issues of manageability, scalability and transparency.

[6] PHP. http://www.php.net.

Lectures' content, HTML documents, images, audio, video and presentation slides are accessed by the web server or the Real Media server. They are static information that do not change frequently. This is the kind of information that is stored directly to the file system. Storing them with another data manipulation mechanism like a DBMS would make the system more complicated or even slower. Especially for the media data files, a new mechanism should have been developed to communicate with the storing and presentations mechanisms. But this solution could affect the systems portability. Furthermore, storing this information on the file system, helps the editors and authors, because they can access the information using the ordinary tools with which they are familiar and be much more independent of the system.

The rest of information is stored to the DBMS. To be more specific an R-DBMS is being used, as a relational model can easily represent the kind of information that is being stored more sufficiently than any other model like object-oriented or hierarchical model.

The reasons that a DBMS storing mechanism is used are many:

- A database is designed, built, and populated with data for a specific purpose. It has an intended group of users and some preconceived applications in which these users are interested.
- It has the ability to handle large amount of data easily.
- It is scalable. A developer can easily alter the database schema without changing all storing and reading mechanisms.
- A DBMS helps the application developer to modify the clients being aware of in which format the data are stored at the server.
- A database mechanism can get over the operating and files system limitations.
- A database can give access to data to multiple users with different roles and different level of accessibility to each one.
- It provides indexing mechanisms that are used for the efficient accessing of large amount of data.
- It also provides mechanisms to easily enforce integrity or referential constraints to data.

The information stored on the database consists of tables containing information about the lectures such as keywords, pointers to the lectures' content at the file system, questions, authors or professors, and students. For each student, a performance and attendance log is kept. Even though the web server is responsible for user authorisation, each user's rights are kept in the database.

Being more specific, there are curricula, which contain groups of courses. Every course has a code name, start and end date, and description. Every course contains groups of lectures. These lectures are the static information like HTML documents, images and multimedia content. A lecture may have two parts. One asynchronous with static data, and another one synchronous. Also, a lecture has keywords so a student or a teacher can easily find a lecture that is interesting for him. Moreover,

there are questions at every lecture, and exercises at the end of every course that the student has to answer and get his grade.

The system also stores information about the users and the administrators. A user can be a teacher or a student or both. Although a teacher can attend a course as an ordinary student, he cannot be a teacher to that course also. For every student, the system logs his attendance and his marks from questions and exercises. The administrator, who has an independent role has the authority to add and remove users, to create new curricula and add the material to the system and to administer courses also.

A detailed description of the database is given in Fig. 5.

8. The ODL services

8.1. Architecture of the asynchronous ODL service

Fig. 6(a) displays the general architecture of the asynchronous open and distance learning (AODL) service.

First of all, the teacher prepares the educational material of the asynchronous lecture and sends it to the administrator. The administrator up-loads the asynchronous lecture and the lecture is available to the students. For the implementation of the AODL service, we use the architecture of Fig. 6(b).

The server of the AODL consists of the Real Media server, the web server of the ODLIS and the database of the ODLIS. The real media server is responsible for the transmission of the video over the network, the web server is responsible for the transmission of the slides and the database is responsible for management of data.

The educational procedure is the following: The teacher prepares the educational material of an asynchronous lecture, which consists of the video and the slides. First of all, the video of the asynchronous lecture must be captured in video for Windows format (.avi) or quick time format (.mov). Then the slides of the asynchronous lecture must be produced in Microsoft powerpoint (.ppt) format. The next step is the synchronisation of the video and the slides of the asynchronous lecture and the conversion of it in the Real Media (.rm) format. The synchronised educational material is sent to the administrator and the administrator up-loads it to the AODL server.

The students in order to attend the asynchronous lecture must have installed to their computer the following software: a web browser with the Microsoft PowerPoint Viewer plug-in installed and the Real Media Player. Through the Real Player students can see the video and through the web browser (and the plug-in) students can see the slides.

The above-described solution uses for the transmission of the video the streaming technology. The streaming technology with the achievements of the recent years (for example the RTSP protocol) has many advantages for the transmission of multimedia data over a TCP/IP network like quality of service characteristics (with the use

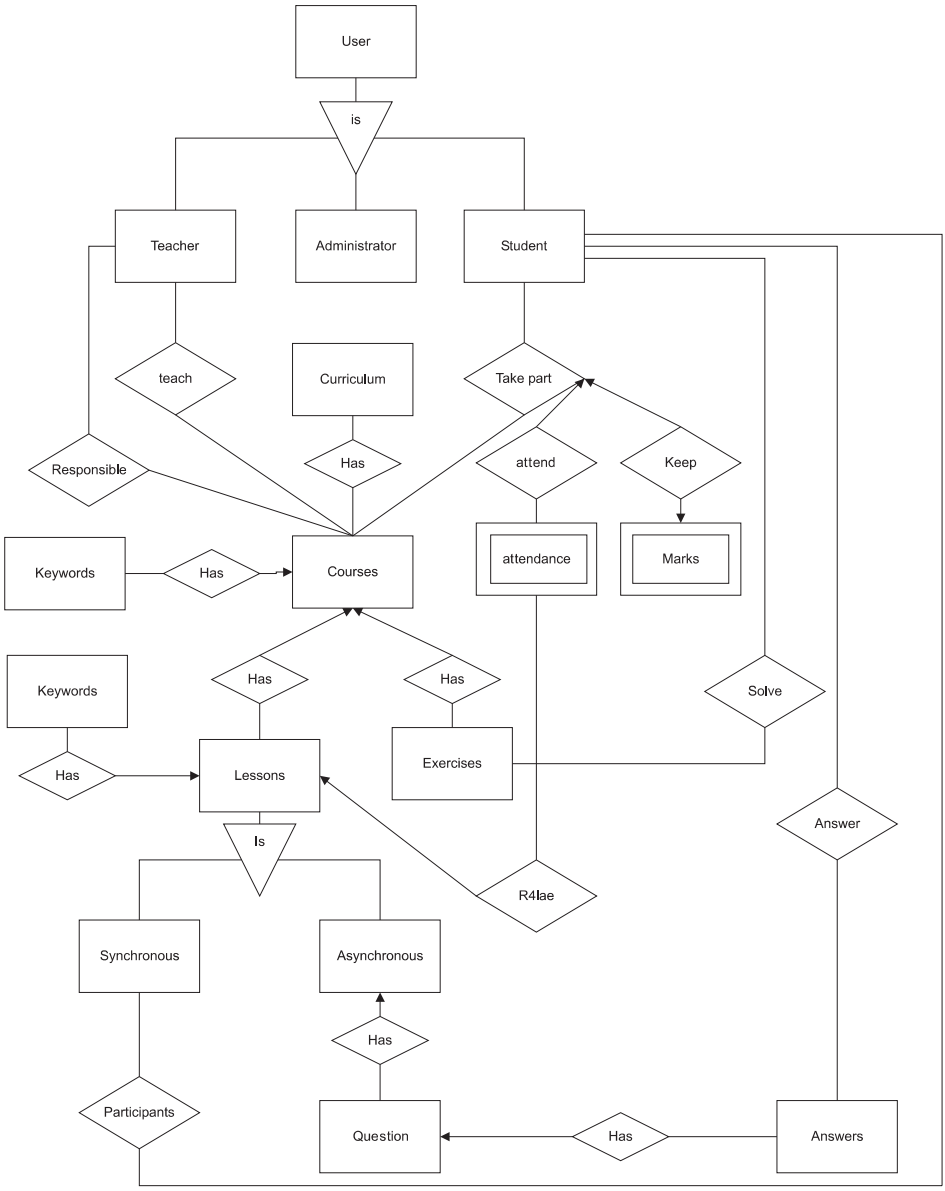

Fig. 5. Figure relational diagram.

of buffering). The above-described architecture did not confine the way that an asynchronous lecture can be transmitted. For example, a teacher can create an asynchronous lecture using a tool of his choice (for example, a macromedia tool) and

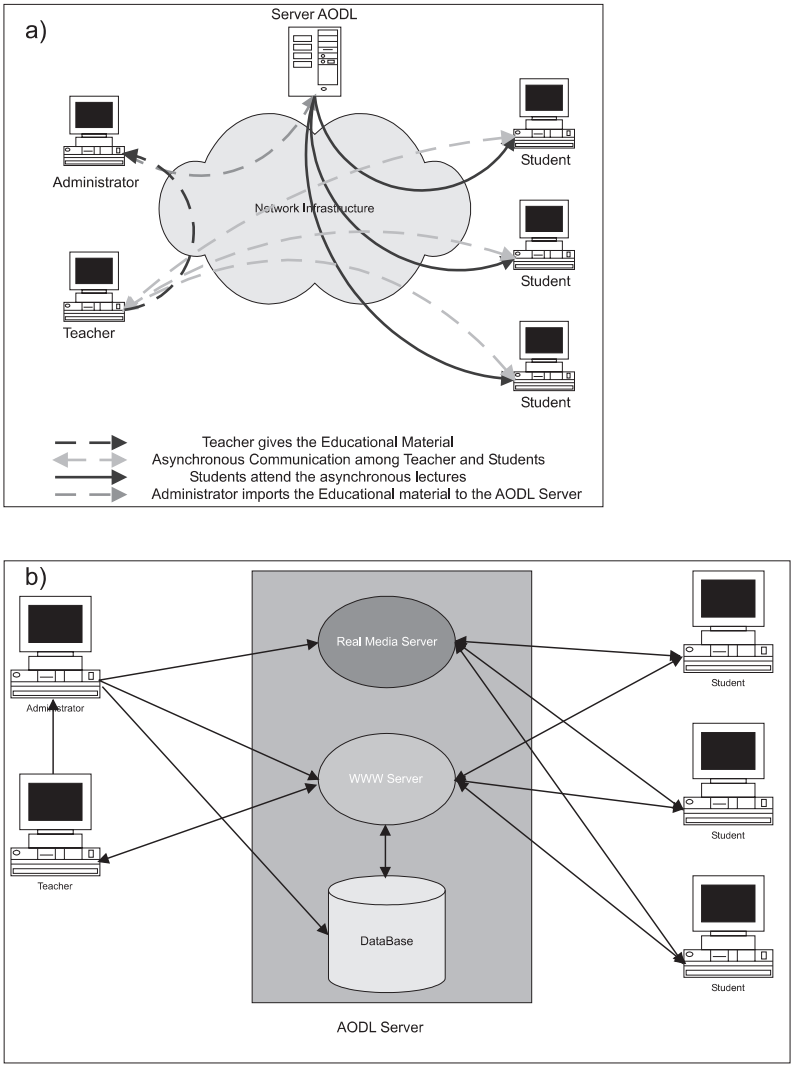

Fig. 6. The AODL service.

suggests to the students to install the appropriate software or plug-in to their computer in order to attend the asynchronous lecture.

8.2. Architecture of the synchronous ODL service

Fig. 7 displays the general architecture of the synchronous open and distance learning service (SODL). First of all, the teacher prepares the educational material of

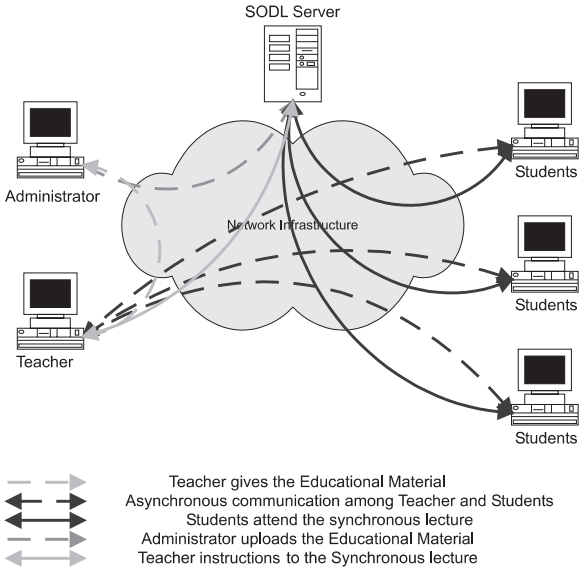

Fig. 7. The general architecture of the SODL.

the synchronous lecture and sends it to the administrator. The administrator uploads the educational material and the lecture is available to the students. The predefined time and day the teacher and the student connect to the SODL server in order to realise the synchronous lecture.

For the implementation of the above-described architecture, we examine two approaches. In the following paragraphs, we describe each one and we present its advantages and disadvantages.

The first approach which is the implementation of the SODL with the use of H.323 reflector, is shown in Fig. 8(a). In this approach, the SODL server consists of an H.323 server, which is responsible for the transmission of the video and a T.120 server, which is responsible for the application and the data sharing and the web server of the ODLIS. The clients of the teacher and the students consist of a H.323 client and a web browser. In this implementation, we use WhitePine MeetingPoint Conference server.

The educational procedure is the following: The teacher prepares the slides of his lecture with the software of his choice and informs the administrator. The administrator announces the synchronous lecture and he binds the appropriate resources to the SODL server for the defined time and day. The defined time and day the teacher and the students connect to the SODL server. Through the H.323 server the participants can transmit video and through T.120 server participants can share data and application. In this scenario, the sharing whiteboard (that almost all H.323

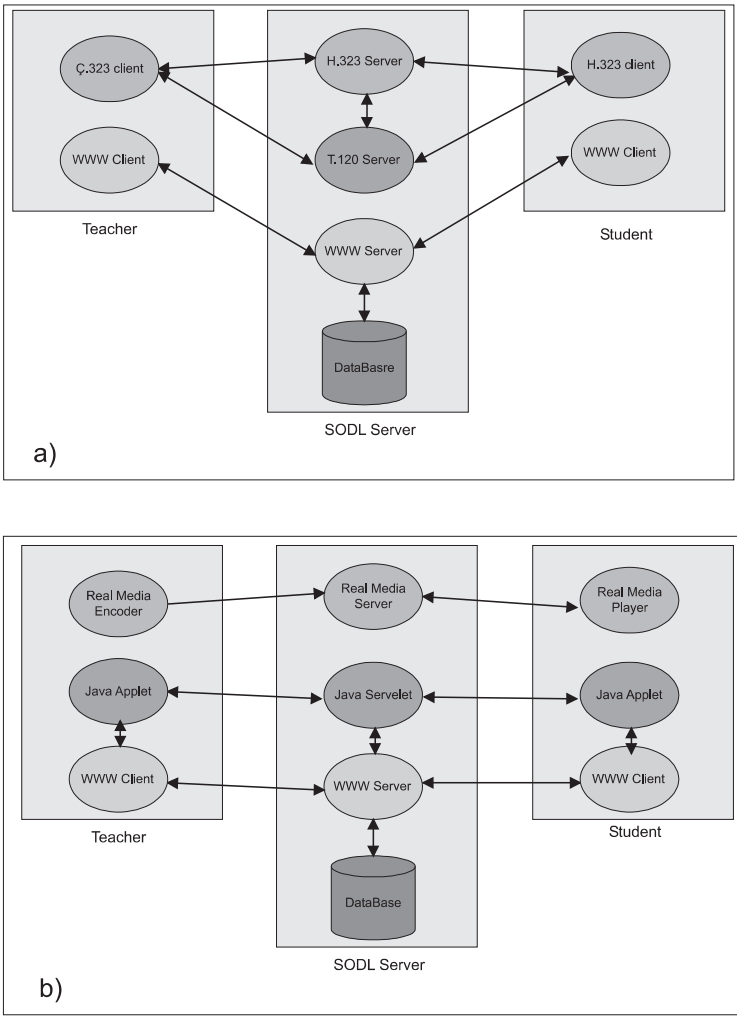

Fig. 8. Implementation of the of the SODL.

clients have) can play the role of a typical blackboard. In addition, through application sharing teacher can show slides with the application of his choice.

The above-described implementation has the advantage that it follows internationally accepted standards (like ITU H.323 and ITU T.120). In addition, this implementation gives the teacher the flexibility to prepare the educational material with the software of his choice. This implementation has the drawback that it uses tools designed for videoconference and not for distance learning. This may create problems to the educational procedure from malicious students.

The second approach, which is the implementation of the SODL with the use of Real Media and Java technology, is shown in Fig. 8(b). In this approach, the SODL server consists of the Real Media server, which is responsible for the transmission of the video, a Java servelet (server application in Java), which is responsible for the management of the synchronous lecture and the ODLIS web server.

The Java server consists of the following four modules: The authentication control module (which is responsible for the authentication of the users), the chat module (which gives to synchronous lecture a chat capability that is controlled by the teacher), the whiteboard module (which gives to synchronous lecture a shared whiteboard capability that is controlled by the teacher) and the control module, through which the teacher controls the synchronous lecture. The users (teacher and students) client consists of the Real Media Encoder and Real Media Player for the transmission of the video, a Java-enabled web browser and the corresponding applets. The communication between the Java applets and Java serverlet is based on TCP sockets.

The educational procedure is similar to the above described, with the difference that the teacher uses the shared whiteboard for lecturing.

This approach has the advantage that the teacher has full control of the educational procedure. In addition, the use of the Real Media platform for the transmission of the video makes the recording of the video and the conversion of it to asynchronous lectures easy. The main limitation is that it does not follow any international standard for data and application sharing like the ITU T.120.

9. Case study: The University of Patras in Greece

The aim in proposing a "Propose of Open and Distance Learning Program" to the University of Patras was the exploitation of its educational experience, of its technological experience and network and computer infrastructure. This lead to the development and operation of an Open and Distance Learning Centre, which has to implement the ODL program. The following components have been designed and implemented:

- The educational material which is the "product" that the Open and Distance Learning Centre offers.
- The ODLIS which supports the Open and Distance Learning Centre.
- The Open and Distance Learning Centre which manages the Open and Distance program.

The Open and Distance Centre offers a number of curricula both to undergraduate and postgraduate students. The Network Operation Centre of the University of Patras supports the operation of the Open and Distance Centre.

The ODL program of University of Patras in Greece uses the above-described information system. In the first phase will operate three curricula, two for undergraduate studies and one for postgraduate studies. In particular, the postgraduate

curriculum on Special Themes on Computer Science and the undergraduate curricula on Computer Science and Neuro-Science will operate. All the curricula will use both asynchronous and synchronous lectures. In the future, the ODL program of the University of Patras will offer more curricula.

Through the ODLIS the University of Patras will offer the following ODL services:

- *Distance learning with the live presence of the trainer* (*synchronous distance learning*). In this category, the lecture takes place on predefined time. The trainees attend the lecture, hear the trainer and have the ability to interrupt the flow of the lecture in order to submit a question. The trainer has all the necessary authority to control the flow of the lecture (like as in a conventional lecture). For saving network resources, every trainee can see only one participant every time (the trainer, or a trainee that submits a question), as result it is not recommended the use of videoconference for the implementation of synchronous distance learning. The educational material of the lecture is distributed to the trainees during the lecture (something that did not invoke problems due to contemporary network infrastructure of the university of Patras).
- *Distance learning during which the trainee selects the time of the lecture* (*asynchronous distance learning*). In this category, the trainee has access to educational material. The trainee has the ability either to download the educational material locally to his workstation and study it, or to study directly the educational material through the network. In both cases, the trainee can control the time and the pace of his study. For the access to the educational material the hypermedia technology is used.
- *Computer support collaborative work for learning* (*CSCWL*). During an CSCWL learning scenario, trainees can submit questions to the trainer and trainer can answer to those questions. Participants can exchange thoughts and ideas through a shared bulletin board. In addition, participants have the ability to exchange files (in several formats) through a shared workspace. The above-described interaction between the trainer and the trainees enhances the educational process.

10. Conclusion – future work

With the advancement of technologies, learning and collaborative work in the future can become radically different from what it is today. Although no one can expect that educational networks will totally replace the traditional lecture. The traditional lecture has some drawbacks: students have to attend at a fixed time, the needs of students with different backgrounds cannot be met and students have no control of their learning pace or environment. Many web-based training and learning platforms have been developed. However, none of these platforms offer an integrated and open platform for learning according to our requirements because:

some of them do not support all the necessary ODL services (synchronous, asynchronous and collaborative learning); and some of them do not support standards (such as H.323 and T.120). In the case of University of Partas, there is another reason: none of the tools support the Greek language so it was vital to implement a new platform according the need of our University. The ODLIS gives a solution to the above-mentioned problems with the use of computer-based instructional technology, which has demonstrated its ability to effectively support numerous educational and training functions. Our next step is to evaluate the usage of the ODLIS through the ODL program of the Patras University in Greece.

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