



STEPS: Supporting Traditional Education Procedures—A TCP/IP Multimedia Networks-Based Model

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Abstract. This paper describes an integrated model for the realization of an Open and Distance Learning (ODL) environment supporting traditional learning procedures, through collaborative learning and active participation of the involved group of students. Internet technologies are used as a vehicle for distribution of interactive multimedia at the user's desktop. We also present off-the-shelf solutions for the architecture and implementation of an Educational Network necessary to support the ODL environment. An Educational Entity (specially shaped part of a legal educational authority) is also prescribed as the central point for the Educational Network, being the content provider and the learning procedure evaluator. It is mainly intended to be used in a higher education setting, aspiring to be an efficient solution for the common educational needs of a group of students and teachers or researchers.

Keywords: multimedia networking, collaborative learning, internet technologies, distance learning environment

1. Introduction

The digital electronic information age opened with the advent of microprocessor based personal computers in the late 1970's. The next phase came with the introduction of multimedia objects: digital images, digital video and sound. The third phase, the World Wide Web, saw the advent of a vehicle for rapid dissemination of multimedia learning resources. Web technology also provides for instantaneous interactivity, essentially eliminating traditional space and time barriers. Web sites can serve as communication hubs for student-teacher, student-student, and teacher-teacher interactions. By providing web-based instructional material teachers can structure the out-of-the-classroom time so the students can use it more productively. Web sites can provide a virtual setting for collaborative peer instruction, which has proven so effective in the classroom.

There are two ways of presenting educational material on the web: synchronous and asynchronous. Synchronous distance learning environments focus on creating an illusion of a classroom. This includes the delivery of live classroom lectures via satellite channels and video recording of live classroom presentations. Internet-based conferencing tools have also been used to create live, networked distributed "classrooms". On the other hand, asynchronous systems are designed to allow students to use the software at any time, without simulating a classroom. With these systems, students proceed at their own pace and are not

assumed to be accessing the same material at the same time as others (there still exists similarity to a textbook referring to a particular subject). The goal of these systems is to serve as a repository of reference material or tutorials.

There is a growing interest in higher education in the use of the WWW as a learning tool. The WWW enables the development of powerful information sources to support learning and facilitates student-centred instruction. It supports and encourages exploration and inquiry, behaviors that are frequently associated with enhanced learning outcomes [17].

However providing students with access to such meaningful content does not always guarantee learning. Contemporary learning theories indicate that learning is achieved through a process of knowledge construction. When a learner is confronted with new knowledge, the learner's intentions and previous experiences are all essential elements in determining what becomes of the knowledge. The effectiveness of any learning environment is based upon the types and levels of cognitive and metacognitive activity engendered in the learners. It is now widely accepted that learning is enhanced in instructional settings where students are engaged in processing personally relevant content and are reflective during the learning process. The use of collaborative learning environments seems a natural way to create such settings [15, 17].

The WWW (World Wide Web) has been established as a standard of distributing multimedia/hypermedia information. There are many applications based on the WWW, such as video on demand, distance learning, home shopping, etc. Recent advances in protocols that enhance the TCP/IP protocol suite to deliver time-critical data formats (audio, video) render even more evident the intertwining of multimedia and the Internet in order to deliver interactive multimedia to the desktop [12].

The subject of distance learning and collaboration has engaged researchers all over the world. Many solutions have been proposed for distance learning and collaboration over TCP/IP networks. Indicative commercial tools for collaboration over the Internet are Microsoft NetMeeting and White Pine Enhanced CU-SeeMe. Various methods have been proposed for synchronous learning [2, 6, 10, 18], asynchronous learning [22, 29], or asynchronous learning with an on-line facilitator [27]. Various models for collaborative environments that cover the communicational needs of collaborative work in a learning environment either synchronous [11, 19], or asynchronous [26] have also been proposed.

This paper describes the method adopted for the implementation of an ODL environment aiming to support a group of learners with common learning objectives and to enhance traditional learning methods. This environment offers collaborative capabilities using Internet technologies to groups of students with common educational/training objectives (or research interests). Various services are offered in the context of a closed user group aiming at collaborative learning with the active participation of students. It is intended for use mainly in a higher education setting. The STEPS model also describes the implementation issues of an Educational Network supporting the ODL environment and the organisation of an authorised Educational Entity that will be the Educational Content Provider. The Educational Entity will host in its premises the central point of the Educational Network.

Currently STEPS is using CGI and Java to overcome the disadvantages of the passive features of HTTP protocol and provide the means for a relatively easy and quick enrichment of the interface and the services developed upon this platform. The basic data formats

(text and images) can be transferred via the HTTP protocol while the data formats that require continuous transmission are synchronized (with relevant “educational material”) and transmitted using RealServer (for audio and video streams) and MBONE technologies offered through the SDK (Software Development Kit) of RealServer. The reasons for this separation stem from the weakness of the HTTP protocol’s ability to accommodate media with real time characteristics, such as audio and video.

In the following sections we will describe the development and the basic architectural and functional characteristics of the STEPS model, from its early days (Determination of User Needs) to the set of rules, management decisions, software modules that have been produced during its development phase.

2. Justification for the implementation of an ODL environment

The major design principles for the STEPS model were obtained as a consequence of the needs expressed by potential (direct or indirect) end users in projects aiming at the exploitation of Information and Communication Technologies (ICT) in support of the traditional learning procedures.

Some of the possible techniques (or combinations of them) that could be used for the establishment of the User Requirements of an ICT project, according to a widely accepted methodology (the Usability Guide, accepted by the European Commission [23]), are the following:

Personal interviews with the end users. This technique offers a useful way to investigate and determine their needs in real life. The main problem of this technique is the enormous number of end users, which often lead to prohibitive costs. A careful selection of a representative group of the initial target audience of the project might allow such a procedure to be more practical and still effective.

Questionnaires. In order to keep the cost down, the use of custom designed questionnaires and surveys is commonly a practical option. The key point of this technique is the construction of the questionnaires, that are representative and reflect all possible user requests. The construction of efficient questionnaires that will lead to the specification of the User Requirements of a project is a complex task. The team that constructed the questionnaires included specialists on the scientific areas that the project deals with, experts on technological issues, as well as representatives of the potential target group.

Organisation of discussion panels for brainstorming and feedback. In these panels, representatives from all sides of the project participate, for a more objective view of the situation. This is useful as a final stage, for verification of the User Needs as they were described by some other technique.

The main goal of specifying the User Requirements in a project is to address the Service Implementation Scheme. This scheme will depict the Functional Specifications that will be taken into account during the design phase of the project.

The distribution of tasks in an application consisting of geographically separated users will impose communication, processing and storage requirements. Apart from the immediately defined User Requirements for storage and information processing, the processes and the end users of the application imply the definition of the communication tasks. The service implementation is an organizational and technical process, which follows once the User Requirements of a Project have been established, and the convergence to a common scheme has led to a “Usage Scenario” (a Usage Scenario is just one possible model to describe the flow of information and the necessary communication tasks, according to the previously defined User Requirements).

2.1. User needs determination in the context of the STEPS model

The methodology mentioned so far, has been followed for the determination of the user needs in the TRENDS/ET-1024—Telematics Application Programme [7] and the OSYDD-PP project in the University of Patras (funded by the Master Plan for Education and Initial Vocational Training/EPEAEK of The Hellenic Ministry of Education) with slight variations.

The methodology adopted and implemented consists of the following steps:

1. Interviewing of a number of representatives or key persons of the target audiences and experts, for a first impression before constructing custom designed questionnaires.
2. Construction of workshops of key persons for discussion on topics related to the strategic plan of the project.
3. Construction (according to the information provided by the interviews and the basic axes that were discussed in the workshops) of questionnaires, and distribution to the potential end users. These users were categorised in two major groups:
 - Users with experience in using ICT for educational purposes.
 - Users with no experience in the use of ICT.

According to the adopted methodology, a number of workshops/round table discussions and interviews were organized firstly, in order to have a starting point and a global view of the User Needs, before constructing the questionnaires that were eventually distributed to the potential end users of the project. Two kinds of questionnaires were distributed, one for the experienced in using ICT for educational purposes and one for the inexperienced users [8].

The participants in the workshops/round table discussions and the interviews included in-service educators of various disciplines, university professors, key persons in policy making for education and training, experts in the fields of Information Technology and ODL, representatives of professional and scientific associations and directors of regional training centres. A group of direct users from the target audience was also interviewed, in order to provide feedback to the construction of the questionnaires that were actually distributed to the direct users.

The participants of the workshops/round tables focused on key issues related to the teacher’s job profile, his/her initial and in-service training and the “new role” of teacher implied by the introduction of new technologies. They also focused on new cognitive

procedures and evaluation methods emerging from contemporary theories for the acquisition of knowledge, and also the access, cost, management and suitability of new technologies.

The areas addressed during the interviews included systemic issues, barriers, educational issues, technical issues and management issues. Visits were followed by discussions within our research team in order to identify the major findings from the interviews. The results extracted from the interviews concern educational policies, the content, forms and aims of further training and the functional scheme for the enhancement of instructional settings by using ODL environments.

Following, is brief presentation of the main results [8] that came to the light while trying to determine the User Requirements of the STEPS model, according to the methodology presented. These results are the synthesis of the primary results concluded by the workshops/round tables, interviews and questionnaires. Our research team conducted the procedure of synthesis of results, in order to determine the framework of the eventual convergence of these needs to the Usage Scenario of the STEPS model (implementation of an ODL environment supporting traditional instructional settings).

2.2. Consolidated presentation of results

The procedure of the determination of User Needs evinced the principle that the use of Information and Communication Technologies in the instructional procedure is not an end in itself. The main aim is the familiarization of the educational community with the potential usefulness ICT can have in the upgrade of the offered educational services.

Within the same context is the realization that the further education of teachers in the fields of ICT will improve their professional skills, change their teaching habits and give them a more positive profile which will contribute to the improvement of the quality and efficiency of their work. This education should cover the following facets of ICT:

- learning to employ the new technologies for educational use, through an integrated and specially targeted for education environment,
- providing further efficiency in the teaching of particular subject matter, and
- learning how to acquire multimedia information and to achieve personal contact by making use of information networks (such as Internet).

Very often the access to and the use of computer or information networks is a discriminating factor for the teachers to be motivated. According to the experts, it is of primary importance to increase the equipment at teachers' disposal, improve the skills of teachers in using new technologies and, in parallel, to pursue politics of support and stimulus.

When speaking about the introduction of innovative technology-based training initiatives, attention must be paid to technological infrastructure and equipment. Actually, at present, schools (or even universities) are not equipped with the same facilities and have not the same networking infrastructure or the same degree of know how. This results in a vicious circle: where the lack of equipment brings about the lack of skilled teachers and, vice versa, skills are missing because there is no suitable equipment.

The simple supply of resources through a specific centre or body does not seem to be able to trigger a demand or an explicit need. A clear example is offered by the numerous

opportunities over Internet, which are under-exploited due to a lack of motivation (in this regard it is worth the notice that among the teachers without experience, 97% have affirmed not to use Internet e-mail services, while having access to them). Hence, the start-up of activities aimed at the acquaintance of educators with the new technologies is an essential step to be taken in order to engage educators with them.

It is essential to link these new technologies with new notions about learning, knowledge, expression and evaluation. Educators should make a break with traditional attitudes in the classroom. One of his or her major roles, under the new circumstances, is to provide the student with the opportunity to construct the new knowledge within an appropriate technological and learning environment. It is deemed essential that the change in the infrastructure and the attitude towards the way a school functions, should take place almost simultaneously—considering that the co-existence of old practices and mentalities the new approach could weaken or even frustrate the whole endeavour.

The general attitude of inexperienced users towards the use of new technologies is quite positive. Most of them said that are particularly interested in initiatives regarding modalities of using new audio-visual and multimedia learning tools. The application of computers for didactic purposes should not be limited to the preparation of learning material or reports. Most users prefer to be trained through examples of real applications, or through a combination of theoretical presentations, empirical applications and suggestions on existing literature on the subject.

It is generally considered significant learning about, and taking advantage of the possibilities of having access to available information resources. These include the Internet and databases maintained by internationally recognised documentation centres, as well as specific information provided through specialised multimedia information networks.

It is an almost unanimous expression, that there is the need for additional scientific knowledge pertaining to particular subject matter. This knowledge ought to either fill in ascertained gaps in the initial training of educators or contribute to the updating of educators on the subjects they teach. The particular scientific/didactic needs of the educators must be taken into consideration. The fulfilment of this requirement could be the provision of additional supervisory bibliography and supplementary didactic material.

The need for further education and the updating of educators on the new didactic methodologies that are developed and applied to each subject matter is deemed imperative. The aim is to familiarize educators with these methodologies and apply them in the classroom, with special emphasis placed on the methodologies that help teachers solve special problems they face in the classroom.

Educators lay emphasis in the following requirements on aspects of didactic methodology that can be positively affected by the contribution of ICT:

- The requirement to learn ways and methods in order to readjust the didactic methodology used by educators in the wake of the new knowledge they will have acquired and the new skills derived from the use of new applications within the context of ICT.
- The requirement for the provision of additional knowledge, regarding pedagogical theories, that can be applied in real everyday school situations.
- The requirement to update and educate students in the new evaluation methods, pertaining to the new instructional setting.

- The provision of means to evaluate and reassess the contribution the new technologies will have on the learning process.

In order to upgrade the educational system, the need for further education and the utilisation of new technologies should be highlighted. The primary goal of an embracing educational policy is to provide multifaceted forms of further education such as school-based teacher training programmes, long distance training methods, interdisciplinary university programmes. There are also some cultural obstacles that can inhibit the change of the educational system. These obstacles can be overcome by means of a gradual introduction of didactic innovations, by providing teachers with the suitable tools to understand the meaning and the use of learning technologies. Also, the teachers should become more acquainted in researching methods and not only skilled in using learning technologies in order to bridge the gap between the degree of technological complexity and the real didactic innovation. The most appropriate way to accomplish this is via small groups or on an individual basis.

Nearly all educators would like to collaborate with colleagues from other countries. The majority of educators affirm that they frequently share experiences and projects with their own colleagues, and they claim that this exchange of experiences should be extended to the international level. Educators need to communicate on matters regarding (the use of primary network services of Internet (e-mail, News, Bulletin Board) is considered as a necessary prerequisite for the majority of the educators):

- information about the innovations in education
- update on the organisation and application of educational procedures aiming at the dissemination of better teaching attitudes, and
- exchange of information between the users of the system.

3. Usage scenario for STEPS model

The definition of User Requirements immediately impose processing and communication tasks that should be provided in the context of any model developed in accordance to the concluded User Requirements. We finalize the User Requirements document and after having carefully studied the outcomes, we concluded to a pertaining model (perhaps not the only one valid) whose interactions among its entities satisfy the processing and communication requirements implied by the potential end users.

It is designated for use in the context of an educational organization for general-purpose education, offering capabilities of defining closed user groups in which instructional services are offered, with the following characteristics:

- *Session creation.* This term describes the ability of defining closed user groups in an ODL environment. These closed user groups should contain users with common educational or research interests or users to follow a common learning scenario towards a common learning objective to be achieved. These users will have well-defined access rights and views to the educational material and the services that will be offered in the context of an

ODL environment. The educational material comprises a structure of documents, images, URLs, etc.

The set of users, educational material, services as well as all the possible interactions between these entities is defined as a session in our model. A session should be considered as an on-going activity between the members of a group that attend a lecture, collaborate in order to exchange ideas and work out problems, work in the elaboration of a project, etc. In every session the person that launches the session is considered to be the session administrator (the one who creates the closed user groups, assigns rights to each participant as far as the educational material and the services offered in the context of a session is concerned, and determines the learning procedure to be followed).

- *Interpersonal communication services.* These are services that are offered in the context of a session. The functional characteristics of these services include:
 - Exchange of e-mail messages supporting multiple data formats in the message body
 - Participation in discussion groups (newsgroups) having subject relevant to the educational targets of the session, usually consisting of a subset of the participants in a session
 - Real-time exchange of textual messages (chat)
 - A Bulletin Board Service (BBS) hosting announcements concerning the activities of the session.
- *Computer supported collaborative learning services.* These are services that are offered in the context of a session with the following functional characteristics:
 - data and application sharing
 - shared editing of documents
 - version control of documents
 - evaluation of the students' progress through exercises that the tutor gives to a (selected) group of participants and are submitted back to the tutor after being resolved by the participants
 - collaboration between participants for the elaboration of a project or (probably) a research result
- *Distance education services.* Two major classes of services can be identified in this area: Synchronous Distance Education service (electronic classroom) and Asynchronous Distance Education service (electronic textbook). In STEPS, only the synchronous interpretation currently exists in the context of the session. Asynchronous distance education service is conceived as a supporting service to the concept of a session. The integration of the services offered in the context of a session along with the asynchronous distance education service generates a general-purpose ODL environment.

Synchronous distance education services. In this case, the lesson is conducted in a predefined and already announced time. The participants in the Synchronous Distance Education procedure (probably a subset of the members of the corresponding session) are attending the lecture, accessing the educational material and are able to see and hear the tutor (not necessarily a member of the session).

The notes of the lecture are presented in a separate window according to the lesson's flow as is determined by the tutor. When a transparency is loaded in the tutor's window it

is automatically loaded in the corresponding windows of the students. The tutor is then able to annotate and comment on the transparencies, broadcast to the group of students a selected screen information (including the pointing device), further clarify a point by writing on a blank transparency so that every participant can see it at the same time, etc. (whiteboard utility).

The audience of the lecture can discontinue the tutor (after the tutor having granted the student the permission for intervention) in order to place queries. In this way the equivalent of a traditional classroom setting is created i.e., an electronic classroom. The tutor has the authority to grant to the audience of the lecture the right of placing questions and permit the discontinuation of the lesson.

Synchronous Distance Education activity can be implemented with the appearance of a window at the user's desktop through which the user can see and listen to the tutor¹ (or his colleague placing a question). There is no need to use videoconferencing tools to implement the electronic classroom. There is only the need for a synchronized audio and video stream to be transmitted from the tutor to the audience of the lecture [2].

The relevant educational material should be distributed to the audience of the lecture either prior to the beginning of the lecture or during the time of the lecture (the latter choice can be insufficient and ineffective if the underlying network infrastructure does not suffice during the time of the lecture).

In the following sections the design and implementation of an ODL environment, able to complement the traditionally offered educational services by exploiting the advantages of ICT, is described. This environment is implemented as a set of software tools adding value to the already existing wide area networking technologies and services of Internet. In this way a wide base of potential learners can be reached and the access to these services is uniform and easy to almost everyone connected to the Internet.

4. Functional description of the software modules

In order to create a complete ODL environment that will satisfy the needs of a group with common learning or working needs, through collaborative learning and active participation of students, two software modules are implemented:

- a software module offering collaboration capabilities (e-mail, newsgroups, bulletin board, chat, data sharing, shared editing), thus realizing a Computer Supported Collaborative Learning (CSCL) Environment, and
- an emulation of a traditional class environment (electronic/virtual classroom), through a Synchronous Distance Education activity.

4.1. Functional description of the CSCL module

4.1.1. Overview. The ODL environment is built upon the idea of a “session”, a combination of a group of users/students, session related educational material and services offered in the context of a session.

A new member is added in each session every time either another member of the session invites him or he applies for participation in the session using a special form. The session administrator decides whether to grant the permission or not (and to which part of the contents of a session) and contacts the Web administrator. The Web administrator is responsible for assigning a valid username/password combination and notifying the new member of the session (most probably with a simple e-mail).

Every member of a session has personal view determined by the access permissions in the contents of the session according to his/her username/password combination. The session administrator (see figure 1) designates this view.

The student accesses the services offered by the CSCL module, through a web browser. Special icons indicating events or actions in the educational material are employed, thus rendering easy the participation in collaboration activities.

The basic page of a session consists of three frames (see figure 1). The upper frame of the application includes a table with the names of the files available for the particular user and retains this information throughout the use of the session. The file names are links to the files themselves, and the user is able to download the file as soon as he clicks on the respective link. Each file is accompanied by a short description, the name of the user that last updated the file, a link to the comments that accompany the specific file and a field that shows if the file is available for changes or not.

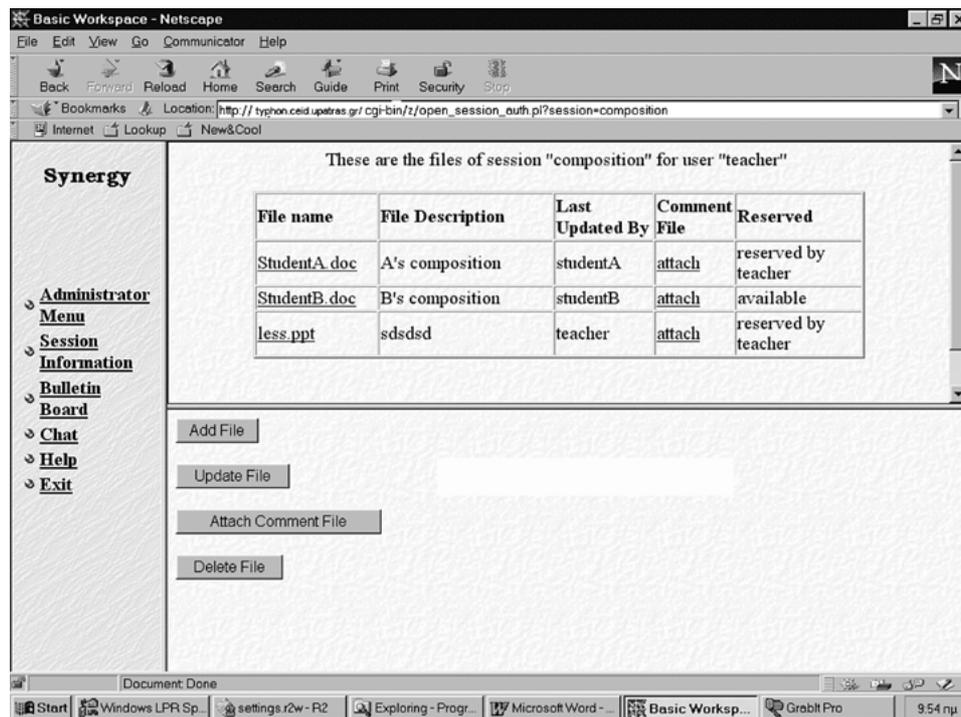


Figure 1. The main window for the CSCL services (English version under improvement).

In the lower frame, the available actions on the files are presented. That is, the choices that have impact on the file list above, which are: *Add File*, for file uploading, *Update File* for overwriting a file with its newest version, *Delete File*, for removing a file and *Attach Comment File*, so as to attach comments to a file.

The left frame of the application refers to actions irrelevant to the file handling and the results take place in the basic lower frame. The actions are distinguished in those available to all users and in administrator actions. Those are Session Info, Bulletin Board, Chat, Help and Exit, whereas the choices visible only to the administrator are Add collaborator, Delete Collaborator, Define Session Properties, See Log File, Clear Comment File.

In the following paragraphs some of the basic functionalities of the CSCL module are presented.

4.1.2. File exchange. The student can easily fetch the files located in the server. The file transfer is managed by the HTTP protocol that is used for most web-based applications. A user may save the file on his local disk, or open it automatically with the application of his/her preference, provided that the web browser is appropriately configured.

The application supports asynchronous file writing, that is, a user (student) creates a file, saves it in the server, another user (e.g., the tutor) downloads it, comments on it, corrects it and uploads it again for the other participants in the session to see it.

The participant of the session has the ability to upload images and URLs. Every particular type of the educational material is represented with a special purpose icon in the user interface.

4.1.2.1. Adjustable configuration. Every session is accompanied by a unique configuration, defined by the administrator. This configuration is flexible as it can be altered on demand during the lifetime of a session.

The administrator approves the students joining a session, and every one of them is identified by his login in the session. The login and the password of the collaborator comprise the unique “key” through which the CSCL server recognizes the collaborator.

The administrator of the session is entitled to assign the permissions of students on each particular file of the session. There are three kinds of permissions:

- *None*: the student does not see the file in the file list at all, as if it did not exist.
- *Read-only*: the student may download it for personal use, but he is prevented from uploading it in the server.
- *Write*: he is entitled to download it, change it locally and send it (with the changes) to the server.

Avoidance of conflicts on changing the files is accomplished by enabling users to reserve a file of their choice in order to modify it. That is, if a user wishes to change locally a file and intends to upload it, later, in the server, he can temporarily reserve the file (a special icon is displayed in the window of the other users after they refresh their views), discouraging other users from tampering with it. A file becomes available again only if the user that has reserved the file uploads it. In this way all the participants are informed about the status of the file, whether it is available or reserved.

A simple form of Revision Control can be realized through the use of Comments File pertaining to each shared file of the session. A special icon indicating changes is used after the upload of file to the server. In order the whole process to be consistent each user must update the Comments File with the changes he made to the parental file.

4.1.2.2. File and session handling. In order to assist the procedure of file exchange and co-operation and to avoid loss of precious time and confusion, supplementary information about the files is provided. There is also the opportunity to attach comments on a file. The comments can be easily seen and appended by any student that has permission to access the file.

At any time a student can view session related information, such as other participants' real names, the administrator's login name, etc.

Furthermore, an administrator is provided with several operations, e.g., clearing the comments pertaining to files and deleting his own session. Also, useful information is retained in a log file, which is only visible to the administrator of the session.

4.1.3. Browser supported mail service. There are lists with the participants in each session where information about each participant is retained (such as real name, business card, e-mail, etc.). The e-mail address of each participant is a link, where, by clicking, e-mail may be composed. This mail procedure takes advantage of the browser's embedded capability of sending mail and is open for extension.

4.1.4. Bulletin board/newsgroup service. Every electronic bulletin board contribution has a topic and everybody can read the contributions sent and send his own. The existing bulletin boards in the Internet support electronic announces in a simple text format, which is chosen as the most appropriate format to be used for the bulletin board in the CSCL environment (see figure 2).

A bulletin board is an "asynchronous" way of communicating among the students. The participation in a session is considered as an automatic way of subscription in the session's bulletin board.

The Bulletin Board can serve as a way of organizing smaller groups of the students of a session wishing to exchange ideas to a special topic of the session. A message that can be contributed to the bulletin board system contains the collaborator's name, the date, the subject and the body of the message. A user can see all the messages posted so far to the session's bulletin board, send new messages, send follow-up messages (that is, replies to existing messages), follow-ups to follow-ups (threads) and so on. In this way the newsgroup functionality is incorporated and provided by the bulletin board facility.

The bulletin board facility is one of the methods used for the announcement of a synchronous distance education activity to the participants of a session.

4.1.5. Chat. Chat is a way of exchanging real-time textual messages among the collaborators of the same session. The collaborators that are simultaneously using the session, can send messages or other textual content to other users use it. Unlike an audio conference, the Chat service consumes few network and computer resources.

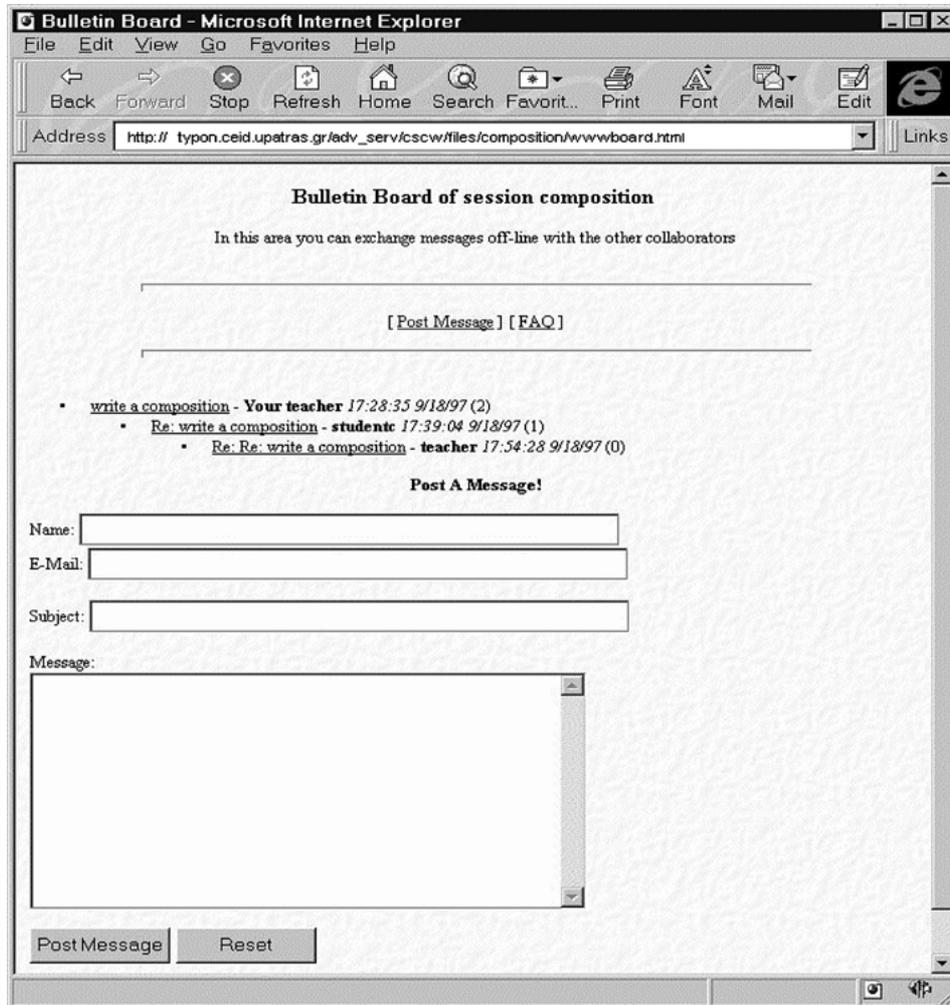


Figure 2. Bulletin board window.

4.2. Functional description of synchronous distance education module

4.2.1. Overview. In this part we present two software modules:

- The Virtual Class Server controls the lesson's flow as defined by the trainer. It is responsible for the interaction between the trainer and the trainees before and during the lecture.
- The Virtual Class Client is comprised of two software modules: the trainer's client and the trainee's client.

The trainer's client grants the capabilities of preparation and presentation of a lecture to a selected audience through a friendly user interface. This client interacts with the server in order to guide the lecture's flow.

Finally, the trainee's client is the component that enables the trainee to attend a lecture and to interact with the trainer through the Virtual Class Server.

4.2.2. Virtual class server. The server part provides both the trainer and the trainees with the following services:

- *Lecture announcement.* Once a lecture is prepared, the server uses the network to announce it by notifying all possible interested trainees, by the bulletin board system or a WWW page (an e-mail distribution list can also serve as an alternative). The notification consists of a simple announcement of the lecture that calls the potential trainees for participation.
- *Lecture registration.* Trainees that have been notified, can simply register their interest in the lecture, through a special form. The server registers the corresponding trainees in order to deliver the course material to them and to automatically handle the network connections during the lecture.
- *Distribution of the material for the lecture.* The server is exclusively responsible for the distribution of the educational material, that may take place either before (off-line) or during the lecture (on-line).
- *Access to previous lectures' material.* The Virtual Class server offers the ability of storing previous lecture notes (a semi-automatic process, conducted with the support of authorised personnel of the Educational Network) to a well-known web server so as to provide access to them to any interested trainee. Thus, the material of any previous lecture will be available to all the trainees for later review.
- *Lecture conduction.* During the actual conduction of a lecture the Virtual Class Server facilitates the learning procedure by offering:
 - *Submission of written questions from the trainees.* The written questions are transmitted to the trainer. The trainer answers the questions and both the questions and the answers are transmitted automatically to all the trainees.
 - *Submission of requests for oral comments.* The trainees have the ability of inquiring and the trainer will either accept or reject the inquiries. In the former case, the trainer will give permission to the requester and the oral comment will be broadcast to all the participants of the lecture. Optionally the requester's video can be transmitted in a window next to the trainer's [16, 24].

4.2.3. Trainer's virtual class client. The trainer's client provides the following services (see figure 3):

- *Asynchronous reading and processing of existing lectures.* Publication of the lecture's material to a well-known web site. This functionality holds only for the trainer that created the lecture or someone who has the appropriate privileges.
- *Selection of the audience.* It allows the trainer to select the members of his audience from those who requested permission to attend a lecture.



Figure 3. The trainee's view of the virtual class client.

- *Guidance of the lecture's flow.* During the lecture, the trainer determines the flow of the lecture. As a result the following abilities are supported:
 - *Interchange and annotation of the slides.* That can be done with the use of the White Board utility (see figure 3). The trainer can support the lecture by making notes in already prepared slides during the conduction of the lecture, drawing the attention of students in difficult parts of the lecture, by emphasising parts of the slides through a toolbox (writing text, drawing lines and rectangles) in an already existing slide or a blank one.
 - *Admission and answering of the questions posed by the trainees.* The trainer is able to admit or not written questions (through the use of chat) or requests for oral statements. He can also respond orally or by writing to any kind of a question. Moreover, he can withdraw anytime the permission for speaking from any of the trainees. Finally, he controls the flow of questions/answers to the rest of the virtual class.

4.2.4. Trainee's virtual class client. The trainee's virtual class client provides the following services:

- *Lecture's attendance.* Through the White Board utility the trainee attend the lecture (the slides and the text that accompany the slides).

- *Questions.* Ability for interaction with the trainer in order to submit questions written or audio-recorded (it is presumed that the appropriate permission is granted by the trainer, the necessary microphone and a sound card is installed in the trainee's PC (camera and video capture card are optional) and RealEncoder is installed).
- *Display of the trainer in an embedded window (video) in the central interface of the application.* Ability to disable that window if the available bandwidth is not able to support the live broadcast of the video of the trainer. A similar ability is provided for the audio support.
- *Store/Delete of lecture.* The hypermedia structure that comprises the lecture's material (the notes that the trainer would distribute in a traditional class) can be stored locally in the trainees' workstations for future use.

4.3. Security issues

Keeping in mind that the proposed ODL environment is a VPN over Internet (or Intranets) it is deemed imperative that special security measures must be included in the STEPS architecture. The security measures must focus in the following two aspects of the STEPS model:

1. Security measures against unauthorized access that should be taken in the educational authority that will host in its premises the necessary equipment and all the server parts of the software (access lists in the routers, firewall software, etc.).
2. Security features that the software part of the model must incorporate techniques such as authentication/authorisation mechanisms and secure transfer of crucial information over the Internet (such as passwords).

The security scheme currently implemented in the STEPS model encompass the following functional characteristics:

1. A new member is added in each session every time either another member of the session invites him or he applies for participation in the session. The session administrator decides whether to grant the permission or not (and to which part of the contents of a session) and contacts the Web administrator. The Web administrator is responsible for assigning a valid username/password combination and notify the new member of the session (most probably with a simple e-mail).
2. Every member of a session has personal view and access permissions in the contents of the session according to his/her username/password combination. The session administrator determines this view.
3. When the participant in a session enters the session "room" the username/password combinations is supplied only once. The username of the member of the session is added in a list when he is eligible (by the trainer) to attend a synchronous distance education procedure. For the other functionalities of a session (i.e., bulletin board, chat) he is automatically supposed to have full access by the time he/she is a member (even with restricted view in the contents) of a session.

5. Implementation issues

In this section we discuss the implementation of STEPS model. More specifically:

1. The architecture of the underlying network infrastructure comprising topology of the Educational Network, traffic pattern used, educational content management, network management, administration and technical support issues.
2. The implementation of the software tools comprising selected technology for custom-designed modules, justification for the selections and integration and customization of commercially available tools for use in the context of STEPS model.

5.1. Architecture of the underlying network infrastructure

An *Educational Network* is a multimedia information network, which permits its users to communicate, interact and receive various services aiming at the upgrade of the traditionally offered educational services [15]. In such a network, information is located in some central points, which are administered, maintained and updated by authorised entities, thus offering educational and instructional services to a community of learners world-wide. Such a setting is supposed to be a Virtual Private Network (VPN), enabling Open and Distance Learning (ODL) to be adopted and exploited.

Open and Distance Learning can be regarded as learning by means of ICT (i.e., the combination of means of telecommunications, information technology and multimedia).

The clients of an educational network can access the offered services through (see figure 4):

- a permanent Internet connection (e.g., members of a campus or corporate intranet), a web browser and a proxy/caching scheme, or
- a dial-up connection, a web browser and a proxy/caching scheme.

Although most local and wide area networking models deal with obtaining the highest capacity communication lines possible, one of the largest expenses associated with most architectures is the recurring costs of these WAN communication lines. In order to maximize performance and alleviate the costs associated with WAN communication lines the network-based caching traffic pattern should be employed in an Educational Network (this is the traffic pattern adopted within STEPS). According to this traffic pattern when a client requests data from WAN, the data are retrieved (if necessary) stored to a proxy/caching server's disk and forwarded to client [28].

The basic idea of a centralised architecture is that there exists an "*Educational Entity*" that holds the entire interaction required between tutors and learners and will play the role of the Educational Services' Provider in an *Educational Network Environment*.

The model proposed in this paper addresses the issue of an authorized educational entity that offers uniform and integrated provision of educational services, under a common platform. This platform incorporates widely available Internet technologies (WWW, Java) for the realization of educational services, thus facilitating access to these services from

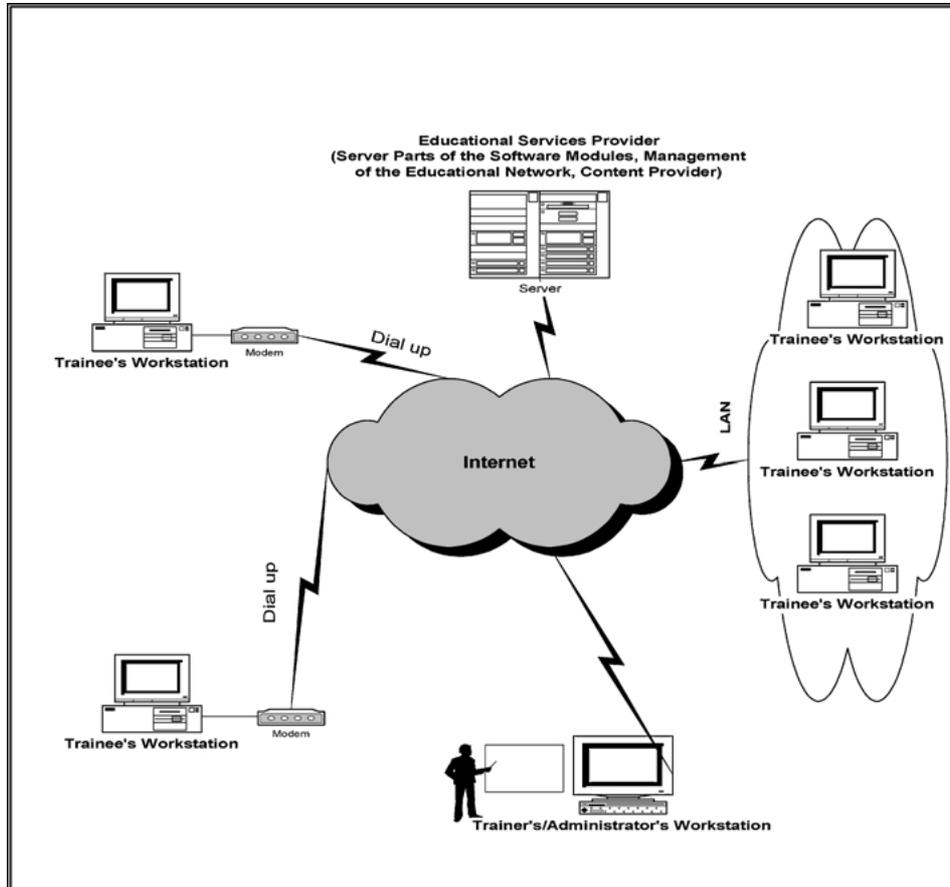


Figure 4. The architecture of the educational network for STEPS.

almost every interested user. The approach of a centralised architecture, using a common platform for the provision of educational services, has the following advantages:

- The training entity can be hosted on the premises of an educational authority, which will be responsible for the content, the instructional objectives and the model of the offered services.
- The technical support will be much more efficient if the hardware and the software modules involved reside mostly in the same place (provided that availability measures are taken by the Educational Entity, such as mirroring of critical files). The administration and technical support services organised by the Educational Entity will be offered on demand to the remote sites of the Educational Network.
- The access to the educational services is offered to almost everyone interested, uniformly (through his LAN or dial-up Internet connection and a Web browser).

5.2. *Selected technology*

The software modules of the STEPS model were implemented with standards based, open architecture, client-server, object oriented and Internet technologies. We have also customized and adapted commercially available tools (through their SDKs) in order to render themselves suitable for the multicast streaming of time-critical data formats (between tutor and the audience) in an ODL environment.

The result was the design and implementation of an ODL Environment integrating already existing primary network services with new services developed for this particular purpose. The development of the ODL environment was based on the use of Internet technologies and the integration of the services under a common and easily accessible user-interface and on the adoption of international standards. The use of Internet technologies enables the deployment of distributed multimedia applications over the wider area network (Internet). The client-server model has been adopted for the implementation of all the necessary interactions between a central point and a number of remotely situated potential users.

The functionalities of the ODL environment mentioned so far are implemented in two server parts. The first one implement the CSCL part and the other the Synchronous Distance Education activities. The services of the ODL environment are offered uniformly by using a common user interface accessed through a web browser that supports Java.

5.2.1. CSCL software module. As it has been earlier mentioned the basic concept of the ODL environment, is the session. Consequently, the use of session dictates the basic architectural principles. A session includes the participants, as well as all the session relevant material and the synchronous distance education activities taking place in the context of the session.

For the collaborative environment, a web server is necessary, where all the session-relevant material will be stored so that it can be easily retrieved. Due to the need for control information and statistics for the educational material and the necessity for definition of privileges and permissions of users on the session files, we have implemented the file system as a database utility. We have used Apache web server for the implementation of the STEPS model.

Technologies employed for CSCL module implementation are presented below.

- HTTP protocol was used over a TCP/IP local or wide area network to provide CSCL services in the group of students and the tutor. The HTTP protocol offers simplicity and standardization.
- SMTP protocol was used to provide the e-mail service over a TCP/IP network. Custom-designed applications offer the bulletin board and chat services.
- Perl 5.0 language was used to create the CGI scripts.

The selection of CGI technology and Perl programming language for the implementation of CSCL module is justified mainly by the following reasons:

- Through CGI (and HTTP) the implementation of client—server applications is greatly simplified. If this was not the case the implementation of a client—server application

through the use of (perhaps) C or C++ would impose much greater effort in the application development process. This is mainly attributed to the combination of CGI-HTTP and HTML in building easily user interfaces.

- The syntax of Perl programming language resembles the one of C, with which we are already familiar. There is also an already existing wide installed base of Perl applications, which implies the existence of efficient technical support.

A disadvantage of Perl programming language is that the HTML code contained in a Perl script cannot be managed in the way it can in other CGI programming languages (e.g., ASP, php).

Perl provides utilities for strings and text files processing. The initial implementation used a check out file system for the educational material contained in a session. The upgrade of file system to a database utility (with the use of Oracle Server v8.0) was considered an essential feature that adds flexibility and robustness in manipulating the educational material (definition of access privileges for the participants, control on sharing the resources). The already developed code in Perl imposed the selection of DBI technology. The Perl DBI is a database access Application Programming Interface (API) for the Perl language. DBI technology defines a set of functions, variables and conventions that provide a consistent database interface independent of the actual database being used.

5.2.2. SDE software module. The Virtual Class Server resides in the Web server used by the CSCL module. The Virtual Class Server operates using the MBONE technology and protocols for exchanging data formats (audio, video, chat, and White Board) and as storage space (WWW server capabilities) for the educational material of the instructional activities.

The Virtual Class Server is run under Unix (Solaris) and is responsible for the communication and interaction between the trainer and the trainees during the synchronous distance education activity. For the implementation of the server we used Java. The Virtual Class Server as a servlet, which co-operates with the web server managing the Synchronous Distance Education procedure. Each part of the server communicates with the corresponding Java applets of the clients. The communication between the server and the Java applets of the clients is based on the TCP/IP sockets network communication model.

The Client for the ODL Environment is a Java compatible web browser that, along with the standard capabilities, supports frames and the RFC specification for the "File" type. The HTML pages and the Java applets of the application, as well as the lesson related files uploaded by the users, are stored in the Web Server.

Network technologies employed for the SDE activity are presented below [3].

- The TCP/IP protocol suite was used to implement the Virtual Class Service-specific protocol that handles all the interactions between students and tutors during a lecture.
- The MBONE technology of the Internet was used in order to avoid the congestion in the Virtual Class Server. Using MBONE, the Virtual Class Server has to reflect the video and audio data only to one MBONE address in which all the interested users have registered to listen. In this way it is avoided to open a unique channel with every potential user to transmit the rather large (and time-critical) volume of data for video and audio.

In order to accomplish the multicast transmission of video and audio streams RealServer multicast features were employed. The tutor must be sitting (preferably) in a specially prepared room capable of hosting live lectures (assuring studio quality of the transmitted audio and video). This room is equipped with all the audio-visual and computer-multimedia equipment required for the live transmission of streams [20]. The RealEncoder tool is installed in the workstation and connected (through a LAN) with the RealServer (reader should not make the assumption that RealServer is running in the same workstation with RealEncoder).

When the synchronous distance education activity is scheduled to begin, two separate streams are transmitted from the tutor's workstation to the RealServer who in turn multicasts them in the (predefined by the tutor) group of students. The two streams are of different quality: one is encoded in order to support the dial-up users of an educational network (28.8 Kbps, low quality) and the other is intended to the users having a permanent Internet connection of some kind (300 Kbps, high quality). The students are able to choose the appropriate speed through a link in the web page of the session in the context of which the synchronous distance education activity is taking place.

Technically, when a student joins a synchronous distance education activity, its client tries to join the multicast session. If the client cannot accept multicast data (the router from which he accesses the Internet does not support multicasting) the server tries to transmit the multimedia data with the UDP protocol. Finally if the use of UDP is not reliable the server opens a TCP connection with the client and transmits the multimedia data.

When a student is granted permission for oral intervention his/her video may be transmitted optionally. If this is the case, when the student is granted the permission, RealEncoder is automatically activated in the student's workstation and a low quality (28.8 Kbps) stream is encoded and sent in a separate file in RealServer, who in turn multicasts the video to all the participants of the lecture.

- The GIF, JPEG formats were used for the compression of the slides that the trainer will present during the lecture.

Real Media Architecture (RMA) is a platform for the development of real—media streaming applications. It incorporates RealAudio and RealVideo in a uniform, open architecture for the development of applications making use of Internet protocols and infrastructure. Real Media System provides concurrently multiple synchronised streams in the same client.

The components of RMA provide interfaces for further extending its utilities. Real Media's SDK offers interfaces for the incorporation of several media types in the Real Media System.

RMA is a mature technology for streaming media types, being one of the most credible solutions, proven by the leading position it holds in the streaming media market.

However, as a conclusion of the test phases of the SDE module, streaming technology does not lend itself extremely useful for synchronous distance education. This holds mainly because of the buffering that takes place in the client and the delays this imposes in the system, especially when participants take turns in oral interventions.

In figure 5 the protocol stack used in the STEPS model is depicted.

We have completed implementation and testing of a timestamp mechanism, for the arbitration scheme between the participants in a synchronous distance education activity that are concurrently requesting permission to speak. We assume zero network delay to the requests, we synchronise the clocks of the clients with that of the Virtual Class Server at the beginning of an SDE activity, we ensure that all requests will be handled and we present the trainer with a sorted list of requests according to their arrival time. The teacher is able to modify the proposed ordering of the permissions. We have implemented the permission

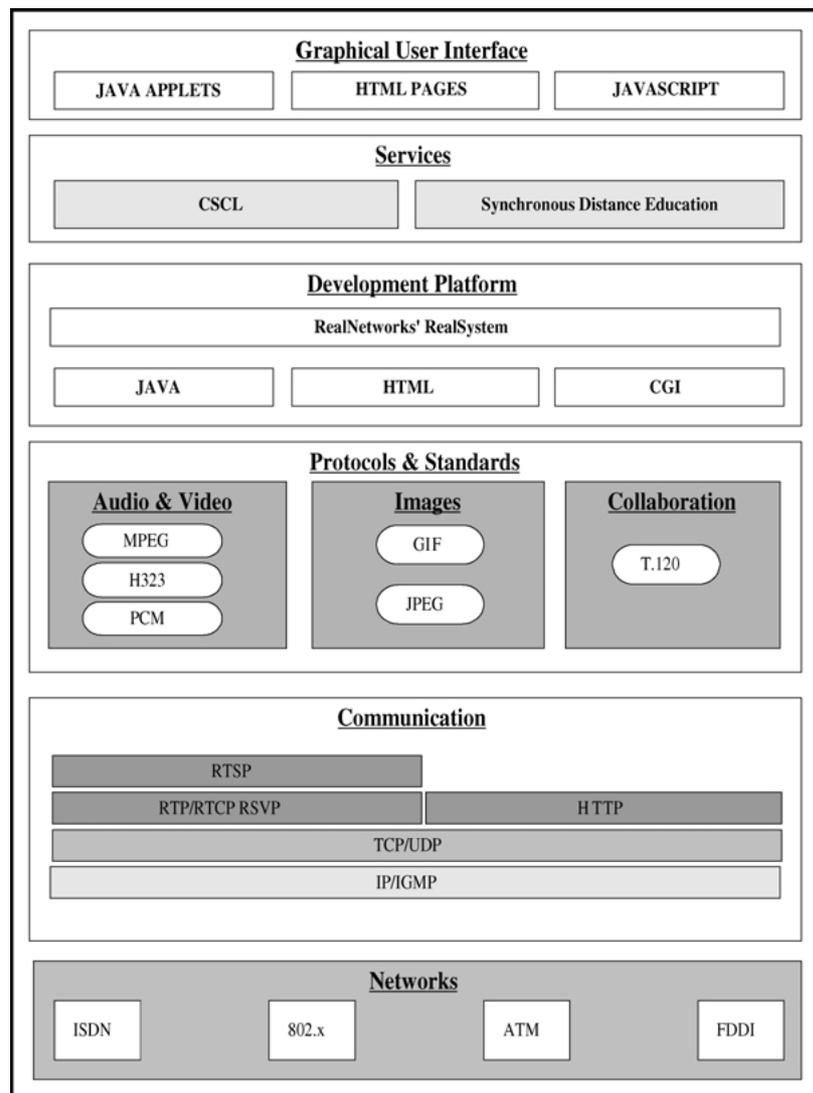


Figure 5. Protocol stack.

request part as a critical region of code, with the use of Synchronized Method Modifier of Java programming language.

The major advantages of the STEPS model are:

- Modular design, fault tolerant use, through the implication of two different servers for the implementation of the services of the STEPS model.
- Interactive communication between users over the Internet, including audio, video and data exchange by using standard and application specific network protocols that are exclusively responsible for the interaction between the clients and the server parts of the application.
- It is an open-environment application, since it was developed in Java and CGI, in order to work independently of platforms.
- Reduced costs of development, maintenance, administration and increased flexibility. This holds basically because of the selection of CGI and Java for programming languages, the selection of network-based caching as the traffic pattern for the STEPS model and it also implies that a single Virtual Class Server is capable of taking over multiple lectures given by different tutors.

6. Conclusions and future work

The model presented so far aspires to be an electronic “complement” in a traditional education procedure. It can be accessed through a Web browser from potentially every one connected (permanently or dial-up) to the Internet. It offers an easy-to-use set of software tools that form a complete ODL environment that can facilitate distance education scenarios to be applied and exploited between users with common educational needs.

The collaboration and learning environment of the STEPS model has been designed, so as to provide a great degree of flexibility, without causing navigational difficulties and cognitive overload for users. The workspace has been carefully divided into sections that interact with each other, avoiding distraction. Menus, hypertext links, buttons and text boxes prevent user from being confused and the on-line help makes the tool easy to use for everyone who has primitive experience in using a Web browser. The careful design of the user interface, together with guidance from the help section, in hypertext mode, makes the tool easily operable.

We are currently working on the implementation of the complete T.120 recommendation for the upgrade of data and application sharing functionalities of the STEPS model.

A “moderated” list of extensions that would add to the functionality and educational usefulness of the STEPS model if implemented, are:

1. Upgrade to a 3D user-interface by using VRML tools (currently under development).
2. Implementation of version control in the documents contained in a session.
3. Implementation of SSL for the authentication/authorisation mechanisms in order to reinforce security.
4. Examination and adoption of bandwidth allocation methods and QoS techniques that can be used in the TCP/IP protocol suite through the use of RSVP. Close investigation of the advancements of the MBONE technologies.

5. Upgrading of the software part of the model in a complete Java-enabled tool.
6. Implementation of a “database” containing pre-recorded educational material with synchronised audio and video streams with documents, transparencies, images, etc. (Asynchronous Distance Education module).

Note

1. Throughout this text, he and she, trainer and tutor, trainee and student are used interchangeably.

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