SYSTEMS, ENABLING TECHNOLOGIES AND METHODS FOR DISTANCE LEARNING: THE STEEL PROJECT

Enrico Del Re
University of Florence and National Inter -University Consortium for Telecommunications (CNIT)
enrico.delre@unifi.it, tel +39 055 4796285
CNIT ★ Via S. Marta 3 ★ 50139 Firenze, Italy

Manuela Delfino
Institute for Educational Technology – Italian National Research Council (ITD-CNR)
delfino@itd.cnr.it, tel +39 010 6475349
ITD-CNR ★ Via de Marini 6 ★ 16149 Genova, Italy

Gianpiero Limongiello
CILEA Interuniversity Consortium
limongiello@cilea.it, tel +39 02 26995264
CILEA ★ Via Raffaello Sanzio 4 ★ 20090 Segrate (MI), Italy

Donatella Persico
Institute for Educational Technology – Italian National Research Council (ITD-CNR)
persico@itd.cnr.it, tel +39 010 6475313
ITD-CNR ★ Via de Marini 6 ★ 16149 Genova, Italy

Immacolata Scancarello
CILEA Interuniversity Consortium
scancarello@cilea.it, tel +39 02 26995264
CILEA ★ Via Raffaello Sanzio 4 ★ 20090 Segrate (MI), Italy

Rosalba Suffritti
National Inter-University Consortium for Telecommunications (CNIT)
rosalba.suffritti@cnit.it, tel +39 055 4796485
CNIT ★ Via S. Marta 3 ★ 50139 Firenze, Italy

Sommario: Obiettivo del progetto STEEL (Sistemi, Tecnologie abilitanti E mEtodi per la formazione a distanza) è lo sviluppo di un sistema di e-learning destinato alla formazione universitaria che integri molteplici media e diverse modalità di comunicazione, e al tempo stesso consenta la fruizione dei corsi erogati da piattaforme stazionarie o mobili. A tale scopo il sistema si basa su un'infrastruttura tecnologica innovativa di tipo satellitare-terrestre. Scopo di questo contributo è presentare il progetto nel suo complesso. In primo luogo verranno illustrati i requisiti metodologici e didattici che sono stati individuati per il corso pilota che verrà erogato nell'ambito degli insegnamenti di un corso di laurea a distanza. Si intende quindi spiegare quali siano i criteri ed il percorso che hanno condotto alla configurazione della piattaforma, con particolare attenzione alla necessità di integrare erogazione sincrona ed asincrona dei corsi online. Verrà infine illustrata la piattaforma hard-ware realizzata per la gestione della qualità del sistema su reti eterogenee.

Summary: The aim of the STEEL (Systems, enabling TEchnologies and mEthods for distance Learning) project is to develop a complete e-learning system based on an innovative integrated satellite-terrestrial network, addressed to higher education, and integrating different media and different communication technologies. In this paper an overview of the whole project is provided. In order to do so, we will describe the educational and methodological requirements identified for the pilot course to be delivered within a distance learning university curriculum. Further, we will illustrate the online platform, focusing both on its technological and educational features and its modularity, that guarantees the integration of synchronous and asynchronous tools. Finally, we will present the hard-ware architecture, designed to manage the distance service delivery over a great variety of access technologies and to guarantee a certain level of Quality of Service to end users.

Parole chiave: Formazione a distanza; Piattaforma e-learning; Reti integrate terrestri-satellitari; Comunicazione mediata da computer; Learning Management System

Keywords: E-learning; E-learning environment; Integrated Satellite-Terrestrial Network; Computer-Mediated Communication; Learning Management System

Systems, enabling technologies and methods for distance learning: the STEEL project

The widespread diffusion of Information and Communication Technology has made a broad spectrum of online learning possibilities available to increasingly demanding and large targets. Terms such as e-learning, web-based learning, online learning, resource based learning and virtual learning communities are being used to identify approaches where different technologies are used to create environments that allow people to learn, granting them with high degree of freedom in the choice of time, place, pace, and depth of knowledge and competence development (for a survey of the field terminology, see Anohina, 2005). In addition, flexible learning and personalised learning are keywords that point to the possibility, for learners, to choose among different study strategies according to their objectives, learning styles, media preferences. Such a large spectrum of terms is not merely a terminological issue, it does reflects the fact that in some cases the focus is on providing a rich repository of learning resources, while in other cases the aim is to build a virtual community that relies heavily on socio-constructivist approaches, and yet in others the emphasis lies in reaching learners wherever they are.

However, in higher education, lecturers and instructional designers will need to choose freely how to support students while learning each subject, while students will need to make informed decisions as to how to go about in their own learning, and to access to the learning platform from wherever they are. This can only be achieved if the learning platform provides for synchronous and asynchronous textual, audio and video communications and integrates them with a learning management system providing high quality ubiquitous learning facilities. Such a platform does not need to be developed starting from scratch: there is a large amount of work that has already been done in several areas: open source software and computer mediated communication systems, as well as terrestrial and satellite technology providing high quality broadband connection everywhere in the satellite footprint.

The STEEL project, described in this paper, aims to develop such a platform by selecting and integrating existing tools with technology developed *ad-hoc* to provide an environment where several teaching and learning strategies can be implemented: from interactive video-lectures to computer supported collaboration, from resource based individual study to self assessment.

1. - THE STEEL PROJECT

STEEL (*Systems, enabling Technologies and mEthods for distance learning*) is a national project funded in 2007 by the Italian Ministry for Education, University and Research (http://steel.cilea.it/).

1.1 – Objectives

The main goals of STEEL are the design and the realisation/implementation of an innovative integrated technological platform, for the development of an experimental distance learning system, fulfilling the educational requirements of today's higher education institutions thanks to the most advanced technology, with special attention to open source systems.

In particular, the project aims to define and implement a satellite-terrestrial infrastructure integrated with a Learning Management System (LMS) for e-learning applications, suiting different kinds of users (e.g., mobile, residential) and terminals (e.g., handheld, portable, fixed). In order to verify the obtained level of quality as what concerns both the technological and educational aspects, the system will be pilot tested by delivering a series of distance learning courses belonging to the university degree in Sport Science.

1.2 – Partners

There are four partners involved in the project, located in different Italian regions:

- *CILEA* – Interuniversity Consortium for Automatic Computation, based in Segrate (Milan), an institution that works in the field of Information and Communication Technologies (ICT) and provides services to universities, research institutes, public agencies and companies. In the STEEL project, CILEA is the leading institution and is in charge of the software implementation of the e-learning platform;
- *CNIT* – National Interuniversity Consortium for Telecommunications, located in Florence, an independent institution active in a number of projects in the field of satellite communication, in areas ranging from transmission techniques to networking; CNIT is in charge of the design and realization of the hardware component of the platform;
- *ITD-CNR* – Institute for Educational Technology, located in Genoa, belonging to the Italian National Research Council and devoted to the study of educational innovation brought about through the use of ICT; ITD is in charge of the pilot test of the e-learning platform;
- *UNI-TEL* – International Online University, located in Milan and supplying graduation courses on Fashion Design, Sport Science and Nutrition and Health Science; UNI-TEL provides the test-bed for the system validation.

1.3 – Work plan

The duration of the project is 36 months (from July 2007 to July 2010) and the work programme is organized in two phases, respectively devoted to the development of the technological components of the platform and to the integration and methodological validation of the system (respectively, Phase 1 and Phase 2). These two phases last 30 months each and they partially overlap so that Phase 1 started in July 2007 and will end in December 2009, six months before the end of the project, while phase 2 started on month 7 of the project and will run till the end of it.

Phase 1 of the STEEL project encompasses all the aspects concerning the design and implementation of the hardware and software architecture of the distance learning system. The aim of this phase is to produce, by the end of December 2009, a technologically tested platform to be used in the field test. This phase encompasses the following activities:

- the definition of the system requirements, in terms of typology of potential users, level of users mobility and desired level of users interactivity;
- the design of the system architecture according to the requirements already identified and through the definition of three functional layers: the *Access* level, the *Network and Transport* level and the *Service* level. In such a system, the aim is to realize a scalable service architecture, in order to guarantee a certain level of Quality of Service (QoS) in the critical segments of the network, as it is the space segment;
- the implementation of the technological components related to *Access*, *Network* and *Service* layers and the implementation of routing functions for the provision of the QoS to end users;
- the design of the synchronous application, the purpose of which is to guarantee real time, multiple connections among teachers and students, thus allowing to schedule live lectures and collaborative sessions with a high degree of interactivity;
- the integration of the satellite network nodes and components with the synchronous application, and the test of the integrated platform, on which the pilot course will be delivered.

The second phase of the project focuses on the design, planning and delivery of a pilot university programme (comprising about 10 courses). The field test is provided by the UNI-TEL online University and consists of the Sports Science Programme. This phase is aimed at:

- the analysis of the technological and didactical requirements of the pilot course. Aim of this activity is to identify a suitable test bed for the platform and to analyse the characteristics of the target population, in order to set up the courses and the define indicators and tools to monitor and evaluate the learning activities within the pilot course programme;

- the development of an e-learning platform integrating synchronous and asynchronous tools. This activity is focused on the technological issues regarding the choice and integration of the software packages more suitable for the educational model. As better explained in Section 3, the research team proceeded on a deep comparative analysis of the national and international existing standards, and on the technologies, procedures and tools available to deliver an online course. The comparative analysis of the most interesting and valuable applications to be developed and/or integrated in a remote educational system is driven by the following issues: (a) the need to make available and share learning materials; (b) the need to support collaboration during the courses; (c) the need to track the level and quality of participation to the online events;
- the design and delivery of the pilot course programme. The teachers, lecturers and tutors will be trained and supported while designing and running the learning activities;
- the formative evaluation of the e-learning system based on the monitoring and evaluation of the pilot courses and their outcomes. Aim of this activity is to obtain information about strengths and weaknesses of both the platform and of the courses. The evaluation of the platform will focus on ease of use, system accessibility and usability, and ease of access to the learning contents. The evaluation of the pilot courses will be based on the analysis of the learning process and the outcomes, from the point of view of both the learners and lecturers.

2 - METHODOLOGICAL AND EDUCATIONAL REQUIREMENTS

The expected output of the STEEL project is an e-learning system that can be used as a reference for academic distance learning in higher education. The target audience is a large and heterogeneous population of adult users with different educational needs and different access to technology. Their training needs are quite diversified, according to the university degree they aim to achieve, but also to the features of the learning context they are situated in. In the following, the main requirements imposed on the system will be described.

2.1 - Space and time variables

The space and time variables have been objects of analysis. On the basis of the space variable, the STEEL users can be divided in three different groups:

- *mobile users*, who need a connection on the move; they generally connect using Wi-Fi to get online and prefer light and handy devices (mobile phones, iPod, etc.);
- *nomadic users* are not tied to any particular location or time, they move from place to place and connect from changing locations (Kleinrock 2003; Podnar, Hauswirth and Jazayeri, 2002; You and Åkerman, 2007);
- *static users*, who generally access to the Web from their desk-top computers.

STEEL users will need to access the system at any time, both for short and long spells of time. However, on the basis of the time variable, users will need to interact:

- in an *asynchronous way*, thus accessing the information or the communication flow already stored or archived;
- in a *synchronous way*, thus requiring to interact with others in real time. In this case, the interactivity levels (McMillan and Jang, 2002) may differ according to various factors, such as the number of online users, their

communication tools, their activities (e.g., a chat session among two people vs. a many-to-many video-conference situation). In the STEEL project, a distinction was made among:

- a *high interactivity* (i.e., interactivity where all the users share the same media richness and bandwidth and are able to act symmetrically);
- a *medium interactivity* (i.e., in cases of disparity and asymmetry of users' media richness and bandwidth);
- the *absence of interactivity* (i.e., in those cases where users are simultaneously connected, but unable to interact).

Given the variety of possible scenarios - not described in this paper for space reasons - the outcoming educational model can be very complex according to the potential educational situations, to the tools and devices used, to the methods adopted.

2.2 - The course in Sport science

In order to test the educational model, the LMS developed as well as the hardware platform (see next sections), a graduation course in Sport science at the UNI-TEL university was chosen as a test bed for the STEEL project.

The graduate course in Sport science is offered online via distance learning and gives students the opportunity to learn about the benefits of physical activity, the aspects related to the execution of human movement and learning, the factors effecting on movement execution. The three years program is designed to develop the competences necessary for understanding, designing, planning, running and managing physical education and/or athletics in different settings. In particular, at the end of the course, graduate students will (1) have a good knowledge of curriculum, instructional practices, and administrative procedures in physical education and sport, (2) know how to communicate – both in writing and in speaking - in another language about their field of knowledge, (3) know how to choose and use the main technological tools related to their working practices, (4) know to cooperate and collaborate with other people. For all these reasons, during the course students will study different subjects, comprising psychology, English language, physiology, health care, physics, human motor development, individual sports and group sports, exercise and nutritional sciences.

2.3 - Learners profile

The data obtained from a questionnaire aimed at studying the habits of the potential target of the UNI-TEL courses show that the majority of students are full time (170 on the total of 250, 68%) and part-time workers (16%), at the first experience with distance learning courses (82%). While a very high percentage declares to be able to study steadily during the year (89%), students show different habits towards the study schedule. While almost half of them are able to study during weekdays (44%), the others study during the weekends (28%) or are not able to foresee the time for studying (26%). Students' studying behaviours are also distributed as regards the daily timetable: 25% studies from 9 a.m. to 6 p.m.; 31% from 6 to 10 p.m.; 30% does not have at a set time. For all these reasons, students are hardly able to participate to face-to-face events and cannot guarantee their presence during synchronous distance learning activities.

Furthermore, students may enrol in the distance degree held by UNI-TEL at any time of the year and are allowed to sustain their first examination three months after the enrolling date. This may prevent the organisation of learning activities that require a high degree of synchronicity among participants.

As regards the reasons to enrol in a distance learning degree program, students prefer it over traditional courses as it represents an opportunity to try new ways of learning (3.8 on a scale from 1 to 6) and because there are tutors supporting each student (3.7 on a scale from 1 to 6). For them, it is very important to have the chance to communicate in a quick and direct way with their teachers (3.6 on a scale from 1 to 4), having the chance to count on an online tutor (3.5 on a scale from 1 to 4). These data emphasize the importance of people able to support students in their learning.

2.4 - Lecturers and tutors profile

Most of the UNI-TEL lecturers have little previous experience with distance learning, let alone online learning. However, the fact that they accepted to work for a telematic university allows us to believe that they should not have the typical resistances to online teaching and learning that university teachers show when they are pushed to use e-learning after they have been working face-to-face for several years (Falowo, 2007; Pajo and Wallace, 2001). Indeed, for some of them this is the first experience as university lecturer ever. Their background is strongly differentiated, due to the large differences between the subjects they teach, even within the same university degree. However, most of them have never had any specific training in education, instructional design or educational technology. There is, therefore, a strong need for training and support on these aspects, which is not easy to satisfy because they are not fully aware of this need; they are not paid for it; and they have little time for it.

The STEEL project must provide such training and support while taking into consideration the fact that most of them already have an idea of how to teach their subject face-to-face and will therefore resist any strategy that entails starting instructional design from scratch. Rather, they will be prepared to revise and adapt those parts of their courses that are clearly unsuitable online. Besides, the training provided will need to address in particular those aspects that are peculiar to online learning. Examples are: how to plan and carry out interactive video lessons? How to prepare suitable slides for such lessons? When and how to design online collaborative activities? When is the chat the appropriate collaboration tool, and when asynchronous collaboration seems to be more appropriate? What indicators can be employed to assess effective online support?

For courses with a significant number of students, it is necessary to provide tutoring services. The roles of online tutors have been widely investigated (De Laat et al., 2007; Conrad, 2004; Salmon, 2004; Berge and Collins, 1996) and include: providing guidance and support to participants, especially at the beginning of a new learning experience; facilitating access to the learning environment and providing help with its use; mediating between the instructional design decisions and the spontaneous dynamics of the learning group; helping individuals (e.g., by motivating, providing materials, explaining tools, reassuring) to work collaboratively towards the achievement of common goals; stimulating discussion on specific contents; promoting cohesion and social presence between students; monitoring the course process and participating in all the course phases. The inside perspective of the tutors allows them both to coordinate the course according to its educational and cognitive objectives, and to adjust the course design decisions, according to the needs shown by the students or perceived by the tutors themselves.

From the above description of the tutors role, it appears that tutors must be competent both in the course domain and in the use of online learning strategies and techniques.

2.5 - Institutional profile

Some telematic universities, in Italy, are very young and quite small. This is the case with UNI-TEL, the partner running the STEEL pilot course. At present, UNI-TEL only runs three university degrees and one of them - Sport Science - will provide the STEEL test-bed. The platform structure will need to support their organisation and provide environments suiting the needs of the staff involved in running the courses.

In the following the problems that need to be faced and the communication flows that such a learning institution has to manage are listed:

- *administrative functions*, that allow to manage the administration of a distance learning degree program, to serve both students and teachers needs (from the students matriculation to the teachers appointment);
- *students secretariat functions*, that organize the students informative spaces and keep the university

registrar (i.e., the repository of students records);

- *teachers secretariat functions*, that organize the teachers informative spaces and the courses archives;
- *communication functions* among teachers, to manage their meetings in order to plan the degree program, to coordinate the courses, and to make educational and organizational decisions;
- *educational functions* concerning every single teaching course, that allow to plan the online spaces concerning the course, presenting a complete course description (including course objectives, detailed program, assessment criteria), giving access to the course virtual space and to the learning materials.

3 - THE E-LEARNING PLATFORM

3.1 – Technological requirements

Together with the definition of the methodological and educational requirements of the context, it is important to focus on the different technological requirements of the pilot courses, related (a) to e-learning standards; (b) to the LMS chosen; (c) to the application context; (d) to the communication system.

Even though the number of Italian institutions offering online courses has grown over the years, still the prevalent paradigm is the transmissive one, characterized by the prominence given to online materials available to conduct self-training, self-assessment tests, and simulations. While, in the past, these learning materials used to depend on the software they had been developed with, the increasing diffusion of courses delivered at a distance required these materials to be independent from their generating systems. To do so, e-learning standards should be adopted in order to guarantee access to materials in different platforms, learning contents sharing, interoperability between the e-learning systems and the results that the students gained in tests and surveys, as well as the students' profiles. Interoperability, re-use, compatibility, and duration are therefore the key advantages of e-learning standards, be them *de jure* (officially recognised) or *de facto* (largely adopted by the learning community). LOM, Guidelines for CMI Interoperability, Dublin Core, IMS Content Packaging and SCORM are the most important e-learning standards taken into account to realize the pilot courses of the STEEL project.

Another technological constraint is represented by the characteristic required by the LMS in order to make different people simultaneously use and connect to the same platform. Not only such systems have to guarantee accessibility to multiple users everywhere and anytime, ensuring acceptable response times, but they also have to trace the connection data and make them available according to the administrators' choices.

In addition to e-learning standards and to these technological LMS' constraints, the STEEL project must consider the institutional contextual constraints required by UNI-TEL. According to the Italian law (the so-called "Moratti-Stanca" Law Decree, Decreto 17/04/2003) aiming at regulating the telematic universities, the technological architecture (systems and networks) must ensure adequate performance for the access and use of services by multiple concurrent users, according to the characteristics specified by the UNI-TEL Academic Regulations and Standards.

Finally, the communication system designed for the STEEL project must fulfil some basic requirements in terms of redundancy, resilience, scalability, efficiency, and integrity.

3.2 – E-learning software system analysis

The STEEL project adopted the Moodle LMS to be integrated with the satellite-terrestrial platform for delivery of the pilot course. The choice of the platform has been achieved through a comparative analysis of different software environments with particular attention to open source platforms, that have the advantage of source code availability, an essential element for customization and integration with other systems. Moreover, many open source LMSs are quite mature if compared to commercial products (CNIPA, 2007). The choice of an open source platform satisfies the ministerial directives in this area and it is not a constraint for the project, but rather a desirable quality.

In order to evaluate if the e-learning platform suits the pilot course needs, the following features have been considered: (1) the analysis of the context; (2) the methodological and educational requirements; (3) the institutional and national constraints of the pilot course; and (4) guide-lines, best practices, as well as the national and international standards.

The indicators are classified through the following categories: (1) technical and technological features; (2) implementation of educational models (the analysis considers how educational models are implemented in LMSs; such as socio-constructivism and collaborative learning); (3) impact on end users; (4) available tools (those typically offered by an LMS and those specifically required by the pilot course context); (5) assessment and evaluation tools (tracking and reporting tools); (6) e-learning standards and accessibility compliance; and (7) documentation and technical support.

A first group of LMSs was identified including those that offer a wide range of features and are best qualified and widely used both at a national and international level.

The selection pointed out the high number of open source platforms at disposal. Considering the already mentioned criteria of selection and some peculiarities of Italian universities the choice focused on the following four platforms for benchmarking: Atutor (http://www.atutor.ca/), Docebo (http://www.docebo.org/), Dokeos (http://www.dokeos.com/), and Moodle (http://moodle.org/). Among these, as explained in the following section, Moodle seems to fit best with the STEEL project requirements.

3.3 - The Learning Management System

Moodle (Modular Object-Oriented Dynamic Learning Environment) is an Open Source LMS created by Martin Dougiamas (Dougiamas and Taylor, 2002, 2003) and now adopted and supported by a large community of developers. Implemented in PHP language, Moodle requires a database and a web server. Developed in the environment referred to as LAMP (Linux, Apache, MySQL and PHP), it provides versions for Windows and for the open source database Postgres.

Easy to use, solid design and architecture, large and widespread community of users and developers are among the strengths of Moodle. Its aim to support the socio-constructionist educational models is potentiated by the flexibility and adaptability, so important for the instructional design process.

Several tools for end users are available in Moodle. They can be classified according to the following categories:

- *tools for individual and collaborative learning activities*. As regards individual learning activities, users can find assignment tools, simulation delivery options (external software), e-portfolio management, glossary, activities scheduling tools (news block, recent activities, calendar, course/site description, RSS feeds), quiz and survey tools, "timer" functions for the activities deadlines. For collaborative activities, a distinction needs to be made between asynchronous (forum, wiki, blog) and synchronous tools (chat and instant messaging). Aim of the STEEL project is to integrate the LMS with a "virtual classroom" application, a description of which is provided in the next section;
- *content delivery tools*. Not only does Moodle provide native formats (text or web pages), but it also allows to upload in the system contents designed outside (with external authoring tools). Moodle supports different types of files (e.g., Office package, PDF, HTML, etc.), multimedia files (i.e., Flash or Java simulations), and standard compliant files (e.g., SCORM-AICC and IMS Content packages). It is possible to manage and organize learning contents in learning units, or in conditional activities (i.e., in those cases in which the availability

of given activities is restricted according to certain conditions such as dates, grade obtained, or activity completion) or to delivery them in scheduled way;

- *tutoring tools*, such as; the presence of announcements area, FAQ, and calendar ;
- *monitoring and evaluation tools*. Moodle offers activity-tracking tools, customizable reports of all recorded data, customizable grade book with different rating scales, and several feedback tools.

3.4 – The synchronous communication application

As mentioned before, the STEEL e-learning platform aims to develop a complete e-learning platform that will be tested to deliver distance learning courses to UNI-TEL end users, in order to verify the obtained level of quality as what concerns both the technological and the educational aspects. This entails the integration in the platform of a synchronous communication application that will allow multiple audio-video connections among teachers and students to deliver live lessons and carry out collaborative activities.

At the moment of this paper, a comparative testing phase of the most interesting, Open Source and commercial, synchronous tools is being carried out, in order to identify the most suitable application to satisfy the project requirements.

All considered tools have some common capabilities, which allow, for example, the exchanging of text messages between the moderator of the session and any student or, directly, among students, displaying live video, share whiteboards, multimedia files, and applications, generally through an intuitive graphical interface. Moreover, these tools also allow to record the delivered live sessions. This is an important feature for those students who have missed a session or those who attended it but would like to review the session.

4 – THE INTEGRATED NETWORK ARCHITECTURE

The STEEL network architecture (Del Re et al., 2009), shown in Figure **1**, aims at offering distance learning services to a large variety of end users displaced in wide areas or in places without an adequate Internet access. The key idea in order to realize such a system, is to consider an integrated satellite-terrestrial platform which allows to have a global coverage by the use of a satellite network and long/short range capability by the various terrestrial segments (xDSL, WiFi, WiMAX, 3G). Moreover, thanks to the satellite technology, the system is able to provide the same quality of service to the users displaced in a wide area. The choice to consider a satellite segment, even if it is very expensive in terms of satellite capacity and of satellite terminals installation, has been made because it has many peculiar characteristics which are very suitable in the e-learning and m-learning contexts, such as:

- the opportunity to deliver both *symmetrical services* (i.e., services able to provide complete satellite interactivity) and *asymmetrical services* (i.e., only broadcast services or services wherein the return link is not satellite but terrestrial);
- *guaranteed QoS* over a large area;
- *rapid deployment* in comparison with other terrestrial networks;
- *usage flexibility*;
- *easy expansion* of the network at regional, national and European level;
- *interoperability* with existent terrestrial networks;
- *available bandwidth* suited for the delivery of video streams (typical values 2-4 Mbps);
- dynamic bit-rate adaptation to media contents;
- *multicast capability* (i.e., the capability to deliver contents to a determined group of end users).

The STEEL network is designed to provide the distance service delivery over a great variety of access technologies. In particular, the main research effort is dedicated to the integration of a bi-directional satellite access with terrestrial extensions.

4.1 – The Space Segment

The space segment of the STEEL network is an interactive broadband satellite system derived from the data over cable standard DOCSIS (Data-Over-Cable Service Interface Specification). The satellite system called *SurfBeam®* (Das, 2006; Das and Miller, 2007), is provided by Viasat Inc. and the related European service named TOOWAY is operated by Eutelsat. *SurfBeam®* is a broadband satellite system designed for use with geostationary spot-beam based satellites in the Ka band (20/30 GHz) or Ku band (12/14 GHz) and provides users with a broadband access comparable to that currently provided by terrestrial modems (e.g., ADSL technology). Although the upper layer protocols are all based on DOCSIS, the physical layer (PHY) has been modified in order to accommodate the unique challenges of the satellite-land channel. The modulation scheme used by user terminals on the return link back to the satellite, is QPSK with a forward error correction (FEC) rate of 1/2 or 3/4, in order to provide a higher robustness to this critical link.

The main space segment components of the STEEL system, shown in Figure 2, are:

- *the user satellite modem* located at end users. It allows local bi-directional access to the satellite network;
- *the HUB* which is a large operator facility (located in Turin) which provides aggregate access to the satellite system;
- *the STEEL gateway*, directly connected to the HUB, which processes the IP traffic generated from STEEL applications, providing advanced network issues, in particular QoS support and traffic shaping functions.

4.2 - Terrestrial Segments

Terrestrial segments allow STEEL users to receive services through a large variety of technologies which converge to a joint IP-based interface, as shown in Figure 3. Residential Internet access (xDSL), WiFi, WiMAX, 3G are only some of them. Different platforms are characterized by specific capabilities as what concerns data presentation, processing and telecommunications aspects. Scope of the project is finding a minimum set of capabilities sufficient for the fruition of the considered distance learning services. The interaction between students and teachers and among students with multimedia contents will be allowed by broadband connections on complex user platforms (PCs). Textual and broadcasted video services could also be delivered to portable devices (e.g., smart phones) in order to provide m-learning services to mobile users too and therefore extend the number of potential students able to follow the courses.

4.3 - IP QoS Provision

In such a system, it is very important to realize a scalable service architecture allowing to guarantee a certain level of QoS in the critical segments of the network, as it is the space segment. Therefore, the considered strategy is to implement an infrastructure using, in particular, a *Differentiated Services* (Diff-Serv or DS) approach (Blake, 1998), in order to manage the provision and guarantee the QoS to end users. DS is a *coarse-grained*, class-based mechanism for traffic management. It relies on a mechanism to *classify* and *mark* packets as belonging to a specific class in order to process them in different ways depending on their priority. The DS architecture is based on a simple model where traffic entering a network is classified and, possibly, conditioned at the boundaries of the network (INGRESS Node), and assigned to different behaviour aggregates. Each behaviour aggregate is identified by a single DS codepoint (Nichols et al., 1998). Within the core of the network (DS Domain), packets are forwarded towards their destination according to the per-hop behaviour associated with the DS codepoint. The nodes handling the traffic in output from the DS Domain are called EGRESS Nodes. In Figure 4, it is shown how the DS mechanism can be implemented in the STEEL satellite-terrestrial infrastructure: the DS Domain is composed by the satellite network in order to guarantee a certain level of QoS, the INGRESS Node is the network node where there are the contents to be distributed and the EGRESS Nodes are located, directly, at end users.

4.4 – STEEL boxes

The advanced routing functions required by the STEEL system will be implemented on Open-source Linux-based routing devices, named STEEL boxes (Figure 5). The architecture of such devices includes:

- a Via C3 fanless microPC board;
- a Linux kernel (2.6.x) with advanced routing modules enabled;
- multiple Ethernet interfaces;
- remote control and configuration of traffic conditioning functions (TC tools).

This architecture allows a complete software definition of the required advanced QoS techniques through the configuration of the kernel routing engine. The operational bitrates are limited by the space segment (1 Mbps) so the software implementation of queuing policies can be easily provided by the selected CPU. The same hardware platform can be programmed to provide the functions of the INGRESS, EGRESS and CORE routers in the selected delivery architecture. Dedicated Ethernet links will be used to emulate error-free unlimited bandwidth connections between various STEEL network entities. The assumption only applies to the set of STEEL services, whose main transport segment is the satellite one.

5 - CONCLUSION

The end of the second year of the project is approaching. For this reason it is not yet possible to draw any conclusion about the project outcomes, nor is it possible to evaluate the results of the pilot course that it is about to begin. However, some considerations can be made about the project developments so far.

The first regards the double soul (i.e., the technological and the methodological soul) that characterizes the STEEL project. The coexistence of these two souls highlighted not the importance for the different teams of researchers involved in the project to understand and share a common vocabulary, but also to make the technicalities related to their backgrounds comprehensible to the others. With this purpose in mind, several activities were carried out from different, complementary standpoints in order to let the different perspectives emerge. A typical example is the testing sessions aiming at analysing the synchronous platforms where each team focused on different aspects, from pedagogical suitability to technical compatibility.

The second consideration regards the need to understand and meet the contextual constraints, which can only be achieved by getting involved in the project all the individuals and institutional stakeholders, such as the distance university that runs the courses and the students, teachers and tutors that will participate in them. Such involvement, since the very beginning of the project, should guarantee usable and useful results and will probably produce a revision of the way the courses are designed, run and perhaps even experienced by their participants. Stakeholders involvement, for one thing,, will prevent researchers and developers from adopting a technocentric approach, where technology development is a priority against the actual solution of the educational problems. As a result of this involvement, it turns out that the pilot courses will consist of an interesting mix of old and new methods supported by advanced and state of the art technology, ranging from e-lectures to CSCL, from interactive video sessions to individual fruition of downloaded learning resources.

REFERENCES

Anohina, A. (2005), «Analysis of the terminology used in the field of virtual learning», *Educational Technology & Society*, 8 (3), pp. 91-102.

Berge, Z., Collins, M. (1996), «Facilitating interaction in computer mediated online courses», *FSU/AECT Distance Education Conference*. Tallahasee FL, June 1996. http://jan.ucc.nau.edu/~mpc3/moderate/flcc.html.

Blake, S., Black, D., Carlson, M., Davies, E., Wang, Z., Weiss, W. (1998), «An Architecture for Differentiated Services», *RFC* 2475, http://www.faqs.org/rfcs/rfc2475.html.

CNIPA (2007), «Vademecum per la realizzazione di progetti formativi in modalità e-learning nelle pubbliche amministrazioni», *I quaderni*, 32.

Conrad, D. (2004), «University instructors' reflections on their first online teaching experiences», *Journal of Asynchronous Learning Networks*, 8 (2), pp. 31-44.

Das, A., (2006), «Enhancing Capacity of a Satellite Broadband system via Adaptive Coding and Modulation», *24th AIAA International Communications Satellite Systems Conference (ICSSC) and 4t*, San Diego, California.

Das, A., Miller, M., (2007), «Remote non-linearity detection via burst power dithering and EM based SNR Estimation», *International Workshop on Space and Satellite Communications*, Salzburg, Austria, pp. 216-220.

De Laat, M.F., Lally, V., Lipponen, L. and Simons R.-J. (2007), «Online teaching in networked learning communities: A multi-method approach to studying the role of the teacher», *Instructional Science*, 35 (3), pp. 257-286.

Decreto 17/04/2003, «Criteri e procedure di accreditamento dei corsi di studio a distanza delle università statali e non statali e delle istituzioni universitarie abilitate a rilasciare titoli accademici di cui all'art. 3 del decreto 3 novembre 1999, n. 509», *Gazzetta Ufficiale* n. 98, 29-04-2003.

Del Re, E., Ronga, L.S., Suffritti, R. (2009), «An Integrated technological platform for distance learning: the STEEL Project», *IADIS International Conference Mobile Learning 2009 proceedings*, pp.378-380.

Dougiamas, M., Taylor, P.C. (2002), «Interpretive analysis of an internet-based course constructed using a new courseware tool called Moodle», *Proceedings of the Higher Education Research and Development Society of Australasia (HERDSA) 2002 Conference*, Perth, Western Australia.

Dougiamas, M., Taylor, P.C. (2003), «Moodle: Using Learning Communities to Create an Open Source Course Management System», *Proceedings of the EDMEDIA 2003 Conference*, Honolulu, Hawaii, pp. 171-178.

Falowo, R.O. (2007), «Factors impeding implementation of web-based distance learning», *AACE Journal*, 15 (3), pp. 315-338.

Kleinrock, L. (2003), «An Internet vision: the invisible global infrastructure», *Ad Hoc Networks*, 1, pp. 3-11.

McMillan, S.J., Jang, S.H. (2002), «Measures of Perceived Interactivity: An Exploration of the Role of Direction of Communication, User Control, and Time in Shaping Perceptions of Interactivity», *Journal of Advertising*, 31 (3), pp. 29-42.

Nichols, K., Blake, S., Baker, F., Black, D. (1998), «Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers», *RFC 2474*, http://www.faqs.org/rfcs/rfc2474.html.

Pajo, K., Wallace, C. (2001), «Barriers to the uptake of Web based technology by university teachers», *Journal of Distance Education*, 16 (1), pp. 70-84.

Podnar, I., Hauswirth, M., Jazayeri, M. (2002), «Mobile push: Delivering content to mobile users», *Proceedings of the International Workshop on Distributed Event-Based Systems*, pp. 563-568.

Salmon, G. (2004), *E-moderating: The Key to Teaching and Learning Online*. London: Taylor & Francis.

You, Y., Åkerman, P (2007) «Virtual Office for Nomadic Collaboration», *Position paper at ECSCW-2007, Limerick, Ireland*, September 2007, pp. 24-28.

FIGURES

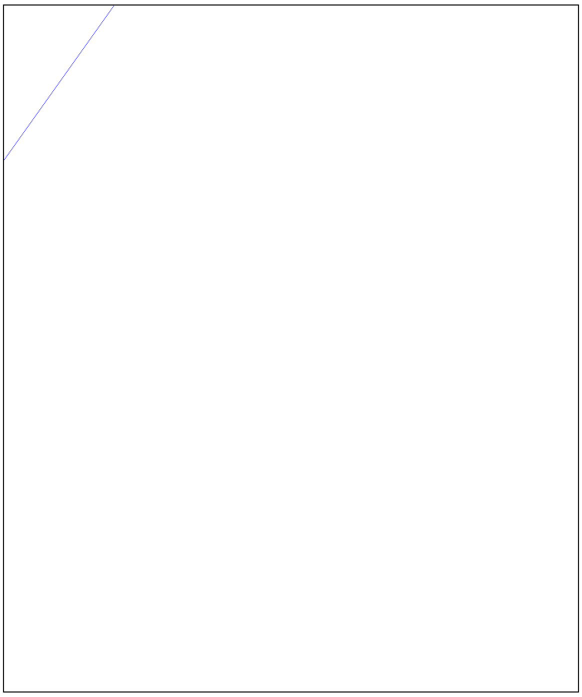

Figure 1: STEEL Network Architecture

Figure 2: STEEL space segment components

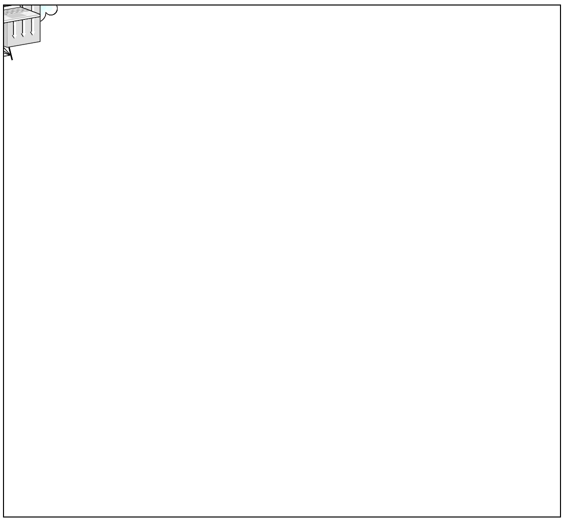

Figure 3: STEEL terrestrial segments

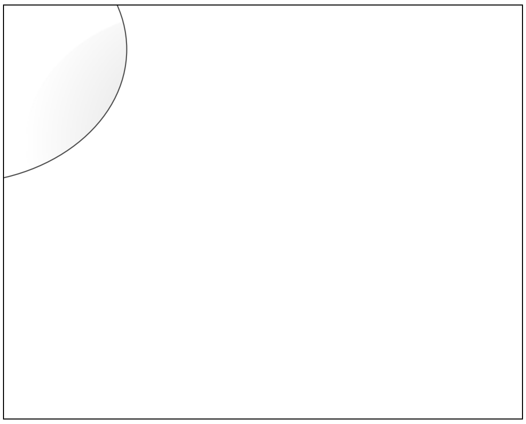

Figure 4: *Differentiated Services* application

Figure 5: STEEL box