Teaching Experiences with E-Learning Network Infrastructures

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Abstract. Computer-based learning environments provide the opportunity to promote students interactivity and meet their individual needs. Because of the advantages of such approach, the computer-based teaching is becoming very popular in universities and in other educational institutes. However, very often the solutions proposed to support the educational activities are not inter-operable and lack of a suitable network infrastructure. In this paper, we report the results of several teaching experiences gathered from more than one year of activities in various research projects. Our first step has been the development of a platform able to fully integrate the new powerful teaching tools, such as the virtual blackboard, and network transport services. From these experiences, we realized that the learning quality would be improved if students interactively participate to the learning process. Then, in a later experimentation, we proposed and validated a model of e-classroom, which would guarantee the mobility to students and preserve their identity. We show that this kind of *mobile-learning* is only possible whereas an advanced networking technology, such as Mobile IPv6, is enabled.

1 Introduction

The use of computers for learning has always received a great attention from educational institutes in that it allows to overcome many timing, attendance and travel difficulties. This way of providing education involves a great variety of heterogeneous equipments, including information transport system and application tools, which often turn out to be scarcely inter-operable. Differently from purely web-based training, where information exchange is inherently non interactive, the e-learning systems arise non trivial problems of real-time data distribution and system management. At this regard, the real challenge is to exploit the available networking technology to build a robust platform for educational purposes. In this paper, we discuss several teaching experiences in this direction, employing the state of the art networking technologies.

In a first experience, we realized an interactive distance learning system where the video of lessons were transferred to a remote classroom. A Multiprotocol

Label Switching (MPLS) [1] network was used to create virtual network paths, so to guarantee a fast and secure transmission of audio-video flows of lessons. The characteristics of the advanced network architecture, combined with the advantages offered by the new teaching instruments, has really encouraged the discussion and the remote students interactivity. This fact convinced us that students attention can be stimulated by the interaction with enhanced teaching tools.

In a second experience, we proposed a model of classroom where the students, equipped by handheld electronic devices, are granted to access the university campus wireless network in order to join students working groups and exchange information and suggestions. Though the phenomenon of mobile learning is not exclusively related to school education, the development of a virtual classroom is a great opportunity to verify the benefits of learning with the aid of mobile devices. Nevertheless, such model leads to considerable problems to guarantee seamless wireless connections and to protect the personal student identity. In next sections, we show how these problems can be solved with the combined support of mobile IP technology and IPsec.

Despite the benefits undoubtedly obtained by the introduction of the new technologies within the school, our models of learning allow the students to get in touch with new equipments and architectures. Working directly with advanced tools may lead to a better understanding of their real usefulness, than just having knowledge of their technical specifications. In other words, the *learning by handling* approach, which is the base of the proposed teaching philosophy, may be much more effective in spreading the knowledge of new technological innovations for many disciplines, than making them known only through purely abstract models.

2 Models of E-Classroom

In this section, we describe in details our e-learning experiences, carried out by our research group at the University of Pisa. These experiences took place in the context of two distinct projects reported in the following sections. The key idea behind both projects is the creation of an e-classroom using a scalable network architecture [2][3]. In particular, the projects addressed to two major issues: providing network accessibility to students through heterogeneous infrastructures and focusing the attention on the students needs rather than teachers needs. With the latter, we means that the target is not the realization of an e-classroom which facilitates the teachers work, but the creation of a context where the students can learn in a better way [4].

2.1 Distance Learning Architecture

Our research group, on behalf of University of Pisa, coordinated the activities for the European research project COBRA (Connecting Local/Regional Communities for BRoadband service Access)[5]. The target of the project was to

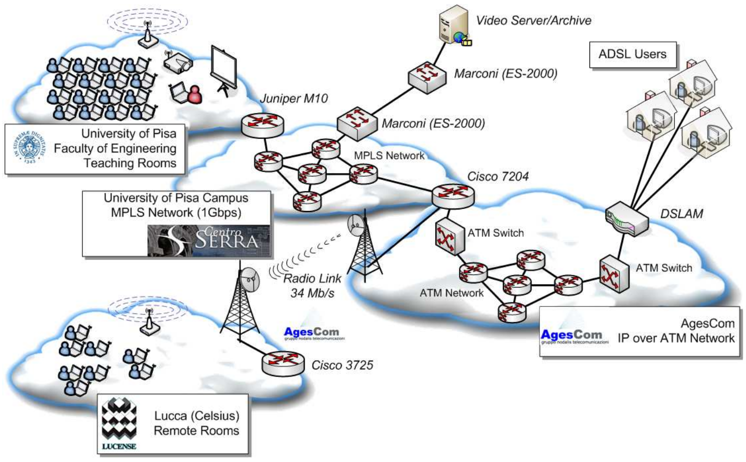

Fig. 1. Schematic representation of network employed in distance-learning project

validate the effectiveness of distance-medicine and distance-learning solutions, involving a partnership between the local/regional carriers and the university. Such kind of collaborations provided benefits both to network operators, which could integrate their connectivity services with a broad portfolio of interactive applications, and to university, which had the opportunity to experiment new educational technologies. Within this project, two demonstration field-trial were built up. The first one, in Germany, was meant to experiment distance-medicine applications, while the second one, in Italy, was oriented to distance-learning.

The fig. 1 shows the network infrastructure realized in Tuscany (Italy) for the COBRA project trial. A 34Mbps radio link connected two sites respectively located in the town of Pisa and Lucca. A teaching room at the Engineering department was arranged to connect a MPLS (Multiprotocol Label Switching) network, which is the main university campus network. Thanks to the MPLS-based architecture, this network is able to realize Virtual Private Networks (VPNs), supporting fast-recovery techniques and implementing the differentiated service network management within the transport layer. Then, the university campus network was connected through an ATM network, obtained by a peering-contract with Agescom company, to a pool of ADSL users able to receive the video streams of lessons. As illustrated in the picture, the distance-learning sessions could be attended both by students at the remote classroom in Lucca and by ADSL users. Moreover, a Video Server, connected to the university campus network through a 1Gbps point-to-point dedicated link, recorded the lessons for future replications.

Considering the described e-learning scenario, we could assume that, except for the possibility of interaction with remote students, the functions offered by our educational system are equivalent to the remote transmission of video lessons, similarly to cable or satellite broadcasting television teaching. On the contrary, the network infrastructure deployed by this project is particularly in-

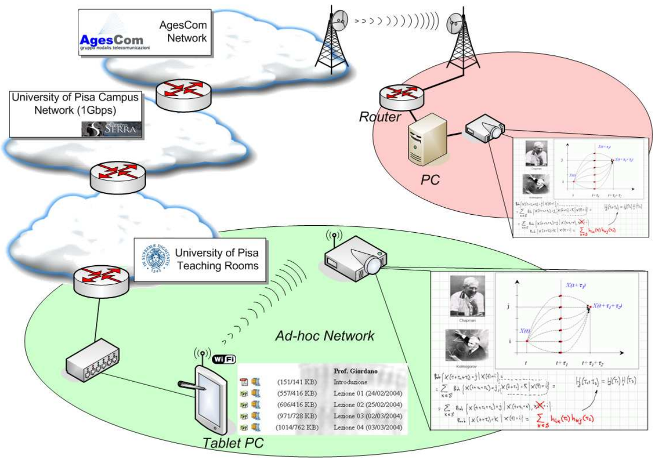

Fig. 2. Example of virtual blackboard experience.

teresting in that it offers the complete integration of network transport solutions with interactive service applications.

Beyond the technological aspects, which are out of the scope of this paper, we observe that the opportunity to realize a distance learning experience leads to change also the educational approach for students attending in the classroom. As shown in fig.2, a wireless LAN (IEEE 802.11) [6] network was employed to communicate from an handheld tablet-PC to a wireless video-projector installed in the classroom. Such equipments resulted very useful to support those lectures where the math explanations require lengthy discussions. Indeed, the employment of a tablet-PC (along with Windows Journal application) allowed the teacher to follow a step-by-step procedure, such as traditional chunk and blackboard approach, avoiding the presentation of slides full of math formulas.

On the other hand, during the teaching sessions is often necessary to display complex diagrams and graphs, which may require a lot of time to be correctly represented on the blackboard. For this reason, we also used the virtual blackboard approach, supported by Windows Journal application, which allowed the teacher to integrate images, diagrams and graphs, previously created with the hand-written information, such as math formulas or equations.

The use of digital blackboards allowed to easily capture and store the virtual image of the blackboard. In order to distribute the digital copy of lessons, we set up a web server that could be publicly accessed by students. In addition to the lessons contents, the web page held several others useful materials as:

- lessons notes and latest exam texts with solutions
- reference books and programs of academic teachings
- lesson calendar and examination dates, according to information provided from faculty server
- access to faculty server to account for examination

We remark that these e-learning experiences, strongly related to several networking problems, from heterogeneous multimedia information management to data transport and storage, allowed to integrate together a set of tools, whose effectiveness could be easily verified by the teaching staff. Also, this project leads to the development of a server able to store at real-time voice and video streams and electronic pages generated by table personal computers.

The technologies employed in our experiences are able to provide a high degree of teacher-student interactivity, which can use a different transmission rate according to the access technology used. However, we handle the theme of student interactivity with a particular care. Indeed, in order to keep the level of audience attention high, we decided that the explanation had not to be disrupted too often by students questions. Moreover, in the absence of a technical assistance staff, the teacher is also in charge of manage the audio/video transaction with the remote site possibly using complex personal computer interfaces.

Thus, in a first experimental phase, we set the remote interaction as follows. The student put an *instant message*, which is delivered to the teacher immediately. The teacher could reply to the request at once, being listened from the student who posed the questions too, and decide to break off the lesson immediately or postpone the clarification to a later more convenient time. When the teacher was ready to answer the question, a vocal communication was possible through a Voice over IP (VoIP)[7][8][9][10] connection. During this phase, the communication was limited to voice, but in a future project, this interaction may take place also through a video-telephony mini-session.

According to the plans of international standardization agencies, the traditional telephony, video-telephony and video-conference applications, which characterized the evolution of circuit switching networks, will be gradually substituted by the analogous applications using packet switching networks. In sight of this, the multimedia audio/video streams will use the same transport technology as Internet, though being carried over different backbones.

Considering that the VoIP (and more in general Multimedia over IP) is one of the most promising IP innovations for voice, its employment in the e-learning system is desirable.

To conclude this short description of COBRA project, we underline that the idea of integration is the key feature of all our activities. Though most technologies could be handled separately, a better technical production is obtained through the design of a common platform, including the network infrastructure, able to satisfy heterogeneous requirements.

2.2 Mobile Learning Architecture

Another E-learning experience, with mobility learning support, was carried out by our research group in the context of an European project, sponsored by Hewlett Packard, regarding mobility support in wireless networks.

Wireless communications, supporting mobile-learning, are often characterized by heterogeneous network architectures, where accessibility can be granted

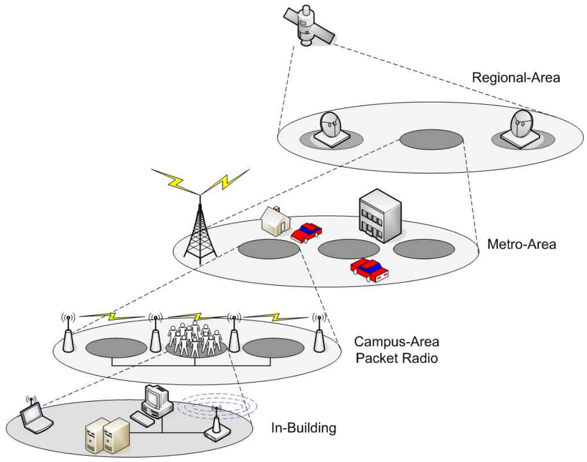

Fig. 3. Nested wireless networks

by satellite connections (DVB-S characterized by an upload link), cellular connections (GPRS or UMTS), wireless LAN connections (as like IEEE 802.11) or wireless MAN (as like IEEE 802.16, better known as Wi-Max).

In this kind of scenarios, the network coverages are often overlapped, as shown in the fig. 3, this means it is necessary to manage user migration from a network to another in a transparent manner, without requesting the user to reconfigure his personal computer.

The project PLATONE (MIPv6-Powered e-cLAss: a Teaching Oriented Network) [11] focused on the Vertical Hand-over, which allows the user to migrate from a network of one kind, for instance a GPRS network, to a different kind network, for instance a Wi-Max network, experimenting service continuity without changing his own identity. This issue has been taken into account by the international standardization organizations in the definition the next generation IP packet format. More specifically, in our project we realized a MIPv6 (Mobile IPv6) [12] network, where the end-users, identified by their so called *home address* can migrate from one network to another without changing their identity when automatically reconfiguring their terminals. This is thanks to the fact that home address is a statically assigned IPv6 address, regardless of the actual point of connection to the network.

Otherwise, the existing dynamic host configuration protocols, as like as DHCP in IPv4, allows the automatic terminal reconfiguration as the user change network, but user identity (coinciding with his IPv4 address) changes as the network changes.

The e-learning implications of the project derives from the idea that, in the near future, each student will be equipped with a notebook. This implies that students will be able to make exercises, follow the lessons, download the lesson materials and also take the exams with their own notebook. The interconnection

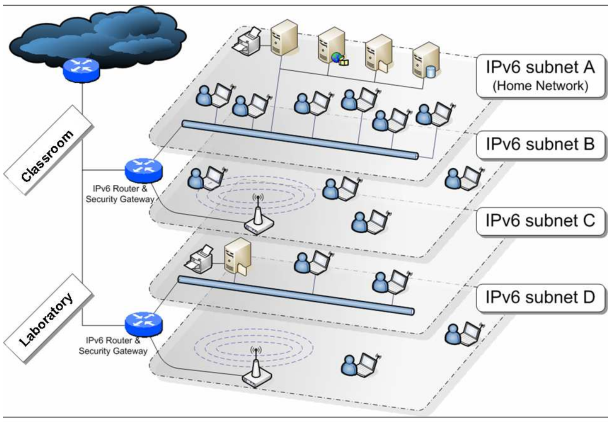

Fig. 4. Reference scenario for the e-class environment

between notebooks can be realized with a wireless LAN, which has to be designed properly in order to avoid network congestion.

The network scenario implemented in the project is shown in fig. 4. The wireless connectivity is granted by two, one for each room, IEEE 802.11g (HP ProCurve) wireless access points. The adoption of 802.11g wireless access provides both a high data rate and backward compatibility with the legacy IEEE 802.11b equipments. In particular, the 54Mbps available bandwidth is shared by the lecturer and eighteen students laptops (all HP Compaq nx9000), equipped with a built-in IEEE 802.11g network interface. Both the classroom and the laboratory offer the network connectivity by means of two subnet each, one associated to the wired portion of the network (a switched Fast Ethernet LAN), and the other associated to the wireless one (the IEEE 802.11g WLAN mentioned above), as exemplified by the logical representation of the e-classroom infrastructure in fig. 4. Outside the classroom and laboratory, the students will continue to be connected to the network inside an e-campus, where they can connect their computers to wireless networks, similar to the ones used in the classroom. This will allow them to move from classroom to laboratory without loosing network connections.

The choice of this architecture is based on the different functionalities and peculiar characteristics of each access technology. In particular, the 100Mbps data rate offered by the wired connection allows the real time streaming of high quality video, including the broadcasting of the live lessons, towards students located in their own seat or in the laboratory. On the other hand, the wireless network access enables the students to create flexible and dynamic working groups during practice cooperative periods of lessons and laboratory. In order to allow the students to move around the classroom maintaining their ongoing connections and reachability, both the networks take advantage of MIPv6 Mobile

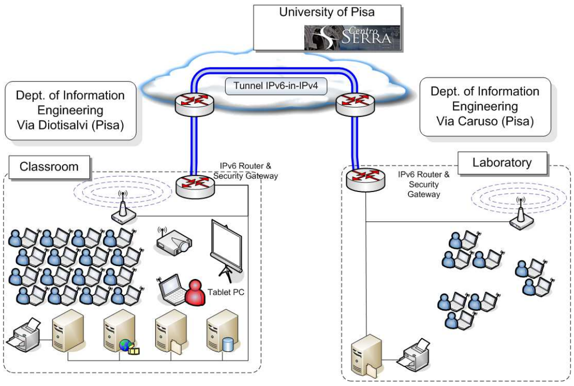

Fig. 5. IPv6-in-IPv4 encapsulation is used to connect two IPv6 networks.

IPv6. The same scenario is also illustrated in fig. 5, where the use of a tunnel is shown. The use of a logical tunnel IPv4-in-IPv6 is necessary since the campus network does not support IPv6. Moreover, as shown in the figure, to secure communications the IPsec [13] protocol has been used.

This topology can be extended to a more generalized scenario, where accessibility is provided, not only by wireless networks, but also by wired technologies (as like as Ethernet or ADSL) in order to achieve the intercommunication between different environments, such as campus, classroom, laboratory and home. In conclusion, this project coped with the same issues related to e-learning and distance learning seen in previous section, but integrating them with mobility and security aspects.

3 Conclusions

Though the distance learning and, more in general, the set of tools devoted to e-learning allow to satisfy the students learning requirements, their permeation into university education is still scarce. The main reason for that is the lack of a framework able to effectively integrate the various components of the complex teaching infrastructure into a single flexible architecture. Therefore, we proposed two network models oriented to pedagogical activities.

In our first experience, the digital image of blackboard was delivered, together with the video stream of classroom scenery, to a remote site. The remote students were able to interact with teacher through short instant messages sent to the teacher console, which stimulated students to actively participate to the lesson with questions. The success of experimentation has to be attributed to the possibility of real-time interaction, which was guaranteed by the underlying MPLS network characteristics. The second experience was instead directed to mobile learning. A mobile network granted the students to remain connected to the wireless network within the school environment while moving along different areas. This possibility motivates the cooperation and the exchange of learning materials among students.

In addition to the opportunity for distance and mobile learning, the availability of a common network infrastructure eases the sharing of university resources through *teaching targets*. Indeed, the laboratory equipments, capable of simulating real working conditions, are very often expensive apparatus prone to a rapid obsolescence. Hence, the support of a communication system oriented to teaching activities is essential both to bring realistic examples to students of technical applications and to save educational investments.

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