# Tele-Learning: A prototype system utilising the new advanced technologies in education

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***Abstract:*** Advances in telecommunication and computer technologies, have enhanced the role of knowledge by converging information and communication technologies towards a more dynamic stage: the *Global Information Society* (GIS). Realising the momentousness of knowledge in the globalise world and becoming aware of the importance of the converged-technologies in GIS, Technological Educational Institute (TEI) of Crete, has adopted a revolutionary way for enabling students to access, and adopt knowledge, any-time from anywhere. This paper describes the architecture of a tele-learning system that enables for distant educational activities, while defining the network configuration that utilises both wired and wireless access. Finally, tests on the system's performance evaluate on the system's QoS.

***Key Words*:** Tele-Learning, Education, Technology convergence, Broadband Networks, QoS

## 1. Introduction

The Information Revolution, and the Information Age that it engenders, is being defined by an on-going process of economic, social, political and technological globalisation. One critical issue that emerges from all of these restructuring processes is the central role of knowledge that has elevated the Education to the role of a global conscience. The globalisation of economy and its concomitant on the workforce requires a different education that enhances the ability of learners to adopt, and apply knowledge, to think independently and to collaborate with others. Advances in telecommunication and computer sciences, have enhanced the role of knowledge by converging information and communication technologies towards a more dynamic stage: the *Global Information Society* (GIS). Some of these technologies include the Internet, World Wide Web, CD-ROM, and printed, audio, video and other electronic media forms. Converging new advanced information and communication technologies, a new system of education and learning may be applied that will aid the professor and the student in breaking the boundaries of time and space; this is the *Tele-Learning* system.

Realising the momentousness of knowledge in the globalise world and becoming aware of the importance of the converged-technologies in GIS, Applied Information Technology & Multimedia (AITM) department, at TEI of Crete, has implemented a tele-learning system that enables students to access, and adopt knowledge from anywhere any-time. In this context, AITM provides access to archived lectures (in video and audio) and other archived course material that is hosted by a dedicated server, which may be accessed by any student. Moreover, AITM utilises this prototype tele-learning system for providing real-time (non archived) lectures, which can occur with the lecture being at the same location or even at a different place from the student. In this context, current tele-learning applications include students located in several TEI of Crete laboratories connected via cables to the local network and a number of selected students that are connected wirelessly. These wireless students may

also be located in the Heraklio downtown utilising the *real-distant student* (given that Line Of Sight conditions exist between their premises and TEI of Crete).
Moreover, AITM has established collaboration with the Institute of Informatics and Telecommunications (IIT) of the National Centre for Scientific Research "Demokritos" for providing real time lectures in the fields of Telecommunications and Information Technology. These lectures are given by professors located at Demokritos premises, while the students are placed at TEI of Crete premises.
In this paper the network architecture and the configuration of the tele-learning system are described, while performance evaluation measurements during a real time tele-training application are presented. Following this introductory section, Section 2 identifies the overall system architecture, Sections 3 and 4 describe in details the configuration of the network at Demokritos and at TEI of Crete premises respectively, while Section 5 evaluates on the system's performance utilising picture and sound quality measurements. Finally, Section 6 concludes the paper.

## 2. Overall System Architecture

The overall system architecture (see Figure 1) consists of two core subsystems, namely the *Lecturer* (located at the Demokritos side) and the *Classroom* (located at the AITM telecommunications laboratory side) 400km apart. The communication between the lecture and the classroom is via the GUNET network (the Greek Universities network that features broadband capabilities) and is based on the TCP/IP protocol stack, while using the unicasting delivery method.
The Classroom can serve a number of students, either locally connected to the Classroom (through an Ethernet link), called throughout as *Wired Students*, or geographically distributed (but in a smaller distance, compared to the distance between the Lecture and the Classroom), called throughout as *Wireless Students*. The communication between the classroom and a wireless student is achieved through a wireless LAN access spread spectrum link in the frequency band of 2.4GHz that makes use of IEEE 802.11 standard.

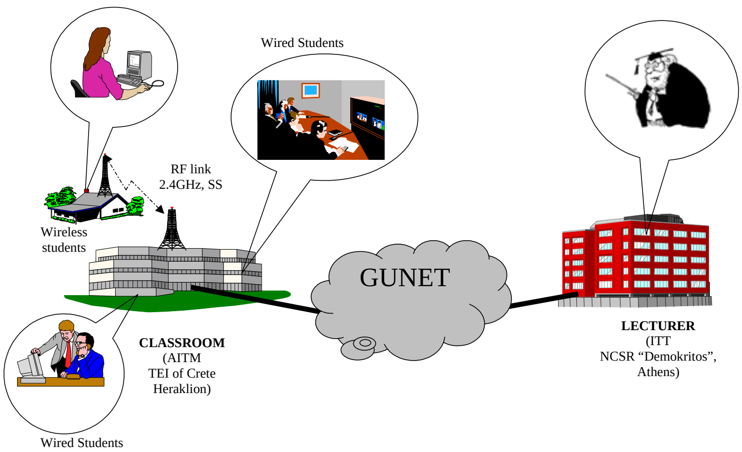



***Figure 1 Overall system architecture***

## 3. Configuration of the Lecturer

Figure 2 depicts the configuration of the Lecturer placed at Demokritos premises.

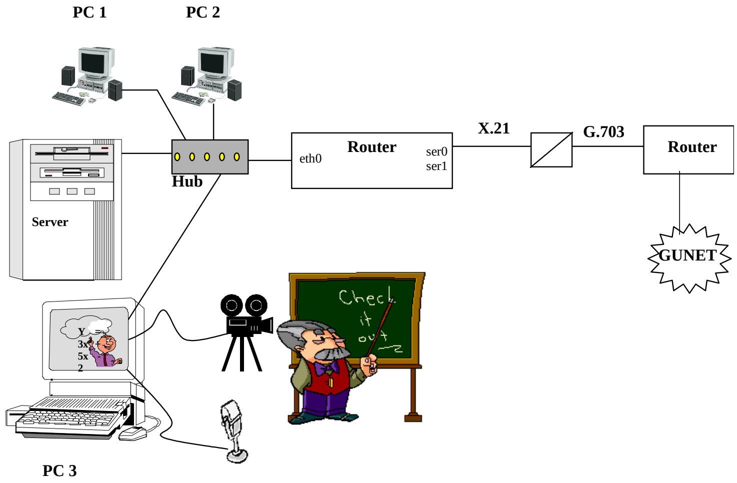



***Figure 2 Configuration of the Lecturer at Demokritos premises***

A multimedia PC, namely PC 3, controls the multimedia devices (e.g. a camera and a microphone), while hosting the appropriate software tool that enables for videoconferencing applications. This software tool utilises the H.323 communication protocol for video and audio transmission, while enabling for file sharing applications (e.g. white board) [1]. Both video and audio data are multiplexed and transmitted over the IP protocol to the Local Area Network (LAN). In the case that the target user (or group of users) is within the LAN, the data are collected by the appropriate PC via its Ethernet card. Otherwise, the data are routed to the appropriate destination via a router/converter chain. The reply signals follow the inverse route back to PC 3.

## 4. Configuration of the Classroom

Figure 3 depicts the configuration of the Classroom located at TEI of Crete. This configuration describes a Wide Area Network that consists of three nodes namely:

- Room 1 located in Telecommunications Lab (TEI of Crete premises). Several students attend a lecture without using PC stations individually.
- Laboratory 1 located in Computer Room (in TEI of Crete premises). Several students attend the lecture via PC stations that are connected to the local network via cables.
- Laboratory 2 located in the Director of Studies Office (TEI of Crete premises). The director of studies is able to attend the lecture via a PC station that is connected to the local network via a wireless link. This link operates in the Industrial Scientific & Medical (ISM) frequency band while making use of the Spread Spectrum technology. The use of such links enables the provision of tele-learning applications to students that are located far away from TEI of Crete (i.e. in the Heraklio down-town) that realises the real distant student, given that Line Of Sight (LOS) conditions between TEI of Crete and the student's premises exist.

Upon a tele-education application, PC 3 (at Demokritos) establishes a point-to-point communication with PC A, located at TEI of Crete (Room 1). Both PCs host the appropriate software/hardware tools that enable for video-conferencing applications. In this way, the transmitted (by Demokritos' LAN) data are received by a router device (at AITM premises) that collects them from the GUNET (via serial port 0) and passes them to the local area network (through the Ethernet port). Finally, the LAN passes the data to the appropriate destination, which is PC A. Upon the reception of the appropriate video-conferencing data stream, PC A passes the video signals to the output of its video card and the audio signals to the output of its sound card.

Students that are located in Room 1, attend the lecture via a projector device (connected to the output of the PC A's video card) that projects the Lecturer's images on a wall screen, while listening to him/her via a speaker set (connected to the line-out port of the PC A's audio card).

Whenever one of these students wants to set a question, he asks it by using the portable microphone or the one that is mounted on a camera that collects and transmits his/her images. These reply video/audio signals are fed onto PC A that forwards them to PC 3 (by utilising the video-conferencing tool).
Students that are located in Lab. 1 and Lab. 2 at TEI of Crete, attend the lecture via individual PC stations running under the MS Windows 98/2000 operating system. In this case, both the video and audio outputs of PC A are also fed onto an MPEG encoder that is hosted by PC B, which runs under the MS Windows NT operating system. Following, PC B (that is also a local server) encodes the incoming video/audio data into MPEG-1 format and produces an IP/Broadcasting stream at the output of its Ethernet card, which broadcasts them onto the TEI of Crete network (point-to-mutlipoint approach). In order to receive, decode and reproduce the MPEG packets, these PCs are equipped with a professional software tool that enables for reception, decryption and reproduction (via the MS Windows Media Player software) of the MPEG stream. This tool enables the student to log onto the appropriate IP/Broadcasting address (i.e. 224.2.127.254), from which the PC will receive the IP packets. Finally, it is the responsibility of the Ethernet card and multimedia software tool's to receive and decode the incoming IP packets and the video/audio cards' responsibility to reproduce them on the screen and the speakers.

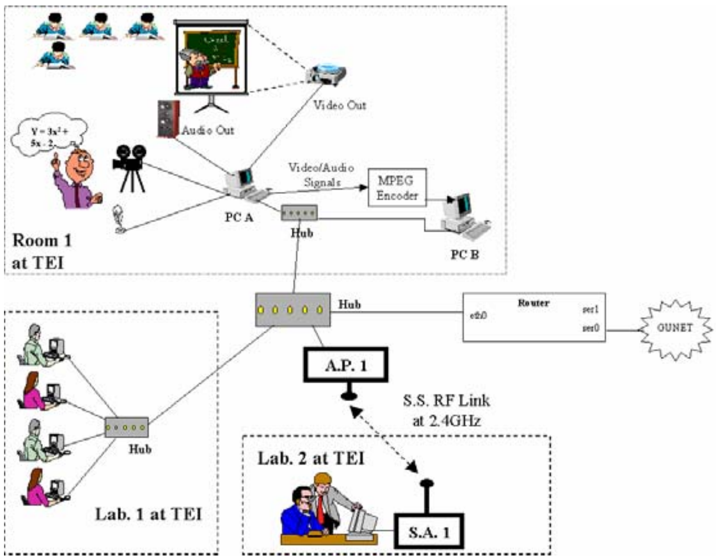



***Figure 3 Configuration of the Classroom at TEI of Crete***

## 5. System Evaluation Performance

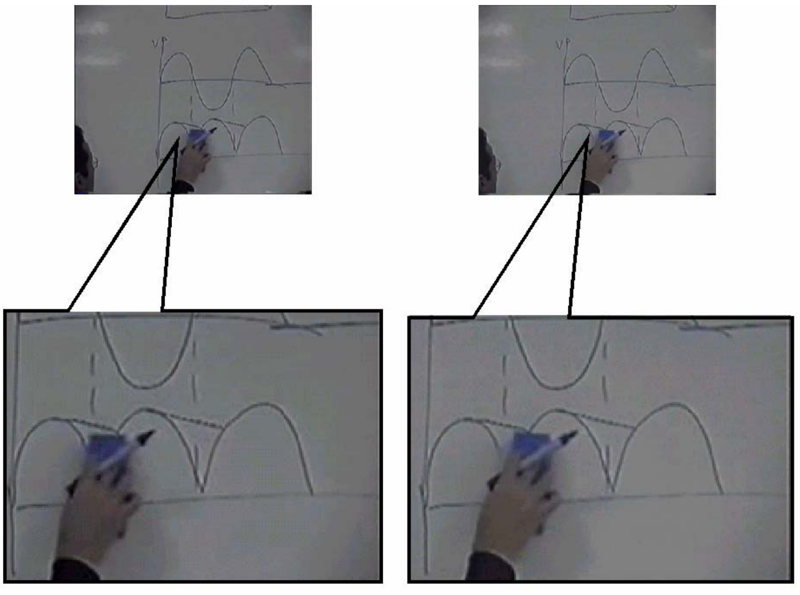
The performance evaluation of the described system was based on picture and sound quality measurements that were conducted under real-conditions environment, during a real-time tele-education application. As there is no subjective way for evaluating the picture/sound quality [2], a panel of ten people audience was used in order to assess the system's QoS. In this context, the panel assessed on the picture/sound quality in respect of both their clarity/clearness and upon the number and the duration of pauses occurred at the end user during a tele-education application [3-5].
Given that clarity and clearness are factors closely related to the encoding rate of the source signal, tests were conducted on the MPEG encoding procedure taking place at PC B (in Lab. 1 at TEI of Crete). In this context, a series of tests were designed and conducted in order to evaluate the picture quality that MPEG-1 standard can provide. These tests included the encoding of the same analogue video signal into eleven MPEG-1 files, each time with different compression rate.

Table 1 depicts the MPEG-1 files with the corresponding video/audio bit-rates, their file duration and their size. This table also indicates the total MPEG-1 stream bit-rate that is the sum of the video and audio bit-rates plus a 2.15% for the multiplexing overhead packets.

| File Name | Stream bit-rate (bps) | Video bit-rate (bps) | Audio bit-rate (bps) | Duration (seconds) | File Size (bits) |
|---|---|---|---|---|---|
| **File 0** | 650.000 | 540.000 | 96.000 | 359 | 233.955.952 |
| **File 1** | 799.600 | 686.400 | 96.000 | 359 | 287.523.064 |
| **File 2** | 1.000.000 | 882.400 | 96.000 | 360 | 360.478.696 |
| **File 3** | 1.200.000 | 1.078.000 | 96.000 | 360 | 432.426.056 |
| **File 4** | 1.350.000 | 1.224.800 | 96.000 | 360 | 487.028.216 |
| **File 5** | 1.500.000 | 1.371.600 | 96.000 | 360 | 541.281.560 |
| **File 6** | 1.800.000 | 1.665.200 | 96.000 | 360 | 649.170.296 |
| **File 7** | 2.000.000 | 1.860.800 | 96.000 | 361 | 722.012.400 |
| **File 8** | 2.500.000 | 2.350.000 | 96.000 | 360 | 902.088.088 |
| **File 9** | 3.000.000 | 2.839.200 | 96.000 | 360 | 1.081.618.056 |
| **File 10** | 4.000.000 | 3.817.600 | 96.000 | 360 | 1.443.073.912 |

***Table 1 MPEG-1 parameters for 11 files with different compression rate***

The spectators watched the 11 MPEG-1 files played back locally on a PC B's screen and expressed their opinion for each one, concerning the picture clarity (clearness) and pleasant viewing. The spectators assessed that for the 4Mbps (stream bit-rate at 4.000.000bps) encoded video the picture quality was very good and the viewing was very pleasant. This was expected as long as the MPEG-1 standard refers to encoding rates up-to 1.5Mbps [6-8]. Consequently, higher bit-rates (i.e. 4Mbps) would provide maximum picture/sound quality. For files with lower bit-rates, such as for the 1Mbps (stream bit-rate at 1.000.000bps), they assessed that the picture quality was not significantly degraded while the viewing was pleasant. An estimate of the picture quality achieved for each encoding stream bit rate is presented in Figure 4.



**Picture 1** **Picture 2**

***Figure 4 Comparison of picture quality for MPEG-1 encoding rates of 650kbps (Picture1) and 2Mbps (Picture2) played locally at PC B***

Figure 4 shows a punctilious comparison of the same frame - during a rapid movement - encoded with 0.65Mbps (picture 1) and 2Mbps (picture 2) respectively. Comparing the two pictures, it can be observed that the edges of figures in picture 2 are sharper than those in picture 1, while the overall picture quality is not significantly degraded. Concluding, this initial experiment shows that an MPEG-1 video programme with transport stream bit rate equal to 1Mbps can be pleasantly viewed.

However, as long as the provided services are delivered over the Internet and distributed to the students over a TCP/IP protocol based network, the system QoS is related to the available bandwidth of the network [9-11]. Given that the described network utilises both point-to-point and point-to-multipoint delivery methods, a series of network throughput tests were conducted concerning the:

- Wired point-to-multipoint link (from (PC A to PCs in Lab. 1 at TEI of Crete).
- Wireless point-to-multipoint link (from PC A to PC in Lab.2 at TEI of Crete).

The network throughput of the point-to-point link between PC 3 and PC A (Internet connection) was not evaluated as long as there are several bottlenecks between them; consequently the available bandwidth is not guaranteed. Nevertheless, tests conducted in daily base verified that the network throughput varies from about 400kbps up to 1Mbps, depending on the link's traffic at a given time during day. However, the picture sound quality that the assessor accommodated during a videoconference application was quite good even at 400kbps data rate. An estimation of the achieved picture quality at this data is depicted in Figure 5.

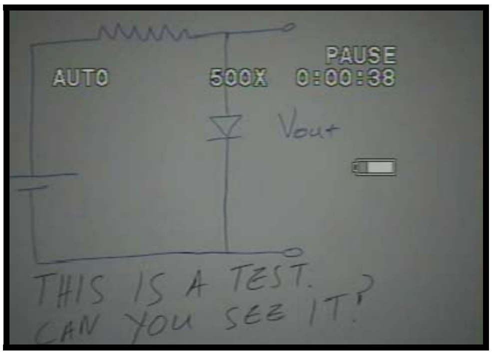
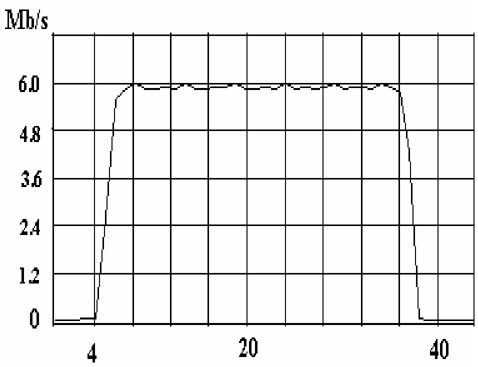



***Figure 5 Picture quality achieved during a videoconference application via the GUNET***

Figure 6 denotes the network throughput during a file transfer procedure between PC B and a student's PC connected via cables to the TEI of Crete LAN. This figure indicates that the nominal network throughput is about 6Mbps. Same file transfer procedures were conducted in order to evaluate the nominal bandwidth and the available throughput of the other two links. In this context, Figure 7 indicates the throughput of the wireless link between PC B and the PC in Lab. 2 at TEI of Crete that is around 1.5Mbps.



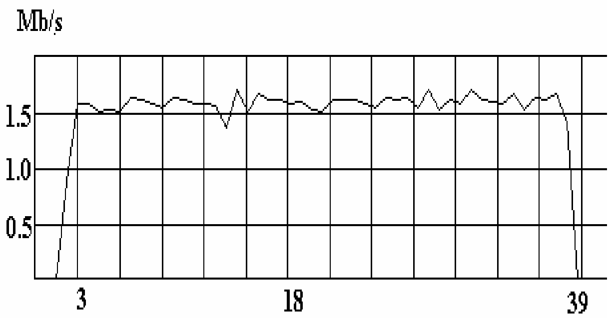




***Figure 6 Network throughput for the wired point-to-multipoint link***

***Figure 7 Network throughput for the wireless point-to-multipoint link between PC B and the PC***

*between PC B and the PCs in Lab. 1 at TEI of Crete* *in Lab. 2 at TEI of Crete*

These results denote that the useful network throughput is around 6Mbps, unless wireless students want to attend the lecture. In this case the useful network throughput is at 1.5Mbps. Consequently for efficient data transmission, the data rate of the provided application should not exceed the useful throughput of the network.

Moreover, given that the IP protocol encapsulates overhead packets during any transmission, it comes that the actual bit-rate of the distributed application is increased by a factor of about 4.5% (due to the overhead packets). In this context, the actual data rate of the distributed application should be at least 4.5% less than the available throughput. For example, in case that the described system utilises the LAN of TEI of Crete with wireless students attending the lecture, the actual data rate should be less than 1.5Mbps - 4.5% = 1.43Mbps.

Figure 8 depicts the actual data rate of an MPEG-1 file with stream bi-rate of 1Mbps when it broadcasted over the TEI of Crete TCP/IP LAN. In this case the actual data rate (average value) is at 130972Bytes/sec = 1047776Mbps (MPEG-1 stream bit-rate at 1Mbps plus 4.5% IP overhead packets).

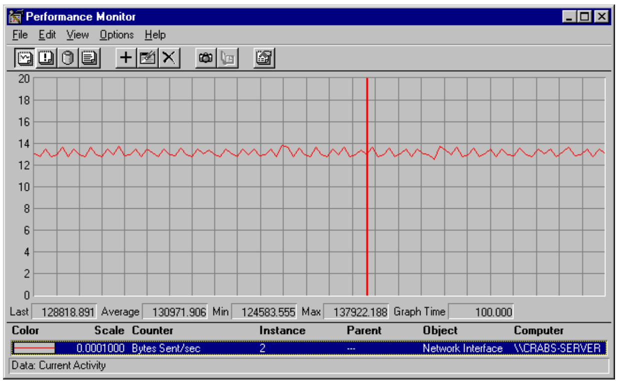



*Figure 8 Actual transmission rate (of an MPEG-1 file with stream bit-rate at 1Mbps) Versus Time*

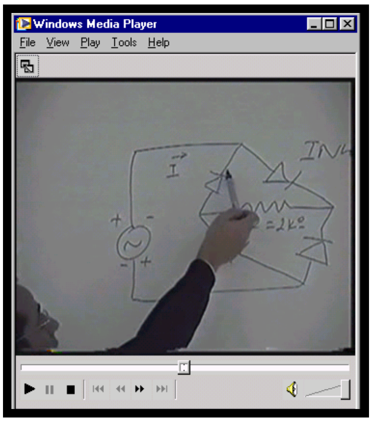



*Figure 9 Picture quality that a wired student accommodates during a tele-education application*

Tests that conducted on the platform for evaluating the system's QoS indeed verified that for actual transmission rates higher than 1.5Mbps (MPEG-1 bit rates higher that 1.4Mbps) the panel of assessors experienced picture and sound delays due to the undelivered in time MPEG-1 packets. The number and the duration of these pauses/delays was proportional to the MPEG-1 data rate. Moreover, the overall picture and sound quality was faded, resulting in unacceptable system's QoS. Results of these tests dictated that broadcasting of MPEG-1 files with stream bit-rate around 1Mbps provides high picture/sound quality and pleasant viewing at both wired and wireless student's PC.

Figure 9 depicts the overall picture quality that a wired user (placed at TEI of Crete) accommodates when a tele-education application with MPEG-1 bit-rate of 1Mbps is active.

## 6. Conclusions

This paper presented the overall architecture and evaluated on the performance of a prototype system adopted by the AITM of TEI of Crete that enables for tele-learning applications. The proposed system enables for wired access to the provided services while utilising the real-distant student by enabling for wireless access facilities. Furthermore, the adoption of the IP broadcasting delivery method enables for real-time lectures, while increasing the number of the attending students to a maximum. However, in such a case the level of interactivity between the students and the lecturer is minimum, as long as only a few return channels exist. Tests that conducted on the networking platform verified that the system's QoS can be

guaranteed, given that the transmission rate of the delivered media does not exceed the nominal network throughput.
Future work is focused on the adoption of a more sufficient communication method that will enable more students to actively participate in the lecture. Towards this, current research is in the area of developing a software/hardware tool that will enable for multi-conference applications.

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