INFRASTRUCTURE FOR PACKET BASED E-LEARNING SERVICES PROVIDED VIA SATELLITE

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ABSTRACT

To improve the quality of education, to reach a new audiences and extend the benefits of digital technology to previously unreachable populations, information and communications technology (ICT) strategies as well as e-Learning programs using wireless technologies are developed. A significant challenge in realizing the full promise of ICT worldwide has been lack of access, particularly in rural communities. Due to the narrow bandwidth of terrestrial access links and the enormous costs for increasing bandwidth in remote, sparsely populated areas and enabling IP-multicast streaming for these areas, a satellite overlay network using Digital Video Broadcasting (DVB) technology has been exploited. This satellite network delivers live streaming content simultaneously to numerous users currently in operation. The prime aim is to investigate the potentialities of high-bandwidth IP-multicast satellite technologies for education. This technology addresses: streaming of audio/video, streaming of desktop screen, streaming of questionnaires, and the synchronisation of this streams. The paper gives an overview of the technical aspects implemented in order to achieve the successful activation of the different already integrated e-learning services. The paper presents packet- oriented services distributed via satellite and infrastructures allowing to receive these services also with return channel.

Keywords: *e-learning, satellite network platform, satellite services, IP-multicast, HAP*

1. INTRODUCTION

Information and communications technologies (ICT) and e-Learning platforms extend the reach of education to broader audiences and provide ways to enhance traditional education, generating significant social and economic benefits to populations who have access to them.

Expanding the reach of ICT and building more effective e-Learning platforms [1-3] offer social, governmental, and business advantages, including:

- Expanded access to educational resources for a significantly larger user base
- Increased availability of information for all users
- Improved lifestyle for citizens regardless of socio-economic status
- Opportunities to exercise entrepreneurial skills regardless of user background

In recent years, two different and important factors are completely changing the features of the educational market inside Learning Centres: first we register a growth of knowledge and information necessary to increase professional life; at the same time, these capabilities are valid only for a short time because they are changing very quickly. Therefore we feel the need of continuous training during our lifetime. In few years, we have seen a fast evolution in distance learning, from the books sent by mail (**first generation of distance learning**) to the integrated use of TV transmission, video and audio recordings (**second generation**) to the interactive real time broadband data transmission (**third generation**) [4].

Cost and the practical limitations of current infrastructures have prevented DSL and cable technologies from reaching many potential broadband users [5]. Generally, DSL only extends about five kilometers from the central office switch. Converting these networks to support high-speed broadband or deploying wired infrastructure to new areas with low subscriber density is generally commercially unfeasible and requires years of disruptive installation. Thus the wide area coverage and availability in non-metropolitan areas make satellite IP/ DVB- based applications very promising for remote educational and training purposes.

In 2003 we started a research and development projects aiming to study the potentialities of streaming technology in education and to develop suitable applications for Slovakian schools. Streaming technology and satellite communication offer to universities and schools three main benefits:

- High-speed IP-Multicast services for schools
- Live e-Learning Sessions combining audio/video and desktop screen streaming with interaction for chats and feedback
- Media-on-Demand Service to update caches with digital media for off-line usage

The satellite services described in this paper aims at building an efficient service of distance learning of third generation: the courses can be attended in real-time by students just connecting to the packet communication network and using simple Personal Computer (PC) running a custom multimedia application. The successful activation and permanence of the services need a perfect integration of all technical, didactical, organizational aspects that characterize the final service. In the next sections of this paper we describe all these elements and we point out its importance.

2. THE E-LEARNING SERVICE: NEEDS AND REQUIREMENTS

The e-learning strategy, aims at recreating a live virtual classroom environment, with a real-time face-to-face relationship and high level of interactivity among the users: the concept of virtual classroom has to be more extended to ubiquitous distributed service, with no kind of limitation for the user's position. With this "direct" contact and control, students are encouraged to pay attention as happens in a real classroom. In order to lead a successful project and stimulate a large and enthusiastic user participation, the whole learning system must be complete, efficient, user-friendly and characterized by having fixed and suitable QoS level. The learning service can be characterized with the following composing elements, needs and features:

- **Network:** a widespread data communication network is necessary to connect all the Learning Centres. A communication network supporting the multicast allows reducing the required bandwidth and obtaining scalability, when the number of student increases.
- **E-Learning software:** The valid and user- friendly e-Learning software application for the real-time transmission of audio, video and data on the network and for the management of all the teaching aspects is the second fundamental element (accounts' management, subscription to courses and lectures, download of teaching materials, etc).
- **Courses contents:** The Learning Service aims at offering a high level of didactic contents made up of interesting courses.

Network, software and courses' contents contribute to create a complete learning service only if they are perfectly integrated and if the access to the service is user-friendly, authenticated and well managed [6].

3. THE SOFTWARE SOLUTION: ANALYSIS OF THE SOFTWARE PLATFORM

A long and deep evaluation phase to choose a complete tool, a so-called "Software Platform", able to provide synchronous and asynchronous service should be conducted. It has to be underline that the performance of this software has to be suitably checked on a real limited bandwidth network.

Table 1 Comparison of e-Learning software platforms

	Vip Teach	LearnLinc	Centra Simposium
Way of transmission	**Complete multicast supp.**	*Multicast server +unicast*	*Unicast + multicast*
Audio & Video Quality	**Good**	**Good**	*Fair*
Slides' management	**Power Point slides' progress**	*jpeg, pointer, html appl. sharing*	*jpeg, pointer, html appl. sharing*
Interactivity	**Good**	**Excellent**	**Good**
Floor Control	**Good**	**Good**	**Good**
Simplicity of utilization	**Good**	**Good**	**Good**
Synchronization and delays	**Good**	*Fair*	**Good**
Shared Pointer	**Yes**	*OK with jpeg no with HTML*	*OK with jpeg no with HTML*
Lessons' recorder	**Yes**	**Yes**	**Yes**
Stability	*Fair*	**Excellent**	Instable!

The software analysis should be developed in two steps: 1st STEP- Evaluation of functionalities, transmission and support for multicast; 2nd STEP- Evaluation of the QoS, reliability and stability.

In the tests was simulated real lectures and was evaluated the general level of quality and the functionalities at both application and network levels. Tests aimed to evaluate a lot of parameters and the results of these tests are summarized in the Table 1.

4. MAIN NETWORK INFRASTRUCTURES

An efficient online learning service is based on a communication network with suitable trade off between bandwidth and cost. In order to provide a good online learning service, it must be considered that reliability, answering the service requirements and integration with all the technical and didactical aspects are critical features for the network.

From recent experiences, one of the key network requirements has been the support for multicast [7], a strong element of innovation and originality, compared with most of the other distance learning systems. During a lecture the teacher does indeed transmit multimedia streaming to all the students connected. With the classical unicast transmission the traffic on the network would be too intense and cause problems of quality degradation. Using the multicast technology, the data transmitted to multiple users are not duplicated in more copies of the same data for every single destination (like in unicast) but just one copy is sent on the network and it's duplicated only where it's necessary (Fig. 1).

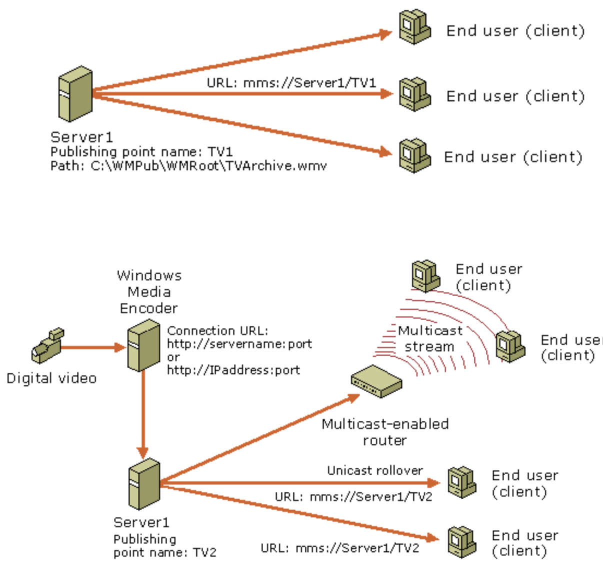

Fig. 1 Unicast vs Multicast

This offers a lot of advantages for e-learning services: extreme bandwidth economizing, scalability when the number of participants increase, good quality of service also for users with not high bandwidth availability.

5. SATELLITE NETWORK PLATFORM

The network introduced in this paragraph is operating over the Skyplex platform, managed by Eutelsat [8]. The Skyplex Ka-band terminal can receive a downlink stream of up to 38 Mbps. This stream is assembled on board the HOT BIRD^{TM} (HB6) satellite from as many as 6 uplink carriers (Fig. 2), each with a net bit rate of approximately 6 Mbps, or 18 uplink carriers, each with a net bit rate of approximately 2 Mbps. HB6 has 4 uplink European regions (Fig. 4). This satellite system enables pan-European broadcast diffusion, due to the downlink Ka coverage of HB6 (Fig. 5). At the network layer, IP is adopted, with multicast capability.

In order to increase its coverage and to allow reaching users with simple inexpensive terminals, the network has been complemented with a Ku part, provided by Aersat, which implements DVB-IP one-way broadcasting. This is based on a receive-only Ku starshaped network with a centralized hub. The flows that are intended to be replicated from the Ka network reach the hub via a receive-only Ka earth station (Fig. 6). The satellite adopted for Ku broadcasting is Eutelsat's W3, positioned at 7° E. Audio/video MPEG2 flows are transmitted at 384 kbps on the Ka band, whereas the current Ku bandwidth is tailored for a service at 256 kbps. The flows are therefore trans-coded at the hub before broadcasting.

5.1. The Ka-Band Network

The Ka-band (20-30 GHz) network is designed to provide high-speed satellite connections, capable of supporting advanced telecommunication services, based on high quality audio, video and data transmission, to be integrated via web interfaces.

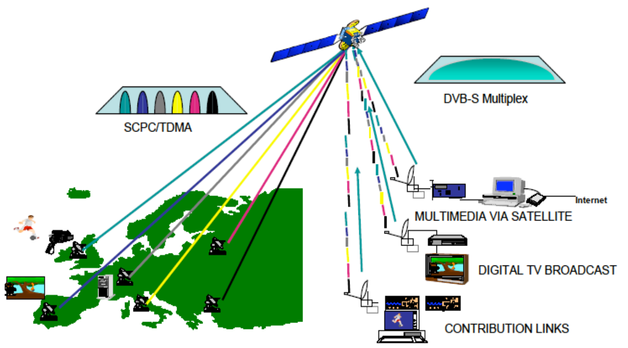

Fig. 2 SkyplexData system architecture

In the SkyplexData platform provided by Eutelsat (Fig. 2) the DVB-S stream [9] is generated onboard the satellite with the contributions at 2 or 6 Mbps, coming from a number of Learning Service Centres that operate in TDMA (Time Division Multiple Access) or SCPC (Single Channel Per Carrier). There is no earth station serving as unique Service Centre, to which all contributions should be directed to form a DVB-S flow. Each content provider can create its own satellite network and operate in complete autonomy. Thus, the architecture uses satellites capable of demodulating the contributions received from the Learning Service Centres and on-board multiplexing (the term Sky-Plex) them to a DVB IP flow. The multiplexed signal is transmitted towards earth terminals, which are composed by an outdoor unit, interconnected in L band to the indoor unit. The indoor unit demodulates the DVB IP flow and feeds it to a network server via an Ethernet interface. Fig. 3 shows the scheme of a possible two-way terminal. The figure also highlights the possibility of switching to a simple set-top box terminal, should be used as receive-only.

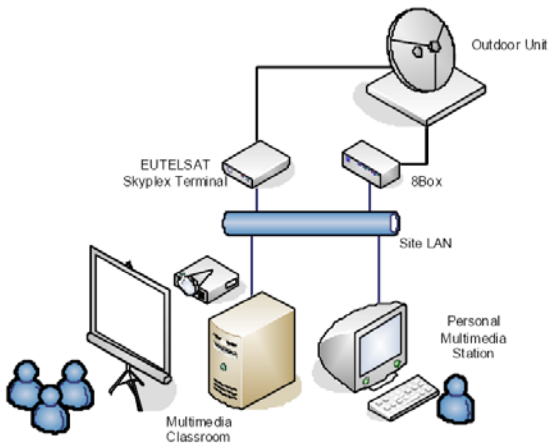

Fig. 3 Satellite user terminal architecture

Figs. 4 and 5 represent the footprints of HB6 for the up- and down-link, respectively. It can be noted that the satellite indeed provides European coverage. However as regards the up-link, this comes at the expense of leasing bandwidth over multiple spots.

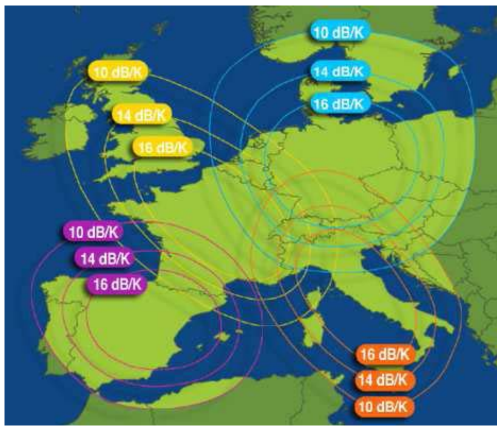

Fig. 4 Four up-links Skyplex footprint

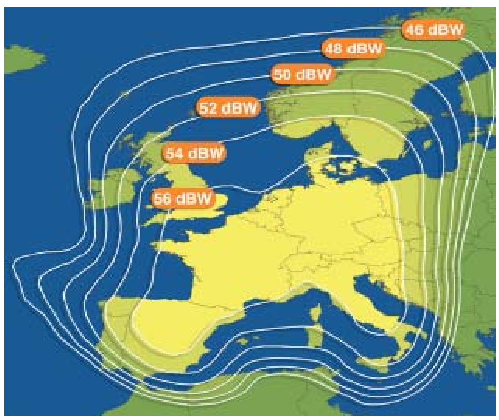

Fig. 5 Down-link Skyplex footprint

5.2. The Ku-Band Network

The Ku-band network segment, whose service is provided by Aersat S.p.A., is based on receive-only technology, with a star architecture, organized with a central hub.

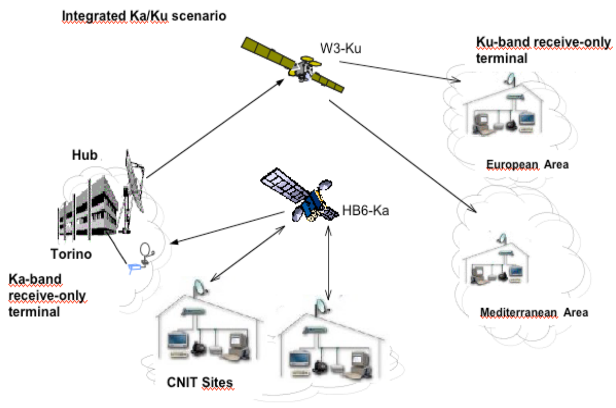

Fig. 6 Integrated Ka/Ku platform

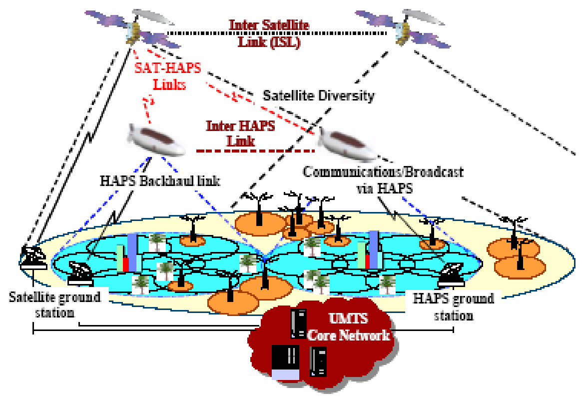

Fig. 8 Configuration of an hybrid network

The IP multicast flows (as no return channel) reach the hub via a Ka-band receive-only station. After transcoding, they are transferred to the multicast hub for transmission to W3. The overall architecture is depicted schematically in Fig. 6. The coverage of W3 is illustrated in Fig. 7.

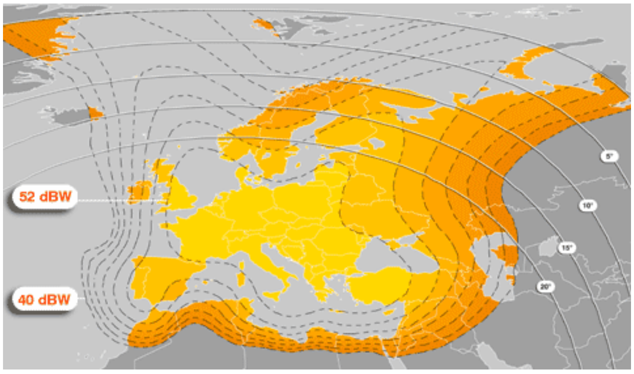

Fig. 7 W3 down-link footprints

6. HAP- SATELLITE HYBRID NETWORKS PLATFORM

The short term vision for fixed satellite access is a conservative evolution of current systems, which introduce requirements on the optimisation and standardisation of current systems.

The rapid deployment of concurrent access technologies and the extension of these technologies for video transport may lead to more rapid changes and evolution towards a longer term target vision, as for instance hybrid networks, where satellites are combined with terrestrial or more specifically lower orbit technology like High Altitude Platforms (HAPs) for fixed and mobile access (Fig.8).

HAPs have the potential to cost effectively deliver broadband services. A HAP is an airship or plane which operates 17-20 km above the earth's surface and provides a platform for communications services. The platform is quasi-stationary and unmanned, but unlike satellites may be returned to earth for periodic maintenance. Thus the reliability constraints (and costs) on components may be less stringent than those for satellites in orbit.

The 17-20 km altitude will allow a wide coverage area. The line of sight radius of coverage of a HAP situated 20 km above the earth's surface is 60-400 km.

High and Low Altitude Platform Stations (HAPS and LAPS) offer the coverage benefits of satellites at costs closer to fixed infrastructure. Several companies are developing different types of HAPS and LAPS technologies in order to provide satellite-type coverage at a fraction of the cost. **SkyTower** has developed a solar-powered, unmanned aircraft that can hover at an altitude of 18 kilometres for 7-14 days and for more than 6 months at lower altitude, covering a range between 80-400 km on the ground. Another company, **Skylinc** has a proposal to deploy 18 tethered air balloons across the United Kingdom that will hover 1.5 kilometres in the sky and supply access within an 80 km footprint.

The key market for LAPS and HAPS will likely be rural areas that are underserved by traditional infrastructure. However, they could also play a key role for newer wireless technologies such as WiMAX. HAPs are planned to provide high capacity to users (as with terrestrial networks), but provide a high coverage (as with satellite systems) [10].

7. E-LEARNING SATELLITE NETWORK INFRASTRUCTURES

Learning Centre's involvement in developing ICT strategies and implementing wireless and satellite technologies in several e-Learning projects provide some examples of how these technologies can deliver of education-focused Internet services to schools. Evaluations and key findings from these case studies can inform future designs and implementations.

7.1. Satellite Link for SchoolSat in Ireland

SchoolSat [11], an initiative funded by the European Space Agency, focuses on improving access to the Internet and delivering education-focused Internet services with an innovative two-way "Internet via satellite" network to remote Irish schools (see Fig. 9). ATiT Ireland managed the project, with Intel Innovation Centre and others providing the architecture and technical expertise.

ATiT Ireland implemented the satellite infrastructure and set up a multicasting service that provided selected educational content from a number of leading sources. Caching the content on a PC server at each school provided local access for students and teachers, which enabled a rich media learning experience. For interactive tasks, such as filling out questionnaires and online research, users could access the Internet via satellite return link.

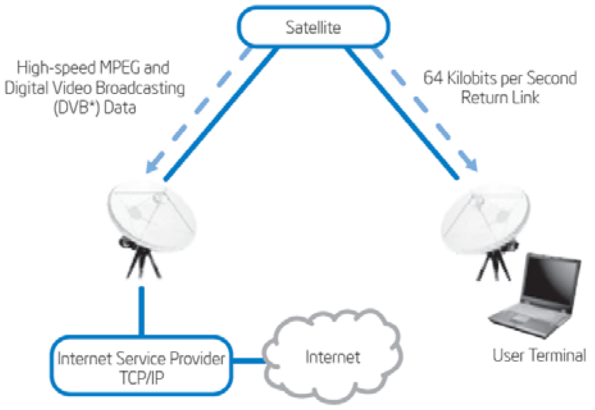

Fig. 9 SchoolSat technology overview

7.2. Streaming ECDL Courses in Austria using DVB-S –based Lecturing

In the centre of Linz [12], known as EDUCATION HIGHWAY operates the video studio as well as the media Encoder (Fig. 10). The streams are sent unicast to the AVD servers at the uplink site of Telekom Austria (TA) in Aflenz using a dedicated link to prevent from packet losses. Via satellite the data is transmitted multicast to the school. Each school is provided with a proxy server and a satellite antenna. The AVD proxy is integrated in the school network so that the workstations in school have access via that proxy.

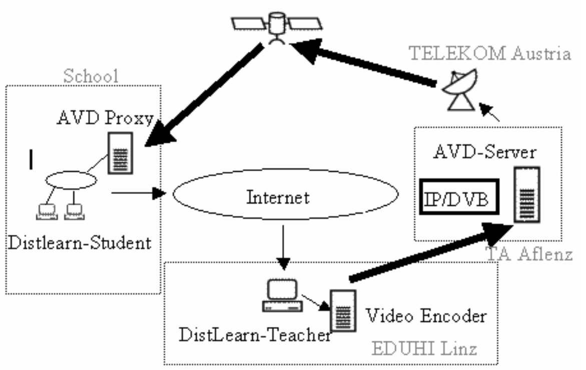

Fig. 10 Technical infrastructure of AVD project of European Computer Driving License (ECDL) courses

The forward satellite link is fed primarily with two IP-multicast streams: one composed of the audio/video generated by a Microsoft Media Encoder and the other one carrying the screen contents of a multicast Virtual Network Computing (mVNC). The audio/video streaming can be set to stay within a certain bandwidth limit. Most of the sessions have been limited to use 250 kbps, which proved to be sufficient and the resulting video quality was well accepted by the users.

Bandwidth requirements by mVNC, is within a few tens of kbps and is well below 1 Mbps during presentation.

7.3. SMART EDU Video eLearning & videoconference worldwide system

SMART EDU [13] combines advantages of a digital television and the Internet. The most important feature is to support of real-time video streaming with TV-quality which is missing in most of e-learning platforms today.

It also enables the interaction between Trainee and Trainer typically missing in television based trainings.

SMART EDU provides wide range of tools and technologies for a provision of trainings, meetings and conferencing incorporating high quality video and audio as most native and appealing media.

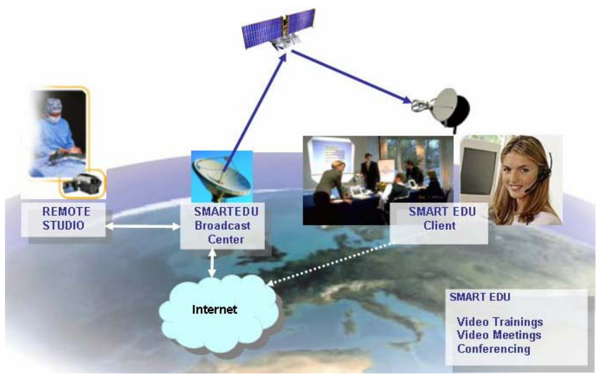

Fig. 11 SMART EDU Video eLearning & videoconference system

SMART EDU infrastructure consists of three main parts (Fig. 11): 1.) REMOTE STUDIO, 2.) BROADCAST CENTRE, 3.) CLIENT.

SMART EDU is a broadband multicast IP platform suitable for broadband satellite Internet networks. SMART EDU requires in average 1-2 Mbps for single audio/video channel real-time streaming. It provides TV quality video using MPEG compression.

Remote Studio provides intuitive interface for the preparation and live broadcast of video based trainings, conferences and meetings. Remote Studio is connected to the SMART EDU Broadcast Centre via a two-way broadband link. This can be through satellite (DVB RCS), land-line (ISDN, ATM, etc.) or microwave on a short distance.

The Broadcast Centre is a communication centre of SMART EDU. It broadcasts signal received from Remote Studio via a Digital TV or multicasts via an IP network. It links Remote Studio with **Clients** within a continent. Broadcast Centre is equipped with Web servers for Web functionality support.

7.4. The Teledoc2 Project in Italy

In the framework of the Teledoc2 Project, CNIT (National Inter-University Consortium for Telecommunications) has set up and operates an advanced proprietary satellite network that connects, in a mesh typology, 24 of its Research Units and Laboratories. The satellite network, based on the Skyplex technology, operates in Ka band and provides a guaranteed bandwidth of 2 Mbps shared among the connected terminals. CNIT selected EUTELSAT as space operator partner.

The main components of the satellite user station are (Fig. 3): an outdoor unit (a 90cm satellite dish); a Skyplex Ka-band terminal (a compact unit able to receive a downlink stream of up to 38 Mbps) and a multicast router (8-Box) both connected to a switch. The stream is assembled on board the HB6 satellite.

The CNIT Satellite network uses the HB6 satellite capacity. This satellite has 4 uplink European regions (Fig. 4): CNIT operates on the Italian spot. The uplink traffic from each single CNIT station is multiplexed onboard by the Skyplex payload. This satellite system will also enable the pan-European broadcast due to the downlink Ka coverage of HB6 [14].

The rationale behind such solution lies in the increased scalability that is achieved, at the expense of renouncing real-time two-way interactivity for the Ku receivers. The Ku receivers may be in principle a very large number, over the W3 coverage area (which includes Europe, the whole Mediterranean and North Africa), without affecting the bandwidth need. With this solution users located in the coverage area of the Eutelsat W3 satellite can attend the Teledoc2 lectures in no-interactive modality: they need a small parabolic antenna, a DVB-IP card and the Vip-Sat-Player software for receiving the lectures' transmission on Ku band network.

The most critical aspect to be taken into account in the local distribution of the Teledoc2 service refers to the management of multicast traffic [15].

7.5. The TUKE Project in Slovakia

At the formation of procedures and educational advances in e-learning we are always limited by ICT infrastructure offer considering the access to resources and process of delivering services. Slovak Universities Consortium in collaboration with other institutions (within the framework of government research and development program called Building Information Community) realize research in the field of methods/procedures, educational advances, learning technologies and e-learning type system architectures (within the case of research and development Utilization of ICT and network platforms for new generation in e-learning).

Within these projects were on the Technical University of Košice (TUKE) suggested an e-learning architecture and pilot e-learning platform to which components of satellite technologies have been implemented. The pilot platform was used for main testing of suggested procedures and educational e-learning advances developed within mentioned projects but also for testing of e-learning type architecture segments (hardware and software platforms). The Fig. 3 illustrates main idea of the satellite user station of the pilot e-learning platform used. The satellite receiving station tested in TUKE was equipped with:

- an outdoor unit (a 120 cm satellite dish);
- a SkyStar 2 PCI card capable for data satellite services or "High speed internet via satellite";
- a PC computer (Pentium4 2.8GHz, 512MB RAM).

We have selected the software that gave good performance according to the Teledoc2 service requirements:

- Quick Time (the digital media standard), with session description protocol *satnex.sdp*, obtain from the coordinator of the Teledoc2 project

On this software we made a lot of tests in other to evaluate the provided e-Learning QoS. For these evaluations we used subjective judgments, expressed by the participants in the tests.

E-Learning services exploiting satellite technologies were successfully tested (Fig. 12) and will in the future make sense for remote as well as sparsely populated areas.

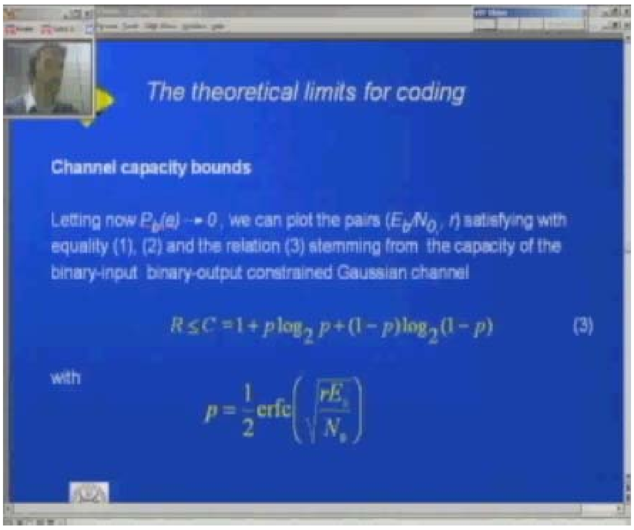

Fig. 12 En example of online Teledoc2 lecture's screenshot during TUKE project

8. CONCLUSIONS

The main characteristics of the satellite network developed by Learning Centres for its own connectivity services and experimental activity have been outlined in the paper. The network is entirely IP-based, with multicast capability to transmit of e-learning lectures.

In this paper a summary of different activities carried out in e-learning satellite network infrastructures has been reported. It is an apparent, the satellite technology used for this type of services offer several advantages:

- Gives schools fast access to the Internet
- Can be installed in any school regardless of location
- Can be installed quickly
- Gives a system capable of providing specific web-based content and digital resources to all schools instantly
- Can be integrated with other compatible services where such services exist

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BIOGRAPHIES

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Stanislav Marchevský received the M.Sc. in electrical engineering at the Faculty of Electrical Engineering, Czech Technical University in Prague, in 1976 and PhD. degree in radioelectronics at the TUKE in 1985. Currently he is a Professor of Electronics and Multimedia Communications Department of Faculty of Electrical Engineering and Informatics of TUKE. His research interests include image nonlinear filtering, multiuser detection, diversity communication over fading channel, power and bandwidth-efficient multiuser communications.

Ján Gamec was born in Stuľany, Slovakia in 1960. He graduated from the TUKE with specialization in Radiotechnics, Summa cum laude in 1985. He reached a Ph.D. degree in radioelectronics at the TUKE, Slovakia, in 1995. Since august 1985, he has been as an assistant professor in electronics and information technology at the TUKE. His main area of scientific research is digital image processing.

Mária Gamcová was born in 1965 in Rožňava, Slovakia. She graduated from the TUKE with specialization in Radioelectronics, Summa cum laude, in 1989. Since 1989, she has been as an assistant professor of electronics at the Department of Electronics and Multimedia Telecommunications of the TUKE. Her research comprises linear analogue systems and digital signal processing.

Slavomír Pillár was born in Bardejov, Slovakia, in 1975. He received the Ing. (MSc) degree in radioelectronics from the Faculty of Electrical Engineering, TUKE, Slovakia, in 2001. He is currently working as an electrotechnical engineer in Teleservis Ltd., Košice. Hi is interested in satellite communications and other satellite's services.