An IPTV service for academic and research communities

P. Balaouras[*,**], S. Sartzetakis[***]
[*]University of Athens, Dept. of Informatics & Telecommunications, Athens, Greece
[**] Greek Academic Network (GUnet), Athens, Greece
[***] Greek Research Network (GRnet), Athens, Greece
P.Balaouras@noc.uoa.gr, stelios@admin.grnet.gr

Abstract—In this paper, the design of an IPTV service developed for the Greek academic and research community, referred to as "grnetTV" service, is presented. The main design requirements were: a) to support a variety of content such as live events, DVB-T channels and pre-recorded material, b) to support academic users located at both multicast enabled academic and research networks and non-multicast networks, e.g., over ADSL lines, c) to provide an access control mechanism, allowing access to part of the content to the academic and research community. The main system requirements were the use of open source tools and compatibility with the most popular browsers and video players.

Several Internet TV channels are available by the "grnetTV" service, such as a) live sessions from the Hellenic (Greek) Parliament, b) digital channels (DVB-T) of the ERT S.A, the Hellenic Broadcasting Corporation, c) live events from the Greek Universities Network (GUnet) Media Center, d) recorded material from events organized by the Greek Research Network (GRnet) and universities.

The project aims to promote a) content creation by the Greek academic and research institutes, b) the use of multicast technology by the academic and research institutes, c) the use of GRnet's AAI infrastructure. More over, it elaborates on the potential and limitations of open source tools in the development of Internet TV services suitable for an academic and research environment.

I. INTRODUCTION

Today, transmitting television channels over IP networks is both feasible and popular. The broadcasting may be over a closed network of an Internet Service Provider (ISP) available only to the ISP's clients, referred to as IPTV service, or over the open Internet, available to the majority of Internet users, referred to as Internet TV service.

New applications and services are available for creating Internet TV channels [1,2]. Since these applications and services are commercial they are designed to meet the requirements of the average Internet user. Academic and research institutes might have different requirements, when designing their Internet TV services. These regard both functional (like restricted access), and technical issues (using open source, free-cost tools and legacy equipment). An issue that arises is how mature are the open source tools and at what degree they can fulfil the academic requirements. Addressing this issue was one of the main aims of the "grnetTV" project [3], which focused on the design of an IPTV service for the Greek academic and research community. Apart from revealing the potential and limitations of open source tools in the development of Internet TV services suitable for an academic and research environment, the project promoted content creation by the Greek academic and research institutes, the use of multicast technology by the academic and research networks, as well as the use of the GRNET Federation Authentication & Authorization Infrastructure (AAI) based on Shibboleth technology [4].

II. RELATED WORK

Several activities exist worldwide aiming at providing Internet TV services to the academic and research community, as well as multicasting Parliament sessions. In this section, three worth to mention cases are presented. The first case, University of Canberra (UC) TV (UCTV) [5], is an excellent example on how to provide DVB-T and DVB-S channels to a local academic community. The second case, the Réseau Académique Parisien TV (RAP TV) [6] demonstrates how to establish Internet TV channels that multicast pre-recorded video material. The last case, HEAnet and Irish Parliament, provides Webcasts and Internet TV Multicasts for the Irish Parliament [7].

The UCTV [5] offers an innovative live Internet TV service where as many as 40 different MPEG-2 broadcast TV channels are available as multicast streams on the campus network. The inputs are Digital Video Broadcast – Satellite (DVB-S) and Terrestrial (DVB-T) channels. UC also provides a Virtual Video Recorder (VVR) service. The aim is to enable the teaching staff to record television. The recorded material may be used in their existing educational environments, e.g., delivering edited portions of the material via their existing web-based learning systems.

The RAP TV [6] provides four IPTV channels, 2 MPEG-2 and 2 MPEG-4 channels, which multicast pre-recorded video disseminating research project results.

Finally, Live and Recorded Webcasts, and IPTV multicasts of the Irish Parliament [7] are provided by HEAnet. The Webcasts are available in a variety of bitrates. The television channels are converted from the Serial Digital Interface (SDI) video format supplied by the Oireachtas Broadcasting Unit, and are multicasted as MPEG2 streams at 3 MBit/sec bitrate.

In comparison to the aforementioned related activities, the "grnetTV" service uses DVB-T inputs, pre-recorded video material and SDI inputs, as in [5,6,7], respectively.

In addition, it broadcasts live lectures in High Definition format and offers Shibboleth based access control [4].

III. REQUIREMENTS

The requirements set for the "grnetTV" service may be classified into three major categories: content issues, users' functionality and technical/cost issues

A. Content issues requirements

During the design phase, the following content was specified for broadcasting: a) live sessions from the Hellenic (Greek) Parliament [8] already broadcasted in a closed cable TV network, b) digital channels (DVB-T) of the ERT S.A, the Hellenic Broadcasting Corporation [9], c) live lectures, from the Greek Academic Network (GUnet) [10] Teleteaching Classroom [11], d) recorded material from events organized by the Greek Research Network (GRnet) [12] and universities. Thus, the support of a variety of input formats was a strong requirement. Specifically, SDI inputs for the parliament's sessions, Digital Video Broadcast – Terrestrial (DVB-T) inputs for the ERT channels, High Definition (HD) camcoder's IEEE 1394 (firewire) input for live session and recorded files in Standard Definition (SD) and High Definition (HD) formats were specified as inputs for broadcasting.

B. User's functionality requirements

The first requirement was for a simple, friendly and attractive user interface (UI) that could be used by any non-expert Internet user. The UI had to be compatible with the most popular browsers. The streams had to be reproduced by free-cost players, and/or open source, if possible. Snapshots had to be periodically produced for the currently available streams, so that the users are aware about the status of the broadcasted channels in a friendly manner.

The second requirement of this category concerns the access to the content. The access should be restricted to academic and research institutes' users. However, access to the content should not only be feasible from campuses and offices but from external locations as well.

C. Technical and cost issues requirements

The main requirement was the use of open source and free-cost video players and tools at the highest degree possible. A second requirement was the use of hardware widely available in the market in order to ensure low costs.

IV. USER INTERFACE

As mentioned in the previous Section, the user interface (UI) has to be simple, friendly and attractive in order to attract and intuitively lead the non-expert Internet users to browse the "grnetTV" service site and watch the available channels. Also, all information should be addressed to users that are not experts. In Figure 1, the English version of the home page is depicted.

The home page was designed to provide introductory information about the "grnetTV" service and to lead the user to follow the proper path according to its Internet connection capabilities, which is crucial because different channels are provided over multicast and non-multicast enabled networks.

Figure 1: grnetTV's home page (English)

Figure 2a: Page for unicast access

Figure 2b: Page for multicast access

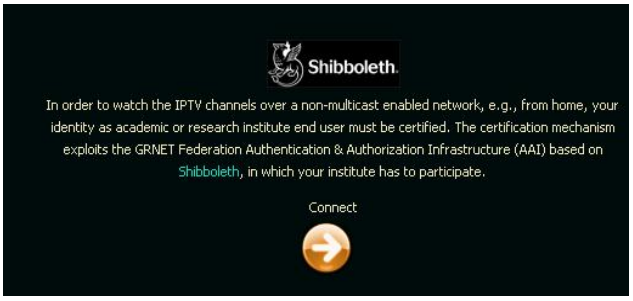

Figure 3: Information about the Shibboleth based authentication mechanism

The following options are provided to the users: i) to check if they are connected to a multicast or non-multicast

network, ii) to check their Internet connection speed. A minimum speed of 3 Mbps is required.

From the home page, the content administrators of the academic institutions are able to follow the administrator's link to upload video files and manage the uploaded video files.

The user may follow the "Unicast" or "Multicast" page, depending on its connectivity. Figures 2a and 2b depict the pages for unicast and multicast access, respectively. Different types of video streams - and consequently players - are supported by the unicast and multicast pages. The reason for different "Unicast" and "Multicast" pages is that does not exist, at least not known to the designers, any mechanism that transparently detects, in real time, whether the network on which the user is connected is multicast enabled or not. If such a mechanism were available, then the proper page (multicast or unicast) could be transparently appeared to the user.

The channels categories are presented as tabs on the upper left area: Parliament channels, ERT channels, National Internet channels, International Internet channels.

Links to information, instructions, help text, or contact form are situated on the upper right area. The help pages for unicast and multicast contain different content focused on the problems that appear in each case.

For each channel the logo, snapshots of the content and the streaming rate along with the players' logo which link to the channel pages appear. The snapshots are to indicate the broadcasting status. If no broadcasting exists, the "Not Available" notification appears, instead of the snapshot.

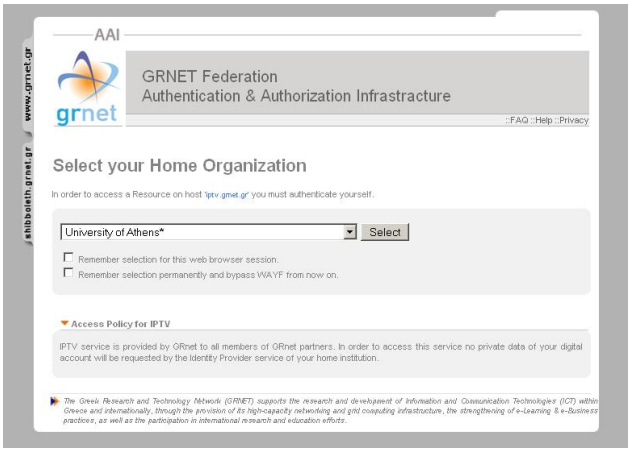

Figure 4: Page for user authentication

The Hellenic Parliament's channels are open-access. However the ERT channels are restricted-access, as discussed in Section 6. When a user follows the link "ERT channels" tab under the unicast case, the page depicted in Figure 3 appears and informs the user about the Shibboleth based authentication mechanism [4]. Then, the page depicted in Figure 4 appears to the user for submitting its account details.

V. ARCHITECTURE

In Figure 5, the service architecture is depicted. The first level, broadcasting, is responsible for delivering the MPEG-2 streams as UDP/Multicast IP flows. The second level, transcoding, is responsible for transcoding at real time the MPEG-2 to MPEG-4 streams and deliver them as RTP/UDP/Multicast IP flows. The third level, reflection, is responsible for reflecting the MPEG-4/RTP/UDP flows to unicast flows in order non-multicast users can receiver the MPEG-4 streams.

A. Broadcasting

For broadcasting the five parliament's sessions, a commercial MPEG-2 encoder that supports SDI inputs is used. Each session is broadcasted over multicast IP as MPEG-2 stream over the UDP protocol in a separated multicast IP address. A commercial encoder was selected for achieving unobstructed operation and high availability of the service. In cases that the cost should be kept low and the unobstructed operation is a lower priority, personal computers equipped with video capture cards might be used in conjunction with the VLC player, instead of a commercial MPEG-2 encoder.

For broadcasting the two ERT's DVB-T channels the following setup, suggested by [13], is used. A DVB-T USB tuner, compatible to the defyne drivers [15], connected to an Apple mini MAC system receives the DVB-T signal. The defyne's simple streaming server (sss) software [14] and the drivers [15] are used in a similar way as presented in [13]. The sss software de-multiplexes the DVB-T channels and sends the data streams of the two channels to local ports as MPEG-2/UDP streams. The VideoLan Client (VLC) [16] tool is used to receive the MPEG-2/UDP streams and multicast them over Internet.

For broadcasting the lectures in High Definition (HD), a consumer HDV camcoder and a PC equipped with a Pentium 4, 2.8 Ghz CPU, 2 Gbytes RAM, Windows XP and Firewire are used. The VLC tool is used to multicast the HD data as MPEG-2/UDP stream at 25 Mbps rate. The supported analysis is 1440x1080. Detailed instructions are available in [3] under the link "How to".

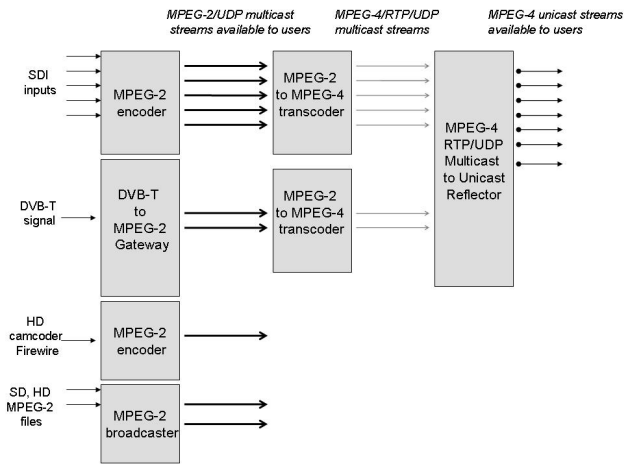

Figure 5. Architecture

For broadcasting pre-recorded MPEG-2 files the VLC software tool and a Linux server equipped with 2 dual core Intel Xeon CPUs (2Ghz) and 1 Gbytes RAM are used. In particular, the VLC is launched with the VideoLan Manager (VLM) module taking as parameter a configuration file that determines the broadcast schedule of the pre-recorded files. A bash shell script has been developed to automatically generate the configuration file every day. The administrator has only to create a directory tree where the files that are to be broadcasted are stored. The script reads the directory structure and calculates the

duration of the video files to create the broadcast schedule. The schedules of two different channels, one that broadcasts standard definition (SD) video files and one that broadcasts high definition video files (1440 x 1080) are included in a single configuration file.

B. Reflecting multicast streams to unicast

The reflection of multicast streams to unicast permits users located at non-multicast enabled networks to watch the channels. A Darwin Streaming Server (DSS) 5.5 [17] installed on the aforementioned Linux system is used as the multicast to unicast reflector. The DSS is capable for reflecting only MPEG-4 streams. Therefore, the MPEG-2 streams have to be transcoded to MPEG-4 streams and encapsulated in RTP/UDP [18] packets in real time. The description of the transcoding process follows in the next paragraph. For each broadcast, an sdp file, that is the file that includes the information about the broadcast, as specified by the Session Description Protocol, has to be placed in the movie directory of the DSS. The users have to access the associated sdp file with the Real Time Streaming Protocol (rtsp) [19] in order to connect to the DSS and receive the MPEG-4 stream as a unicast stream. An RTSP URL corresponds to each channel. This URL links to the channel's associated sdp file. A user has to know and follow the RTSP URL to watch a channel over unicast. Any site may provide the channel's URL to direct the users to the channel.

C. Transcoding

The MPEG-2/UDP streams are transcoded on the fly to MPEG-4/RTP/UDP streams by the VLC tool. Two systems are used for the transcoding. An Apple mini MAC system transcodes the two streams originated from the DVB-T, whereas a Linux system, transcodes the streams originated from the Hellenic Parliament.

D. Getting snapshots

A bash shell script has been developed in order to periodically create snapshots of the video streams. The script is listening to the multicast addresses and the ports of the broadcasts and creates images in the jpeg format by using the VLC tool. These images are available to the users from the service's page. The existence of a channel snapshot indicates that the channel is being broadcasted.

VI. ACCESS CONTROL

All channels are available over multicast. Since, traditionally only the academic and research institutions' networks are open multicast enabled, the content is restricted to users situated within the academic networks.

Some of the channels, i.e., Parliament and ERT channels, are available over non-multicast enabled networks as well. These channels are distinguished to open (Parliament) and restricted access channels (ERT). The open-access channels are available to all Internet users. However, the restricted-access channels are only available to users of academic and research institutes. In order the latter users to receive the streams over a non-multicast enabled network, e.g., from home, their identity as academic or research institute user must be authenticated. The authentication mechanism makes use of the GRNET Federation Authentication & Authorization Infrastructure (AAI) in which the user's institute has to participate. The AAI is based on the Shibboleth System [4]. Below, we elaborate on how the access control is implemented.

A. Open-access channels

As already mentioned in Section V.B, an RTSP URL corresponds to each channel. In our approach, even for the open-access channels, the content of their sdp files is protected from the users so that they are accessed only from the official site of the "grnetTV" service. There are two reasons behind this: to facilitate the central collection of statistics for the access to the channels over unicast, and at the same time to prohibit easy "repackaging" of the service by others.

When a user follows a unicast link (see Figure 1), soft links to the sdp files, one per channel, and a new http page for the open-access channels (actually the Parliament channels page shown in Figure 2a) are created dynamically by a PHP script. Each soft link, referred to as sdp link, has a unique random name for the specific user and is located in the movie directory of the DSS to be accessible by the player over RTSP. The dynamically generated http page includes an http page per channel which includes a RTSP URL pointer to the sdp link. For instance, the following http page:

```
http://vodserver:8080/viewsource/template.html?n
5vr58wtqq58gjxBqeoj20feBa2Es7tix2geBCECm74An4tg
```

includes an RTSP URL pointer of the following type:

```
rtsp://vodserver:port/uni_free/olo/random.sdp
```

A cron script runs periodically every 3 minutes and removes the sdp links. The sdp link is available for 1.5 minutes at average. After this period, the user has to access the page again. So, even if an end user would make known the unique RTSP URL, this URL would be useless as it would already have expired.

B. Restricted-access channels

Upon a user provides its credentials and is successfully authenticated, a PHP script dynamically generates the http page of the restricted-accessed channels (see Figure 2b). The dynamically generated http page includes an http URL per channel which includes a RTSP URL pointer to the sdp link, similarly to the case of the open-access channels. The PHP script is located in a directory that is protected by the Shibboleth mechanism. For example, in the following URL, the script ert_channels.php is located in the directory /unicast/secure of an apache server, which is protected by Shibboleth.

```
http://server/unicast/secure/ert_channels.php
```

So, each user is forced to be certified by using the Shibboleth based authentication mechanism. The Shibboleth concept and the authentication process are discussed in the next paragraph.

C. What is Shibboleth?

Shibboleth is open source software for providing access control. In a Shibboleth based access control mechanism, a user authenticates with his organizational credentials, e.g. its account detail in his university. The organization (or identity provider), e.g., his university, passes the minimal identity information necessary to the service manager, e.g., the "grnetTV" service in our case, to enable an authorization decision. Let us elaborate on the authentication process.

First, the user has to authenticate at his Home Organization, e.g., 'University of Athens'.

Therefore, the user's web browser gets redirected to the WAYF ('Where Are You From') server. In this example it is on wayf.grnet.gr. The role of the WAYF server is to present a list of Home Organizations to the user. The user selects his Home Organization 'University of Athens' (see Figure 4) and is redirected to its login page at University of Athens. In case the Home Organization has been selected earlier and remembered by the web browser, this step might be skipped.

The user sees the familiar login page of 'University of Athens' and provides his login name and password. If login name and password match, the user is redirected back to the resource, e.g., "grnetTV" service page, he initially requested.

After successful authentication of the user at his Home Organization, the resource decides on granting or denying him access. In the background, the Home Organization provided minimal user details to the Resource, which is required for the access authorization decision and for delivering its service. Data protection is assured.

Basically, the Shibboleth login process is like any other login process. To access a protected resource, e.g., a protected video link, the user has to authenticate. However, in the Shibboleth case, the user authenticates himself not at the resource, e.g., GRnet, itself but at his Home Organization, e.g., his university. He does not need an additional account at each resource nor has he to provide his username and password to third parties, but only to his Home Organization.

Once a Shibboleth user is authenticated, he can access any other Shibboleth-enabled resources, e.g., other protected video links, without providing his login name and password again. This is only necessary if the user closes his web browser or if no Shibboleth resource is accessed for some time. For a series of technical explanations of how Shibboleth works, from easy to expert, refer to [4,20].

VII. COMPATIBILITY ISSUES

As mentioned in Section II, the user interface should be compatible with the most popular browsers, whereas the video streams should be reproduced by free-cost or open source players, if possible.

In the case of multicast streaming, for reproducing the MPEG-2 video streams, the VLC player is used either embedded (VLC plug-in) or in standalone mode. The VLC plug-in is compatible with the following browsers: Internet Explorer 8, Firefox 3.0.5, Opera 9.6, and Safari 3.1. In case the users encounter problems using the embedded VLC player, e.g. if they use a non MS-Windows system, they may use the VLC player in standalone mode. In that case they have to follow the link of the m3u symbol, which will load the VLC player, provided that the .m3u file type extension is associated with the VLC player.

In the case of unicast streaming, for reproducing the MPEG-4 video streams, a variety of popular video players may be used: the embedded QuickTime player, the VLC player embedded or in standalone mode, the RealPlayer in standalone mode and the Windows Media Player in standalone mode, provided that the VBrick plug-in [21] has been installed and the .m3u file extension is associated with Windows Media Player. The QuickTime player and the VLC plug-in are compatible with the following browsers: Internet Explorer 8, Firefox 3.0.5, Opera 9.6, Safari 3.1. Table I presents the compatibility matrix

TABLE I. COMPATIBILITY MATRIX

Types of stream	Players	Browsers
MPEG-2 multicast	VLC plug-in, VLC	IE8, Firefox 3.0.5, Opera 9.6, Safari 3.1
MPEG-4 unicast	QuickTime plug-in, VLC plug-in, RealPlayer, VLC, WMPlayer with VBrick plug-in	IE8, Firefox 3.0.5, Opera 9.6, Safari 3.1

VIII. OTHER FUNCTIONALITY

In the previous sections, the following functionalities, addressed to users, were elaborated: a) checking the network capabilities, b) creating snapshots to monitor the status of broadcasting, c) providing access control via Shibboleth. Apart from these functionalities, extensive help is provided to users in the form of "How to" instructions and Frequently Answered Questions (FAQ). In case a user can not resolve the problem s/he encounters, a contact form is provided for reporting the problem in a formal way.

The functionality of uploading large video files for broadcasting in GRnet's channels is provided to the content administrators of the academic and research institutes connected to GRnet.

The following functionalities are provided to the service administrator: i) a user report management application which enables the administrator to manage problem reports submitted by the users; ii) an application that enables the administrator to manage the uploaded video files, the administrator may review, approve or reject content submitted for broadcasting by the institute's content administrators; iii) a script that generates the configuration file that includes the schedule of the file broadcasting; iv) a NAGIOS based service [22] that monitors the broadcasting and sends e-mail notifications to the administrator, if the broadcasting fails.

IX. FURTHER WORK

The "grnetTV" service may be extended to support the following new functionalities and features.

A. Recording option and integration with VoD services and grid transcoding

Authenticated users will be able to request recording of a channel for a specific time window. The service would record the video file which will be provided through a Video on Demand (VoD) service. The users will be able to select the desired video format, as well. In that case, the recorded video file may be transcoded by exploiting a video transcoding service based on GRID infrastructure.

B. On line scheduling

A web-service that would enable the service administrator to schedule the broadcasting on line. That is, the administrator will be able to select a series of video

files from a pool of files and create a channel that broadcasts the files in a specific order.

C. H.264 encoding

Support of the H.264 encoding format for broadcasting, instead of MPEG-4 format. This is expected to increase the perceived quality of the video streams for the same bandwidth consumed or decrease the bandwidth consumption for the same perceived quality.

X. SERVICE STATUS AND USAGE

Although, the "grnetTV" service is in productive status, its usage, shown in Table II, is rather limited due to technical and marketing factors.

The service has been promoted only to the network administrators of the academic and research institutions as well as the Hellenic Parliament's broadcasting unit. Each institution has to take some technical preparation actions before the "grnetTV" service become available to its end-users, such as: a) enable the multicast feeds in its routers and internal network and b) join the Shibboleth based GRnet Federation for Authentication & Authorization in order its end users be able to authenticate and receive the restricted unicast-based channels. It is expected that in the next few months, after the preparation actions, the service will be available and promoted to the end users, and consequently its usage be increased. Taken into account the above, the limited usage shown in Table II for the open-access multicast-based channels and the unicast-based restricted channels (ERT's channels) is reasonable.

TABLE II. USAGE STATISTICS (01/01/08-31/08/08)

Channels	Visitors	Views	Access
Unicast			
Parliament	18954	92531	Open
ERT	1240	8291	Restricted
Multicast			
Parliament	698	5205	Open
ERT	656	3162	Open
grnetTV	946	7603	Open

In opposite, the open-access unicast-based channels of the Hellenic Parliament present a relatively significant increased usage. Apart from the fact that no technical action is required for accessing these channels, a factor that affects positively their usage is that these channels are promoted by the Hellenic Parliament's site [8].

XI. CONCLUSIONS

The development of an IPTV service for the Greek Academic and Research community was presented. It was shown that provision of IPTV channels is feasible using open source tools and low cost equipment. A variety of content type, i.e., parliament sessions, DVB-T channels, lectures and live events, recorded events, as well as a variety of inputs, i.e., SDI. DVB-T signals, camcoder's firewire, video files can be supported. A rich set of functionalities can also be supported: a) watching MPEG-2 channels over multicast (SD and HD channels) and MPEG-4 channels over non-multicast IP networks; b) providing access control via Shibboleth; c) checking network connection capabilities; d) providing snapshots; e) monitoring the status of broadcasting; f) providing problem reports and management applications; g) video file uploading and management application; h) a script for creating the broadcast schedule for channels based on pre-recorded video material.

New functionality, such as recording, transcoding and H.264 based encoding can be added.

The overall service is compatible with the most popular browsers, i.e., Firefox 3.0.5, Internet Explorer 8, Opera 9.6, Safari 3.1 and video players, i.e., VideoLan (VLC 9.8a), QuickTime Player, RealPlayer and Windows Media Player under conditions.

ACKNOWLEDGEMENTS

The authors would like to acknowledge their colleagues for their contribution to the project management and service development: Zenon Mousmoulas (GRnet), Stavroula (Stevy) Georgiadi (GUnet), Prof. Lazaros Merakos, Dr. Spiros Bolis, Vanessa Skiadelli, Dr. Michalis Gatzonis, Pavlos Dandrakis, Nikos Voutsinas (UoA).

REFERENCES

[1] Joost – TV. http://www.joost.com
[2] Mogulus. http://www.mogulus.com
[3] The grnet TV service. http://iptv.grnet.gr
[4] The Shibboleth System. http://shibboleth.internet2.edu
[5] University of Canberra TV. http://uctv.canberra.edu.au/about-uctv
[6] The RAP TV http://www.rap.prd.fr/services/tv.php
[7] Oireachtas Webcasting and Multicasting Service. http://www.oireachtas.ie
[8] The Hellenic Parliament. http://www.parliament.gr
[9] The Hellenic Broadcasting Corporation (ERT). http://www.ert.gr
[10] The Greek Academic Network (GUnet). http://www.gunet.gr
[11] Support center for eLearning and Media Production – GUnet. http://mc.gunet.gr
[12] The Greek Research Network. http://www.grnet.gr
[13] George Bray, James Steele. Stream Digital TV. Technical report 2007. University of Canberra TV http://uctv.canberra.edu.au/documentation/mac-mini-tv-relay/
[14] John Dalgliesh. Defyne's Simple Streaming Server (sss). http://www.defyne.org/dvb/ under "Development
[15] John Dalgliesh. Defyne's DVB Drivers for Mac. http://www.defyne.org/dvb/driver.html
[16] The VideoLan Client (VLC). http://www.videolan.org
[17] The Darwin Streaming Server. http://www.apple.com/quicktime/streamingserver/
[18] RTP: A Transport Protocol for Real-Time Applications. http://rfc.sunsite.dk/rfc/rfc3550.html
[19] The Real Time Streaming Protocol. http://rfc.sunsite.dk/rfc/rfc2326.html
[20] SWITCH Federation site.http://www.switch.ch/aai/demo/easy.html
[21] Vbrick player. www.vbrick.com/software
[22] Open Source host, service and network monitoring program. http://www.nagios.org