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# Glossary

| Abbreviation / acronym | Description |
|---|---|
| ADSL | Asymmetric Digital Subscriber Line |
| AVC | Advanced Video Coding |
| CA | Conditional Access |
| CAS | Conditional Access system |
| CC | Continuity Check |
| CW | Control word |
| DSL | Digital Subscriber Line |
| ECM | Entitlement Control Messages carry the keys that are used to unlock the encrypted content |
| EMM | Entitlement management message |
| H.264/MPEG-4 AVC | Codec developed by the ITU-T Video Coding Experts Group |
| IDR | I-frame known as an instantaneous decoder refresh (IDR) frame |
| Metro Network | A metropolitan area network (MAN) is a network that usually spans a city. An MAN usually interconnects a number of local area networks (LANs) using a high-capacity backbone technology, and provides uplink services to wide area networks (or WAN) and the Internet. |
| MGS | Medium Grain Scalability |
| MPEG | Moving Picture Experts Group |
| NAL | Network Abstraction Layer |
| OP | Operation Point is defined as a unique combination of temporal and quality levels |
| PAT | Program Association Table |
| PCR | Program Clock Reference |
| PDA | Packet Dropping Algorithm |
| PDD | Packet Dropping Device |
| PID | Packet Identifier |
| PMT | Program Map Table |
| Priority ID | Priority ID is associated to the pair of {T (temporal layer), Q (quality layer)} provided by the NAL unit header. |
| PSI | Program Specific Information, metadata about a program (channel) and part of a MPEG transport stream, the PSI data contains five tables:<br>PAT (Program Association Table)<br>CAT (Conditional Access Table)<br>PMT (Program Map Table)<br>NIT (Network Information Table)<br>TDT (Time and Date Table) |
| RTP | Real-time Transport Protocol |
| SPTS | Single Program Transport Stream |

| | |
|---|---|
| STB | Set-Top Box |
| SVC | Scalable Video Coding |
| TS | Transport Stream |
| UDP | User Datagram Protocol |

# 1. Executive Summary

The main goal of this project is to develop an efficient solution for IPTV operators to provide HD video streams to users which have a limited access bandwidth and to optimize bandwidth usage for IPTV video streaming. WP7 deals with the System Integration.

This document describes the system integration strategy with its different phases according to the integration planning defined in D.7.1 and the list of tests performed from unitary to end to end tests for the two approaches presented in [1] and [2] for providing an HD IPTV service of quality:

<u>Approach 1: AVC video encoding with multiple profiles</u>

For the system integration of this approach, live encoders are used, which generate multiple H.264/AVC [4] streams encapsulated in MPEG-2 TS [6] at different bit rates as indicated in [2]. The whole IPTV chain is built checking also with an existing commercial STB that the described solution works properly and the promised benefits under limited access bandwidth are achieved.

For this approach several streams of the same content are generated at the Head End at different rates and are encapsulated in MPEG-2 TS in a single program, i.e. a Multi-video SPTS is generated. This Multi-video SPTS is sent in multicast diffusion and adapted at the Packet Dropping Device (PDD) [1], which forwards a unique version of the video contained in the Multi-video SPTS, i.e. the PDD forwards a Single-video SPTS. The PDD is responsible for switching from one video version to another depending on the available throughput and the signalization in the stream where switching points are marked, as described in [2].

<u>Approach 2: SVC video encoding</u>

For the system integration of this approach an offline encoder is used generating an SVC [5] stream using MGS SNR scalability which is encapsulated in MPEG-2 TS [6] packets and, subsequently, in a set of RTP packets as described in [2], achieving thus multiple bitrates mapped to different amount SVC layers. The whole IPTV chain is built and an emulated STB is used for testing that the described solution works properly and the promised benefits under limited access bandwidth are achieved.

For this approach a Single-video SPTS is sent from the Head End with the SVC encoded content. During the encapsulation process, a special tagging mechanism is performed consisting in signalling the different operation points that can be achieved by forwarding a different amount of data, i.e. performing bitstream shaping. This method is more explicitly explained in [2] but basically it consists in assigning different priority values (Priority IDs) to the different RTP packets depending on the contained data. Different Operation Points (OPs) are defined based on the *temporal_id* and *quality_id* in the SVC extension header of the NAL units [5] of the SVC stream. Then, based on the defined OPs, the MPEG-2 TS packets are encapsulated into RTP [10] streams where, depending on the OP to which the data in the MPEG-2TS belong to, a given Priority ID is assigned. This Priority ID is added into the SSRC field of the RTP, so that the PDD can find this information and decide whether to drop or keep a packet in the stream which is delivered to the STB. Thus, depending on the available throughput, a different amount of layers or different operation points are delivered to each STB.

# 2. Introduction

The deliverable D.7.2 - Integration Test Report describes the procedures taken for integration and the problems found during integration, as well as the solutions that have been applied for overcoming the detected problems.

# 3. Description of the Integration

As defined in D7.1 the integration plan was divided in 3 main phases: the pre-integrations test, a first phase of the integration and a second phase of the integration. Once finalized these three phases the IPTV solution developed within OptiBand is ready for carrying the live Test in WP8.

## 3.1 Update on IPTV Components

During the integration of the equipment into the IPTV system some problems have been encountered. Therefore, additional components have been added to the system as a backup to the potential problems that will be explained in the following sections. The components (cf. Figure 1 and Figure 2), which the built up system consists of, are listed in Table 1, where the new components (with respect to D7.1) are marked in blue:

***Table 1: IPTV System components***

| Component | Description | Partner |
|---|---|---|
| Live Multi-video-Encoder | This component refers to the H.264/AVC Multi-video SPTS with embedded Multiplexer defined in section 4.3 in [2]. The input of this component is video content via an HD/SDI interface and the output is a Multi-video SPTS over UDP. | TVN |
| Live Single-video-Encoder | This component refers to the Nx[H.264/AVC Single video SPTS] described in section 4.2 in [2]. The input of this component is video content via an HD/SDI interface and the output is a Single-video SPTS over UDP. | OPT |
| SVC Content generator | This component refers to the SVC based Head End described in section 5 in [2]. It encapsulates pre-encoded content and transmits it to the network. This component can be used as a VoD server, which provides content on request or can also emulate Live content from the pre-encoded content. The encapsulation into a transport format and scrambling are performed in a live manner. | HHI |
| MPEG Multiplexer | This component is described in section 4.2 in [2] and is responsible for creating a Multi-video SPTS out of several Single-video SPTS of the same content. Its input is several Single-video SPTS of the same content at different rates and the output is the corresponding Multi-video SPTS over UDP. | TVN |
| Middleware | As described in section 3.3 in [2] the middleware is a client-server software that connects end users to the video head-end, e.g. allowing end users to browse media content available in networks. The middleware at the server side contains information of the multicast channels and the middleware at the client (STB) exchanges information with the middleware at the server for service discovery. | INTEROUD |
| STB (Web:TV) | This component is described in section 3.5.1 in [3] and it is an AVC-capable set-top-box integrated with the INTEROUD's middleware. As part of the OptiBand project, this STB was integrated with the conditional access system (CAS) provided by IRD. | INTEROUD |
| STB | This component is an AVC-capable set-top-box that has an integrated conditional access system (CAS) from | IRD |

| | | |
|---|---|---|
| | IRD (section 5.5.2). This component does not use the INTEROUD's middleware but it can be used to test the CAS in separation from the STB-head-end interaction. | |
| SVC STB Emulator | This component is described in section 3.5.2 in [3] and it is a PC based client that is used as a STB emulator capable of decoding SVC streams. | UDC/HHI |
| Encryption/Decryption components:<br>- IRD Key Management System<br>- IRD IPTV Scrambler<br>- IRD KeyServer | These components are described in section 4.4 in [2]. The encryption components (at the server) take the input MPEG-2 TS, scramble the content and introduce the ECMs into the stream so that the decryption component (at the client, i.e. STB) can descramble it and produce as an output a clear MPEG-2 TS content. | IRD |
| Descrambler | The component was purchased by IRD to mitigate the risk of the delayed CAS integration on the STB. The descrambler can be placed before the STB, so a scrambled MPEG-2 TS is decrypted by the descrambler and is passed to the STB as a clear MPEG-2 TS. The component allows testing the CAS system and the PDD in separation from any STB. | IRD |
| MB-PDD | This component refers to the Multi-Bitrate Packet Dropping Device (MB-PDD) described in section 3.1.2 in [1]. The input of this device is different Multi-video SPTS and the output is the different channels with a Single-Video SPTS. | CSL |
| SVC-PDD | SVC-PDD refers to the device in Section 3.2.2 in [1]. The input is a Single-video SPTS with several layers transmitted over RTP for priority tagging, as explained in section 3.1.2 in [2]. The output of the SVC-PDD is a Single-video SPTS with a possibly varying number of layers of SVC over RTP or directly over UDP. | HHI |
| 2 PCs | These PCs are configured as sniffers, in order to allow a better debug, sequences recordings. | TI |
| Further laboratory equipment | See section 8.1 in D7.1 | TI |

## 3.2 Updated IPTV System

Figure 1 and Figure 2 show the result of the system integration, i.e. the complete IPTV system solution developed within this project, for the two different approaches: the AVC multi rate and the SVC approach. It consists of all the components developed by all partners. Similar schemes have been presented in D7.1 but some updates have been done showing the currently installed solution in TI.

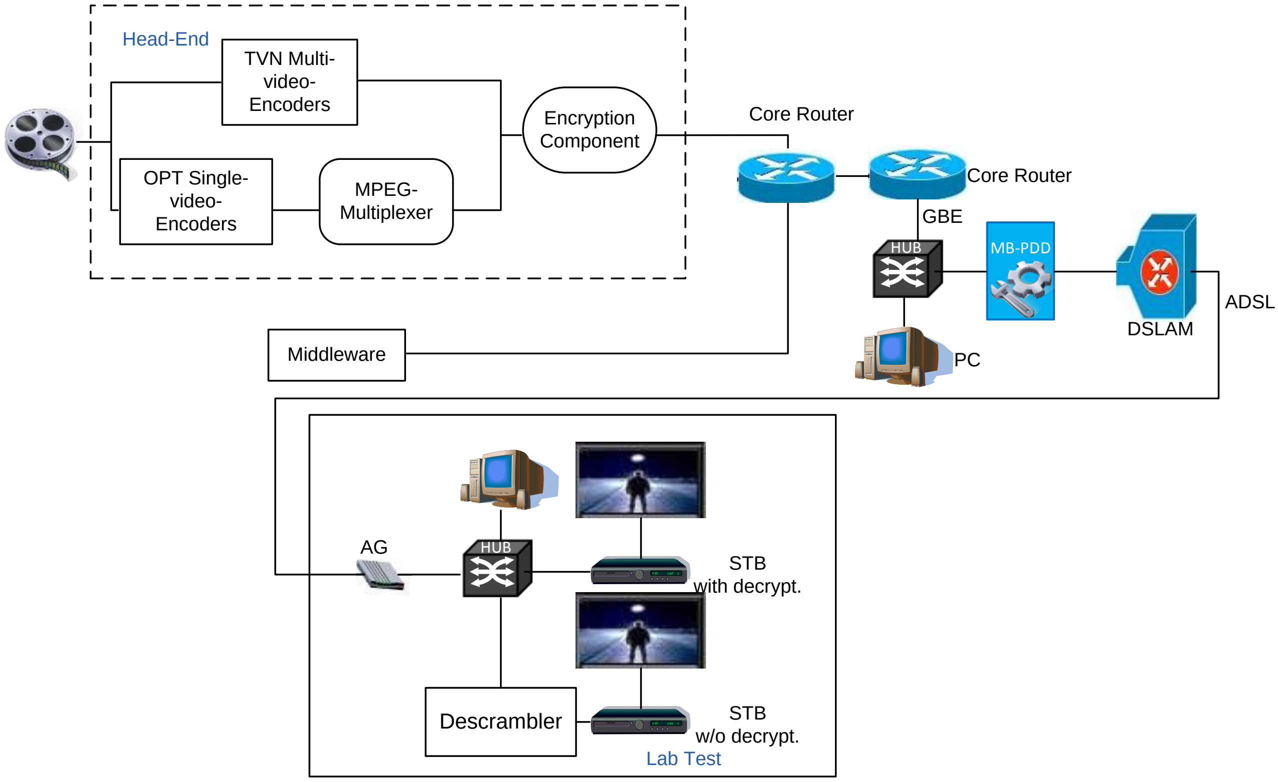


*Figure 1: System Architecture of the complete integrated IPTV for the AVC multi rate approach*

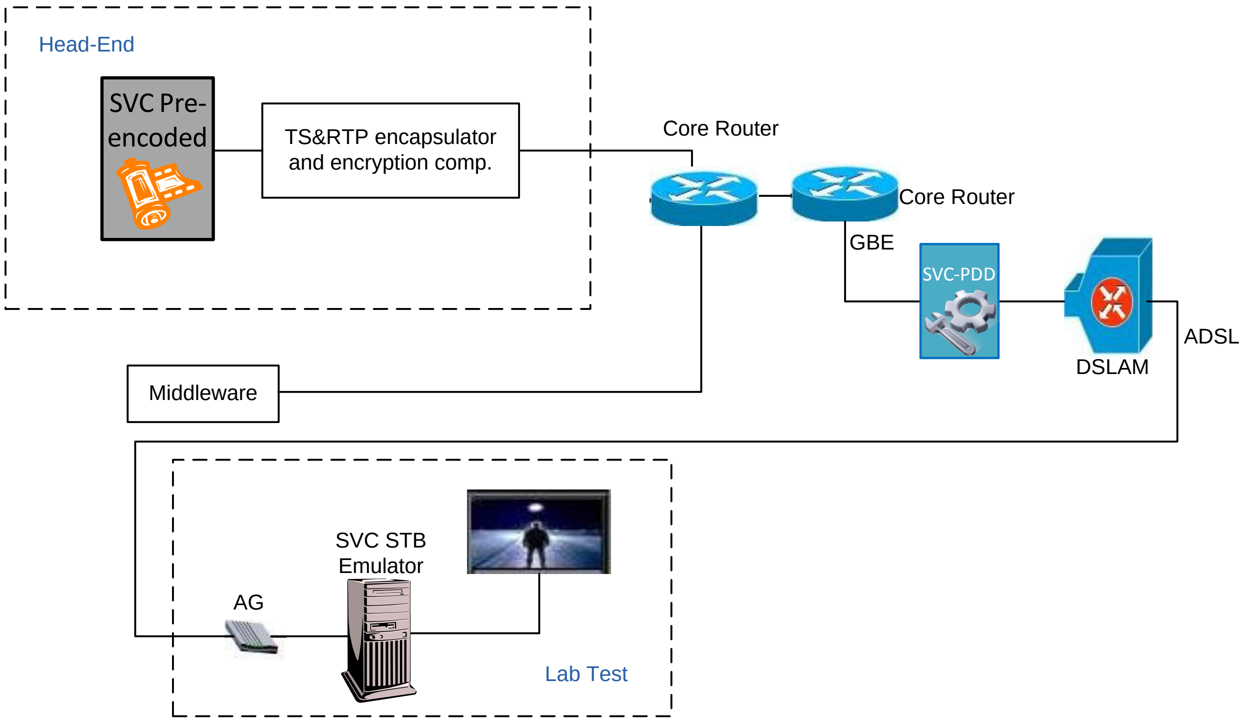


*Figure 2: System Architecture of the complete integrated IPTV for the SVC approach*

# 4. Pre-integration step

As described in D.7.1, during these steps partners have collaborated to make sure that the developed equipment work properly and interact with other components to avoid finding out problems when integration is done in TI and therefore prevent unnecessary problems by fixing them before the installation.

## 4.1 PT-I: Interoperability between Middleware and STB

This test has been carried out by INTEROUD and UDC. The STB and the middleware are connected together, the middleware is configured so that it advertises some multicast channels and it was proven that both devices exchange information for channel discovery and that the STB finds the information configured at the middleware.

For the AVC-based approach, the Web:TV STB, a commercial AVC-capable STB, is used, while for the SVC-based approach the SVC STB Emulator developed by UDC/HHI is used.

## 4.2 PT-II: Interoperability between Encoders and STB

### 4.2.1 AVC-based approach

In order to allow checking that the content generated by the encoders is correct and can be consumed and processed by the STB, the generated streams have been recorded and sent to INTEROUD.

Table 2 and Table 3 show the characteristics of the streams send to INTEROUD by TVN, while Table 4 and Table 5 show the streams sent to INTEROUD by OPTEC. In both cases, the streams were played without any problem by the STB.

***Table 2: Recorded Single video SPTS streams for the Live Multi-video-Encoder (TVN)***

| H264 Single video SPTS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Reference Clips** | **Standard** | **Video mode** | **GOP length** | **Program number** | **PMT PID** | **PCR PID** | **video PIDs** | **Encoded rates Mb/s** | **Video Format** | **Single video SPTS sequences files** |
| documentary DOCU_A | H264 | CBR | variable | 1 | 100 | 1000 | 1000 | 7.26 | HD 1080i 1440 | TVN_DocuA_HD1440SinglevidSPTS_7.26.trp |

***Table 3: Recorded Multi video SPTS streams for the Live Multi-video-Encoder (TVN)***

<table>
<tr><th colspan="11">H264 Multi video SPTS</th></tr>
<tr><th>Reference Clips</th><th>Standard</th><th>Video mode</th><th>GOP length</th><th>Program number</th><th>PMT PID</th><th>PCR PID</th><th>video PIDs</th><th>Encoded rates Mb/s</th><th>Video Format</th><th>Multi video SPTS sequences files</th></tr>
<tr><td rowspan="3">documentary DOCU_A</td><td rowspan="3">H264</td><td rowspan="3">CBR</td><td rowspan="3">variable</td><td rowspan="3">1</td><td rowspan="3">100</td><td rowspan="3">1002</td><td>1000</td><td>7.26</td><td>HD 1080i 1440</td><td rowspan="3">TVN_DocuA_HD1440MultividSPTS_7.26_5.81_4.3.trp<br><br>LongseqTVN_DocuA_HD1440MultividSPTS_7.26_5.81_4.3.trp</td></tr>
<tr><td>1001</td><td>5.81</td><td>HD 1080i 1440</td></tr>
<tr><td>1002</td><td>4.3</td><td>HD 1080i 1440</td></tr>
</table>

*Table 4: Recorded Single video SPTS streams for the Live Single-video-Encoder (OPTEC)*

| H264 Single video SPTS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Reference Clips | Standard | Video mode | GOP length | Program number | PMT PID | video PIDs | Encoded rates Mb/s | Video Format | Single video SPTS sequences files |
| Action | H264 | CBR | fixed | 1 | 100 | 1001 | 8.0 | HD 1920i 1080 | OptTestFile1.ts |
| Action | H264 | CBR | fixed | 1 | 100 | 1001 | 6.5 | HD 1920i 1080 | OptTestFile2.ts |
| Action | H264 | CBR | fixed | 1 | 100 | 1001 | 4.95 | HD 1920i 1080 | OptTestFile3.ts |
| Action | H264 | CBR | fixed | 1 | 100 | 1001 | 3.45 | HD 1920i 1080 | OptTestFile4.ts |

*Table 5: Recorded Multi video SPTS streams for the Live Single-video-Encoder (OPTEC)*

| H264 Multi video SPTS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Reference Clips | Standard | Video mode | GOP length | Program number | PMT PID | video PIDs | Encoded rates Mb/s | Video Format | Multi video SPTS sequences files |
| | | | | | | 1001 | 8.0 | HD 1920i 1080 | |
| | | | | | | 1002 | 6.5 | HD 1920i 1080 | |
| | | | | | | 1003 | 4.95 | HD 1920i 1080 | |
| Action | H264 | CBR | fixed | 1 | 100 | 1004 | 3.45 | HD 1920i 1080 | OPT_MSPTSMUX.ts |

### 4.2.2 SVC-based approach

In case of the SVC approach, the SVC STB Emulator is fed with SVC content. The partners responsible for this test are HHI and UDC. The encoded SVC stream is encapsulated in TS forming a Single-Video SPTS and further encapsulated into RTP and the SVC STB Emulator is fed with this stream. As expected, the content can be played back correctly.

Furthermore, since SVC is AVC backward compatible it is also tested that the AVC capable STBs can process the SVC Single-video SPTS, decoding the base layer. Therefore, HHI recorded the generated SVC content, and was sent to INTEROUD. The base layer could be processed by the AVC-STB. For later tests in the Lab the AVC-STB is not used, since the SVC solution will be VoD and RTSP and RTP are used. Instead, a VLC without SVC decoder is used to show backward compatibility to AVC-capable STBs.

## 4.3 PT-III: Interoperability between Live Single-Encoder and MPEG multiplexer

In order to test in advance the correct operation of the Live Single-video-Encoder with the external MPEG Multiplexer, TVN sent the multiplexer to OPTEC premises. There, the MPEG multiplexer was configured and specific smoothing modules were added by OPTEC to its encoders to achieve a correct configuration of the multiplexer. The output of the multiplexer was analysed, checking that the PIDs of the different streams of the Multi-video SPTS were correct, as well as PCRs and priority_flags in TS packets were consistently written. The Live Single-video-Encoder and MPEG Multiplexer worked correctly.

## 4.4 PT-IV: Interoperability between Encoders (and optional MPEG multiplexer) and PDD

### 4.4.1 AVC-based approach

The same streams shown in Table 2, Table 3, Table 4 and Table 5 were sent to CSL. These streams were used to feed the PDD and it was checked that the streams were correctly generated and that the PDD was able to operate with the received streams, adapting the content from one stream version to another.

### 4.4.2 SVC-based approach

For the SVC-based approach, SVC content was used for the SVC-PDD at HHI. It was checked that the SVC-PDD can process properly the data, generating an RTP stream with a variable number of SVC layers. It was proven that the SVC-Head End and SVC-PDD work properly together.

## 4.5 PT-V: Interoperability between Encoders (and optional MPEG multiplexer) and Encryption component

The same streams shown in Table 2, Table 3, Table 4 and Table 5 were sent to IRD. The provided streams were scrambled and descrambled by IRD, proving that the output of the encoders can be correctly handled by the encryption components.

## 4.6 PT-VI: Interoperability between Encryption component and PDD

### 4.6.1 AVC-based approach

The output of the PDD when switching from one stream to the other was verified by IRD for the presence of the correct MPEG-2 TS program specific information that is required for successful descrambling of the content and for the continuity of the TS packets, showing that the developed solution is working as expected.

## 4.7 PT-VII: Interoperability between Encryption component and STB

In order to allow checking that the content scrambled by the encryption component can be processed by the STB, three sub-tests were defined as follows:

1) The first test was to verify that the scrambling and descrambling were performed correctly by the encryption component and the STB, respectively. IRD created a SPTS that was scrambled with a single control word (CW) and provided the stream along with the control word to INTEROUD. INTEROUD accessed the test stream by the STB, while providing the descrambling component

integrated on the STB with the abovementioned CW. The test allowed checking the scrambling functionality in separation from the ECM/EMM handling. The test stream was played successfully on the STB, proving the basic interoperability between the encryption component and the STB.

2) The second test was to check that the processing of the ECMs was done correctly by the STB. IRD created a scrambled SPTS, where the control words were carried by a ‘special-purpose’ ECMs that could be processed by a STB without the need of EMMs. INTEROUD played the test stream on the STB, with the control words being successfully extracted from ECMs. The test proved that the ECMs were encrypted correctly by the encryption component and were processed correctly by the STB.

3) The third test was to prove that there was a full interoperability between the encryption component and the STB. For this test, the STB had to register with the IRD Key Management System, process EMMs that were sent by the KMS, process ECMs and then decrypt content.

The completion of the third test was delayed due to technical problems in the CAS integration with the Web:TV STB.. However, with the other two approaches it is confirmed that encryption does not interfere with the solution proposed in the OptiBand project. As a mitigation step, IRD has delivered a set-top-box that offers an integrated conditional access system (CAS). The abovementioned STB has successfully passed the interoperability tests, proving that the encryption is transparent for the end to end system and can be used for further testing if necessary. Finally, after detecting and solving the CAS integration issues, the Web:TV STB is able to play encrypted contents with the IRD CAS system, although not integrated in TI since the other mitigation strategies had been already installed and passed the interoperability tests.

## 4.8 PT-VIII: Interoperability between output of PDD and STB

### 4.8.1 AVC-based approach

The output of the PDD when switching from one stream to the other was sent to INTEROUD and the correct processing of the data was checked, showing that the developed solution was working as expected.

### 4.8.2 SVC-based approach

In order to check whether the output of the PDD could be correctly decoded and presented at the STB-Emulator, the PDD was configured to perform switching from one operation point to another. The SVC STB-Emulator decoded and presented the content correctly.

# 5. Stand-alone installation of components

This section describes the stand-alone installation of the components explaining found problems and applied solutions.

## 5.1 Network installation and Setup

The installation and setup of the network was carried out by TI and entailed the arrangement of the rack that hosts the equipment. The Network Switch was configured as well as the DSLAM, the latter in IGMP snooping mode. Two Windows servers were installed for the SVC solution, where the SVC Head End and SVC PDD were installed. The set-up of the authoring tools that was used to feed the live encoders was also installed in the network and the network for remote access to equipment was arranged. This network was used for installation, configuration and debug of the rest of components.

## 5.2 EI-I: Middleware installation

The Middleware was remotely installed the 7th of November, consisting in installing an auto-installable DVD in the server. The image was uploaded to TI's FTP and then installed in the middleware servers.

The first versions of the install DVD had some problems with the RAID controller. Therefore, a new version of the installer was created to be able to install the middleware in TI's servers (shown in Figure 3).

TI has been entitled to manage the Middleware through a remote administration interface, being able to provision STBs and configure channels. Testing correct operation of the middleware is carried out remotely. It was checked that new channels could be added and that the middleware answers to the requests done to the advertised URLs: either by answering “user not authorised” or by providing the information of the "available" multicast channels. After carrying out these tests it was concluded that the middleware has been correctly installed and is properly working.

***Figure 3: Middleware***

# 5.3 EI-II: STB/SVC STB Emulator installation

The installation of the STB or SVC STB Emulator consisted in connecting the STB or SVC STB Emulator to the network as shown in Figure 4 and Figure 5 respectively. Further, the STB had to be configured with the URL of the middleware server, as well as the credentials already configured in the middleware server.

## 5.3.1 AVC-based approach

As described in D.7.1 and shown in Figure 4, the next step was to install the STBs. The STBs were sent by mail to TI and were installed the 7th of November by TI with support from INTEROUD. The STBs were checked with the testing sequences available in the middleware server, and it was checked that the advertised channels were seen at the STBs.

The problems encountered during the installation of the STB were that NTP date configuration was not updated via DHCP as the STBs don't support that option. Therefore, the STBs showed problems after been turned on for a long time. Zapping from the remote did not work any longer and STBs had to be restarted. Although this was not in principle a big problem, since the STBs worked for a long enough time not to cause problems during the live tests, a solution was found to solve the NTP problem, by generating specific firmware images with a hardcoded configuration so that they could take their time configuration from TI's NTP date servers. Since INTEROUD tried to reproduce the stability problems in their Lab unsuccessfully and this problem did not appear any more, this problem was concluded to disappear with current middleware version.

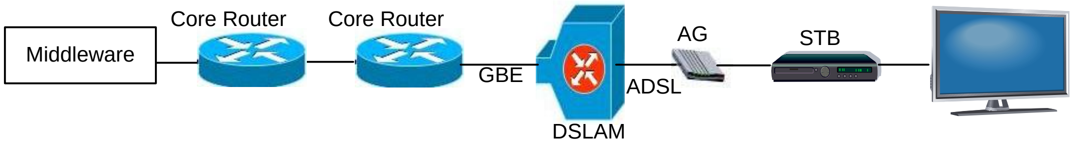


***Figure 4: AVC capable STB installation***

## 5.3.2 SVC-based approach

For the SVC case, a Laptop was shipped to TI and was installed in the network as shown in Figure 5. The software corresponding to the STB emulator was sent to TI at the beginning of January and guidance in the installation was provided. However, the software provided by HHI was protected with some licensing that was not correctly working so it was repaired by HHI at in February, when they attended to install the complete SVC solution.

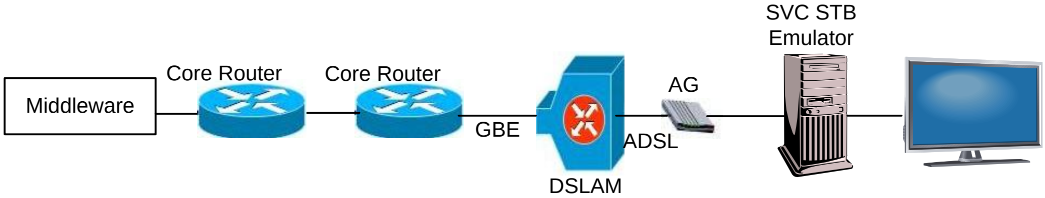


***Figure 5: SVC STB Emulator installation***

In order to not hinder the AVC installation by adding VoD channels that cannot coexist with the AVC setup, after checking the capability of the SVC STB emulator of exchanging information with the middleware, the information about the channels was configured in the STB emulator directly.

# 5.4 EI-III: Real Time Encoder or SVC Content generator installation

## 5.4.1 AVC-based approach

For the AVC-based approach, there are two techniques as described in [2]:

- The 2 [Single-video STPS encoder] (here referred to as “Single-video-Encoder”) followed by an external multiplexer, each Single-video-Encoder producing 4 versions of the same content.
- The Multi-video SPTS encoder with internal multiplexer (here referred to as “Multi-video-Encoder”). In D.7.1 it was stated that the Multi-video-Encoder would produce 2 versions of the stream per encoder but that the possibility of increasing the version (bitrates) of streams in the multi-video SPTS would be analysed. The currently installed Multi-video encoder cluster produces now 3 a SPTS with 3 bitrates.

In this step the two techniques are installed as shown in the following figure.

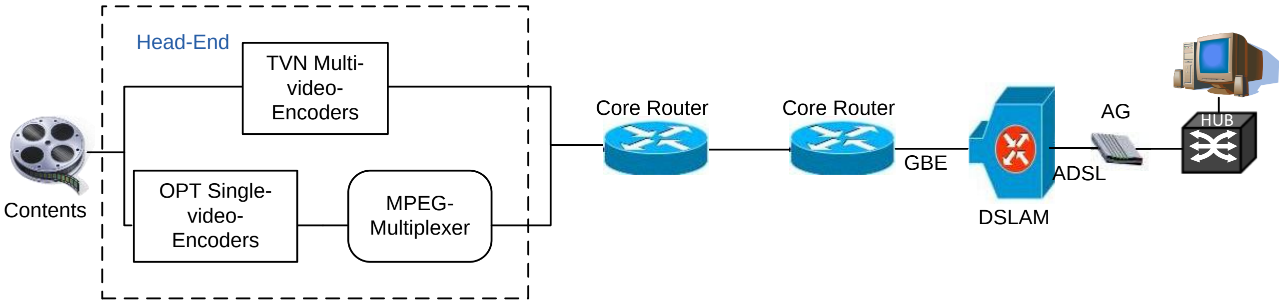


***Figure 6: Installation of head-end of the multi-rate approaches without encryption component***

### 5.4.1.1 Multi-rate SPTS AVC encoder with external Mux

The installation of the 2 Single-video-Encoders was also carried out during the second week of January on the 10th and 11th, where OPTEC came to TI premises to install their equipment.

The installation was done according to the system architecture defined in D.5.2. Optibase provided multi-rate encoding solution based on the company H.264 encoding blades with modified software.


***Figure 7: TVN and OPTEC Multi-rate Encoders in the System rack***

Two OPTEC multi-rate encoders were installed inside 1U chassis and connected to the HD SDI source as shown in Figure 7 on the top (see Encoder1 and Encoder2). The output of the encoders (multi-TS over UDP) has been sent over the LAN towards TVN multiplexer. Management and data interfaces were configured according to the TI addressing plan as depicted below.

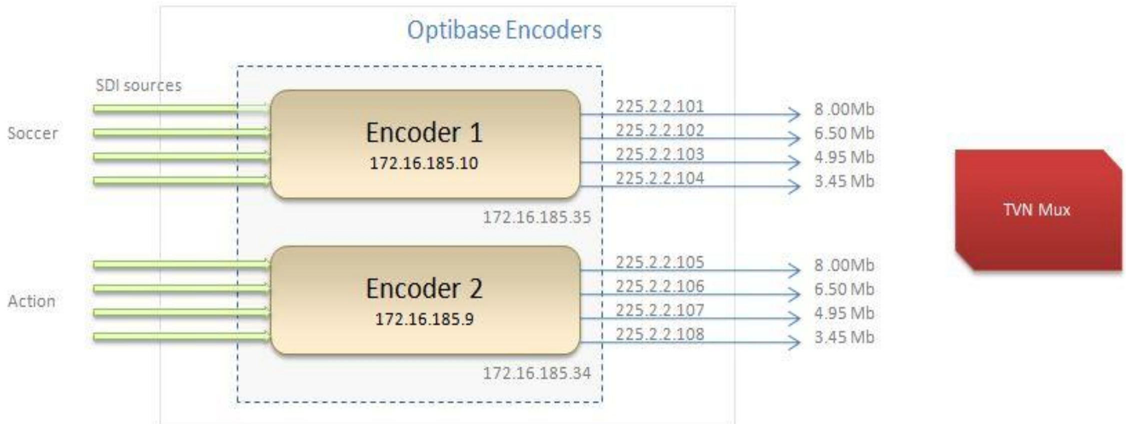


***Figure 8: OPTEC Multirate Encoders network configuration.***

Generally, each encoding blade comprises 4 independent H.264 encoders. Every encoder consists of IO module and main processing module. In order to comply with the TI setup SDI IO board has been used. The encoders capture the HD SDI source and encode it into HD H.264 video. The embedded audio is extracted and encoded into AAC format being multiplexed with each of the encoded video versions. The resulting elementary streams are sent to the internal MPEG TS multiplexer, which multiplexes all versions dropping all audio streams but one. A memory buffer with multiplexed packets is sent to specially developed Packet

Processing module which performed IDR lookout and tagging, as defined in OptiBand architecture. The output of the Packet Processing module is provided as an input to the rate shaping (smoothing) mechanism, and then to the UDP streamer. Additionally, a special control mechanism has been implemented in order to synchronize all the 4 streams inside each board. The resulting output are 4 SPTS, each of them composed by a different H264 encoded video with a given bitrate with an AAC encoded Audio (the same for all SPTS).

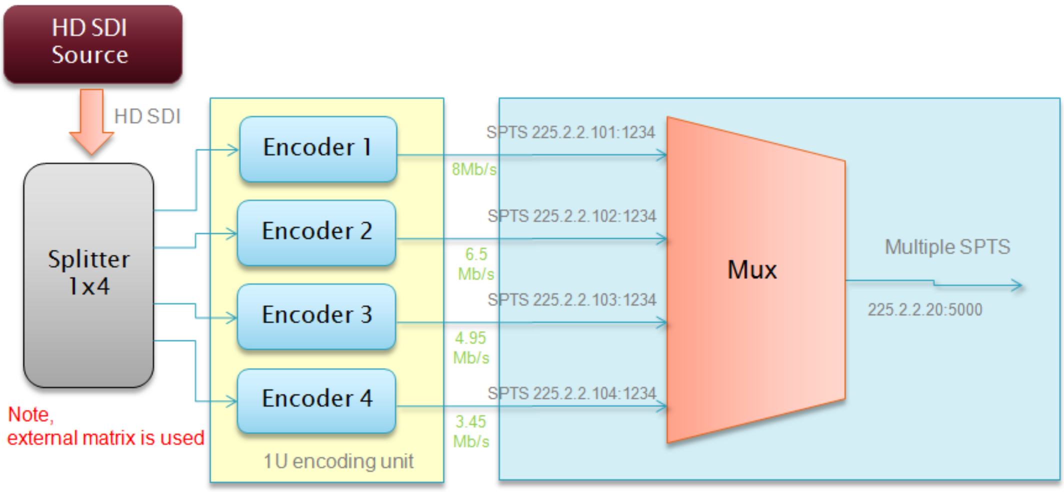


***Figure 9: Encoder blade with external Mux.***

The 4 SPTS streams are then used for input of the external multiplexer as shown in Figure 9. The multiplexer outputs a multi video SPTS with all the 4 SPTS streams multiplexed but only keeping an audio stream, by removing the duplicated audio streams on other SPTS.

The MPEG multiplexer was installed on both MGMT and DATA network according to TI addressing plan. Once the Single-video-Encoders validation was done by OPTEC, the MPEG multiplexer was checked for MGMT and DATA network. The TS over UDP streams coming from the Single-video-Encoders and sent in multicast diffusion were accessed by the MPEG multiplexer to create the required Multi-video SPTS. A configuration was created on site for two Multi-video SPTS. Each Multi-video SPTS was composed by four different H264 encoded video (with four different rates) and one AAC encoded Audio. Both 4 streams Multi-video SPTS ran smoothly on the Blu:Sens Set Top box.

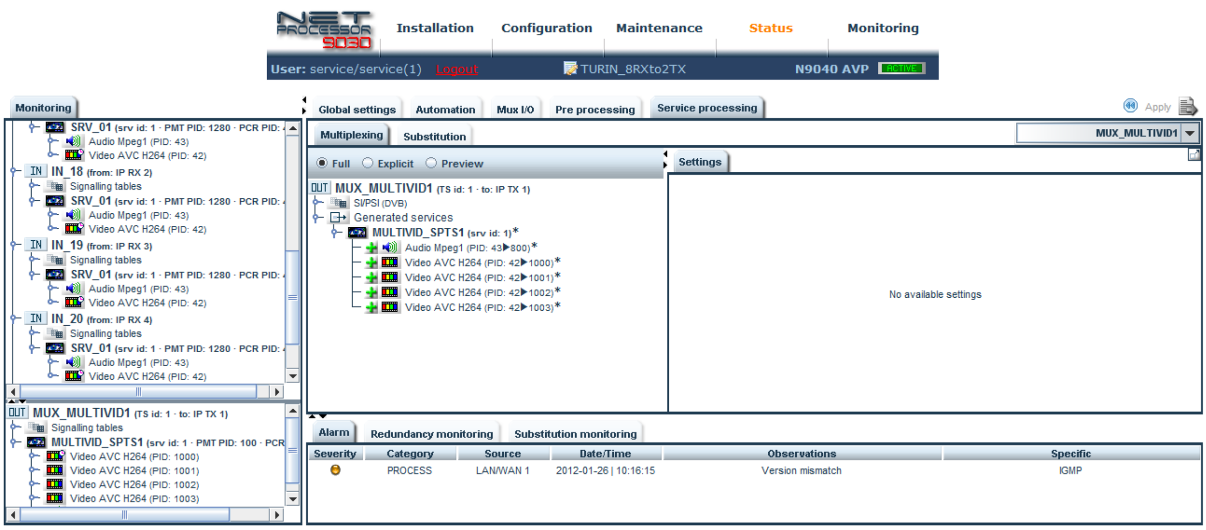


***Figure 10: 8RX to 2TX Multi-video SPTS Mux configuration***

The new Multi-video SPTS streams were sent in multicast diffusion (@IP: 225.2.2.21 : 1234 and @IP: 225.2.2.22 :1234), the STB accessed to these multicast address so as to check the consistency for H264 video and AAC audio pre-encoded contents. The characteristics of such an output are shown in Figure 11 in terms of cumulative bitrate as follows. The lowest bitrate corresponds to the highest video bitrate, the next bitrate shown corresponds to the highest video bitrate and medium high bitrate. The next bitrate includes, besides the mentioned bitrates, the video with medium low bitrate, while the next bitrate also includes the video with medium low bitrate. Finally, the last bitrate value corresponds to the whole SPTS, i.e. including also audio.

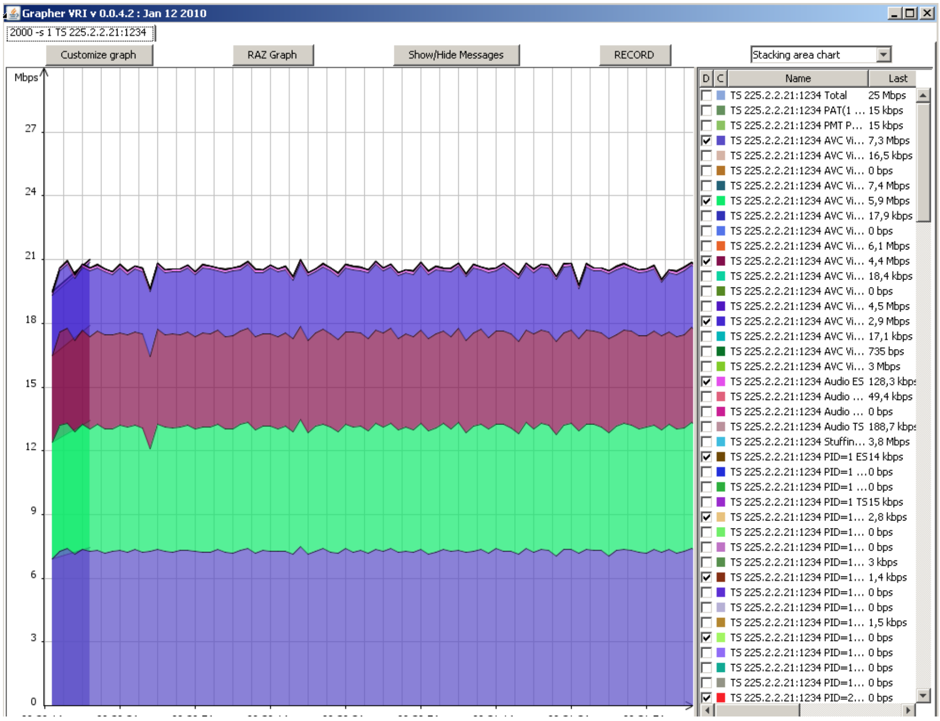


***Figure 11: Four rates Single-video SPTS + Mux sequence with one audio recorded on site***

The configuration of the encoders is shown in the following table:

***Table 6: Encoder Configuration***

| 1st Encoder | 2nd Encoder |
|---|---|
| **User/Password**<br>Administrator/Administrator<br><br>**Management**<br>172.16.185.10<br>255.255.255.0<br><br>**Streaming**<br>172.16.185.35<br>255.255.255.224<br>172.16.185.33<br><br>**Output**<br>225.2.2.101-104:1234<br><br>**Bitrates**<br>8000000<br>6500000 | **User/Password**<br>Administrator/Administrator<br><br>**Management**<br>172.16.185.9<br>255.255.255.0<br><br>**Streaming**<br>172.16.185.34<br>255.255.255.224<br>172.16.185.33<br><br>**Output**<br>225.2.2.105-108:1234<br><br>**Bitrates**<br>8000000<br>6500000 |

| | |
|---|---|
| 4950000<br>3450000 | 4950000<br>3450000 |

After the installation each encoding channel was independently checked with software player as well as compliant STB in order to verify that the encoded stream, as for the Multi-video-SPTS. Streams were also captured and analysed whether they contained the OptiBand tagging bits and whether they were correctly set. Tests with TVN multiplexer were performed in order to verify the encoder/mux interoperability and as for the Multi-video-Encoder, sequences were captured and sent to CSL for verification, as shown in the following table.

***Table 7: Single-video SPTS with external Mux on site recordings***

| H264 Single video SPTS + external MPEG Multiplexer | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reference Clips** | **Standard** | **Video mode** | **GOP length** | **Program number** | **PMT PID** | **video PIDs** | **PCR PID** | **audio PIDs** | **Encoded rates Mb/s** | **Video Audio Format** | **Multi video SPTS sequences files with TVN and TI tools** |
| | | | | | 100 | 1000 | 1000 | | 7.26 | HD 1080i 1920 | GrapherDump_20120111_110836_TS225.2.2.21_1234_.pcap<br>GrapherDump_20120111_112758_TS225.2.2.21_1234_.pcap<br>GrapherDump_20120111_113727_TS225.2.2.21_1234_.pcap<br>GrapherDump_20120111_114500_TS225.2.2.21_1234_.pcap<br><br>Avatar-Enc1.mpg(1 loop)<br>DieHard-Enc1.mpg(1 loop)<br>Soccer-Enc1.mpg(1 loop) |
| | | | | | | 1001 | 1000 | | 5.8 (-20%) | HD 1080i 1920 | |
| | | | | | | 1002 | 1000 | | 4.3 (-40%) | HD 1080i 1920 | |
| | | | | | | 1003 | 1000 | | 2.9 (-60%) | HD 1080i 1920 | |
| Action or Soccer | H264 | CBR | fixed | 1 | | | | 800 | 0.128 | AAC audio | |

During the installation process some issues arose. The platform was not responding after arrival to TI, since during the shipments some electrical wiring was displaced, which was repaired on site. However, encoding blades were not stable overnight, and while debugging the multiplexer setup one encoder's network configuration caused it to stop responding. Furthermore the encoders' management failed and they could not be configured with neither the keyboard nor the mouse, since they did not work. All this small problems were repaired, by taking the flash card of the encoders, which was carried later by CSL in one trip to TI. During the tests done it was discovered that not all 4 streams were perfectly synchronized, but only three of them, being one of the streams slightly unsynchronized.

After making some work in OPTEC, some problems that were discovered in the software were repaired and it can be said that everything is working fine, as expected.

## 5.4.1.2Multi-rate SPTS AVC encoder with internal multiplexer

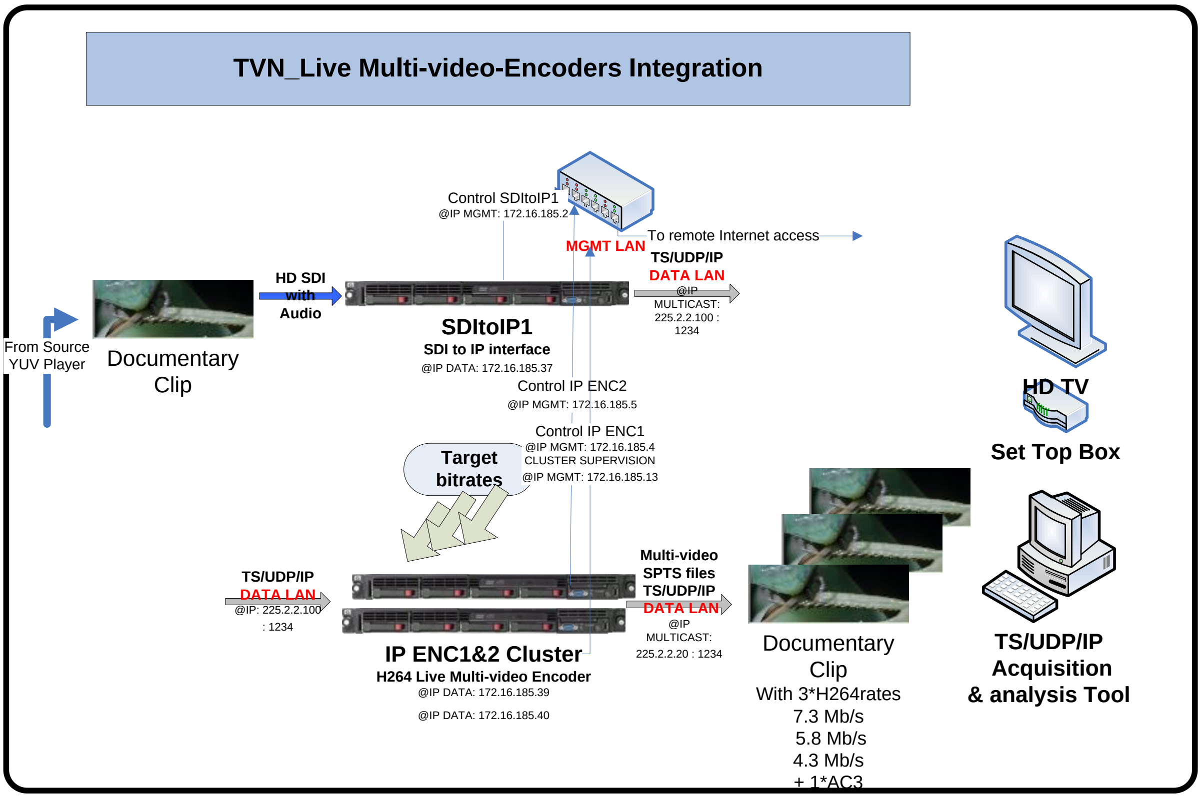


***Figure 12: Installation of the Multi-video-Encoders in the IPTV system***

The installation of the Multi-video-Encoder solution was carried out the second week of January on the 10th, 11th and 12th, in TI where TVN went to install their equipment. The installed equipment can be seen in Figure 7 (see IP ENC1 and IP ENC2). It entailed connecting the original content player via an HD/SDI interface to the SDItoIP1 interface, connecting the SDItoIP1 interface to a cluster of Multi-video-Encoders using the dedicated DATA LAN and the Multi-video-Encoders output to the switch. The final output is a Multi-video SPTS over UDP as in this solution the multiplexer is embedded within the encoders cluster. The SDItoIP1 interface and the multirate cluster solution (IPENC1 and IPENC2) were installed on both MGMT and DATA network according to TI addressing plan (see D7.2).

First the SDItoIP1 interface was checked for MGMT and DATA network:

a) Using an AVATAR pre-encoded video test pattern embedded in the SDItoIP1 interface in a first approach to free from the Live HD/SDI input and then,

b) Using the Live HD/SDI input stream.

A TS over IP stream was sent in multicast diffusion (@IP: 225.2.2.100 : 1234), the STB accessed to this multicast address so as to check the consistency for H264 video and AC3 audio pre-encoded contents.

After this first validation, the multirate cluster solution was checked for MGMT and DATA network.

The TS over IP stream coming from the SDItoIP1 interface and sent in multicast diffusion was accessed by the cluster to create the Multi-video SPTS using a dedicated workflow as shown below.

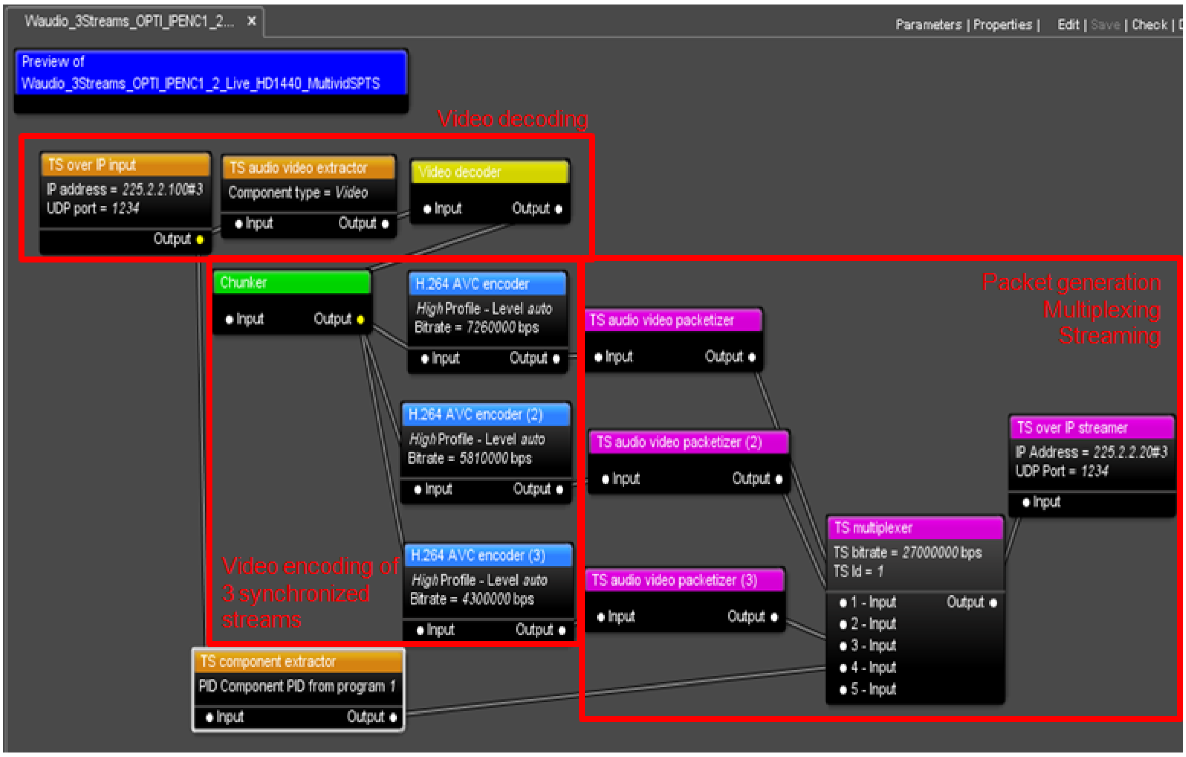


***Figure 13: Multi-video-Encoders workflow***

TVN developed for OptiBand project a Multi synchronized audio/video encoding dedicated workflow in order to create the required Multi-video SPTS. This framework is based on a pipeline architecture of processing modules. The workflow is composed by modules connected together and parameters for each module are filled in (e.g. GOP size and structure, encoding rates, MPEG TS metadata, streaming multicast address). Once the workflow is defined, it is required to be instantiated in order to launch the corresponding processing job.

The first part (red block) “Video decoding” corresponds to the processing modules of TS/UDP/IP acquisition, video component extraction (IP and MPEG2 system layers extraction) and then decoding to YUV internal format.

The second part “Video encoding of three synchronized streams” corresponds to the processing modules, Chunker module for synchronizing GOPs for the different encoded streams so that the same frame is encoded as IDR in all streams every 2 seconds, i.e. in all three H264/AVC 1080i encoding modules with the three defined bitrates.

The third and last part corresponds to the processing modules for MPEG2 system packetization module multiplexing of the three synchronized streams and audio component and final module for TS/UDP/IP live streaming.

The DTS (Digital Theatre System) audio component previously de-embedded from SDI stream by the SDItoIP1 interface is AC3 encoded in the aftermath. So the AC3 audio component is just multiplexed and streamed by the cluster.

The output result achieved on site is a Multi-video SPTS composed of three different H264 encoded video (with three different rates) with one AC3 encoded Audio. This Multi-video SPTS is sent in multicast diffusion (@IP: 225.2.2.20 : 1234). In order to check the consistency of the three different H264 encoded video and AC3 audio encoded contents, the STB accessed to this multicast address. The characteristics of such an output are shown in Figure 14 in terms of cumulative bitrate, where the lowest bitrate is for the audio, the next bitrate shown corresponds to the audio and highest video bitrate, the next bitrate also including the video with medium bitrate and the last bitrate value corresponding to the whole SPTS. As can be seen, while TVN encoders are initially fully CBR as used to be implemented for IPTV, in order to be compliant with the 2 seconds GOP OPTIBAND target, the whole data is required to be transmitted for the three rates before the 2 seconds at each GOP so as to avoid any artefacts when changing rates. That specific process implemented within the encoders introduces some peak rates at the beginning of GOPs. TS stuffing has been added at TS level as TVN encoders can only deal with CBR streams, the latter stuffing being removed by the PDD to avoid unnecessary ADSL bandwidth consumption. After numerous optimizations with the PDD, encoding bit rates were fine-tuned to limit the peak rates and avoid exceeding the nominal bandwidth of the ADSL line.

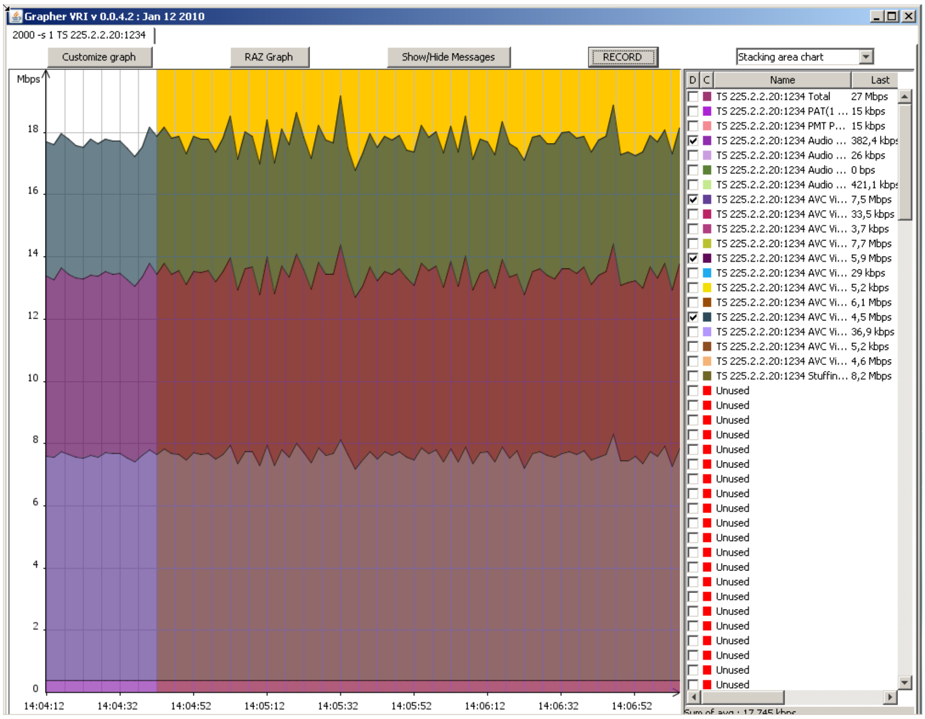


*Figure 14: Three rates Multi-video SPTS sequence with one audio recorded on site*

During the installation of the STBs, interaction with the middleware was already tested. The data generated by the encoders were sent to the multicast addresses advertised by the middleware. As a first test, the embedded multiplexer functionality was bypassed (using a specific test internal workflow) and the streams sent were Single-video SPTS streams, at a single bitrate, in order to be able to test if the IPTV eco-system without the solution proposed in the OptiBand project worked properly. Thereafter the Multi-video SPTS streams were streamed and tested that the STBs were compliant with the streams. Both specific test single-video SPTS and 3 streams Multi-video SPTS ran smoothly on the Blu:Sens Set Top box.

In order to check the correct operation of the several encoders, PCs were connected and configured so that they receive the multicast data. The tools used for processing the SPTS/UDP were:

- TVN Internal tool to capture the selected IP frames on the DATA network.
- TVN Internal tool to extract the TS file from the IP encapsulation
- TI tool to capture the selected IP frames on the DATA network.
- TI MTS400 tool to extract the TS file from the IP encapsulation
- VLC to play the TS video stream to control the correct streaming from the encoders
- Internal analyser to identify Random Access Points (RAP) in the transport priority flag in TS packet header, PCR synchronization analysis, T-STD simulation, and TS metadata analysis (such as Program number PID , PMT PID , Video PIDs, Audio PIDs).

The tests done with these tools have shown that the Multi-video-Encoders were working properly.

These PCs were capable of processing the different SPTS/UDP data and it was checked that the data was displayed for the selected videos, as well as that the MPEG metadata, such as Program number, PMT and audio/video PIDs, and that also video rates and resolutions were correct. The tool is shown in Figure 15.

Moreover, it was checked that the IDR frames were produced every 2 seconds and the corresponding TS priority flag was set, as shown in Figure 16.

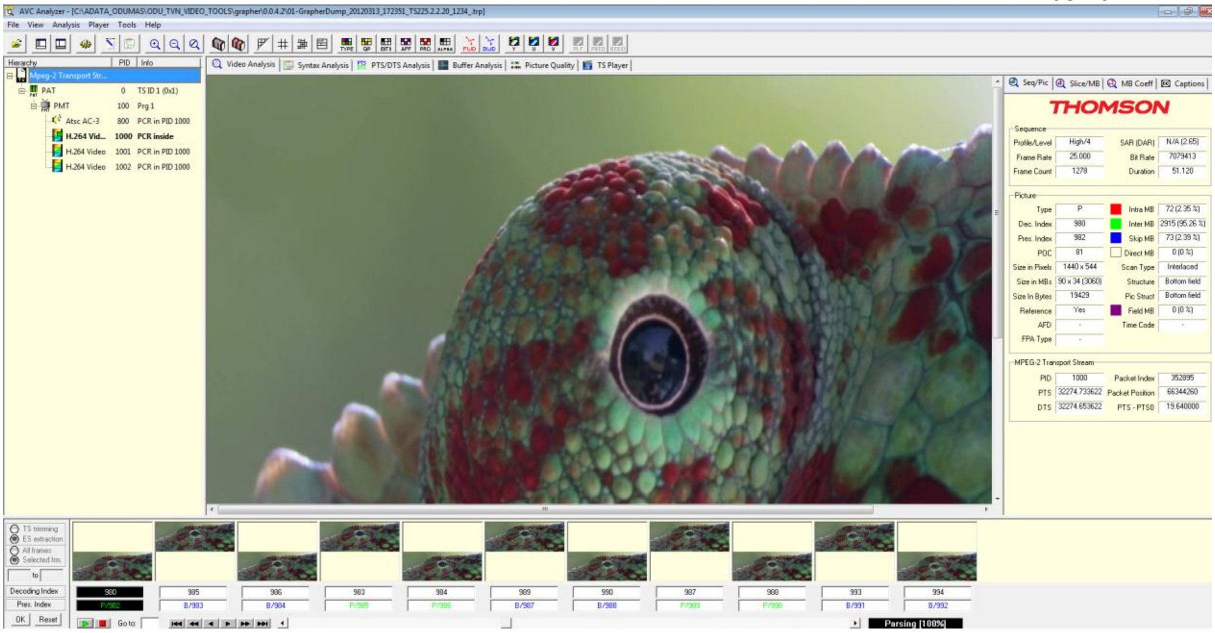

***Figure 15: Three rates Multi-video SPTS sequence analysed on site using TVN tool***

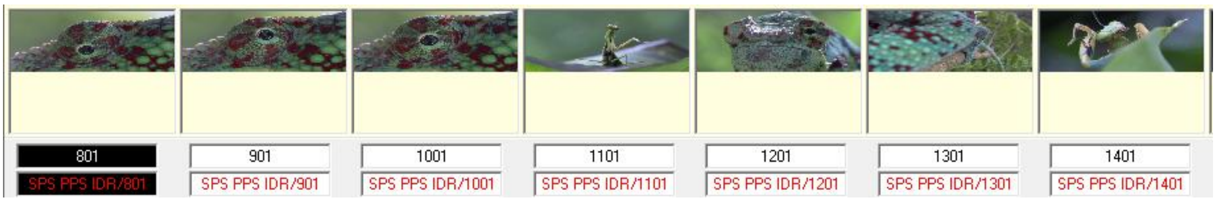


***Figure 16: IDR frames analysed on site using TVN tool***

RAP were checked on site for IDR frames every 100 fields which correspond to 50 frames (2s GOP). IDR are on set Top field as shown in Figure 16. Moreover the TS priority flag presence was also checked for IDR frames for the three PIDs of the Multi-video SPTS, as shown in Figure 17.

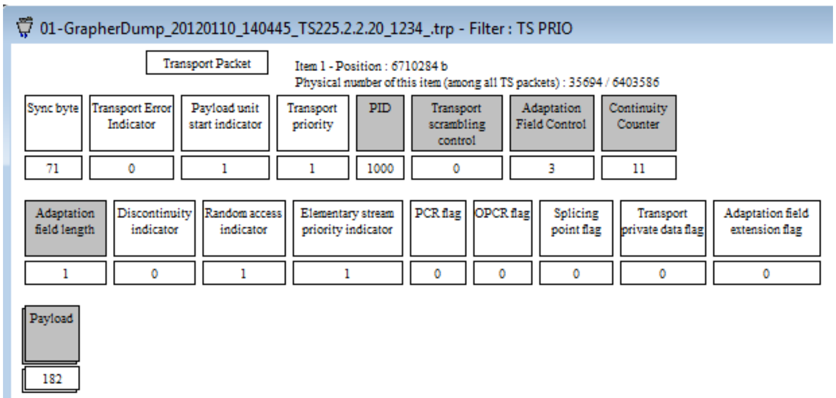


***Figure 17: TS priority flag check for IDR frames***

In order to facilitate the integration phase with the PDD, two Multi-video SPTS sequences were recorded on site so as the PDD could be improved and validated using these sequences in CSL premises before integration in TI. These sequences were uploaded in TI ftp server so as CSL could download them for analysis.

The recorded sequences were based on DOCUMENTARY content, one complete loop with three different H264 encoded video and one AC3 encoded Audio and a longer sequence with two complete loops using the same parameters. An additional complete loop was recorded with TI tools. The characteristics of these recordings are shown in the following table.

***Table 8: Multi-video SPTS on site recordings***

| H264 Multi video SPTS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reference Clips** | **Standard** | **Video mode** | **GOP length** | **Program number** | **PMT PID** | **video PIDs** | **PCR PID** | **audio PIDs** | **Encoded rates Mb/s** | **Video Audio Format** | **Multi video SPTS sequences files with TVN and TI tools** |
| | | | | | 100 | 1000 | 1002 | | 7.26 | HD 1080i 1440 | GrapherDump_20120110_140445_TS225.2.2.20_1234_.pcap (1 loop) |
| | | | | | | 1001 | 1002 | | 5.8 (-20%) | HD 1080i 1440 | |
| | | | | | | 1002 | 1002 | | 4.3 (-40%) | HD 1080i 1440 | GrapherDump_20120110_143332_TS225.2.2.20_1234_.pcap (2 loops) |
| documentary | H264 | CBR | variable | 1 | | | | 800 | 0.384 | AC3 | Documentary.mpg (1 loop) |

As a conclusion for the Multi-video-Encoders, it can be said that after making many tests to the encoders and checking the characteristics of the output, the installation is finished and they are working properly, indeed the content generated can be processed without any problem by the STBs. As an additional remark, as pointed out in D.7.1 and aforementioned, TVN worked to be able to provide 3 streams instead of 2 as initially planned. The solution found requires that the resolution provided by the encoders is 1440x1080 instead of 1920x1080, but this is not considered to be an issue. In fact, as an example, in France, since May 2011, all the HD terrestrial channels are encoded with this resolution and it has been proven to be satisfactory for the audience.

## 5.4.2 SVC-based approach

The network setup after installation of the SVC Head-End is shown in Figure 18.

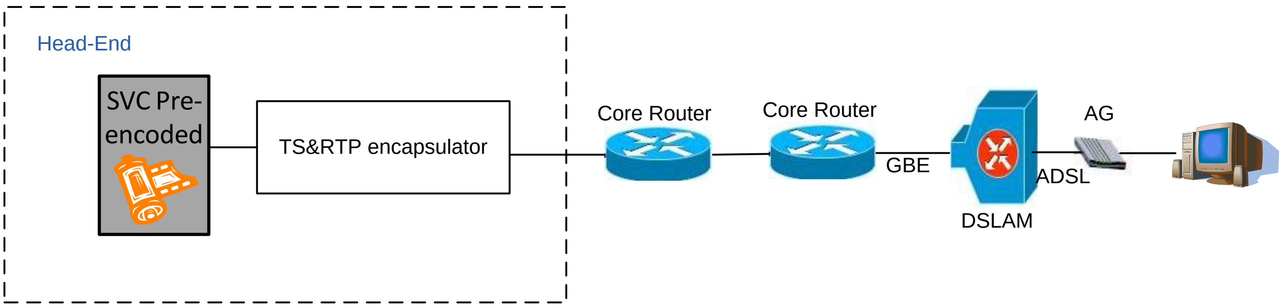


***Figure 18: SVC Content generator (SVC Head End) installation***

TI installed a server with IP address 172.17.185.42 with windows so that the SVC Head End could be installed. The server can be seen in Figure 19. The RTSP server developed by UDC based on Erlang programming language, the VLC with the Head End plugins developed by HHI and the pre-encoded SVC streams were installed in the server. The correct operation of the server was tested by running a VLC instance in the PC at the other side of the DSLAM and making an RTSP request for checking that the streaming was started. Everything worked fine as expected.

*Figure 19: Installed servers for the SVC solution*

## 5.5 EI-IV: Encryption component installation

The target result of integration of the encryption component and the components forming the Encryption component are shown in Figure 20. The initial planning assumed that the encryption component at the head-end scrambles content streams and, after the streams go through the delivery network and arrive to the STB, the STB descramblers them using a smartcard as a security agent.

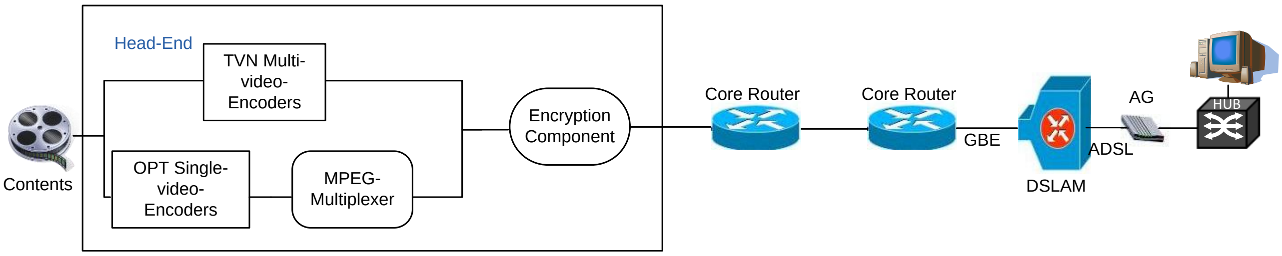


*Figure 20: Encryption component installation for the multi-rate approach*

Integration of the STB with the encryption system encountered a complication due to lack of support of the smartcard interface by the STB manufacturer. Putting an extra effort into collaboration with the STB manufacture to develop a support for smartcard interface resulted in a delay of the integration. To mitigate the risk to the integration test and the live test, two alternatives have been proposed and implemented by consortia:

1. using a third-party STB with integrated IRD security component, but without INTEROUD middleware (section 5.5.2) and
2. adding a component (descrambler) that can be placed before the STB, so a scrambled MPEG-2 TS is decrypted by the descrambler and is passed to the STB as a clear MPEG-2 TS (section 5.5.3). In this case, the INTEROUD middleware is used.

Both alternatives allow testing the CAS system, the PDD performance as well as verifying that the solution that has been developed by the OptiBand consortia is transparent to any standard-compliant conditional access system.

### 5.5.1 Encryption components at the head-end

Figure 21 shows components of the encryption system as they are installed in the TI laboratory. The equipment consists of IRD IPTV Scrambler, IRD KeyServer, and IRD KMS. Specifically to support descrambling of content before it reaches a STB, IRD IPTV Scrambler is equipment with a descrambler board.

***Figure 21: Encryption components: IRD IPTV Scrambler, IRD KeyServer, and IRD KMS.***

### 5.5.2 Using a (third-party) STB

Figure 22 provides a detailed diagram of the system that relies on STBs to handle descrambling. The content comes from the multiplexers described above and, once scrambled, is transmitted to a STB over a delivery network. The delivery network typically contains a number of network devices (e.g. routers, DSLAMs); it may also contain the PDD. All these devices, however, are transparent to the conditional access system, and therefore are not shown on Figure 22.

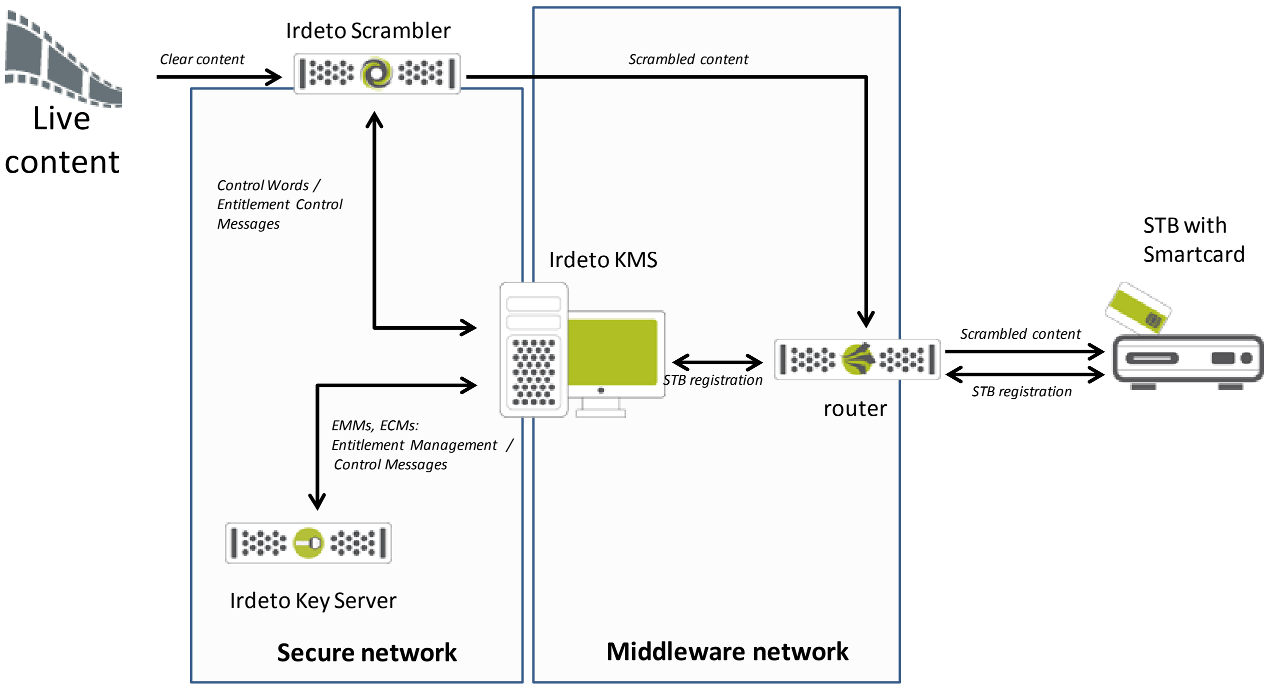


***Figure 22: Description of the encryption configuration for the STB-based descrambling***

The third-party STB is implemented using a DVB over IP approach. Although, that solution is slightly different from a typical IPTV, the IRD security components (KMS, KeyServer, and IPTV Scrambler) do not need to be changed since the DVB-over-IP solution uses the same interfaces.

Figure 23 demonstrates the test setup that uses a third-party STB integrated with IRD security (a DVB-over-IP STB by Altech UEC, model DID4614).


***Figure 23: Test setup – IRD-enabled STB***

The network configuration of the components is performed as follows. IRD KMS has two network interfaces – one in the secure network zone to communicate with other security components and one in the middleware network zone that is used to communicate with client devices. IRD KeyServer has a single network interface in the secure network zone to communicate with IRD KMS. IRD IPTV Scrambler has four network interfaces – two in the secure network for accessing Network Management Interface (a web-interface to configure the IPTV scrambler) and SimulCrypt Synchronizer (a logical component that creates control words and acquires ECMs, and synchronizes their play-out), one in the encoder network to receive streams from encoders, and one in the middleware network to send out processed streams.

The configuration information is summarized in Table 9.

***Table 9: Network configuration of the encryption components***

| Component | Network zone | IP address | Purpose |
|---|---|---|---|
| **IRD KMS** | Secure | 172.16.185.66 | Communication with all security components |
| | Middleware | 172.16.185.101 | Communication with client devices |
| **IRD KeyServer** | Secure | 172.16.185.67 | Communication with KMS |
| **IRD IPTV Scrambler** | Secure | 172.16.185.69 | Access to Network Management Interface |
| | Secure | 172.16.185.68 | Access to SimulCrypt Synchronizer |
| | Encoders | 172.16.185.43 | Data input |
| | Middleware | 172.16.185.99 | Data output |

## 5.5.3 Using a descrambler

Figure 24 provides a detailed diagram of the system that relies on the standalone descrambler to handle decrypting of content. The content comes from the multiplexers described above and, once scrambled, is transmitted to a STB over a delivery network. Prior to arrival to a STB, the content passes through a descrambler that decrypts it and forwards it to the final destination.

The initial setup of the security component is similar to the one discussed in the previous section. The major difference is that since there is only one input and output board for the IRD IPTV Scrambler and it should be used for scrambling and descrambling, we need to loop and merge two IP flows while at the same time keep the IGMP management intact.

For the descrambler-based solution, no security-related communication from the STB is required.

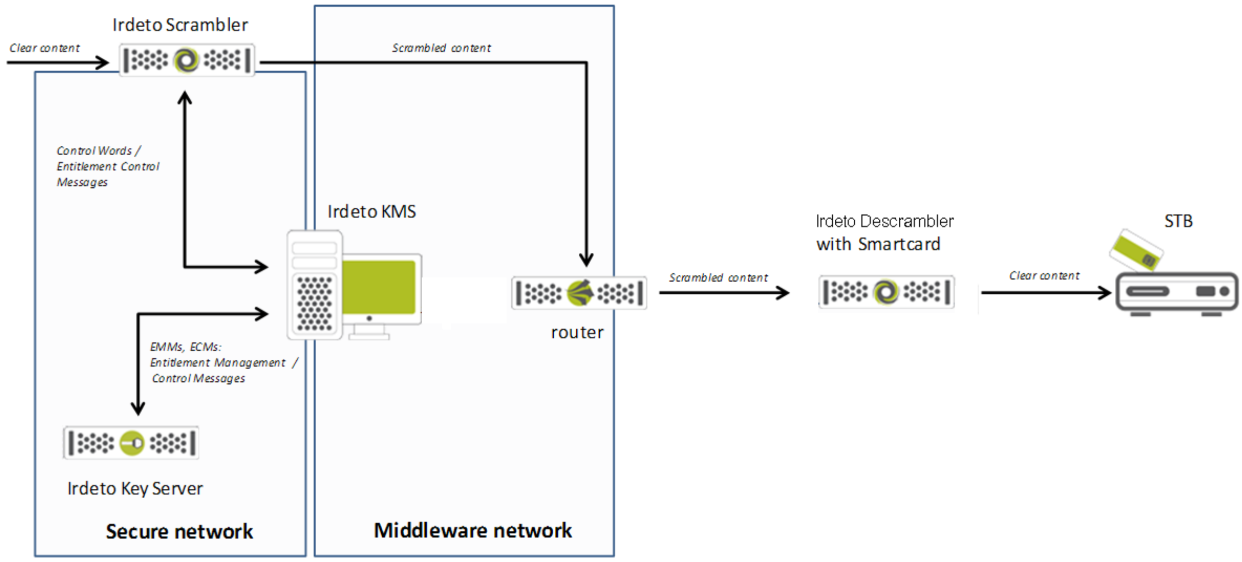


***Figure 24: Description of the encryption configuration for the descrambler-based descrambling***

## 5.5.4 Using the Web:TV STB

The first option to demonstrate that the OptiBand solution works with encryption was to integrate the Web:TV STB, which was the STB used in the OptiBand project to carry out all the tests, with the encryption system provided by IRD. In doing so, a smartcard provided by IRD was integrated with the Web:TV STB. To do that, as it was explained in section 4.7, this task was performed following several incremental steps. However, the completion of this task was delayed due to the technical problems explained in this section..

First, it was checked the basic interoperability between the encryption component and the STB, playing a SPTS provided by IRD and scrambled with a single control word. As a second step, a full integration with the IRD CAS server was tried. For this test, the STB had to register with the IRD Key Management System, process EMMs that were sent by the KMS, process ECMs and then decrypt content. However, during this integration, a problem with the SoftCell's socket virtual driver (provided by IRD) was found and the IRD support system advised INTEROUD to implement the version 1 of it instead of the already implemented version 2. After that, the system failed to work and IRD proposed to ease the integration by providing offline streams that did not need the use of EMMs.

The first SPTS provided by IRD to test this scenario was scrambled with multiple control words but contained additional protection that prevented the stream from being decrypted in this scenario. As a result, IRD provided an additional SPTS without this protection and some progress could be done on the integration, but other problems were found.

The STB was only able to decrypt some slices of the content. After the analysis and diagnosis of the problem by INTEROUD and IRD using the traces of the communication between the STB and the encryption component, it could not be identified the cause why the STB could not play the entire content correctly.

Also, during these tests, it was detected that the smartcard used for development hung sometimes. However, although it caused some problems on the integration, this was not the main cause of the problem, because, after replacing the smartcard reader with another model, it did not hang anymore.

Then IRD suggested implementing the version 1 of the ECM filter virtual driver. After doing so, the result was exactly the same as with the last implemented version (version 2), i.e., only some slices of the content could be decrypted by the STB. The analysis of the traces that INTEROUD sent to IRD did not reveal which was the cause of the problem, but the main suspicions are related to CPU usage and threads priority, because, although the ECMs and video keys are correctly received, it seems that, sometimes, the keys are set out of time.

After a more detailed analysis of the problem by INTEROUD, it was found that the parity of the key was being ignored when it was set it in the cipher. Once this problem was solved the content that IRD provided to INTEROUD can be played correctly in the Web:TV STB, either as a single file or a multicast channel streaming that content. The following figure shows the Web:TV STB playing the encrypted content provided by IRD using the entitled Smartcard provided by IRD:

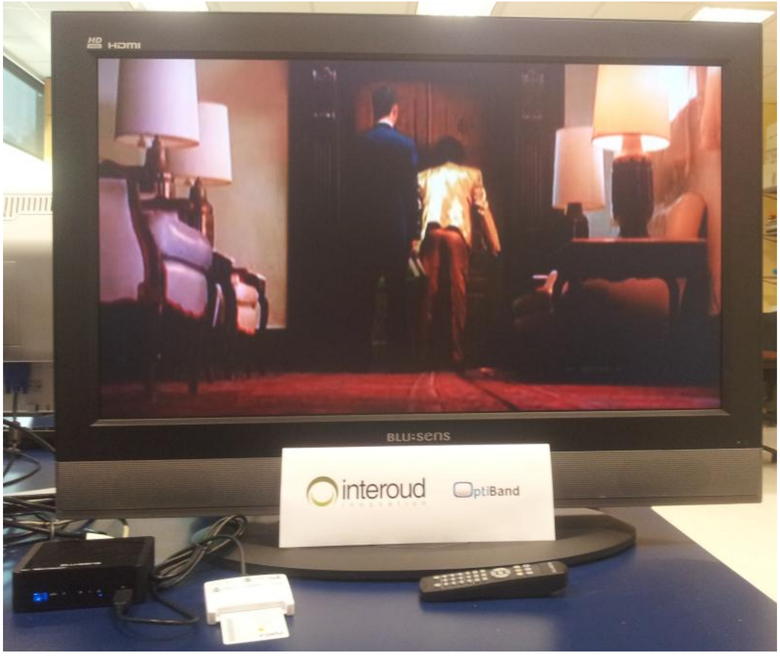


***Figure 25: Web:TV STB integrated with IRD libraries***

Therefore, apart from the successful execution of the alternative plans described in sections 5.5.2 and 5.5.3, we have a fully integrated solution that confirms that the OptiBand infrastructure works correctly with encrypted contents, fulfilling the goal of the OptiBand project of proving that encryption is transparent to the OptiBand solution and does not interfere at all with the PDD solution.

# 6. First Integration Phase (without PDD and encryption)

During this step of the system integration, the full IPTV eco-system transmitting a Single-video SPTS was verified.

## 6.1 AVC-based approach

Figure 26 illustrates the resulting IPTV architecture of this stage to carry out the first tests.

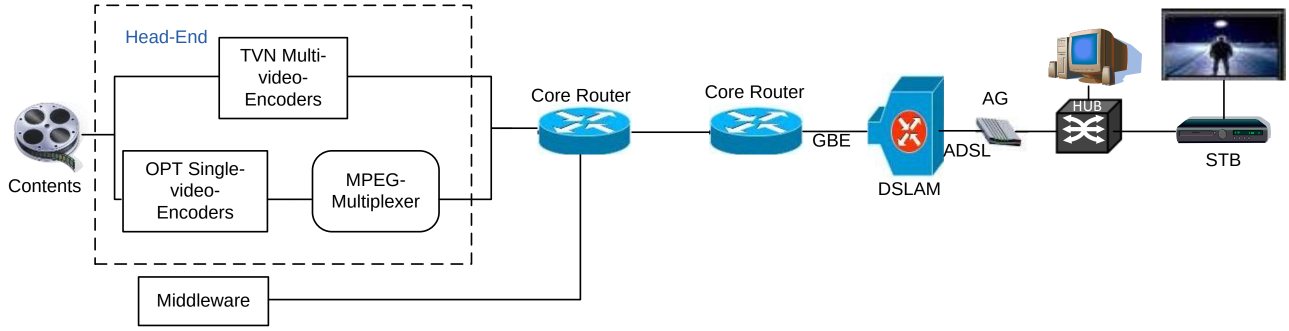


***Figure 26: Full IPTV eco-system without encryption for multi-rate approach***

Most of the problems detected during this phase have been already reported in the previous section. The main tests carried out here were on switching channels from one channel to another and testing the correct operation of the encoders. During the installation of the Encoders the output of these had been analysed with the tools as described before. The correct setting of the metadata for access points (switching points), synchronization among streams and correct placement of PCR had already been checked. During this step the correct operation of the encoders and STB was tested. Small stability issues were detected during this tests as already mentioned e.g. for the STBs. Although the components were working properly among them for a time, sometimes after a long period of some days stability issues appeared that were corrected when restarting the components. Partners worked at their premises to correct these issues and remote updates of the firmware were carried out solving the problems that appeared. Since the PDD was not installed yet, the more extensive tests were let for later.

## 6.2 SVC-based approach

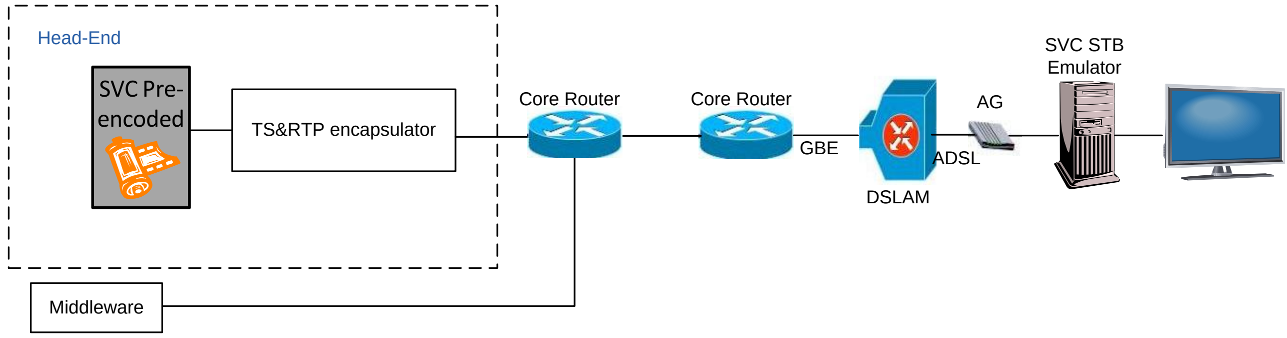


***Figure 27: Full IPTV eco-system without encryption for SVC-based approach***

In the SVC case, the architecture shown in Figure 27 was the tested. In this case, as mentioned before the STB emulator and SVC Head End were working properly. Switching from one VoD channel to another was tested as well as connecting more than one user. At this point some issues were discovered at the Head End. When clients request the VoD service to stop, the Head End continued streaming. The problem was due to the fact of a change in the version of the VLC used at the server that was using different control messages with the remote controlling plug-in. Once detected the RTSP server was modified so that the new controlling messages were used by the RTSP server to control the VLC with the encapsulation plug-ins for SVC.

# 7. Second integration phase (with PDD)

In this second phase, i.e. the last step in the integration plan of the OptiBand project, the packet dropping device (PDD) was integrated ante tested. This phase was again divided into two: SP-I and SP-II (Second Phase 1 and 2).

## 7.1 SP-I: Integration of PDD without encryption component

### 7.1.1 AVC-based approach

The installation of the PDD for the AVC solution will be summarized in the following lines. Figure 28 shows the network architecture that was tested to check the correct operation of the PDD.

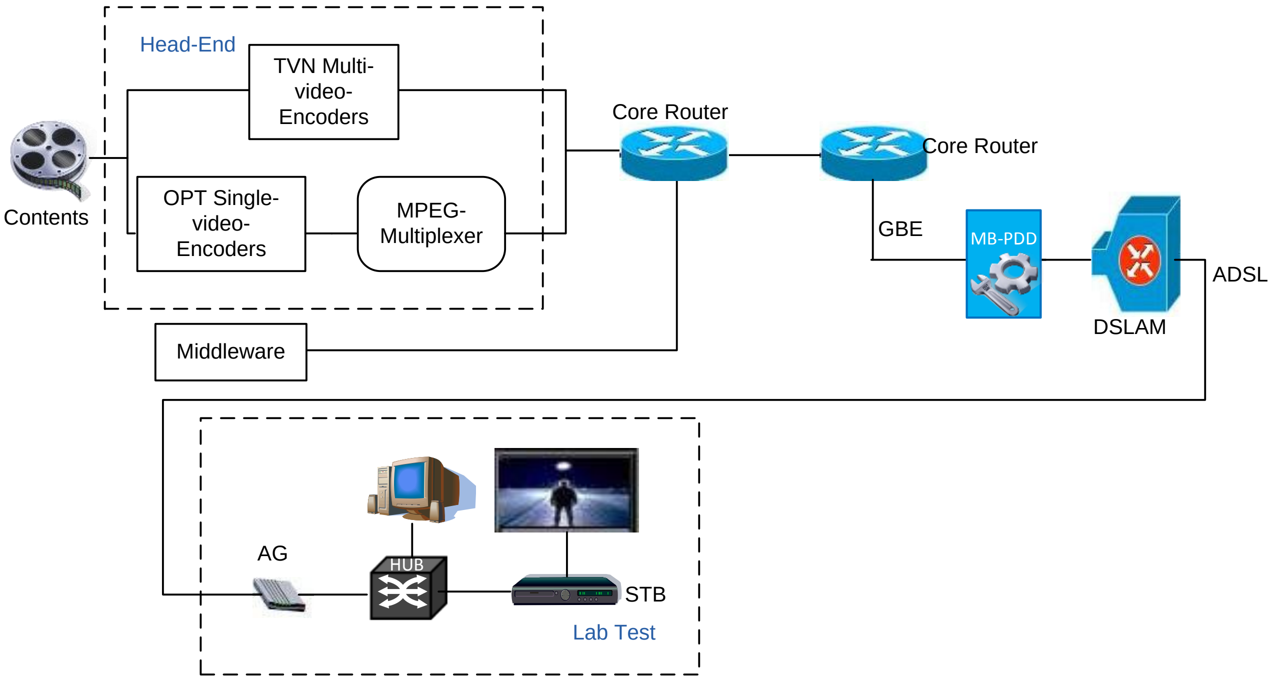


***Figure 28: IPTV system without encryption component with PDD integrated for the multi-rate approach***

CSL travelled to TI 4 times to achieve the installation of the PDD and test the AVC end to end solution: on 23th-26th of January, on 13th-16th of February, on 27th of February - 1st of March and on 12th-16th of March, which coincided with the 2nd annual review. The installed equipment can be seen in Figure 29.

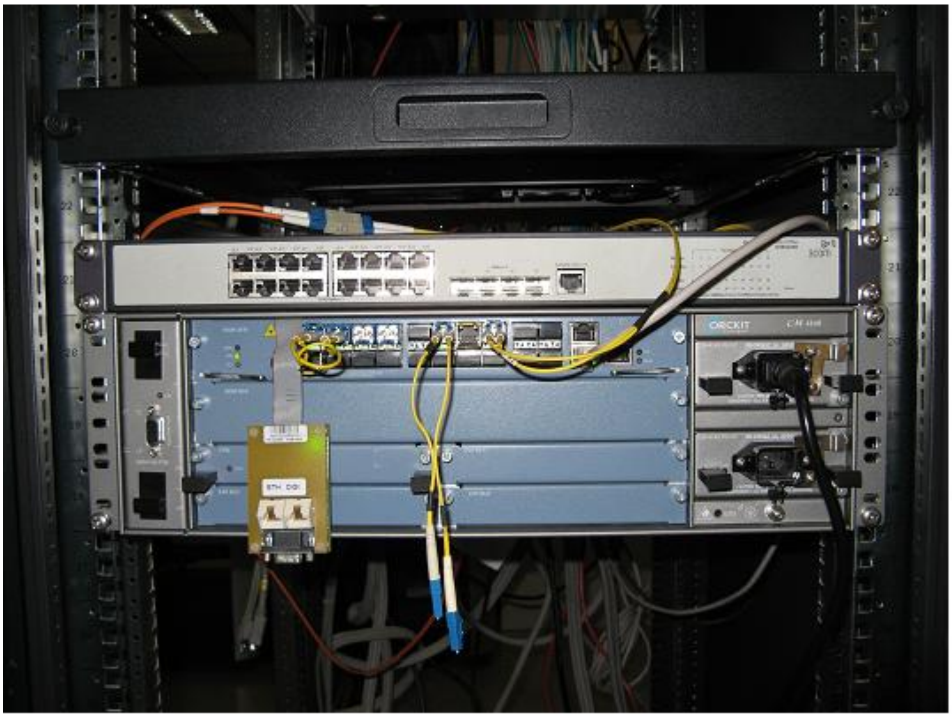

***Figure 29: Packet Dropping Device (PDD)***

During the 1st on site integration the 1st step was to install the PDD and other related components such as control computer and external switch. Problems with the "auto-negotiation" configuration between the external switch and the DSLAM/Router were encountered.

When the problems were solved three problems were detected:

1. The router expected to receive "IGMP join" request. Otherwise it did not send Video traffic. The PDD was not designed to pass IGMP packets from the DSLAM to the Router, as it was assumed that the video would be streamed the whole time to the PDD.
2. In TILab, all IPTV traffic runs over the same VLAN (trunk interface). The PDD was designed to use different VLAN for each DSL line.
3. The Middleware from which the STB configuration is fetched also passes through the PDD. In the lab setup in CSL premises, the middleware was installed in the "home network".

As these problems could not be fixed on site, another integration phase was rescheduled 2 weeks later.

The changes made to the PDD caused the removing of the external switch in the 2nd on site integration. Thus the first thing was to reconfigure the new setup. Again there were problems with the "auto-negotiation" that had to be overcome.

When the setup was ready some further problems were found:

1. After a short time the PDD worked with a random manner. The STB configuration was sometimes successful and other times not.

Some debugging was done on-site to understand the problem. Traffic was captured so it would be possible to reproduce the same scenario in CSL premises. After fixing the problems in the PDD, the "real" integration of testing the video quality could start.

During this 3rd integration phase some problem were detected with the IGMP scheme. The DSLAM that was configured to work in "IGMP snooping" mode blocked IGMP leave messages to multicast groups that were being watched by another TV (all "join messages" were passed). This caused a problem to the PDD since it must know when a TV is turned off so the bandwidth can be assigned to the other TVs.

In a real installation, this issue should be addressed. It would probably be the middleware's responsibility to notify the PDD that one of the TVs was turned off (using "IGMP query"). In OptiBand project, we do not have a ready solution but a "work around" in the PDD was done to overcome this issue.

The following optimizations and parameters and scenarios were tested:

1. **DSL shapers in the PDD**. The PDD has a per DSL shaper to shape traffic to the DSL line rate. Different parameters were set for the shapers (line rate and burst size). In the end (in 4th integration phase) it was come to the conclusion that the best results are when the shapers are disabled. Shapers introduction solves the case of incoming bursts but it has a bad effect on the STB. This means the video coming into the PDD must be shaped.
2. **Zapping.** The zapping affect was tested. Two problems were detected. The first problem observed is that following a zapping event, in some cases, the streaming rate, momentary, exceeded the DSL line rate. To overcome this problem the PDD was fixed (tested in 4th integration phase) so that such a peak rate would be avoided. The second observation was that zapping in one TV caused jumps in another TV. This phenomenon happened when a "rate change" occurred and the rates were not synchronized (Optec encoders). To solve this issue Optec had to fix their encoders, as already mentioned before.
3. **Priority table.** Part of the OptiBand project allows the user to define a priority for each genre and each STB. The user preferences are loaded to the PDD. Different preferences for the genre and of STB were tested and made sure the PDD algorithm follows these preferences.

In this last trip to TI, the problems mentioned before were repaired. More tests and more scenarios were run to check system stability. The fix of "multi rate synchronization" that Optec provided did not work and was fixed later.

The last issues that will be still carefully checked before the beginning of the live tests are summarized in the following.

1. **Checking behaviour after Optec fix of rate synchronization**. With the last version of the OPTEC encoders the lack of synchronization should not appear and therefore further exhaustive checks will be done.
2. **Finalizing preference table for the live test**. The preference table elaborated for the live test should be finalized and fined tuned so that the quality is the desired one. Then, the corresponding configuration should be loaded to the PDD and tested to behave correctly.
3. **Finalizing video rates**. After all other issues are solved a fine-tune of the video rates will be done so that the best results are obtained. Since the best results were obtained when we disabled the DSL shapers in the PDD, we should configure the encoders so the peek rate combination does not exceed the line rate.
4. **Analyse test scenario**. When the test scenario and preference table are defined, a last analysis of the test (run the drop algorithm offline) and fetch the video rate will be performed, the viewer will watch in each phase of the test.

During the tests for correct operation of the solution it was noticed that the quality of the soccer sequence was not good enough. Therefore a new capturing of another soccer sequence had to be done to reach a good content quality before starting the live tests. A Tape was send by OPTEC to TI, were TI and HHI performed the capturing to an adequate format for the encoder feeders and valued the content as better. The content was used for feeding the encoders and the output was sent to the partners to reach a consensus whether the soccer sequence should be changed, which resulted favourably for the new soccer sequence.

### 7.1.2 SVC-based approach

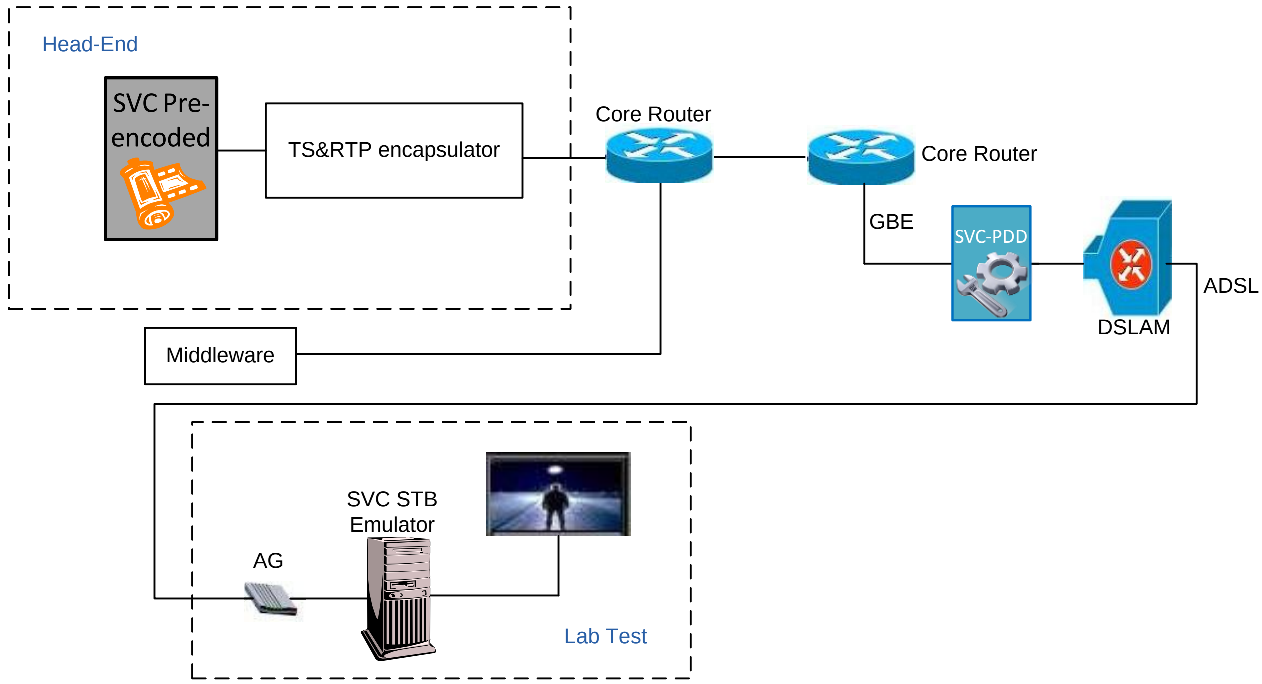


***Figure 30: IPTV system without encryption component with PDD integrated for the SVC approach***

HHI travelled to TI three times for integration of the SVC solution: on 28th of February - 1st of March, on 7th-13th of March and on 16th-17th of April. As for the AVC-based approach, the SVC PDD is integrated between the head-end and the SVC STB Emulator as shown in Figure 30. The SVC PDD as explained in WP3 and D7.1 is a software based implementation. The developed software was installed in the other windows server (see Figure 19) that TI installed in the laboratory with IP address 172.16.183.195. The bandwidth could be limited at the PDD and the allowed bandwidth was measured to be the correct one. The installation of the SVC PDD was done in March during a second on-site integration. When multiple users connected through the PDD to the Head End some problems were discovered:

1) The second coming users did not receive any data.

2) Since the content generated by the SVC Head End was VBR the PDD had to perform a rate-shaping but this was not enough, so that small burst of packets for small intervals were done and some packets went lost degrading strongly the quality of the video.

3) Furthermore the audio was not integrated in the SVC part.

The first problem was discovered to be due to the assignment of the same session id to all the sessions started for all the requesting clients. This problem was solved on -site by UDC by making a small update in the RTSP server, and giving a unique id to each session.

The other two problems were resolved in HHI and a third travel to TI in April was done to finish the SVC integration. The audio was included in the pre-encoded content and encapsulated in such a way that was compatible with the developed solution, i.e. the audio was encapsulated so that it was transmitted to the base layer of SVC within the lowest operation point with the highest priority. For the issue with the rate shaper, this was modified so that it operated in a much more accurate way. In order to do so, the sending intervals of the rate shaper were reduced at each maximum possible. However, when integrating in TI it was noticed that by reducing this sending interval too much the system was slowed down a lot and the data could not be sent on real-time. One possibility would have been to use much more powerful equipment but instead in order not to change the setup, the limit of the PDD was set with a secure margin not to overpass the DSL line rate, i.e. the DSL line rate was set to be higher than the PDD output rate.

For the SVC case only the Action content and Documentary content were successfully generated. Due to the lack of success in finding an available soccer sequence of quality for SVC, the soccer sequence was discarded from the SVC solution.

## 7.2 SP-II: Integration of PDD with encryption component

The purpose of the test is to

- verify that the encryption works end-to-end within the deployed OptiBand ecosystem, and

- confirm that the PDD work is transparent to the security system (note: this is one of the goals of the whole project).

The services (content type and multicast address) setup used in the test is summarized in Table 10. Figure 31 shows configuration of output services featuring different types of content on IRD KMS. Figure 32 shows output configuration of IRD IPTV scrambler. Figure 33 demonstrates the scrambler configuration of the active service.

***Table 10: Test setup***

| Content type | Input multicast address:port | Output multicast address:port |
|---|---|---|
| Documentary | 225.2.2.30:1234 | 225.2.2.20:1234 |
| Soccer | 225.2.2.31:1234 | 225.2.2.21:1234 |
| Action | 225.2.2.32:1234 | 225.2.2.22:1234 |
| Action[1] | 225.2.2.50:5004 | - |

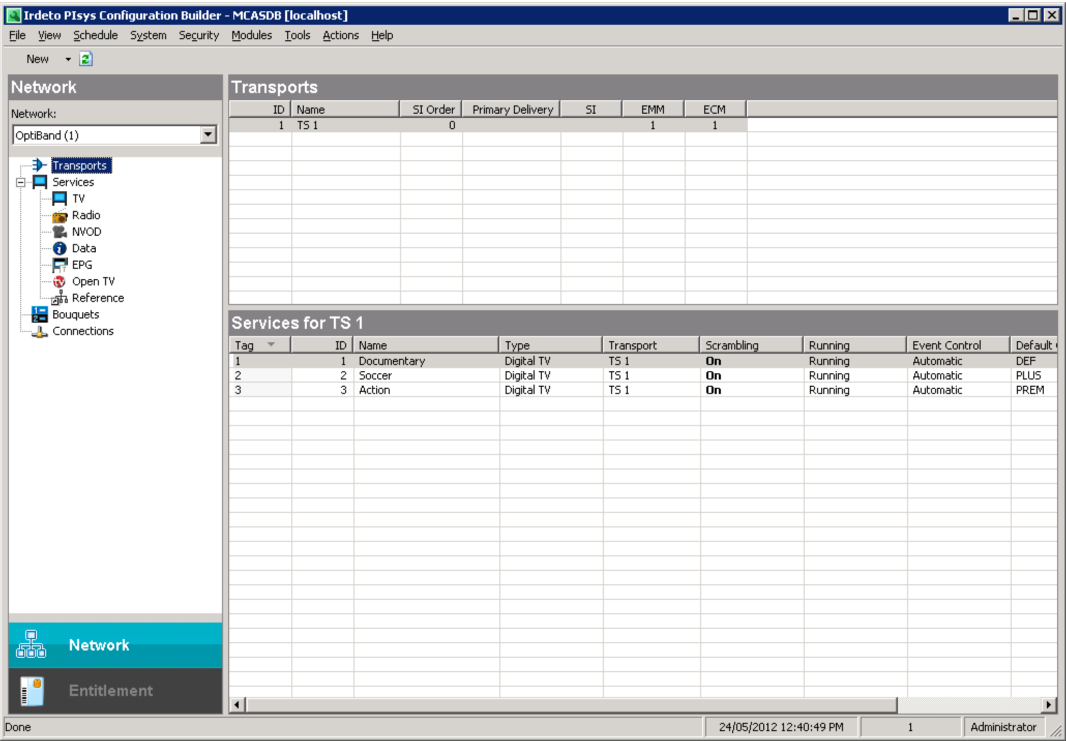


***Figure 31: Configuration of output services on IRD KMS.***

[1] The additional test with action video on 225.2.2.50:5004 is used with the system configuration that does not contain a PDD to verify that there is not dependency between the PDD and the encryption components.

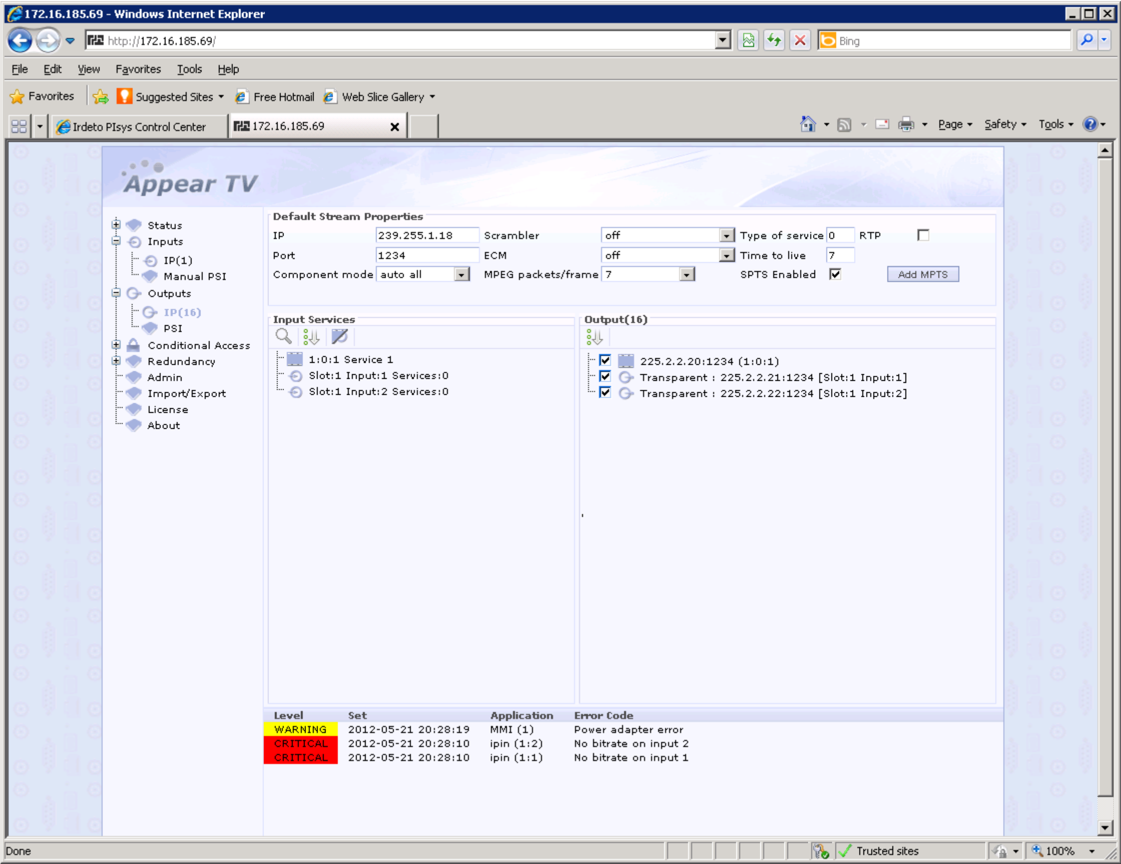


*Figure 32: Output configuration of IRD IPTV scrambler.*

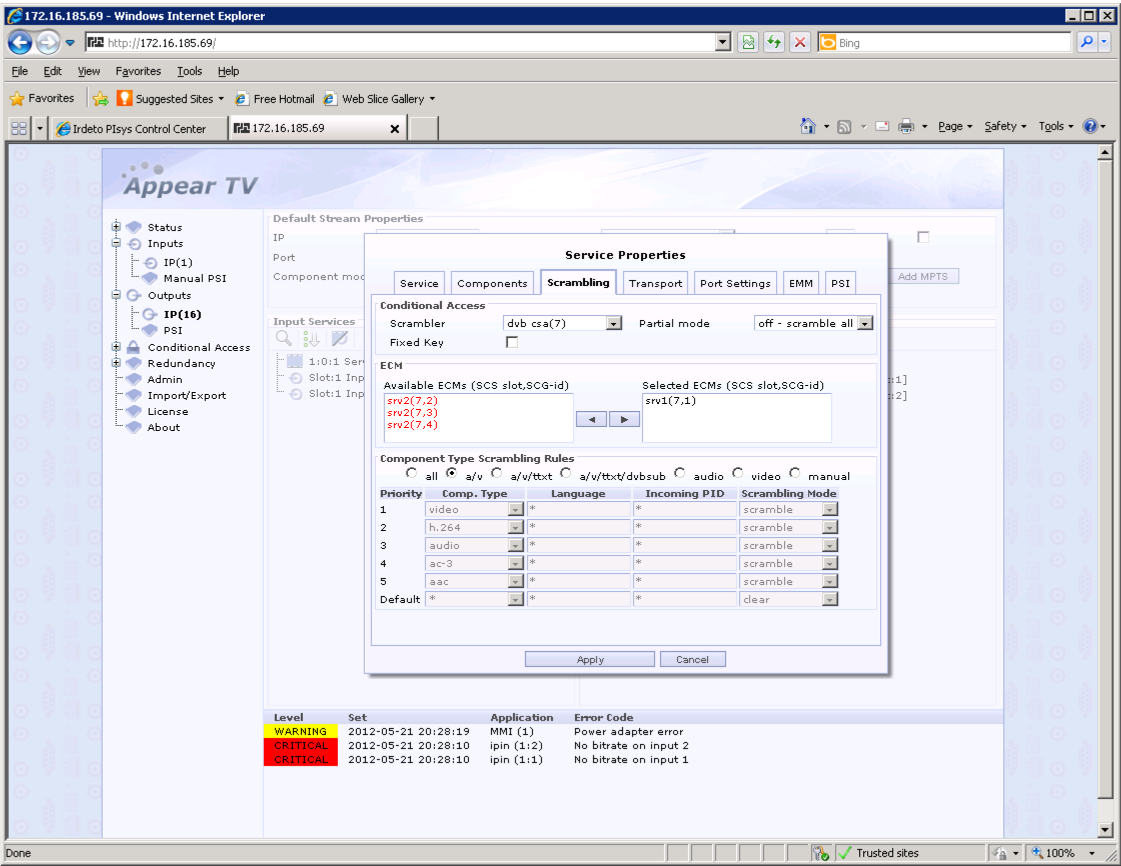


*Figure 33: The scrambler configuration of the active service.*

The execution of the test followed the pre-defined pattern of events:

1. The first STB requests the documentary sequence and displays it on the TV,
2. after ~30 seconds, the second STB (from the same household) requests the soccer sequence and displays it on the TV,
3. after ~30 seconds since the previous request, the third STB (from the same household) requests the action sequence and displays it on the TV.

The test was repeated 4 times.

To verify the presence of the encryption, we used an additional STB that has no conditional access to tune to the same multicast stream as the test STB. The additional STB was not able to access the media content.

During the test, we were able to scramble and descramble services on the STB without any problems and, as expected, switching bitrates on the PDD did not cause any artefacts.

# 8. Final Tests

## 8.1 AVC-based approach

For the AVC solution end to end and final test we checked the performance of the built solution following a pattern of switching events as shown in Table 11, which follows the user scenarios described in D3.4.2. The stability of the equipment was checked during the installation as described in previous sections. The goal of this final test was to check whether the implemented solution performs as expected in terms of delivered bitrate for different request combinations and smooth transitions between different versions performed by PDD. The final verification implied performing the shown switching pattern and checking that no artefacts appear in the video due to the deployed solution in OptiBand. The tests done showed that everything was working as expected.

***Table 11: Switching pattern and expected received Bitrate***

| Use case | Clients | Receiving stream | Bitrate (Mbps) |
|---|---|---|---|
| #3.1 | STB1<br>STB2<br>STB3 | Soccer<br>X<br>X | 8 |
| #3.2 | STB1<br>STB2<br>STB3 | Soccer<br>Action<br>X | 8<br>6.5 |
| #3.3 | STB1<br>STB2<br>STB3 | Soccer<br>Action<br>Docu | 6.5<br>3.45<br>4.95 |
| #3.4 | STB1<br>STB2<br>STB3 | Action<br>Docu<br>X | 8<br>6.5 |
| #3.5 | STB1<br>STB2<br>STB3 | Docu<br>X<br>X | 8 |
| #3.6 | STB1<br>STB2<br>STB3 | Soccer<br>Docu<br>X | 8<br>6.5 |

| | | | |
|---|---|---|---|
| #3.7 | STB1<br>STB2<br>STB3 | Soccer<br>Docu<br>Action | 6.5<br>4.95<br>3.45 |
| #3.8 | STB1<br>STB2<br>STB3 | X<br>Docu<br>Action | <br>6.5<br>8 |
| #3.9 | STB1<br>STB2<br>STB3 | Action | 8 |

Note that although Action content should be prioritized to Documentary content (see QoE results in D2.4), since documentary has only three possible bitrates in case of #3.3. and #3.7 Documentary content receives more bitrate than Action, since there is not a lower bitrate and more bitrate is needed for Soccer.

## 8.2 SVC-based approach

However, for the SVC solution, as explained before the available soccer sequence was not good enough for providing a good quality and no other available good sources were found. It was proven that the switching from one quality to another was smooth and no drawbacks were found, i.e. there were not artefacts in the presented content. Due to the lack of a better soccer source sequence, in the last setup the SVC solution was done for two sequences and 10 Mbps output rate from the PDD instead of 15Mbps as before. A similar table is shown in the following, slightly modified from D3.4.2, since soccer sequence is not available:

| Use case | Clients | Receiving stream | Bitrate (Mbps) |
|---|---|---|---|
| #2.1 | STB1<br>STB2 | Action<br>Docu | 6.5<br>3.5 |
| #2.2 | STB1<br>STB2 | Action<br>X | 8 |
| #2.3 | STB1<br>STB2 | Action<br>Action | 5<br>5 |
| #2.4 | STB1<br>STB2 | Docu<br>Action | 3.5<br>6.5 |
| #2.5 | STB1<br>STB2 | Docu<br>Docu | 5<br>5 |
| #2.6 | STB1<br>STB2 | Docu<br>X | 8 |

All the tests were passed, concluding that the integration phase has been satisfactory and the installed solution is adequate for starting the Live Tests.

# 9. Integration Plan achieved

In the following, a Gantt chart is shown comparing the initially planned schedule as presented in D7.1 compared to the actual dates, where each of the steps was successfully integrated.

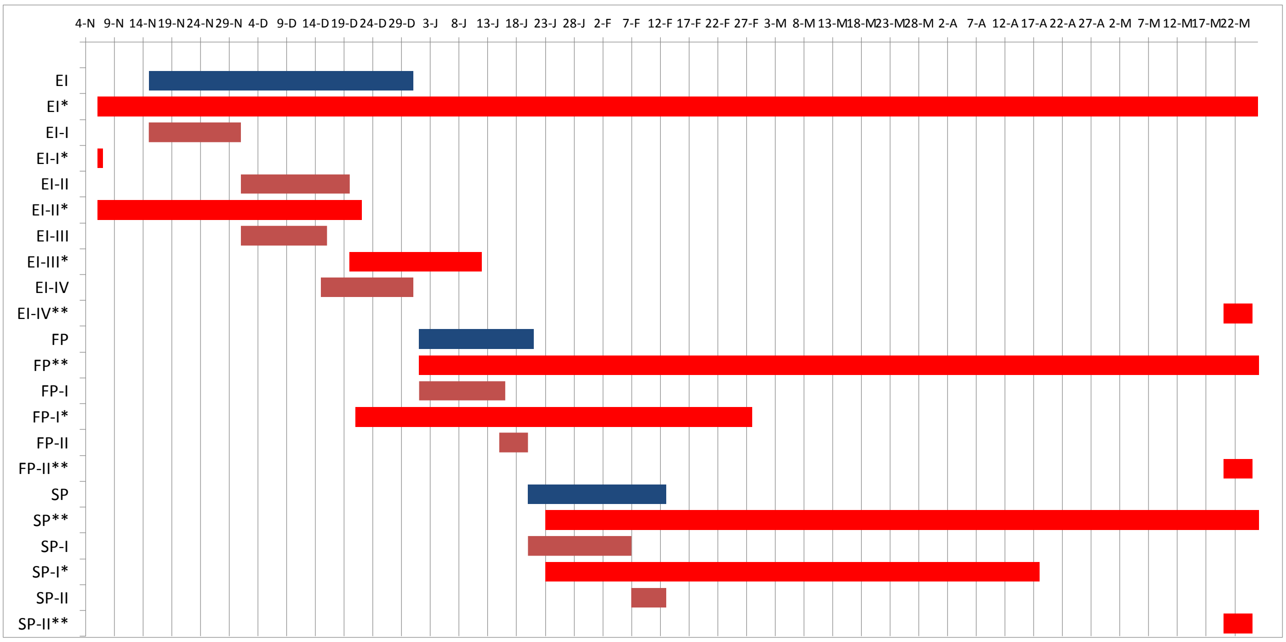


***Figure 34: Actual integration and installation finalization dates***

In the figure the actual dates where the installation and integration from equipment was finished is represented with the intense red colour, and correspond with the names followed by and "*". All equipment has been installed and the OptiBand solution has been tested.

# 10. Bibliography

[1] D3.4.2 IPTV data dropping algorithm prototype Version 2 and associated documentation

[2] D4.5.2 Head end prototype Version 2 and associated documentation

[3] D5.2 System Architecture & Functional Definitions

[4] T. Wiegand, G. J. Sullivan, G. Bjøntegaard, and A. Luthra, “Overview of the H.264/AVC video coding standard,” IEEE Trans. Circuits Syst.Video Technol., vol. 13, no. 7, pp. 560–576, Jul. 2003.

[5] H. Schwarz, D. Marpe, and T. Wiegand: “Overview of the Scalable Video Coding Extension of the H.264/AVC Standard,” IEEE Transactions on Circuits and Systems for Video Technology, Special Issue on Scalable Video Coding, Vol. 17, No. 9, pp. 1103-1120, September 2007.

[6] ITU-T Rec. H.222.0, “Information Technology — Generic Coding of Moving Pictures and Associated Audio Information: Systems,” May 2006

[7] Thomas Wiegand, Ludovic Noblet, and Fabrizio Rovati: “Scalable Video Coding for IPTV Services”, IEEE TRANSACTIONS ON BROADCASTING, VOL. 55, NO. 2, JUNE 2009.

[8] Broadcom, System-on-Chip solution for Full-Resolution HD 3DTV supporting SVC (and MVC) http://www.broadcom.com/products/Satellite/Satellite-Set-Top-Box-Solutions/BCM7425 , (accessed April 29, 2011)

[9] SVC Reference Software (JSVM software), http://ip.hhi.de/imagecom_G1/savce/downloads/SVC-Reference-Software.htm, (accessed Mai 9, 2011)

[10] RTP Payload Format for MPEG1/MPEG2 Video, IETF, RFC 2250, http://tools.ietf.org/html/rfc2250