

# Content Adaptation of IPTV Services in Interactive DVB-T systems

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**Abstract**—This paper discusses how Content Adaptation of IPTV Services may enable decentralized Interactive DVB-T systems (IDVB-T) to optimize the utilization of their network resources, while offering End Users the higher possible QoE. The paper describes the design and overall architecture of a regenerative IDVB-T infrastructure, where content adaptation processes are performed following either a centralized or a distributed approach, setting the basis for a real time accommodation of IPTV services to the available network resources (i.e. bandwidth) and capabilities of End Users terminals (i.e. processing power, screen resolution, codec support). Validity of both Content Adaptation approaches is experimentally verified, with the initial test-results indicating similar performance.

**Index Terms**—Interactive DVB-T, Content Adaptation, Distributed, Centralized, IPTV, QoE.

## I. INTRODUCTION

The advent of Digital Video Broadcasting (DVB) standard and its exploitation over terrestrial channels (DVB-T), enabled for the realization of Interactive DVB-T (IDVB-T) networking infrastructures, interconnecting Service Providers (SPs) and End Users (EUs) to each other. Such IDVB-T infrastructures can be based either on a centralized architectural approach, where the SPs/EUs are directly communicating with the broadcasting platform [1], [2], [3], or on a decentralized architecture, where communication is carried via intermediate distribution nodes (namely Cell Main Nodes-CMNs) exploiting dedicated uplinks [4], [5], with the decentralized predominating over centralized ones when scalability and single-point-of-failure issues come to the foreground.

In the direction of proving IDVB-T's value as a networking infrastructure the authors at [6] proposed, evaluated and presented a decentralized IDVB-T able to provide always on

connectivity and triple play services to EUs. Furthermore, additional research efforts (e.g. [7], [8], [9]), enabled IDVB-T to manage/reserve its network resources (i.e. bandwidth) according to the services QoS requirements. In other words, IDVB-T network was enhanced with the “intelligence” to react/adapt to the services network requirements, thus increasing its value as a networking infrastructure.

On the other hand, Network Resource Management (NRM) alone, may not always provide for an optimized network utilization and at the same time respect End Users Quality of Experience (QoE). For example, lets assume that a new IPTV service  $s$  with terminal requirements  $r$  and bit rate  $b$ , is requested to be transferred through an IDVB-T network with an unreserved bandwidth  $f$ , to an EU having a terminal with capabilities  $c$ , with terminal requirements/capabilities referring to hardware/software attributes, such as processing power, screen resolution and codec support. The following cases exist:

- 1)  $f \geq b$  and  $r \leq c$ : Network has the required bit rate, while EU's Terminal capabilities suffice for service consumption.
- 2)  $f \geq b$  and  $r > c$ : Network has the required bit rate, but EU's Terminal capabilities do not suffice for the proper service consumption.
- 3)  $f < b$  and  $r \leq c$ : Network does not have the required bit rate, while EU's Terminal capabilities suffice for service consumption.
- 4)  $f < b$  and  $r > c$ : Network does not have the required bit rate, neither EU's Terminal capabilities suffice for service consumption.

It is evident that the problematic cases are 2,3 and 4,

even if IDVB-T exploits an efficient NRM (i.e. reallocating a portion of bandwidth reserved to lower priority services). More specifically and for case 3, if bandwidth reallocation is not possible, IDVB-T can either deny to transfer the new IPTV service, therefore not utilizing further its network resources, or transmit it as Best Effort, thus affecting negatively EU's QoE. Finally for cases 2,4 and regardless NRM capabilities, it does not make any sense to transfer the service at all, since QoE will be always degraded, which in turn leaves IDVB-T's available network resources unused.

Towards addressing the above issues, this paper proposes that IDVB-T should, complementary to NRM, be enhanced with the "intelligence" to adapt the Content (whenever appropriate) of the IPTV services to its remaining network resources and the EUs terminals characteristics. In this way, IDVB-T exploiting content adaptation techniques, such as transcoding/transrating, could enable:

- IDVB-T to optimize its network utilization.
- EUs to receive IPTV services at the higher possible QoE allowed from their terminals capabilities and the currently available network resources.

Following this introductory section, the rest of the paper is structured as follows: Section 2 presents the centralized and distributed Content Adaptation approaches, while Section 3 elaborates on their initial validation. Finally, Section 4 concludes the paper and identifies fields for further research.

## II. IPTV CONTENT ADAPTATION IN IDVB-T

The overall architecture of a decentralized IDVB-T system is depicted in Fig.1, where a set of Cell Main Nodes (CMNs) are exploited as intermediates between the Service Providers/End Users and the DVB-T platform. In this configuration SPs and EUs send their services/requests to their intermediate CMN, which in turn forwards them to the DVB-T platform through a dedicated point to point uplink (reverse path channel). There, DVB-T platform broadcasts, via VHF/UHF (forward channel), all the received traffic which is then received by the CMNs prior routing it to the corresponding SPs/EUs.

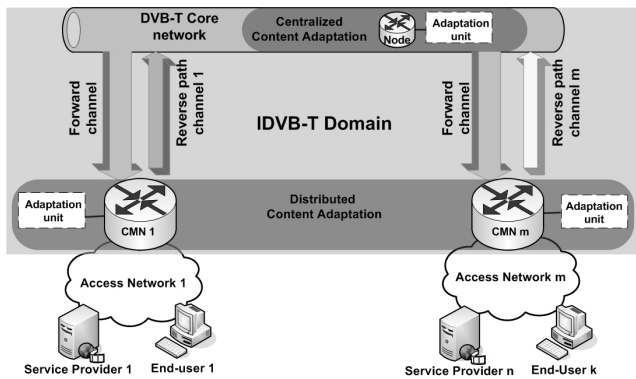


Fig. 1. IPTV Content Adaptation approaches in IDVB-T

As Fig.1 depicts there is a centralized and a distributed approach towards implementing Content Adaptation for IPTV

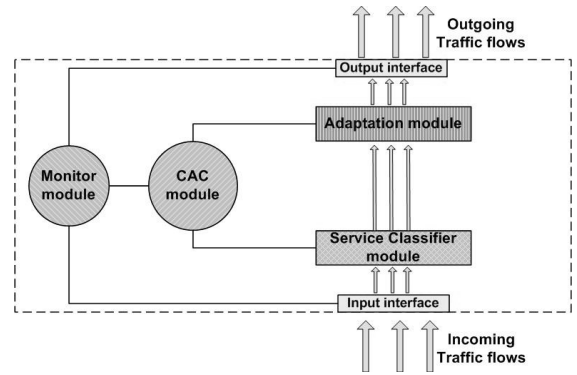


Fig. 2. Content Adaptation unit

services in IDVB-T systems. More specifically in the former, adaptation can be performed at the DVB-T platform (i.e. before DVB encapsulation) by one dedicated unit (e.g. Node in Fig.1), while in the latter each CMN can be enhanced with the ability to adapt the IPTV content. Taking into account, that each approach has its benefits and disadvantages regarding issues of complexity, scalability, single point of failure, e.t.c., this paper proposes a Content Adaptation Unit (CAU) that could be exploited from both approaches. In this direction and as depicted in Fig.2 the proposed CAU utilizes: i) a Monitor module; ii) a Call Admission Control (CAC) mechanism; iii) a Service Classifier (SC) module and iv) an Adaptation element.

More specifically, the Monitor module is used for providing information regarding the services network /terminal requirements (e.g. bit rate/codec support), EU terminal capabilities (i.e. processing power, screen resolution, codec support) and available bit rate in the IDVB-T network. This paper assumes that all information concerning bit rate availability is provided through IDVB-T's Network Resource Management (NRM) unit while all information regarding terminal capabilities and service network/terminal requirements are already stored in an accessible database.

Call Admission Control mechanism is exploited for providing a "Yes"/"No" answer about Content's "adaptability", with a positive answer triggering CAC to discover the most beneficial Adaptation type (e.g. container format, codec, coding rate). Towards this, CAC has to be informed from the Monitor module regarding the maximum available bit rate, the service network/terminal requirements and destined terminal capabilities. Table I presents a simple algorithm, which enables for Content Adaptation. If the algorithm grants adaptation, CAC will instruct the Service Classifier and Adaptation modules to take the appropriate actions, while if not, IDVB-T could deny transferring the IPTV service or instructing for its transportation under the Best Effort scheme.

The SC module (see Fig.3) utilizes a filtering mechanism to segregate the incoming services flows by analyzing their packets header fields (i.e. address, protocol, port number), and forwards each one to the respective marker. The markers, in turn, assign a specific value, into an appropriate field of each packet header, indicating the type of content adaptation which

TABLE I  
ALGORITHM FOR ENABLING CONTENT ADAPTATION

```

Sr : Service's terminal requirements
Sb : Service's bit rate requirements
FDVB : IDVB-T free network resources
Uc :End User terminal capabilities
Ar : Adaptation Service Rate
Acn : Adaptation Container
Acvd : Adaptation Video Codec
Acad : Adaptation Audio Codec

If (Sb > FDVB) OR (Sr > Uc)
{
  If (ServiceAdaptable())
  {
    AdaptationInfo=[Acn, Acvd, Acad, Ar];
    AdaptationInfo=FindBestAdaptationType(Sr, Sb, Uc, FDVB);
    FDVB=FDVB·Ar;
  }
}

```

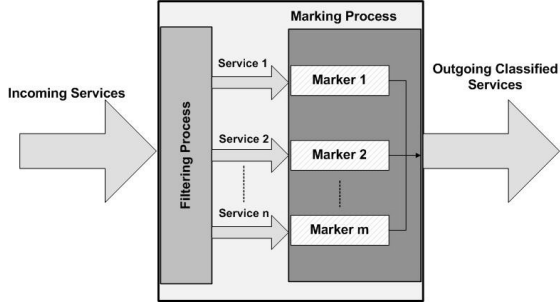


Fig. 3. Service Classifier Module

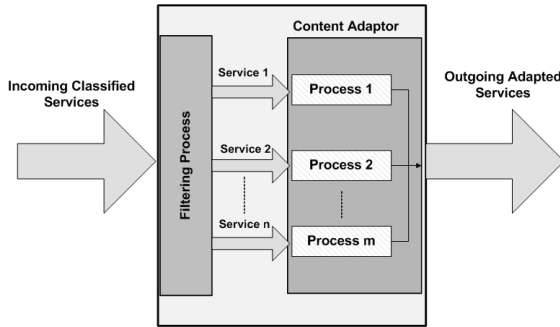


Fig. 4. Content Adaptation Module

will be applied to the service.

Following, the marked services are forwarded to the Adaptation element (see Fig.4), where a filtering mechanism segregates the incoming marked services based on the value assigned by the SC module and forwards them accordingly to a specific adaptation process, each one corresponding to the adaptation type chosen from the CAC module. The outgoing adapted services are then forwarded by IDVB-T to their destination.

### III. EXPERIMENTAL VALIDATION OF IPTV CONTENT ADAPTATION IN IDVB-T

#### A. Testbed

Towards validating the performance of IPTV Content Adaptation (CA) for both the centralized and distributed approaches, several experiments were conducted under real transmission/reception conditions environment. More specifically an experimental IDVB-T test-bed was created including:

- The DVB-T platform, located at the premises of Technological Educational Institute of Crete (TEIC), where the common DVB-T stream is created in channel 40 of the UHF band (i.e. 622-630 MHz), utilizing 8K operation mode with 16QAM modulation scheme, 7/8 code rate, 1/32 guard interval and the multi-protocol encapsulation mechanism (MPE) for the distribution of IP datagrams.
- A CA aware node (Node in Fig.1) located in the DVB-T platform, able to analyze and adapt the services stemming from the CMNS according to the network status and EUs terminal capabilities. This node is exploited from the Centralized Content Adaptation approach.
- A CA aware CMN (namely CMN 1 in Fig.1), located at TEIC premises, enabling SPs to provide IPTV services. The communication between this CMN and the DVB-T platform was based on a one-way point-to-point link of IEEE 802.11g technology (reverse path channel 1 in Fig.1) while the interconnection between SPs and CMN1 was carried out via a IEEE 802.11g WiFi network (Access Network 1 in Fig.1).
- A CA aware CMN (namely CMN m in Fig.1), located in a rural area 10km away from the DVB-T platform, where only PSTN (reverse path channel m in Fig.1) is currently available, enabling users to access the offered IPTV services. The interconnection between EUs and CMN m was carried out via a local IEEE 802.11g wireless network (Access Network m in Fig.1).

Finally, the total available bandwidth of the DVB-T stream (20.5 Mbps) was allocated between the TV and IP services as follows: 16.5 Mbps were dedicated to five digital TV programmes (MPEG-2 non-live broadcasts), while the remaining 4 Mbps were dedicated to IP services.

#### B. Service Scenario

In order to emulate, a real service-scenario, where IPTV services originating from multiple SPs located at CMN 1 and are accessed from EUs located at CMN m, VLC application [10] was used for the IPTV services provision, configured so that multiple IPTV flows over IP/UDP to be delivered from a PC (Service Provider 1 in Fig.1), via the same network interface, but over different protocol ports. Another PC (End User k in Fig1) was receiving through multiple instances of VLC, the IPTV services. Each IPTV service was consisting in streaming the same MPEG-2 video file encoded at a Constant Bit Rate (CBR) of 1.5 Mbps.

The Service scenario was consisting in the simultaneous provision of two IPTV services (IPTV1, IPTV2) for a period

of 300 sec, whilst introducing at the 120th sec, a third IPTV service (IPTV3) for the remaining 180 sec. Finally, it is noted that this service scenario was repeated for the following cases:

- Content Adaptation (CA) was not enabled. The three IPTV services were competing for the network resources under the Best Effort Scheme.
- Centralized CA was enabled. The CA unit was enabled in a Node residing at the DVB-T platform.
- Distributed CA was enabled. The CA Adaptation unit was enabled in the CMNs only. Towards avoiding redundancy and conflict issues, it was arbitrarily decided that only CMN 1 would perform the actual Content Adaptation.

For both CA approaches the unit was adapting IPTV3 by transcoding it to H.264 format (MPEG-4 codec) at an encoding rate of 600 kbps. It is noted here that the service classifier was implemented by exploiting the marking capabilities of iptables application [11] while the transcoding operation was realized by utilizing VLC software.

### C. Evaluation methodology

IPTV Content Adaptation effectiveness was tested against the issues of network performance and QoE. In this direction and regarding network performance it was assumed that IDVB-T should treat all IPTV services as International Telecommunication Union (ITU-T) Rec. Y.1541 proposes for Class of Service (CoS) 0, that is with a maximum One Way Delay (OWD) of 50 ms and packet loss ratio of 0.001%. For QoE evaluation, Mean Opinion Score (MOS) was utilized using the ITU-T Recs P.800 and P.800.1, five point MOS scale (see Table 2). More specifically the personnel of PASIPHAЕ Laboratory was kindly requested to assess the Quality of the provided IPTV services using Table II metrics for every service-scenario round.

TABLE II  
SUBJECTIVE QOE METRICS

MOS	Quality
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

### D. Evaluation Results

The overall network performance of the described IDVB-T infrastructure was initially evaluated, providing for 5 minutes one IPTV service. The experimental results regarding network performance gave an average One Way Delay (OWD) of 27.38 ms [12] and no packet losses [13]. In addition the QoE for this one service was assessed by PASIPHAЕ Personnel as Excellent (MOS of 5).

Following the initial evaluation, the previously defined service scenario was performed and the experimental results regarding OWD and losses are presented at Fig.5 and Table III respectively. It is evident that in contrast with the

no Adaptation case, both approaches of Content Adaptation (CA) allowed IDVB-T for the transmission of all IPTV services according to their network requirements (OWD<50ms, Losses<0.001%), indicating a good network performance. Furthermore and regarding QoE, for the no Adaptation case all three IPTV services were graded as Bad, whilst for both CA approaches IPTV1, IPTV2 were graded as Excellent and IPTV 3 as Good.

Taking into account the above results, and the fact that when no CA is supported, it is better not to transfer the IPTV3 service (degrades QoE) and therefore not further utilize IDVB-T's available network resources, it can be concluded that CA enables:

- IDVB-T to optimize its network utilization.
- EUs to access the offered IPTV services at the highest possible QoE allowed from the available network resources and EUs terminal capabilities.

TABLE III  
LOST PACKETS RATIO FOR IPTV SERVICES

	IPTV1	IPTV2	IPTV3
<b>No Adaptation</b>	20%	6%	11%
<b>Centralized Adaptation</b>	0%	0%	0%
<b>Distributed Adaptation</b>	0%	0%	0%

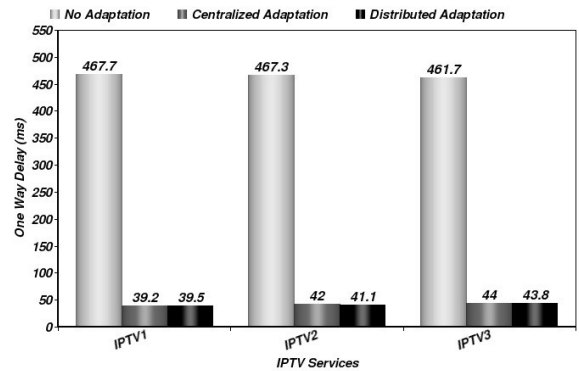


Fig. 5. One Way Delay for IPTV services

## IV. CONCLUSIONS

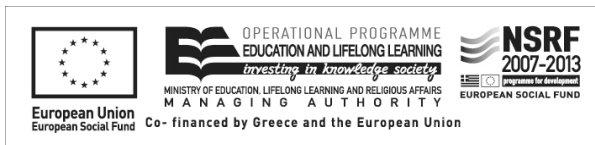
This paper presented how Content Adaptation (CA) of IPTV services could be realized in decentralized IDVB-T systems utilizing either a Centralized or a Distributed approach. An initial validation was performed by conducting a number of tests under real transmission/reception conditions, concerning the CA effectiveness of both approaches. It was experimentally verified that Content Adaptation performed equally well with both approaches, thus paving the way towards a maximized network utilization while enabling End Users to receive services at the higher possible QoE allowed from their terminal capabilities and the available network resources.

As a future work, the authors will focus on a more thorough comparison of the Distributed and Centralized Content Adaptation approaches, taking into account the issues of complexity, scalability and fault tolerance. In addition further research effort will be carried out towards designing and implementing an algorithm, which taking into account the available network bit rate, service type and terminal capabilities could efficiently answer the following questions:

- What? (i.e. what type of Content Adaptation is the most beneficial?)
- Where? (i.e. should CA applied on the SPs or EUs CMN?)

#### ACKNOWLEDGMENT

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