ADVANCED METHODS AND TOOLS FOR ONLINE EVALUATION OF MULTIPLEXING SERVICES AND ENCODING PARAMETERS IN DIGITAL VIDEO BROADCASTING

Alexandru Florin ANTONE, Radu ARSINTE
Technical University of Cluj-Napoca, Faculty of Electronics, Telecommunications and Information Technology, Communications Department, Tel: +40-264-595699, Str. Baritiu 26-28,
antonealexandru@yahoo.com, Radu.Arsinte@com.utcluj.ro

Abstract: The paper contains a practical study regarding some aspects of multiplexing and encoding implementation in DVB systems. Starting from the ITU-R DTV model, the main blocks are investigated from theoretical point of view, emphasizing the points where is still possible to bring improvements in optimized practical implementation. The theoretical considerations are followed by an experimental study, performed online, using as a core element TSReader Pro, a software package developed to realize the analysis of different aspects (services, multiplexing, RF channel) in DTV (Digital TV). The results are useful in future service improvements, revealing, for example, the unused capacity in each distribution scenario.

Keywords: *ITU-R DTV model, DVB, Statistical multiplexing, Multiplex analysis*

I. INTRODUCTION

DVB is already a mature technology, verified over more than 15 years in many countries. With its variants S/T/C of the first generation, and T2/C2/S2 of the second one, DVB is used by a large number of audio/video content distributors around the world.

Broadcasters, network operators direct satellite broadcasting and other digital video services providers are seeking to increase the number of services transmitted in a fixed channel bandwidth, while maintaining high quality video. Today, for this purpose, it is used the statistical multiplexing system with a feedback between the multiplexer and encoders.

Considering implementation of DVB as digital fixed and mobile television in the world, providers and end-users are looking for optimizations in the transmission chain. Optimization is desired both from technical point of view and from business point of view, distributing more attractive services, lower maintaining costs etc. Statistical multiplexing is a critical factor in static or mobile DVB, with the (still) reduced data capacity of the mobile network. Even the basic generations of DVB (T/S/C) are taking a benefit from statistical multiplexing, applying new methods bringing the increase of audio-video streaming capacity. One of key factors in obtaining this desiderate is the statistical multiplexing. It implies a better use of network capacity through medium bandwidth allocation of every link connection, instead of absolute/dedicated bandwidth allocation.

Statistical multiplexing architectures in DVB allows media broadcasters the increase the efficiency in distributing digital services, thing that leads to an increase of profits along with customer satisfaction due to a broad variety of audio video services. It has been noticed that in case of video coders operating in constant bit rate mode, complex video scenes don't have sufficient bandwidth and therefore are error prone (for e.g. art effect can be noticed) opposed to simple video scenes which don't require as much bandwidth. Therefore in case of simple video scenes most of bandwidth is wasted. Conducted studies analyzing several parallel video streams showed that simultaneous existence of complex video scenes in parallel video streams are very rare. Therefore an advantage is to use a variable coding bit rate (of such streams) using a lower coding rate for simpler video scenes and allowing a higher coding rate for other streams with complex animations, taking advantage of a higher bandwidth. Another advantage is to use the gained bandwidth (by using lower coding rates for simpler video scenes) for inserting additional services (as text or other non time-critical application).

In this paper, we are focused on conducting a study of classical or statistical multiplexing, used by different service providers of DVB content, transmitted by telecommunications satellites or terrestrial, having as a final goal a better usage of channel capacity, and the possibility to offer new services in DVB networks. A secondary objective is to evaluate the encoding methods.

II. DTV DISTRIBUTION MODEL

All digital TV broadcasting systems are following the general model proposed by ITU, two decades ago. ITU established a model of a digital television broadcasting system and this was used as the basis for all DVB implementations. The model was divided into four subsystems (or three in some approaches). The model, presented in figure 1, has mainly three blocks.

Source coding and compression – contains the bit-rate reduction methods also known as data compression and error protection techniques that are appropriate for

Manuscript received April 21, 2013; revised May 28, 2013

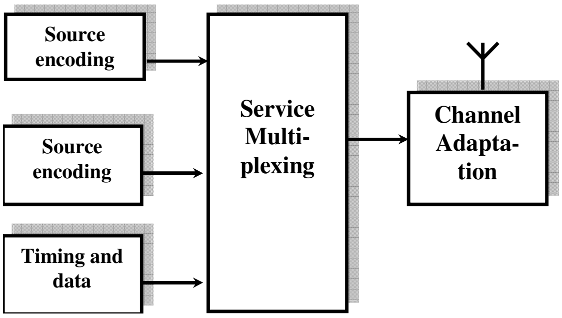

Figure 1. ITU DTV distribution model

application on the video, audio, and ancillary digital data streams, The term "ancillary data" includes control data, including conditional access control, and data associated with the programme audio and video services such as closed captioning. "Ancillary data" can also refer to independent programme and data services

Service multiplex and transport - the means ensuring dividing the digital data stream into "packets" of information, the means of uniquely identifying each packet or packet type, and the appropriate means of multiplexing the video data stream packets, the audio data stream packets, and the ancillary data stream packets into a single data stream. Interoperability or harmonization between digital media such as terrestrial broadcasting, cable distribution, satellite distribution, recording media, and computer interfaces is an important consideration in developing of the transport mechanism

The physical layer (adaptation) - use of digital data stream information to modulate the transmitted signal. The implementation of modulation techniques includes channel coding and error protection techniques using both single carrier and multiple carrier schemes.

III. MULTIPLEXING AND ENCODING IN DVB

The aim of Statistical Multiplexing is to increase the capacity of the multiplex taking advantage of the variability of bit rate along time of the different services when a sufficient number of them are combined into a Transport Stream. Statistical Multiplexing has been developed successfully in other DVB networks such as DVB-T, DVB-H or DVB-S.

A. Modes of Statistical Multiplexing

There are four modes to set the encoding speed.

- **Mode Variable Bite Rate (VBR) (Fig. 2)** Coding rate is selected in accordance with a given image quality. It normally fluctuates around a certain mean value.
- **Mode Capped Variable Bit Rate (Capped VBR) (Fig.3)** Speed is selected in accordance with a specified image quality, but with the forced setting of the upper limit. As in the first mode, the speed will fluctuate within a certain range of the average, do not exceed the ceiling.
- **Mode Available Bit Rate (ABR) (Fig.4)** Encoder uses the bandwidth that is allocated to it on an fixed basis.
- **Mode Constant Bit Rate (CBR) (Fig.5)** As in the previous mode, the encoder uses the maximal data rate allocated permanently, and the remaining gaps are filled with null packets.

CBR (Constant Bit Rate) is a term used when media contents has an encoding margin. This complication makes multiplexing in bursts more difficult than normal “continuous” multiplexing, since it introduces a new constraint which must be taken into account ([1]).

VBR (Variable Bit Rate) encoding, opposed to CBR, varies the amount of information per time segment. This means that complex parts of the encoded source are allocated with more capacity while the less complex parts are allocated with less capacity and so the perceived quality remains constant. This variation in bit rate normally fluctuates around an average bit rate which refers to the average amount of data transferred per unit of time ([1] [2] [4]).

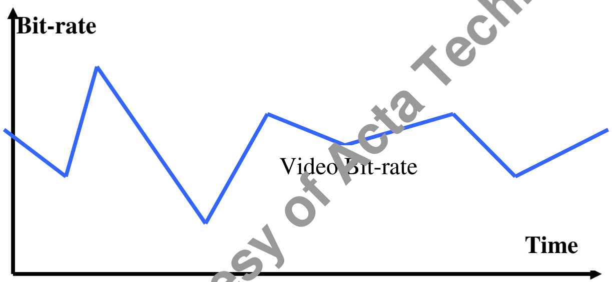

Figure 2. Mode Variable Bit Rate (VBR)

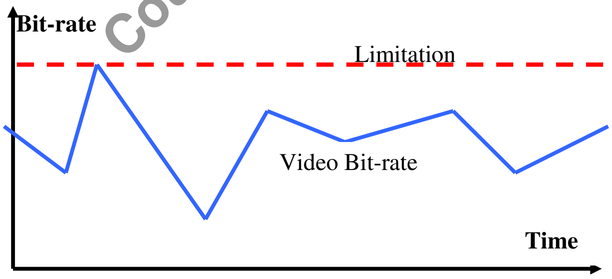

Figure 3. Mode Variable Bit Rate (VBR)

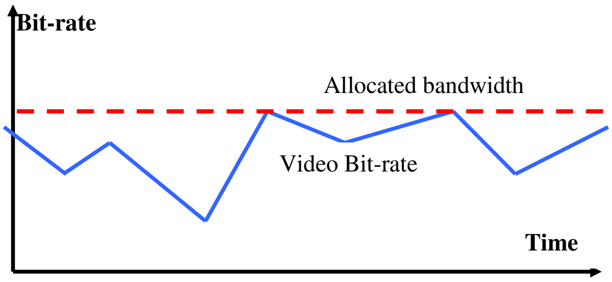

Figure 4. Mode Available Bit Rate (ABR)

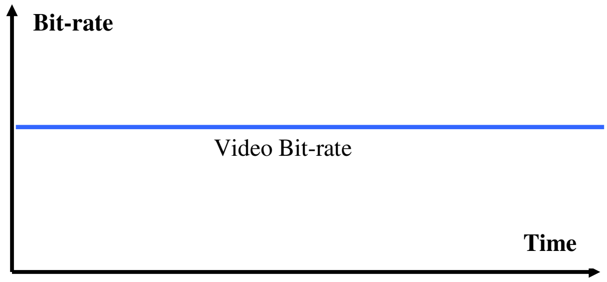

Figure 5. Mode Constant Bit Rate (CBR)

Technical methods to achieve optimized multiplexing and rate adaptation are different. We will describe few approaches in the following paragraphs.

B. Statistical multiplexing with feedback (Closed Loop)[2]

In a system with feedback (Fig.6), the encoders transmit the information directly about the complexity of each video sequence to the statistical multiplexing system, which assigns individual flow rates. Such a scheme is often used at the Headend, where all encoders are in the same place. The presence of feedback allows the bandwidth to be used more efficiently.

C. Statistical multiplexing without feedback (Open Loop) [2]

If the initial exchange of information between the encoder and multiplexer system is missing, the system is without feedback. This variant is sometimes called rate-shaping statistical multiplexing.

Reducing the flow rate in the system is achieved by the following methods:

1. Manipulation of the input compressed streams for avoiding simultaneous occurrence of high-speed peaks. Speed peaks appear at times when coders work in the load mode. The time shift input flows through their buffering to spread peaks, minimizing the peak rate of the overall flow.
2. Incoming stream is encoded at CBR, and can contain up to 10% of null packets in the multiplex, which can be removed.

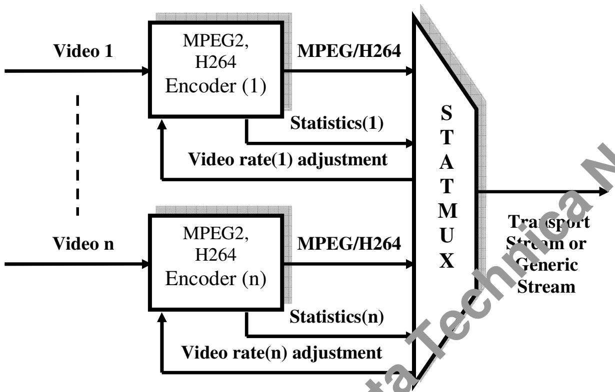

Figure 6. Generic Bit Rate adaptation in channel encoders

3. The flow rate can be reduced by optimizing the coefficients of the quantization matrix of input compressed stream (Fig. 7 – Mquant input). This method is used in cases where the flow will pass on a narrower channel than the one on which it was passed in the first stage. This procedure is often performed on flows from satellite DTH packages before they are relayed to the IPTV networks. Sometimes it is called trans-rating. Systems without feedback are the typical Headend cable TV networks and IPTV, where the re-multiplexing streams are already encoded in remote broadcasting centers.

D. Organization of the system, depending on network

In traditional satellite networks that form MPEG-2 (or MPEG-4) packets for DTH reception, the dominating system is with feedback, where the featured encoders are

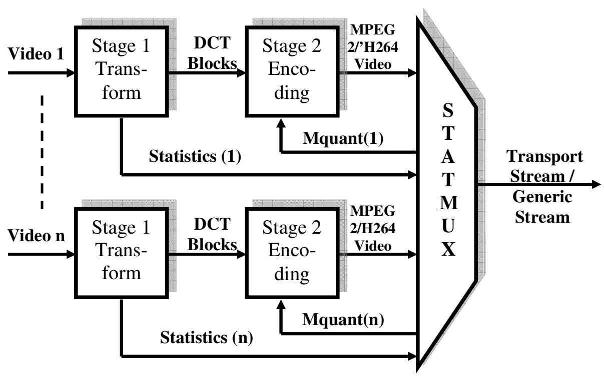

Figure 7. Detailed bit rate adaptation blocks in channel encoders

connected to the multiplexing system via a reliable LAN. However, many applications are not allowing such a connection to the encoder system. Organization of the return channel can be expensive or simply is not possible to provide the required reliability of the channel encoders and tight synchronization. At the same time, content owners increasingly are engaged in a compression of the material, creating a need for distributed statistical multiplexing.

A necessary condition for such a system is the possibility of organizing a global network of reliable channels connecting the station with all remote locations. Despite the complexity and high cost of technology, it is a realistic option for many applications, especially in those cases where recompression is necessary. In the world of digital television, statistical multiplexing is used as a mean of obtaining a 30-40% efficiency for a given transmission channel (terrestrial, satellite, cable); as a proprietary and accepted technology by all broadcasters.

The concept of statistical multiplexing in DVB is based on the fact that only changing or highly complex video scenes require a higher bandwidth and that the rest of the video data can be sent at a lower bit rate. The bandwidth setting on CBR encoders has to be established that these complex scenes can be transmitted with good quality, meaning that the encoders would generate on average more bandwidth than they would really require.

E. Advantages of using Statistical Multiplexing

The achieved gain by using statistical multiplexing in digital video television may be used to enhance the video quality of the available services while keeping their number constant or transmit more video services of the same quality on the same available network transmission bandwidth.

Statistical multiplexing provides significant effectiveness in terms of operation and use of transportation resources, as well as a significant reduction in costs. It provides the following key benefits:

• Any service can be included in any package that provides flexibility and scalability;
• Simplification of content aggregation by eliminating distance limitations;
• One-step statistical multiplexing leads to a more efficient use of transport resources, optimizes content aggregation scheme and make possible to balance the load of primary and secondary (backup) system;

F. Empirical Statistical multiplexing algorithms
In the literature some theoretical studies ([4]) proposed two statistical multiplexing algorithms that are based on the empirical rate-distortion prediction algorithms and equal distortion bandwidth algorithm. Based on those approaches, the bandwidth allocation performed once every GOP (group of pictures) in two stages: first, the rate-distortion functions of the next GOP is predicted for all input channels, second, an optimal bandwidth allocation is computed for every channel based on predicted rate-distortion functions and the total bandwidth so that the expected distortion of every input channel is equalized and the total bit rate is under the budget.

A statistical multiplexing algorithm can be divided and distributed on the encoders and then the multiplexer. Based on the system structure, every encoder calculates the relevant statistics of the current GOP and sends them to the multiplexer at every GOP boundary. After receiving all the statistic, the multiplexer first predicts the rate-distortion functions of the next GOPs from the corresponding statistics. Then the multiplexer assigns video rates for all the input channels. Finally, the multiplexer sends back bandwidth allocation to every encoder. Upon receiving its video rate sent back from the multiplexer, the encoders continue to compress the next GOP of video sequence using the specified video rate (as described in Fig. 7)

G. Analytical statistical multiplexing algorithms
Other studies ([4]) are proposing two statistical multiplexing algorithms based on the theoretical rate-distortion model. Based on the rate-distortion model ever input channel computes and sends the relevant statistic of its current frame to the multiplexer at the end of the transformation stage. After receiving the relevant statistics of the current frame for every encoder, the multiplexer first estimates the rate-distortion functions from the corresponding statistics, the, it computes the quantization scale factor for every encoder based on the estimated rate-distortion functions and the available bit budget of the current frames, so that the expected distortion of all input channels are equalized and the expected total bits (used to encode the current frames) are under the budget. Then, the multiplexer sends back calculated values to the corresponding encoders.

Upon receiving, the encoders continue the second stage of video compressing process (encoding stage), which quantizes the transformed frame with the specified values and encodes the quantized DCT (Discrete Cosine Transform- via Mquant) blocks and motion vectors into an MPEG-2 video stream (as illustrated in Fig. 7). The same architecture is applied even for newer standards (MPEG4, H264).

Video sequences may be considered: simple, moderately complex, complex, extremely complex. Several simulation trials ([5]) were conducted to evaluate overall performance of the statistical multiplexing algorithm. The multiplexer evaluates the output bit rate of each encoder (MPEG Video) and adjust (using Mquant output) the encoding algorithm to keep the Transport Stream bit rate within allowed limits.

The algorithm is designed to achieve: the reducing of the average distortion (improving average picture quality) of a set of channels given with a fixed bandwidth, the increase in the number of channels without increasing the average distortion given a fixed bandwidth, decreasing the total bandwidth required to compress the same set of video sequences without increasing its average distortion. Different bibliographic sources ([4],[5],[6]) are presenting various aspects of statistical multiplexing in DVB.

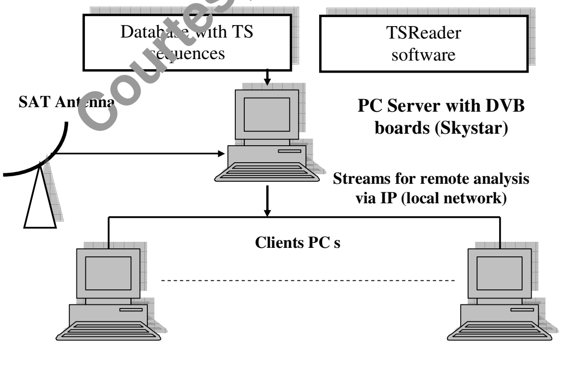

Figure 8. DVB services test system

IV. EXPERIMENTAL RESULTS

Experimental setup (Fig. 8)
In this experimental research, a first step was a study on the implementation of multiplexing methods, classical or statistical, used by different service providers of DVB content transmitted through telecommunications satellites. The research was facilitated by a set of software tools, recommended in different studies ([7],[9]). Our previous experiments in this area ([8]) were particularly useful. An additional study was conducted on the encoding parameters (chosen codecs) and bit rates resulting from this choice. Unlike previous studies, the evaluation described in the paper was realized online, acquiring in real-time the described services.

Protocol analyzer - TSReader
For all aspects of evaluation we are using TSReader Pro. This software package furnishes general information about multiplex at RF level such as IF, polarization, Signal to Noise Ratio (SNR a.k.a. C/N), transponder symbol rate, multiplex useful bit rate, type of receiver card, and modulation type. It also provides TS information and program visualization by identifying and decoding MPEG-2 audio/video, table specific information packets. The application displays the programs from the multiplex (Video Decode section).

It also shows data about elementary streams from the TS such as Program Allocation Table (PAT), Program Map Table (PMT), Conditional Access Table (CAT), Network Information Table (NIT), Service Description Table (SDT), Event Information Table (EIT), programs bit rate, and received multiplex time information.

Evaluation of a DVB multiplex
As an example, in this paragraph we are presenting, the evaluation of the multiplex from Astra 19,2E fleet (12552MHz,V,22000,QPSK) [10].

Fig. 9 is presenting a graphical form of the structure of the multiplex, with the contribution of each program, expressed in percents. It is clear that all the services present in this multiplex are Variable Bit Rate and the multiplexing method is Statistical. To adjust the bit rate to the fixed value requested by transmission mechanism (transponder) null packets are used (top layer). The analysis program is offering detailed information

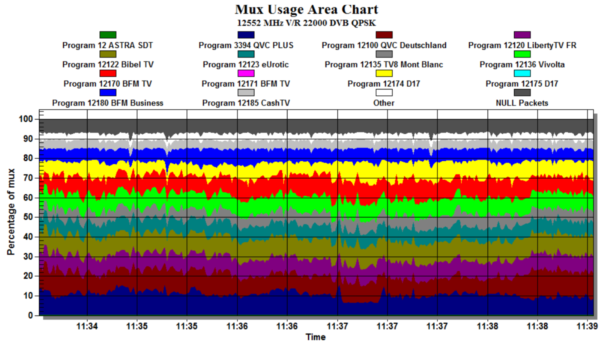

Figure 10. Bit rate of different programs in the multiplex

regarding the components of the multiplex for each program.

Table 1 contains the basic parameters (instantaneous values) of the programs included in the multiplex, highlighting the bit rate values for audio, video and ancillary data. A special remark for the NULL packets, revealing the fact that 6-7% of the effective capacity remains unused, even after the implementation of statistical multiplexing.

Table 1- Service structure and bitrates of the multiplex

Nr.	Program	Component	Bit rate (Mbps)
1.	QVC Deutschland	Video	2.565961
		Audio	0.133167
		Data	0.189471
2.	LibertyTV FR	Video	2.580020
		Audio	0.133167
		Data	0.119976
3.	Bibel TV	Video	3.057906
		Audio	0.203760
		Data	0.213165
4.	TV8 Mont Blanc	Video	1.482420
		Audio	0.407358
		Data	0
5.	BFM TV	Video	2.659369
		Audio	0.203679
		Data	0.464517
6.	D17	Video	2.099729
		Audio	0.203679
		Data	0.464558
7.	BFM Business	Video	2.760239
		Audio	0.133167
		Data	0.464517
8.	Cash TV	Video	1.352031
		Audio	0.133167
		Data	0
7.	Null Packets	Data	2.594295

It is still possible to see individual channels and the instantaneous or averaged bit-rates. Figures 10 and 11 are presenting the corresponding diagrams of D17 program from the multiplex. It is easy to see that video bit rate has rapid variations during the observation window.

The overall conclusion of analysis for this multiplex, is the general use of VBR encoders and statistical multiplexing.

The second example presents a brief analysis of The WDR multiplex (12604MHz,H,22000,QPSK), from the same Astra 19E fleet. From this trial we are presenting first the evaluation of RF channel stability for 5 minutes. Figure 12 contains the variation of SNR (C/N) of the selected channel. Since the time window is relatively

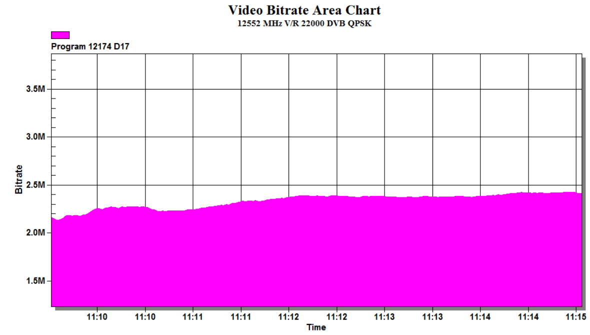

Figure 10. Averaged bit rate of D17 program

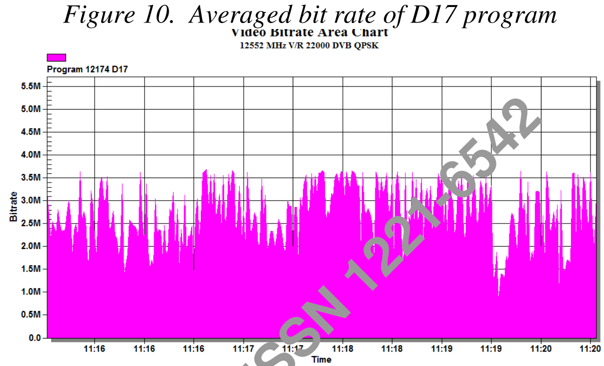

Figure 11. Un-averaged bit rate of D17 program

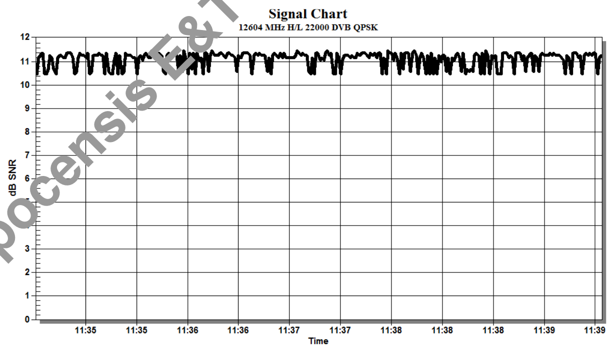

Figure 12. Variation in time of SNR for WDR multiplex

short, there are no significant modifications in the quality of reception (values of SNR around 11dB).

This multiplex has a unique feature: it contains characteristics from both standards (DVB-S/S2). Shortly, the multiplex, using DVB-S style modulation, contains both SD and HD programs, encoded in MPEG2 and H264 respectively. This unique situation, to have simultaneously the same content encoded in both formats, convinced us

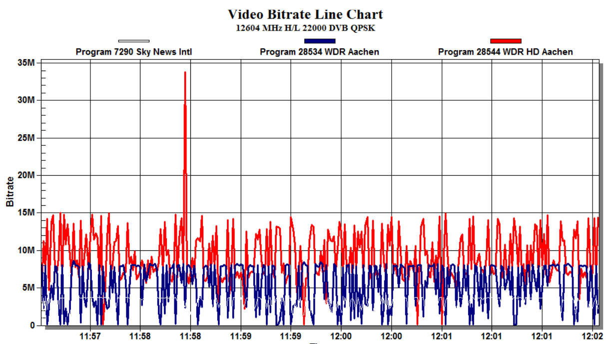

Figure 13. Variation of video bitrates for H264 (upper-red) and MPEG2 (lower-blue) streams

to build the bitrates of both streams on the same diagram (figure 13). Additionally, Table 2 contains the measured values of video bitrates for the basic programs composing the multiplex.

Table 2- Video bitrates of WDR multiplex streams

Nr.	Program	Resolution	Minimum bit rate (Mbps)	Maximum bit rate (Mbps)	Approx Average bit rate (Mbps)
1	WDR HD Aachen	HD	0.0893	14.903	9
2	WDR Aachen	SD	0.0834	9.762	7.5
3	Sky News Intl.	SD	0.4061	3.773	3.2

The TSReader allows to evaluate the encoding methods and details of the video and audio components. An evaluation of GOP composition, obtained using the specific component of TSReader, is presented in figure 14.

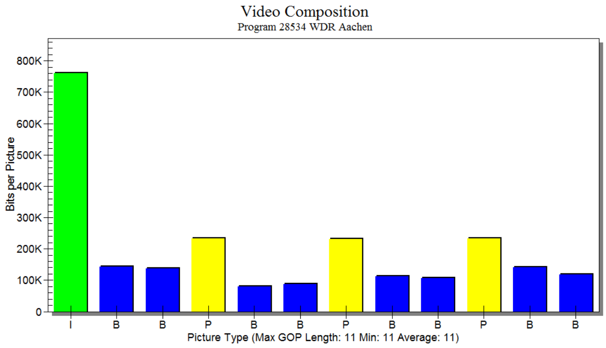

Figure 14. Structure of GOP for a stream (WDR SD)

V. CONCLUSIONS

The analysis conducted in this research has, as a principal goal to analyze the encoding services and multiplexing methods in DVB transmissions. The conclusion is that statistical multiplexing is present in almost all transmission systems. Statistical multiplexing is widely used in the world of digital television as a means to obtain an efficiency boost of 30-40% for a given transmission channel (terrestrial, cable or satellite) and the technology it is mastered and accepted by broadcast operators. The principle is based on the observation that only changes or highly complex scenes require a higher band width and the rest of the image data can be sent with a lower bit rate. Setting the bandwidth of a CBR encoder must satisfy the requirement for complex scenes to be sent with high quality, i.e. encoders to generate more bandwidth than actually required. Statistical multiplexing required replacement, in last years, of old equipment with new one implementing the new multiplexing algorithm, which could be costly for small DVB operators. This study revealed that all multiplexes still have provision (in null packets) for additional services.

This will be one of the future direction of the research, to investigate the impact of statistical multiplexing of DVB services through distribution in IP based networks. According to different studies ([2]) the use of statistical multiplexing in IP-based networks, distributing DVB, could have many advantages. Statistical multiplexing IP provides significant effectiveness in terms of operation and use of transportation resources, as well as a significant reduction in costs. It provides the following key benefits:

- Any service can be included in any package that provides flexibility and scalability leading to simplification of content aggregation by eliminating distance limitations;
- One-step statistical multiplexing allows more efficient use of transport resources, optimizes content aggregation scheme and make possible to balance the load of primary and secondary (backup) system;
- Using the Ethernet-equipment simplifies the system and reduces its cost;
- More flexibility to increase the reliability of backup services;
- Self-managed infrastructure could simplify system management.

Our future research will try to build local IP based distribution systems, starting from DVB transported streams.

ACKNOWLEDGEMENT

This paper was supported by the project "Improvement of the doctoral studies quality in engineering science for development of the knowledge based society-QDOC" contract no. POSDRU/107/1.5/S/78534, project co-funded by the European Social Fund through the Sectorial Operational Program Human Resources 2007-2013.

REFERENCES

[1] A. Lopez, J. Mas, G. Fernandez, „Comparing static and statistical multiplexing in DVB-H", *Proceedings of IEEE International Symposium on Broadband Multimedia Systems and Broadcasting BMSB '09*, 2009, pp.1-4
[2] Boris Felts, Jean Kypreos, Thomas Guionnet, "Envivio IP-based Statistical Rate Control", *Envivio, White Paper*, Dec.2006 http://www.envivio.com/files/white-papers/IPStatRate_Final.pdf [last accessed on 15th April 2013]
[3] Aldo Cugnini, "Transition to Digital Handbook-Multiplexing", *Broadcast Engineering World*, December 2010, pp.16-18
[4] Qiang Wu, „Statistical Multiplexing for MPEG-2 Video Streams", *Master Thesis*, MIT 1999, pp. 33-43, pp. 69-82
[5] Dr. Manfred Kuhn, Dr. Joschen Antkowiak, "Statistical multiplexing – What does it mean for DVB-T", FKT *Fachzeitschrift für Fernsehen, Film und elektronische Medien* – April 2000
[6] Hamed Ahmadi Aliabad, Sandro Moiron, Martin Fleury and Mohammed Ghanbari, „No-reference H.264/AVC Statistical multiplexing for DVB-RCS" , *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, Volume 43, 2010, pp 163-178
[7] Alexandru Antone, Radu Arsinte, „An experimental study of quality analysis methods in DVB-S/DVB-S2 systems", *Acta Technica Napocensis- Electronics & Telecommunications*, no.4/2010, pp.7-13
[8] A.F. Antone, R. Arsinte - "Investigating the Impact of Statistical Multiplexing in DVB Systems - A Practical Study for DVB Services Improvement", *Proceedings of The 1st Virtual International Conference on Advanced Research in Scientific Areas (ARSA-2012),* Slovakia, December 3 - 7, 2012, pp.2005-2010
[9] http://www.tsreader.com/legacy/ [Last accessed on 3th April 2013]
[10] http://en.kingofsat.net [Last accessed on 17th April 2013]