STATISTICAL PROPERTIES OF MPEG STREAMS AND ISSUES FOR TRAMSMISSION OF VIDEO INFORMATION IN HIGH SPEED NETWORKS

Marek Natkaniec, Krzysztof Wajda
{wajda,natkanie}@kt.agh.edu.pl.
Telecommunications Department, University of Mining and Metallurgy,
Aleje Mickiewicza 30, 30-059 Cracow, POLAND

Abstract. ATM network is a flexible environment to provide efficient transport of multimedia traffic. MPEG-encoded video information constitutes significant amount of transmitted data in broadband network. The paper investigates a gain which can be obtained when using results of statistical studies on stored MPEG files. Performance of transfer of MPEG information via CBR and rt-VBR links is studied.

Keywords. MPEG, broadband network, ATM, traffic management, simulation

INTRODUCTION

Transport of MPEG-based video information through ATM broadband network is a challenging topic at present days. Complex time-spatial structure of MPEG stream has to be explored in order to fit statistical features of MPEG file with ATM connection traffic category and its specific parameters.

We have focused studies on simulations made using general-purpose COMNET tool. Specifically, we would like to approximate bandwidth demand for single VC carrying data traffic containing MPEG encoded video.

The distributed system of service provisioning consists of transmitting terminal (computer, VoD server with MPEG player, voice terminal), network resources (shared) and receiving terminal (computer, set-top-box, voice terminal). There is certain level of interoperability between the terminal and the transport network in terms of efficient bandwidth allocation and control for the purpose of transport of multiple streams.

Transport of MPEG information via "pure" link brings a problem of link capacity/buffer size decision. When using ATM technology, the number of potentially available solutions increases significantly because of usage of ATM traffic categories concept (considered with parameters to be specified). The goal is to preserve required QoS objectives and get some gain from statistical multiplexing.

Regarding operations on transmitted MPEG-encoded stream one can classify concepts of data transmission (from network independent to ATM standard specific) as:

- network transparent
  - CBR (PCR – Peak Cell Rate oriented) – bufferless approach,
  - CBR (ABR – Available Cell Rate oriented) – large buffer approach,
- application oriented
  - Shaping mutual phase of traffic streams (proper synchronization)
  - Introducing system of priorities for frames
- traffic shaping according to traffic categories and traffic parameters in ATM
- with implementation of policing issues

We model VoD traffic using statistical parameters available from few files which are available in the Internet server (we are using an empirical pdf function for I, P, B frames).

We aim at evaluation of few options available for transfer MPEG streams via network. These options were specified and tested against their usefulness and efficiency.

MPEG FILES

In order to investigate performance issues we have used 3 files encoded using MPEG-1 standard with very different content type. These files were coded at Institute of Computer Science (University of Wuerzburg) using software coder UC-Berkeley MPEG-1 [9]. All files have following common parameters:

- Frame frequency: 25 frames/second;
- GOP structure: : IBBPBBPBBPBB (12 frames);
- Quantizer scales: 10(I), 14(P), 18(B);
- Motion vector search: logarithmic/simple, reference frame: original;
- Input to the coder: 384x288 pixels with 12 bits of color information per pixel;
- Number of frames in each file: 40000 (about 0.5 hour of movie).

Investigations were carried using three different (in content type) movies:

- ***lambs*** – „The silence of the Lambs"; (slowly changing content);
- ***race*** – Formule 1 race in Hockenheim/Germany 1994; (dynamic content);

- ***mr. Bean*** – three comedy episods, (medium dynamic content);

Below in Table 1 the main parameters of chosen files are presented. They are considered as parameters reflecting statistical properties of MPEG files. We do not consider any correlation aspects of MPEG streams.
Following Table 2 contains detailed statistics of I, P, B frames for considered video files.

In order to give some background results we have studied transport of MPEG stream in "pure" channel with changed link speed and buffer capacity (no specific transport protocol was used). Information is fragmented into packets containing 600 bytes. The results are presented in Figure 1.

It can be seen from Figure 1 that using information about content of recorded MPEG files can give significant hints what network resources are necessary in order to transfer such content via network.

Table 2. Statistics of encoded sequences

Movie	Compression level X:1	Frames			GOP structures		
		Mean size[bits]	CoV	Maximum/ mean	Mean [bits]	CoV	Maximum/ mean
Lambs	363	7,312	1.53	18.4	87,634	0.60	5.3
Mr. Bean	150	17,647	1.17	13.0	211,368	0.50	4.1
Race	86	30,749	0.69	6.6	369,060	0.38	3.6

Table 2. Detailed statistics of I, P and B frames for considered MPEG files

File	*Lambs*			*Mr. Bean*			*Race*		
Frame type	**I**	**P**	**B**	**I**	**P**	**B**	**I**	**P**	**B**
Number of frames	3334	10000	26666	3334	10000	26666	3334	10000	26666
Mean frame size [bits]	38023,77	7436,29	3424,86	75161,18	18282,28	10214,24	79241,32	38200,54	21891,86
Minimum frame size [bits]	15120	528	288	14272	1720	344	36972	6040	4192
Maximum frame size [bits]	134222	88600	54976	150176	119216	129072	186048	202416	165448
Standard deviation [bits]	12813	8051	3184	19458	14318	6697	20826	18235	9997
Sum [bytes]	15846407	9295367	11415921	31323423	22852858	34046647	33023820	47750679	72971062

SIMULATION MODEL

We have implemented a model of ATM-based transport of MPEG streams in COMNET simulation environment. The detailed structure of MPEG information – I,P,B frames – is modeled by using a concept of triggered session sources (with triggering delay equal to 40 ms). Each source has detailed information about probability density function which is built-in using stored histogram of frame sizes. These histograms were obtained by thorough scanning of MPEG files. Such approach ignores correlation between scenes but for the purposes of defining the ATM connection parameters should be sufficient.

TRANSPORT IN "PURE" CHANNEL

It should be pointed out why we have used not just follow frame structure generated by terminal equipment.

TRANSPORT IN ATM NETWORK

ATM traffic options – traffic categories and AAL versions

Transport of application information through ATM networks requires set-up of VC connections with chosen traffic category, parameters specific for such category and conformance definition for connection. Also together with traffic category it is necessary to choose AAL version for connection. There is suggested mapping of traffic categories and AAL versions. For simplicity we consider that choice of AAL version has only influence on protocol overhead, no extra function is performed. So: AAL1 adds 1 byte (+ 5 bytes of ATM layer header), AAL3/4 adds 4 bytes and for AAL5 we assume no addition of any AAL layer overhead what is reasonable simplification for long upper layer frames.

Significant impact on behaviour of traffic stream in ATM has the GCRA function which is used as a tool to check compliance of cells and conformance of whole connection.

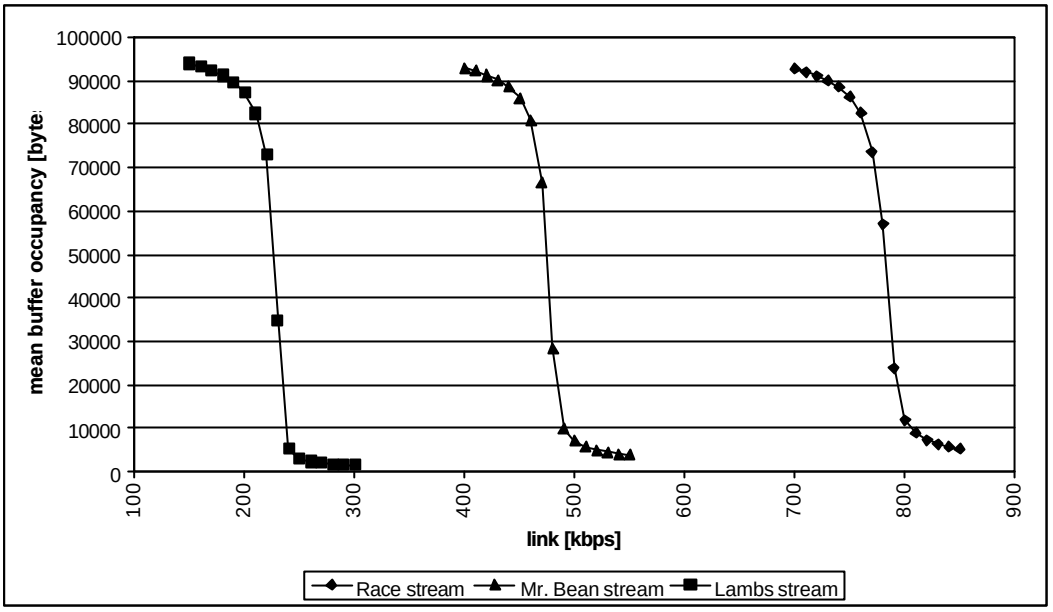

Figure 1. Quality parameters when transmitting MPEG files in „pure" channel

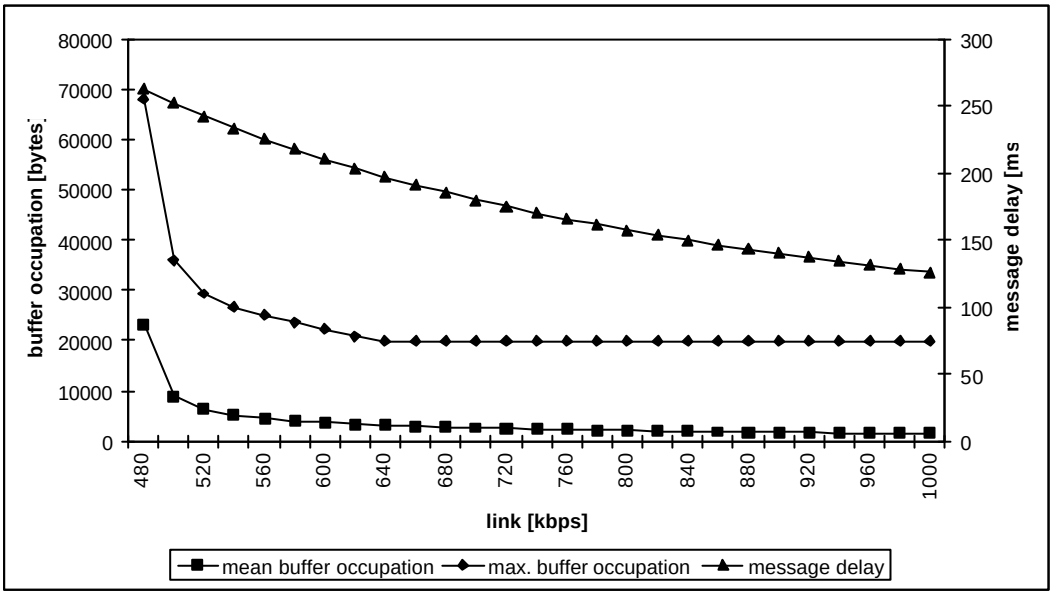

Figure 2. Quality parameters when transmitting 1 stream of „Mr. Bean" in CBR channel

Configuration of GCRA modules depends on traffic category but the goal is to shape PCR, SCR and MBS parameters.

Basic characteristics – transport in CBR channel

At least PCR can be specified, what means some level of freedom in parameter specification (trade-off between losses and delays experienced in the system by video traffic). Other parameters influencing performance of the system in this case are: output link bandwidth and buffer capacity. Transmission in ATM CBR channel requires definition of GCRA parameters GCRA(1/PCR_{0+1}, CDVT), where PCR is Peak Cell Rate for all cells (i.e. with CLP=0 or 1) and CDVT is Cell Delay Variation Tolerance.

Results obtained from simulation model when transmitting 1 and 5 MPEG streams ("Mr. Bean") are presented in Figure 2 and Figure 3, respectively.

Wide range of possibilities – transport in VBR channel

Already at first glance transport of constant-quality MPEG-based video information using rt-VBR traffic category seems to be most attractive options. In fact, it assures both keeping losses and delays on appropriate levels. The problem is how to choose necessary parameters: PCR, SCR and MBS. It is evident that such parameters should be chosen according to known statistical characteristics of prerecorded MPEG files.

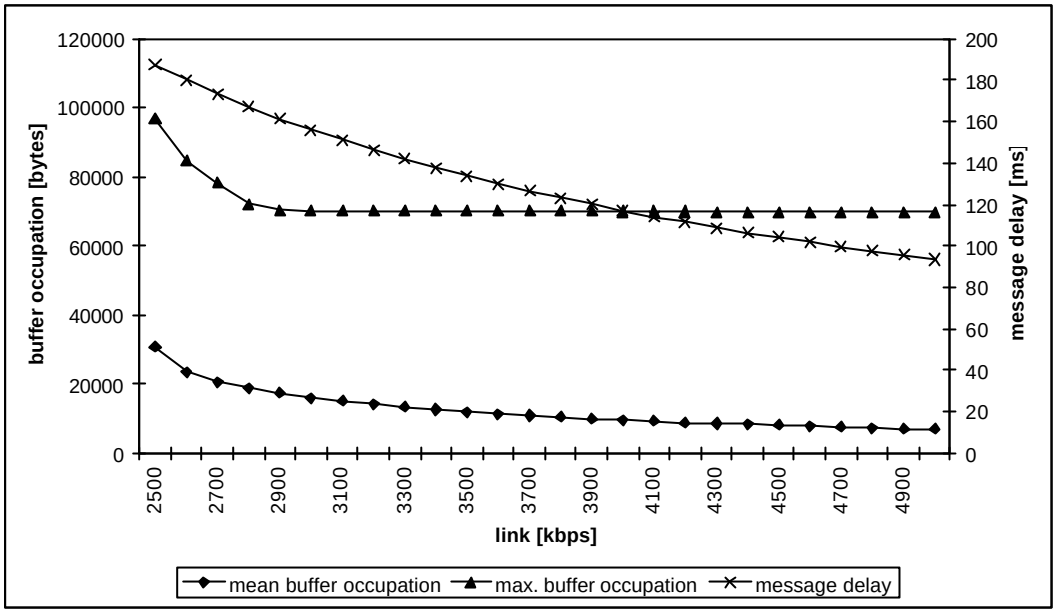

Figure 3. Quality parameters when transmitting 5 streams of „Mr. Bean" MPEG in CBR channel

The values for PCR, SCR and MBS have to be chosen at the connection set-up time. They are in fact not independent each other. The choice of parameters has to consider user requirements (to get required level of service and not to pay too much) and also network operator goals (to keep whole traffic under control and to get some gain from statistical multiplexing – to sell bandwidth few times). Rather than giving simple (and automatic) solutions it is easier to point out not acceptable sets of parameters. PCR should be sufficient to allow for fast transfer of biggest frames. SCR should reflect mean value of information stream. MBS is generally considered jointly with SCR – there is a trade-off between these parameters. The user can not get more bandwidth then SCR*(1+MBS/t) where t is measurement interval. There is situation not advantageous for network suppliers: very big PCR, very small SCR and very big MBS (this means spreading of information over long period).

PCR for VBR transport with AAL5 option (disregarding overheads of AAL layer) is equal to BFS (bits/frame)/(48*8 bits/cell) * 25 frames/sec expressed in cells; where BFS is size of biggest frame (I frame).

CDVT is difficult to define since it is dependent on behaviour of MPEG decoder (robustness of decoder against delay jitter) and following [5], [8] we suggest CDVT = 17 ìs for 25 Mbps ATM link.

SCR is chosen to be between PCR and mean cell rate and is variable for out simulation investigations.

BT should be chosen in close relation with SCR.

For VBR.1 traffic category there are 2 GCRA modules used in order to shape 3 parameters: GCRA(1/PCR_{0+1},CDVT) and GCRA(1/SCR_0, BT+CDVT), CLP is not considered.

For our studies we have chosen GCRA parameters adjusted for MPEG stream: for "Mr. Bean" stream PCR is 9777 cell/s (we have assumed 10000) and SCR is 1148 cells/s (but we have assumed 1150). It comes from statistical properties of MPEG streams of Mr. Bean file.

Figure 4 presents message delay and mean buffer occupancy as experienced by 1 MPEG stream (Mr Bean) sent via rt-VBR channel. It can be seen that system gives better delay characteristics when using smaller MBS values. PCR and SCR values are chosen according to information known from statistical features of MPEG file. Figure 5 presents message delay and mean buffer occupancy as experienced by 5 multiplexed homogeneous MPEG streams. In this case we have compared quality indices for first source observed (among 5).

What's new – other possibilities in ATM network

We have studied the basic options of transport MPEG streams in ATM networks, widely accepted and studied – using CBR and rt-VBR traffic categories. The main stress is laid on choosing proper traffic contract parameters in a situation of availability of basic statistical parameters of MPEG recordings, such as short and long term mean value of bytes (i.e. for GOP and scene). The results are presented above.

The problem about the best traffic category for transport of MPEG streams is well defined and has satisfactory solution at present. It still needs further investigations how to choose traffic parameters for network contract. Usage of other traffic categories, for example ABR category which gives an opportunity to adapt channel specification to available resources, or GFR category, recently advocated by ATM Forum for frame-based traffic, are still open questions.

When studying performance issues for ATM connections it is of great importance to consider influence of background traffic (traffic sent by other services). In most cases only

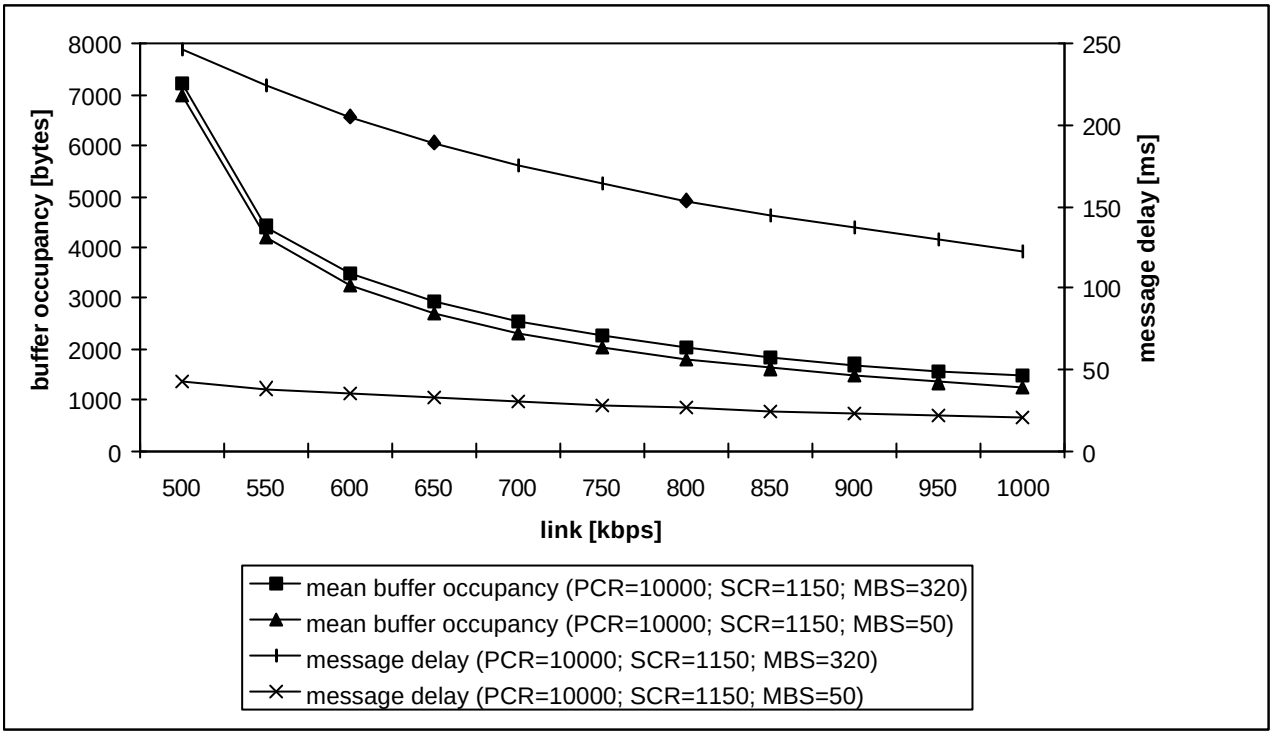

Figure 4. QoS parameters for transport of single stream with VBR traffic category

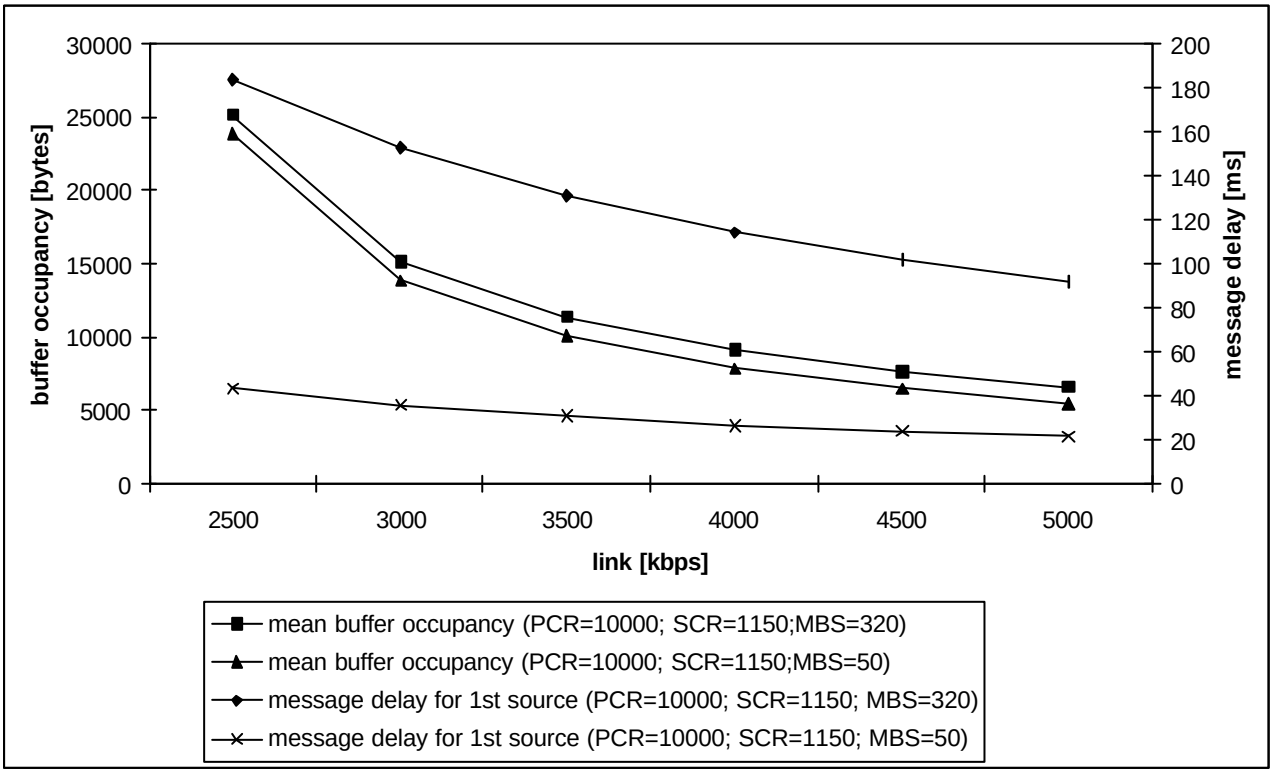

Figure 5. QoS parameters when transmitting 5 streams with VBR traffic category

traffic for specific service is considered and this is valid approach for VP-based traffic management with VP separation and enforcement. However, in certain situations, such as corporate multiservice network or access network with limited resources, mixing of different traffic streams can be admitted.

CONCLUSIONS

The goal of this paper was to study basic options for transport of MPEG files with known statistical characteristics obtained by scanning of prerecorded files. Such approach enables create and manage real-time, cost effective VoD

service over ATM network. Performance of transfer of MPEG information via CBR and rt-VBR links were studied and significance of known information about statistical properties of MPEG files was shown.

Further investigations are necessary in order to find an impact other traffic categories and chosen parameters on MPEG transport quality indices.

REFERENCES

[1] Gringeri, S., Knasnabish B., Jimenez-Rivera, A., Egorov, R., Salamam, V., Lewis, A., Bash, B.: Traffic analysis of veriable rate MPEG1 and MPEG2 video, ATM Forum Contribution 97-0549, July, 1997.

[2] Key, P., Macfadyen, R., Nilsson, M.: VBR Video, Policing and Dimensioning, ATM Forum Contribution 97-0308, April, 1997.

[3] Reibman A.R: Traffic Descriptors for VBR Video Teleconferencing Over ATM Networks, IEEE/ACM Transactions on Networking, VOL. 3, NO. 3, June 1995, pp. 329-339.

[4] ATM_Forum, Contribution 97-0435, Suh D.Y., Gyun. Han S., Park S.H.: Traffic Contract for CBR, VBR.1, VBR.2 and VBR.3 Services of VBR Encoded Real-time MPEG Traffic, February 1998.

[5] ATM Forum, "Traffic Management Specification Version 4.0", April, 1996.

[6] ATM Forum, BTD-SAA-AMS-VBRMPEG2-02.02, VBR MPEG-2 - Baseline Text, Anaheim, February 1998.

[7] ATM_Forum, Contribution 97-0435, Mendelson, J.: Traffic Management Requirements for the transport of variable bit rate MPEG 2 encoded content over ATM, Chicago, May 1997.

[8] ATM Forum 98-0079, Suh, D.Y., Han, S.G., Park, S.H.: Traffic Contract for CBR, VBR.1, VBR.2, and VBR.3 Services of VBR Encoded Real-time MPEG Traffic.

[9] Mpeg files available by ftp from ftp://ftp-info3.informatik.uni-wuerzburg.de/pub/MPEG.

Krzysztof Wajda

Marek Natkaniec studied at the Univesity of Mining and Metallurgy, Cracow, Poland. In 1997 he received the M.A. degree in telecommunication and joined the Telecommunications Department of the UMM. Since then he has been working on wireless local area networks, high-speed networks and multimedia systems. He co-authored several papers.