Nandakishore Ramaswamy

Advanced Data Networks (EE 6364)

Term Paper on

MULTIMEDIA OVER ATM

Instructor: - David Wang

Abstract
Transmission of multimedia content over a high-speed network such as ATM for applications such as Video on Demand (Vod) is slated to become one of the fastest emerging applications in the real world. Due to the low delay and high QoS (Quality of service) constraint posed by these applications, various issues arise such as selection of AAL (ATM Adaptation Layer), service class selection and others have to be addressed. This paper provides an overview of the underlying technology and methods used to transport multimedia over ATM.

Introduction
The growth of high-speed networks such as ATM and Internet and with the advent of the latest video coding standard H.264 makes it now possible to carry high data generating multimedia applications such as video on demand and telephony in real time. Transportation of compressed video over ATM backbone networks has already been standardized by the ATM Forum [2]. The ITU-T (formerly known as CCITT) has also recommended ATM as the transport vehicle for BISDN [3].

ATM is characterized by its ability to provide high QoS guarantees to multimedia applications. The classes of service: Constant Bit Rate (CBR), Available Bit rate (ABR), Real time Variable Bit rate (RT -VBR) and Unspecified Bit Rate (UBR) exist in ATM, which can be used to provide the required bit rate for multimedia applications [4]. The CBR service is used to serve applications that require a constant bit rate and low delay. These parameters are negotiated before data transfer takes place and remains constant throughout the duration of the connection. This results in low efficiency of the network resources. The ABR service instead is viable for non real-time applications that can vary their transmission rate according to the congestion level in the network. The Minimum cell rate (MCR) and a maximum cell rate are the parameters to be negotiated. RT-VBR service is used for real time applications that transmit at variable rate. The last is the UBR, which is a best effort type of service, and QoS cannot be guaranteed. [5]

In [1] the authors discuss the advantages of using ATM over other networks. These are

- Merging of voice, video and data networks into a single network.
- ATM is a standard that allows different QoS and bandwidth guarantees and thus being the ideal choice for all the three kinds of data.

H.264/MPEG-4 Part 10 Video Coding Standard
H.264 is a joint venture between ITU-T’s VCEG (Video Coding Experts Group) and ISO/IEC’s MPEG (Moving Picture Experts Group). H.264 provides a 2:1 coding gain over other compression standards [6]. The block diagram of the coding engine is shown in Fig1.

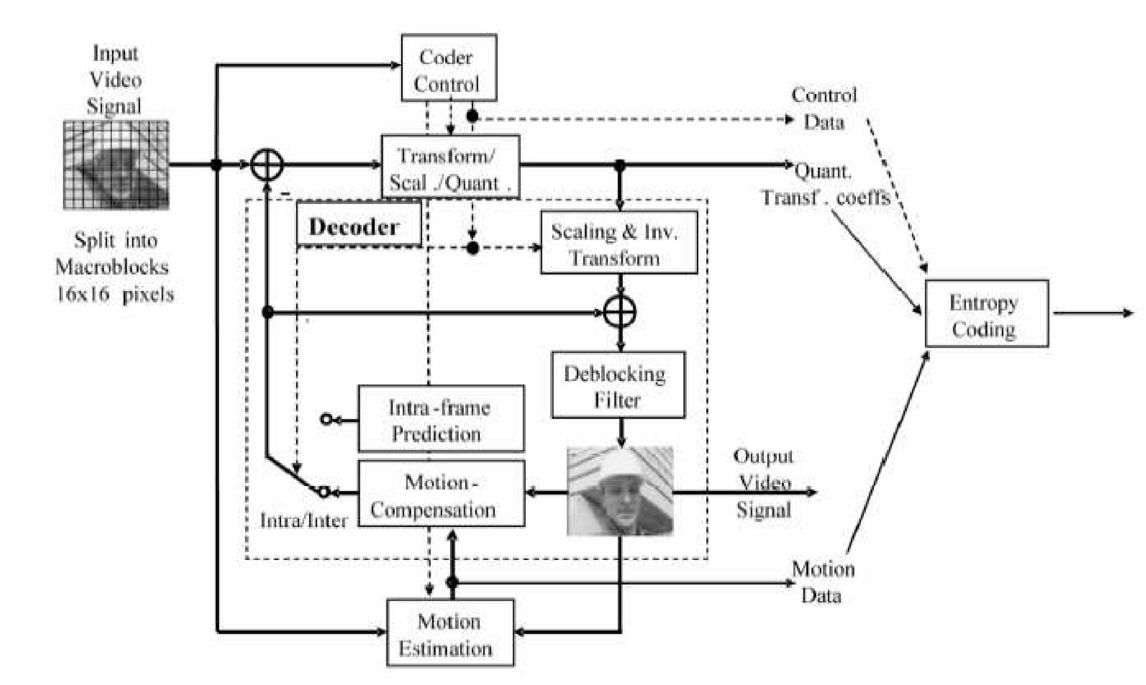

Figure1. Basic coding structure for H.264/AVC for a macroblock.
Source: -[6]

The coding engine employs a mixture of both Intra-frame Prediction and Motion compensated prediction to achieve maximum compression efficiency. Intra coding is done on a 4X4 block level and predictively coded. A 4X4 integer DCT transform is applied and coded using Entropy Coding. Motion compensated prediction may be done on a 16X16, 16X8, 8X16, 8X8, 8X4, 4X8 and 4X4 level. The motion vectors are predictively coded and later Entropy coding is applied to the blocks [6]. The standard also abstracts the coding part from the transportation part. The coding is done in the VCL (Video Coding Layer) and transported over a network by NAL (Network Abstraction Layer).

Video on Demand
Vide on Demand is a service wherein the video is transported over a network to be played at the customer premises [7]. The VoD system is shown in Fig2. The main elements of this system are

Video Servers/Library: - The movies compressed using the H.264 standard or any of the previous compression standards are stored in the video library and retrieved and loaded in the video server when the customer requests it.

STB: - Set top box is the device installed at the customer premises that is used to request the video. The memory requirements of the set top box are given in Table1.

TABLE I
SET-TOP BOX MEMORY OPTIONS

set-top box	storage feature	memory requirement
minimal memory	buffers less than a second of a two-hour movie	few dozen frames
moderate memory	can buffer a portion of a two-hour movie	1 MB - 1GB
full memory	can buffer an entire two-hour movie	> 1GB

Source: - [8]

Service Gateway: - The Service gateway is the interface between the customer premise equipment and the video server.

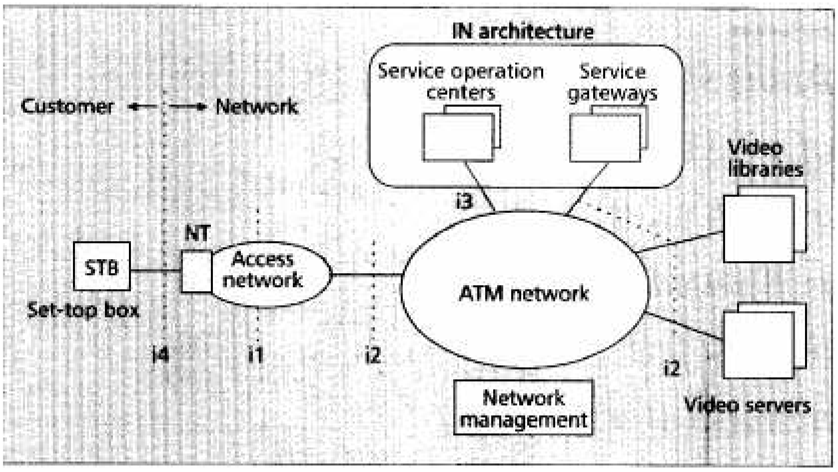

Figure2. VoD Network Architecture
Source: - [7]

Service Operation Center: - This element provides management functions such as billing, subscription management etc.

VoD offers the following types of services:
IVoD-i: - This service enables the client to retrieve the multimedia content and plays it immediately along with interactive functions such as fast forward, pause etc.
IVoD-d: - The client requests the video but there is a waiting time before the video is displayed. This also provides the same level of interactivity as IVoD-i.

Transport of Compressed Video over ATM
The issues involving transport of compressed video over ATM are
Selection of Service Class
Adaptation Layer

Selection of Service Class

Video over ATM with CBR: - To transmit video over CBR, the bit rate has to be negotiated first and is fixed during the length of the connection. In case of video the PCR has to be the same as the bit rate of the video [1]. But due to video streams being bursty in nature, bandwidth is not utilized properly in CBR.

Video over ATM with ABR: - One way of transmitting video over an ABR connection is to keep the output rate of the video encoder under control by using network feedback. Figure3 shows the encoder. In [9] the authors' state that the closed loop feedback mechanism of ABR makes it suitable for video transmission. Also, the flexible bandwidth renegotiation during transmission improves the network efficiency.

The Minimum cell rate M_{CR} for bandwidth constrained ABR connection to guarantee no underflow for an inactive user is:

$$M_{CR} = \max\left(\frac{F}{n-n_T}\left(\frac{\beta+\alpha K}{\alpha+\beta}\sum_{i=1}^{n} x_i - \frac{I_{CR}n_T}{F}\right)\right)$$

where $n \in [n_T+1, N]$.

Source: - [9]

Where

F= Frame rate of video in frames/second

n_T= Number of frames transmitted before the first RM cell comes back

β= Time parameter for user at interactive mode

α= Time parameter for user at playback mode

K=Speed factor for interactive fast forward or fast backward operation at user.

x_i=Number of cells for the i^{th} frame

I_{CR}=Intitial Cell Rate in cells/second

The feasibility condition for an ABR connection to exist at a given QoS desired by a user for a given interactive level if and only if for a given buffer size B and Initial cell rate

$$\max\left(\frac{F}{n-n_T}\left(\frac{\beta+\alpha k}{\alpha+\beta}\sum_{i=1}^{n} x_i - \frac{I_{CR}n_T}{F}\right)\right) \leqslant \min\left(\frac{F}{n-n_T}\left(\frac{\beta+\alpha}{\alpha}B + \frac{\beta+\alpha k}{\alpha}\sum_{i=1}^{n} x_i - \frac{\beta+\alpha}{\alpha}\frac{I_{CR}n_T}{F} - \frac{\beta}{\alpha}\sum_{i=n_T+1}^{n} x_i\right)\right)$$

for all $n \in [n_T, N]$.

Source: - [9]

The ICR can be determined for a given network latency n_L and video fastforward/fastbackward speed factor K during the interactive mode as

$$I_{CR} \geqslant \frac{F}{n_T}\left(K\sum_{i=1}^{n_T} x_i + (K-1)\sum_{i=n_T+1}^{n_T+n_L} x_i\right)$$

Source: - [9]

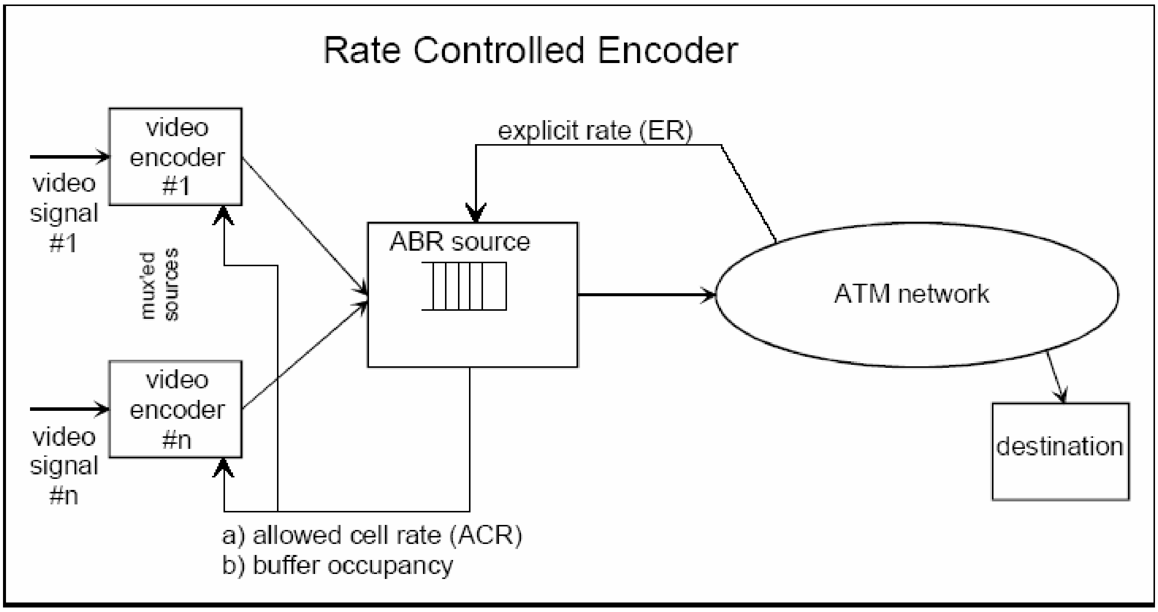

Figure3. Source: [10]

Video over ATM with VBR: In dealing with transporting video over ATM using VBR the following issues are dealt with [1]

- Traffic shaping and Rate Control
- Bandwidth allocation/Management
- Congestion Control
- Buffer and Memory requirements
- Source Model and Behaviors
- Coding Technology
- Quality Control

Video over ATM using UBR: Since there is no feedback control the video stream is transported in a best effort manner similar to Internet [4].

Table 2. summarizes the ATM services characterizes and Figure 4 shows the bandwidth utilization for MPEG video for the services discussed.

Service type	Parameters during connection setup	Bandwidth renegotiation	Bandwidth guarantee	QoS guarantee	Bandwidth utilization	Cost
CBR	PCR rate	No	Yes	Yes	Very low	Very high
VBR	PCR, SCR	No	Yes	Yes	Low	High
ABR	MCR, PCR, ICR, TBE, RIF, RDF, etc.	Yes	Only MCR	Acceptable	Very high	Very low

. *Characteristics of ATM services which are suitable for multimedia.*

Table 2 Source: [11]

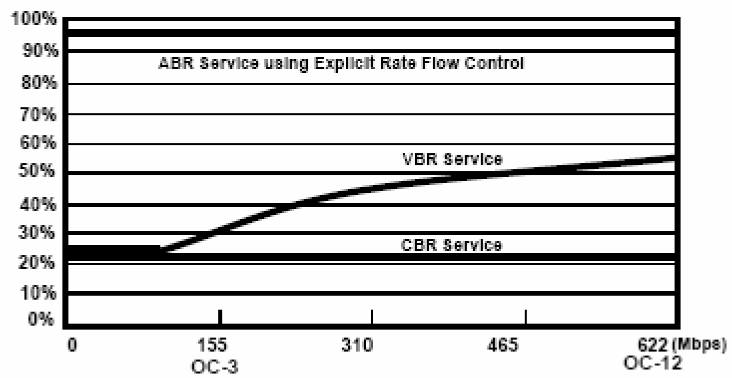

Figure 4. Bandwidth utilization for transmission of MPEG video over ATM for the 3 services.
Source: [1]

Selection of Adaptation Layer

AAL layer abstracts the network behavior from the applications. AAL1, AA2, AAL3/4 and AAL5 are the adaptation layers defined in the ATM standard. We focus on AAL1 and AAL5 in this paper.

AAL1: AAL1 was proposed for class A services and ca be used for applications such as circuit emulation services, constant bit-rate data, delivery at the same bit rate and transfer of timing information between sending and receiving applications. It can also handle cell delay variation and detect lost or misrouted cells [5].
AAL1 is ideal for transporting CBR H.264 stream over ATM since the characteristics of CBR H.264 stream is constant bit rate, which demands constant end to end delay. But the problems involved in transporting of MPEG over AAL1 is [4]

- It cannot be used to carry VBR-MPEG that is going to be the application of choice in the future.
- Nationwide networks that usually consist of several carriers and unsynchronized clocks cannot support AAL1.
- ATM network interfaces signal using AAL5, therefore using both AAL1 and AAL5 increases the cost.

AAL5: AAL5 is used for Class D services and it does not have any real time constraint. In case of AAL5, error or missing SDU's are not compensated for [5]. It can be used to transport VBR MPEG data. The advantages of using AAL5 are [4]:

- It is the most commonly used adaptation layer in the industry. UNI 4.0 signaling messages are encapsulated by AAL5 and it is also able to provide best effort traffic unlike AAL1.
- The complexity required to implement AAL5 is significantly less than AAL1.
- It can support VBR MPEG data.

The disadvantages with AAL 5 are [4]

- It does not support forward error correction.
- Since MPEG bit stream is compressed, loss of transport packet results in severe quality degradation.

The ATM forum has recommended AAL5 for both CBR and VBR multimedia traffic [12][13].

In an IEEE Communication survey [4], taxonomy of issues associated with the transport of MPEG-2 over ATM networks was presented. Figure5 illustrates it.

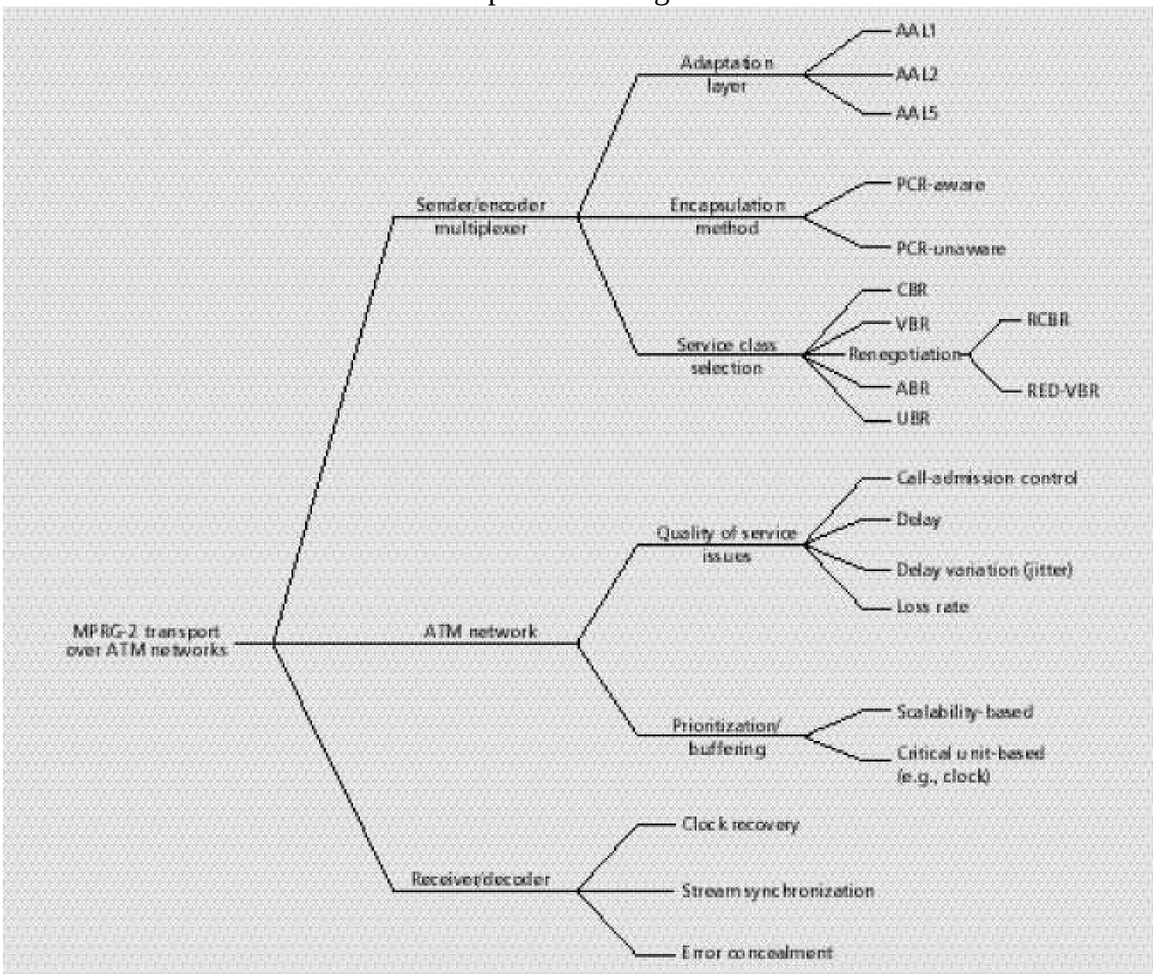

Fig5. Taxonomy of issues with the transport of MPEG-2 over ATM networks
Source: [4]

In the same paper, the authors also present a MPEG specific architecture, which is illustrated in Figure6.

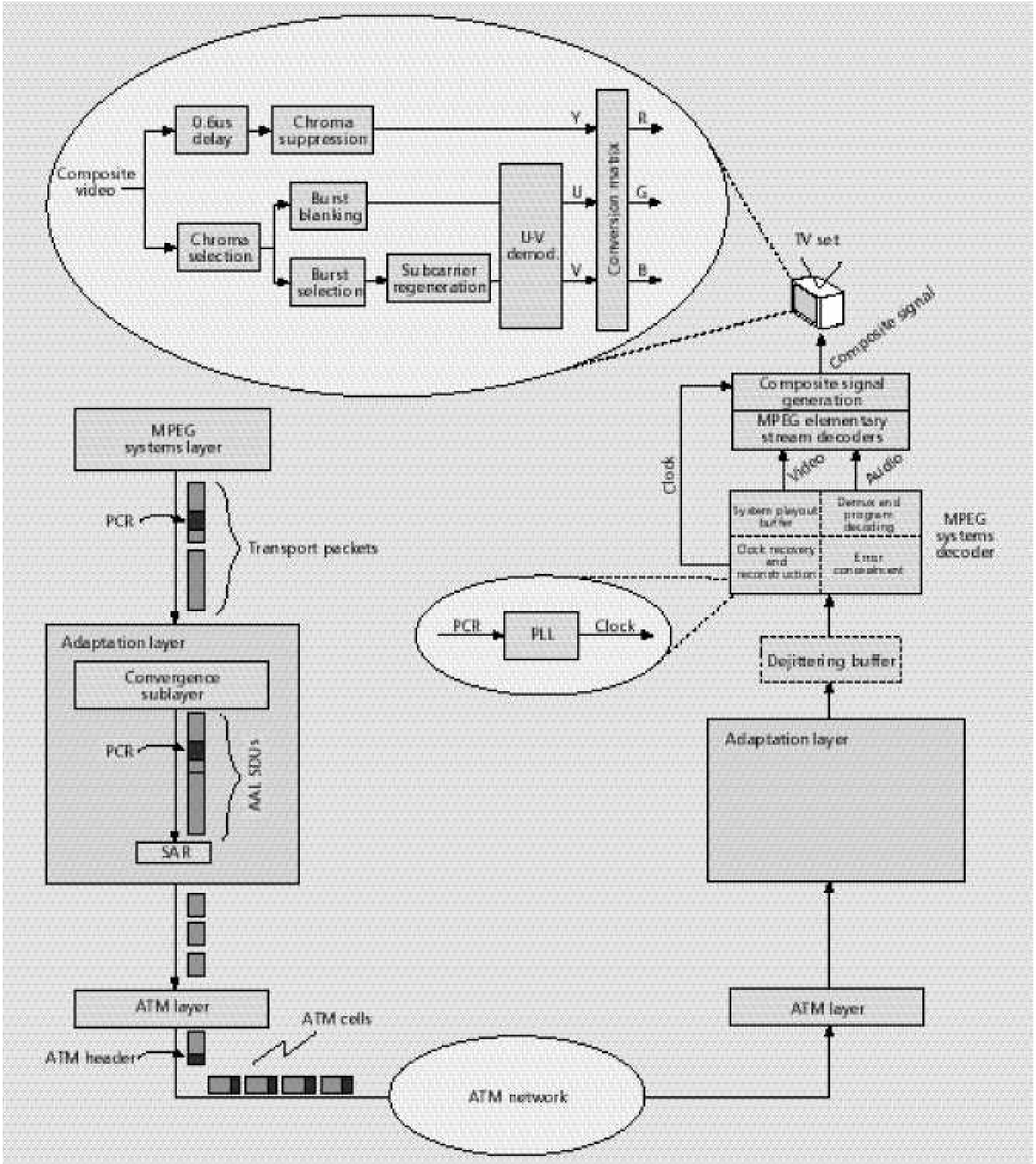

Fig6. MPEG 2 over ATM networks
Source: [4]

Conclusion:

This paper presented an overview of the Video-on-Demand system over an ATM network. Issues such as selection of service class and adaptation layer were discussed along with each one's advantages and disadvantages. ATM can also be used to transport streams of H.264, the latest video-coding standard.

REFERENCES

[1] Multimedia over ATM: progress, status and future
Bing Zheng and *M. Atiquzzaman*
IEEE 7th International Conference on Computer Communication and Networks, 1998

[2] ATM Forum Technical Committee, "Video on Demand Specification 1.0," tech.rep., ATM Forum, December 1995

[3] CCITT Recommendations, I series (B-ISDN), July 1992

[4] MPEG-2 Transport over ATM Networks
Christos Tryfonas and *Anujan Varma*
IEEE Communication Surveys. http://www.cosmoc.org/pub/surveys
Fourth Quarter 1999, vol.2 no.4

[5] An Introduction to ATM Networks
Harry G.Perros
John Wiley & Sons, Ltd

[6] Overview of the H.264/AVC video coding standard
Wiegand.T, *Luthra.A*, *Sullivan.G*, *Bjntegaard.G*
IEEE Transactions on Circuits and Systems for Video Technology. July 2003

[7] Interactive Video On Demand
Daniel Deloddere, *Willem Veribest and Henry Verhille*
IEEE Communication Magazine, May 1994

[8] Video-on-Demand over ATM: Constant Rate transmission and transport
Jean M.McManus and Keith W.Ross
IEEE Journal on Selected Areas in Communication. August 1996

[9] Interactive video on demand over high-speed networks
Bing Zheng and *M. Atiquzzaman*
Journal of High Speed Networks 9 (2000) 175-190, IOS press

[10] Video transmission using the Available Bit rate service
Thesis by *Ronald Bollow*, Berlin University of Technology
http://citeseer.nj.nec.com/bollow97video.html

[11] Traffic Management of Multimedia over ATM Networks
Bing Zheng and *M. Atiquzzaman*
IEEE Communication Magazine, January 1999

[12] The ATM Forum Technical Committee, Audiovisual Multimedia Services: Video on Demand Specification 1.1, Mar.1997.

[13] The ATM Forum Technical Committee, Audiovisual Multimedia Services: VBR MPEG-2 Baseline Text, Feb 1998.