Multilayer QoS Management for Residential Broadband Services

R. J. Green, N. W. Garnham* and S. I. Woolley

The University of Birmingham, School of Electronic and Electrical Engineering,
Edgbaston, Birmingham, B15 2TT, UK

Tel +44 121 414 7521 e-mail R.J.Green@bham.ac.uk, S.I.Woolley@bham.ac.uk

*Fujitsu Telecommunications Europe Limited, Solihull Parkway, Birmingham, B37 7YU, UK

Indexing terms: MPEG transport, ATM adaptation, Quality of Service, Video on Demand

This letter presents an approach to managing quality-of-service (QoS) for a residential Asynchronous Transfer Mode (ATM) video-on-demand (VoD) service employing MPEG-2 transport streams. We consider the complex multilayer propagation of ATM layer parameters, over an underlying physical layer, and their relationship to video quality. The implication of ATM adaptation schemes on the resulting spatio-temporal video playback performance of the service is also addressed.

Introduction: Use of the public access network for the provision of broadband services is now feasible with the availability of Asymmetric Digital Subscriber Loop (ADSL) and fibre technologies. Home users will be able to use VoD and the internet by connecting to service providers via multiplexers to a new ATM backbone network. Development of broadband access networks is commercially viable as consumer demand for VoD is thought to be high - however, the delivery of video at satisfactory quality levels requires an understanding of the cumulative effects of QoS propagation through multiple protocol layers.

The standards for VoD and ATM connectivity are defined by a number of bodies, the most notable of which are the ATM Forum and the Digital Video Broadcasting (DVB) group. Many years of activity in the area of video coding has established the work of the Motion Picture Coding Experts Group (MPEG) as an industry standard. The coexistence of these standards means there is now a platform for the adaptation of MPEG-2 streams [1] across ATM.

The aim of the work described in this paper is to analyse QoS for a specific set of protocols so that lower-layer transport parameters can be translated into video QoS metrics. It will be shown that a direct relationship can be suggested between the performance of the ATM transport layer and the resulting video quality, be it by minor losses in video quality to more substantial degradations caused by losses of crucial clock reference data.

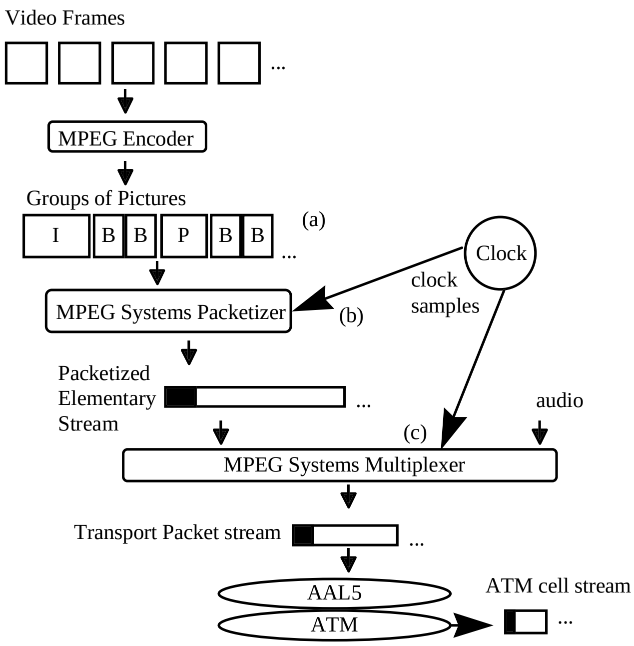

Figure 1. MPEG Transport of Video over ATM

MPEG video streams: consist of groups of pictures ((a) in figure 1) containing I-, P- and B-frames. (I)ntra frames are coded on the basis of spatial information contained within them and without reference to other frames. (P)redicted difference frames are derived from I-frames, and (B)i-directional frames are estimated from past and future I- and P-frames [2]. For the purpose of successful video decoding, the I- frames should be error-free and the clocks, associated with their presentation, reliable. A decoder uses periodic timing references to playback a video stream containing groups of pictures. *Decoding timestamps* indicate when to start decoding a video frame and *presentation timestamps* dictate the time to display a frame to the user ((b) in figure 1). Together, these timestamps aid long-term synchronisation and are supplied at least every 700ms. Transport packets, carrying video and audio data, are received at irregular intervals due to the accumulation of delay variations (jitter) within the broadband network. Unique Program Clock References (PCRs), occurring at least every 100ms, are used by the decoder to reconstruct the encoding clock ((c) in figure 1). This enables synchronised data delivery at a Constant Bit Rate (CBR) to the audio and video decoding stages. To maintain jitter bounds in the CBR environment the baseline VoD model proposed by the ATM Forum delivers 2 transport packets (2 x 188 bytes) in each frame of ATM Adaptation Layer 5 (AAL5) data; where AAL5 [3] provides the means to deliver frames between sender and receiver at a given quality of service (e.g. delay, error rate and jitter).

Provided that PCR-carrying packets are delivered within acceptable delay bounds the elementary streams (for video, audio, other data) can be regarded as decodable.

Assumptions and QoS Translation: In making a proposal for the efficient management of QoS, we make the following assumptions: 1. the subset of MPEG transport to be used is standardised; 2. the dedicated set top box decoder is capable of resolving system resource issues; 3. AAL5 is used for the transport stream; 4. cell losses due to congestion are solved by the current use of CBR delivery.

A generic technique for the translation of AAL QoS to overall ATM QoS is presented in [4]. The paper includes a case study for CBR video using AAL1 (having a greater overhead than AAL5) where network performance parameters (cell loss from congestion; bit errors - assumed negligible for fibre - causing cell misinsertion errors; delay; jitter) and the use of error correction techniques in the AAL is translated into AAL access point performance bounds. However, a simple memoryless model is used to describe the cell loss process; and therefore cannot model data losses, caused by congestion, or long bursts of bit-errors.

A range of video artefacts is presented in [5] which considers the impact of errors and delay effects on the MPEG transport stream. By default, AAL5 discards erroneous data; if this action is disabled and a cell is lost, two AAL5 data units are merged. Discarding erroneous data can severely degrade video quality and it is better to pass the correct length of data to the MPEG decoder than to discard it. Delivering satisfactory video quality is essential, since the overall QoS may be constrained in a service-level agreement.

Multilayer QoS Management Approach: The sensitivity and vulnerability of PCRs to loss is considered in relation to the resynchronisation points within the transport and video stream (primarily I-frames). Subsequent work will investigate these effects using the following model.

Managing errors can be achieved by defining and classifying scenarios at the ATM layer, given the underlying network characteristics (bit error rate, propagation delay and jitter) and an understanding of the damping of their propagation effect on video quality, such that the effects fall into acceptable limits. Damping is achieved by concealment layers, shown by the shaded regions in Figure 2.

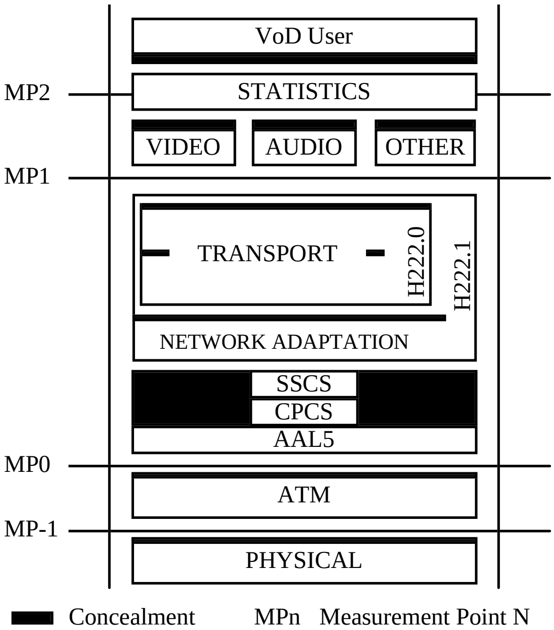

Figure 2. A Measurement Point Model for Network Termination and MPEG Protocol Layers

The essence of this approach is essentially a bottom-up analysis, centred around the ATM-layer. From the physical layer MP-1 (a measurement point), ATM layer parameters can be calculated. These can be translated from MP0 up to MP1 where the elementary streams can be assessed and checked for validity (loss, delay and synchronisation). Where the video decoder architecture is known, the resulting picture impairments (Quality Metrics) can be derived and discriminated into *acceptable* (tolerable); *perceivable* (disturbing) and *imperceivable* classifications using deterministic bounds. This localises the analysis of error propagation, due to the implementation of motion compensation and passive concealment between MP1 and MP2.

Conclusions: In this paper a direct relationship between broadband network characteristics and the spatio-temporal performance of MPEG-transported video has been described. Of particular importance is the relationship between timing references and the ability to resynchronise in the presence of jitter and data errors. We have presented a reasoned multilayer QoS management approach, enabling this relationship to be analysed with the aid of the defined measurement points. The approach can thereby enable residential services to be provisioned to meet service-level agreements. This approach is intended to address the long-standing issue of providing a means for other developers to consistently compare their results.

Acknowledgements: This work is funded by the UK Engineering and Physical Sciences Research Council, in collaboration with Fujitsu Telecommunications Europe Limited.

[1] ITU-T recommendation H.222.0 ‘Information Technology – Generic Coding of Moving Pictures and associated audio information: Systems’, July 1995

[2] KARLSSON, G., "Asynchronous transfer of video", IEEE Communications Magazine, 1996, 34(8), pp 118-126.

[3] ITU-T recommendation I.363 ‘B-ISDN ATM Adaptation Layer (AAL) Specification, March 1993

[4] JUNG, J-L., "QoS in telecommunications Part II: Translation of QoS parameters into ATM Performance Parameters in B-ISDN", IEEE Communications Magazine, 1996, 34(8), pp 112-117.

[5] GRINGERI, S., KHASNABTSH, B., LEWIS, A., SHUAIB, K., EGOROV, R., and BASCH, B., "Transmission of MPEG-2 video streams over ATM”, IEEE Multimedia, 1998, 5(1), pp 58-71.