Towards An Efficient ATM Best Effort Video Delivery Service

Ahmed Mehaoua [1], *Raouf Boutaba* [2], *Song Pu* [3], *Yasser Rasheed* [2], *Alberto Leon-Garcia* [2]

[1] University of Cambridge - CCSR
10 Downing Street
Cambridge, United Kingdom
a.mehaoua@ccsr.cam.ac.uk

[2] University of Toronto - ECE Dept.
10 King's College Road
Toronto (On.), Canada
{rboutaba, yrasheed, alg}@comm.utoronto.ca

[3] Newbridge Networks Corporation
600 March Road
Kanata (On.), Canada
songpu@newbridge.com

ABSTRACT

This paper addresses the transport of real-time multimedia traffic generated by MPEG-2 applications over ATM networks using an enhanced UBR best effort service (UBR+). Based on the factors affecting the picture quality during transmission, we propose an efficient and cost-effective ATM best effort delivery service. The proposed service integrates three components: A dynamic framelevel priority assignation mechanism based on MPEG data structure and feedback from the network (DexPAS), a novel audiovisual AAL5 SSCS with FEC, and an intelligent packet video discard scheme named SA-PSD, which adaptively and selectively adjusts cell drop level to switch buffer occupancy, video cell payload type and forward error correction ability of the destination. The overall besteffort video delivery framework is evaluated using ATM network simulation and MPEG2 video traces. The ultimate aim of this framework is twofold. First, minimizing loss for critical video data with bounded endtoend delay for arriving cells. Second, reducing the bad throughput crossing the network during congestion. Compared to previous approaches, performance evaluation shows a good protection of Predictiveeoded and Bidirectionnal Predictive Coded frames at the video slice layer.

Keywords: ATM, Packet Video, Priority, Cell Discard, FEC.

I. INTRODUCTION

MPEG2 and ATM have been adopted as the key technologies for the deployment of broadcast and interactive video services. The confluence of these two international standards aims to provide all the advantages of transmitting variable bit rate video over packet networks, i.e. better video quality, less delay, more simultaneous connections, and lower cost.

However asynchronous transfer of video requires careful integration between the network and the video end systems. A number of issues must be addressed in order to tackle the problem on an end-to-end basis. Among these issues is the selection of: The ATM bearer capacity, the ATM adaptation layer, the method of encapsulation of MPEG-2 packets into AAL packets, the scheduling algorithms in the ATM network for control of delay and jitters, and the error control and correction schemes.

Various proposals have been made for selecting the type of service under which MPEG-2 video streams are to be transported over ATM [1][2][3][4]. Unspecified Bit Rate is the true and simplest ATM Best effort service available. Since it is expected that this service will be widely available in the future and is based on the excess bandwidth in the network with lower usage cost, it is predictable that it will also support a non-negligible part of the multimedia traffic. Unfortunately, UBR as initially defined in [5] is not appropriate for carrying such demanding traffic. Therefore, this paper particularly focuses on unidirectional delay-tolerant video applications that can efficiently make use of an enhanced version of this simple and low-cost transport service.

In order to ensure optimal end-to-end quality, each component along the transmission path must be designed to provide the desired level of QoS. Therefore, optimizing only specific components in the path may not be sufficient for ensuring the QoS desired by the application. For example, designing a good Forward Error Recovery (FEC) scheme for the adaptation layer while using a poor cell discarding algorithm (e.g. randomly discarding) for the switch will not be sufficient to maintain the end-to-end performance of video application at the receiver. Consequently, the adaptation layer, encapsulation scheme, scheduling discipline in the ATM switches and error recovery mechanisms at the receiver must all be cooperatively designed and harmonized to provide the desired level of quality at the receiver (i.e., end-to-end). Therefore, the framework proposed in this paper integrates the three following schemes: An AAL5 Service Specific Sub-layer with FEC control capability described in [6], an intelligent video data partition and prioritization mechanism located at the sources, and an efficient cell scheduling policy with adaptive video slice drop at the switch.

The paper is organized as follows. We describe in Section 2 the different components of the proposed best effort video delivery service including the scheme for dynamic video cell priority assignation, and the intelligent packet video discard scheme. In section 3, we evaluate the performance of the framework using simulations, and discuss the obtained results. Finally, we conclude in section 4.

II. A BEST EFFORT VIDEO PACKET TRANSPORT SERVICE

2.1 A DYNAMIC EXTENDED PRIORITY ASSIGNATION SCHEME

Since the ATM cell header only embeds one bit (CLP) to discriminate between video data, it can not capture the full range of MPEG data structures. Thus, we propose a video data formatting and prioritization scheme based on the Extended CLP (ExCLP) field [7] and the Dynamic-Priority Assignation Scheme [8]. The new mechanis is referred to "*Dynamic and Extended Priority Assignation Scheme*" (DexPAS). The mechanism is sufficiently generic to be performed at any MPEG data layer (e.g. frame, slice, macroblock, or block).

In this paper, the emphasis is on the video slice and frame layers. The data partition is made at the video slice layer and the priority assignation is performed at the frame level. Traditional use of the classical CLP bit and the adjacent PTI ATM-user-to-ATM-user bit (AUU) restricts the number of cell priority to two and under utilizes ATM capabilities.

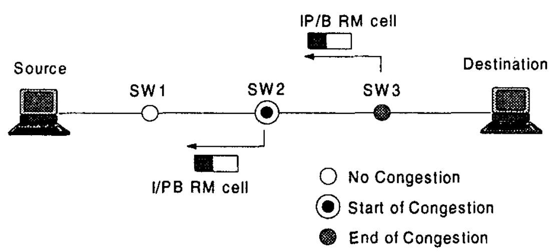

Fig. 1 - DexPAS Operation with Transmission of RM cells

DexPAS uses ExCLP field to dynamically assign cell priorities according to the current MPEG frame type, e.g., (I)ntra (P)redictive or (B)i-directional predictive, and the reception of backward congestion signals from the network (see Figure 1).

Table 1 presents the mapping of MPEG data frames into the ExCLP field. Cells belonging to Intra-coded frames (I-cells) are assigned a high priority while B-frame cells (B-cells) have the lowest priority. P-cells are alternatively assigned a high or a low priority depending on the network load. At the beginning of the transmission, P-cells are initialized with a high priority. When the switch buffer Queue Length (QL) exceeds an upper threshold, an early congestion is detected and the switch sends a feedback signal to the source, which in turn adjusts P-cells priority level to low. When QL decreases below a lower threshold, P-cells priority are switched back to a high priority with an IP/B Resource Management cell. The cells having their ExCLP field set to '10', are referenced as 'End of control Block' (EOB) and delimits a group of video cells under FEC control. The PTI AUU bit is commonly employed to indicate whether it is the last cell of an upper message (e.g. TCP packet).

Cell Type	*CLP*	*PTI-AUU*	*Priority*
I-/P- frame	0	0	High
P-/B- frame	0	1	Low
End of CB	1	0	Very High
End Of Slice	1	1	Very High

Table 1: New ExCLP Field Mapping for DexPAS

We propose to define a similar flag to distinguish between successive video slices. The cell having its ExCLP flag set to '11' is referred to as the End of video Slice (EOS) cell. Both EOB and EOS cell will be treated as of a very high priority in our implementation, that is, they are preserved with the most effort. As a result, DexPAS takes the advantages of both static I/PB and static IP/B priority partition techniques [8]. Moreover, it extends ATM capabilities to provide up to four priority levels whereas the traditional approach restricts the number of possible cell types to two.

As evaluated in [9], this dynamic priority assignation strategy minimizes loss of critical video frames and provides better performance than static CLP- based techniques. The main drawback of the scheme is that its efficiency is stringently dependent of the round trip time delay, and thus of the network topology and link distances.

2.2 A PARTIAL VIDEO SLICE DISCARD SCHEME WITH FEC.

Random cell Discard (RD) during congestion is not suitable for video transmission. An improvement is to take into consideration the cell's priority when discarding, i.e., a cell with low priority is dropped first; if congestion persist, this approach gradually begin to drop the high priority cells. This is called Selective Cell Discard (SCD). However, the useless cells, in our case, the tail of corrupted slice may still be transmitted and congest upstream switches. In [9], a scheme called Adaptive Partial Slice Discard (A-PSD) has been proposed to cope with this problem. The proposed approach consists to select the packet (i.e. slice) to be dropped with respect to MPEG data hierarchy and congestion level (e.g. switch queue length).

In [10], we have proposed enhancement to the Adaptive Partial Slice Discard (A-PSD) to support Forward Error Correction feature. The new scheme, named FEC Adaptive Partial Slice Discard (FEC-PSD), is performed at both control group (CB) and video slice levels. Our approach is to reduce the number of corrupted slices by assuming that a number 'T' of cells per control block can be recovered by the destination SSCS using FEC based on both Reed-Solomon and Parity codes. Let us define the parameter 'T' as the Drop Tolerance (DT) which corresponds to the maximum number of cells per CB that may be discarded by SA-PSD before considering the CB as definitely lost.

Therefore, unlikely the simple A-PSD, FEC-PSD stops discarding cells when the congestion decreases and the number of previously dropped cells in every CB is below DT. Using this approach, the proposed scheme acts at a finer data granularity, e.g., Control Block, and better preserves entire slices from elimination. The flexibility proposed by this mechanism can not be achieved without the use of DexPAS which allows the detection of both slice and control block boundaries at the cell level.

The integration of the two mechanisms (e.g. DexPAS, FEC-PSD) with the enhanced AAL5 AV-SSCS [6] provides us an efficient and intelligent video delivery service with quality of picture (QoP) control optimization. The aim of this scheme is to ensure graceful picture degradation during overload periods as well as increase of network performance, e.g., effective throughput. It allows accurate video cell discrimination and progressive drop by adjusting dynamically FEC-PSD mode in respect to cell payload types, switch buffer occupancy, and Drop Tolerance.

III. PERFORMANCE EVALUATION

3.1 NETWORK SIMULATION MODEL

The simulation network topology is depicted in figure 6. It consists of two ATM switches, and ten MPEG2 video connections crossing the bottleneck link with a capacity of 155 Mbps (OC-3). We evaluate the framework in LAN configuration by setting the backbone link to 1 km. All the other link distances, between the source/destination and the switch nodes, are constant and set to 0.2km. The ATM switches are implemented to be non-blocking, shared finite output-buffered. Switch buffers size varies from 80,000 to 220,000 cells for both SWITCH-1 and SWITCH-2 in the simulation experiment.

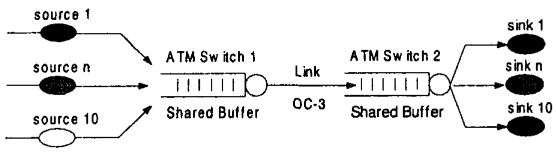

Fig. 2 - Network Simulation Model

The video sources generate MPEG2 data at a rate specified in a trace file obtained from Michael R. Izquierdo, IBM Corporation. The video sequence shows a flower garden located in the bottom half of the screen and a row of houses in the background towards the top of the scene. The camera tracks this scenery from left to right. A detailed description of this file could be found in [11]. The video sequences uses SIF format and were encoded at a resolution of 352x240 pixels per frame, a frame rate of 30 frames/sec, and 15 slices/frame. The Peak and Mean Cell Rate are 20 and 5 Mbps respectively.

Figure 3 shows the number of ATM cells per slice for the first 20 frames. We notice that distinctive pulses occurring at deterministic time intervals. The pulse period is determined by the GOP pattern, that is, every forty-five slices. There are also alternating pulses caused by I and P frames. The spacing between pulses is B frames.

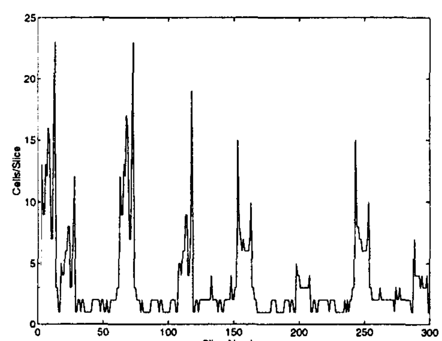

Fig. 3 - Number of ATM cells per slice for the first 20 frame of the MPEG2 video sequence.

We use the same file for all of the senders. Since each sequence has the same I/P/B frame pattern, I frames will always overlap for the duration of playback if the source send video streams at the same time. For this reason, we shift the send time so that I and P frames from one sequence would overlap B frames from another source. Figure 4 shows the results of multiplexing the shifted MPEG2 traffic. No distinctive peaks and valleys are shown in contrast to the single sequences.

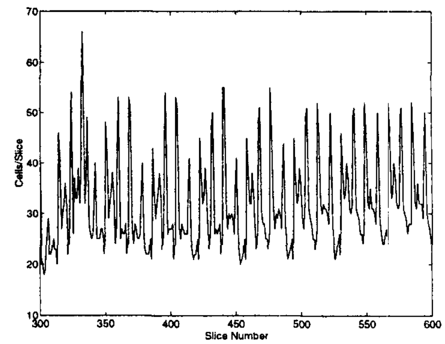

Fig. 4 - Number of cells per slice slot time after multiplexing of all sources with time shift.

The level of congestion is monitored through the occupancy of the switch buffers and three congestion thresholds (LT, MT and HT). We carried out our simulation with seven switch buffer configurations from 80,000 to 220,000 cells length. An AV-SSCS-PDU contains 3 MPEG2 Transport Stream (12 cells) and a Control Block is built with 15 AV-SSCS-PDUs (except for the last CB).

The video Slice Loss Ratio (SLR) is measured at the MPEG2 application layer and take into account decoding, e.g., cell loss, and propagation delay, e.g., late cells. In addition, it also takes into consideration FEC capacity to decide if a slice is recoverable or not at destination.

We compare the performance of the proposed framework (Dex_FEC_PSD) at the video slice level with the three following schemes associated with the classical AAL5:

- Random Discarding with no Priority Assignation Scheme (No_RD)
- Selective Cell Discarding with Extend Priority Assignation Scheme (Ex_SCD [7]).
- Partial Slice Discarding with Extend Priority Assignation Scheme (Ex_PSD [9]).

3.2 RESULTS ANALYSIS AT THE VIDEO SLICE LAYER

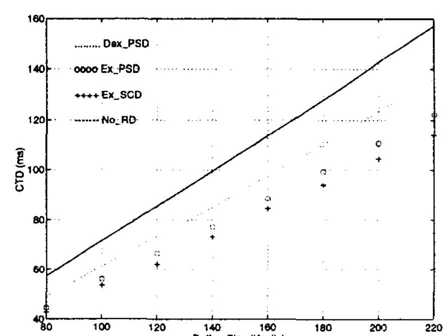

Fig. 5 - Mean Cell Transfer Delay

From Figure 5, we observe that the mean cell transfer delay (CTD) increases proportional to the buffer size. As expected, No-RD has the largest mean CTD. An explanation of that is as follows: No_RD accommodates every cell in its switch buffer until it becomes overflow. Thus it increases the queue delay. We also notice that Dex_FEC-PSD has longer mean-CTD than the other two schemes even though it tries to drop low priority cells at the light congest stage in order to leave space for the high priority ones. This is mainly due to its overhead, which results to larger switch buffer occupancy. On one hand, it preventively discards low priority cells at light congestion and switches to slice level to discard the whole slice as in Ex-PSD, which reduces the average queue length. On the other hand, it introduces 15% percent overhead due to stuffing bits and FEC redundancy codes, which dramatically increases the average queue length.

Ex_SCD and Ex-PSD start to drop B-cells when light congestion occurs and thus reduce the buffer occupancy while minimizing the transfer delay of the high priority cells. This can be also shown by the buffer occupancy status, as in Figure 6, Figure 7, Figure 8 and Figure 9.

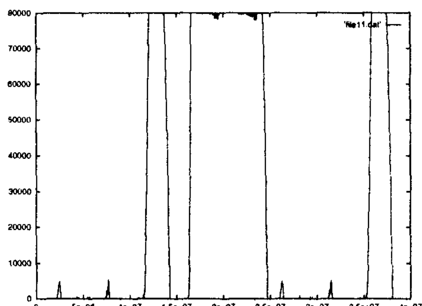

Fig. 6 - Buffer Occupancy with No_RD

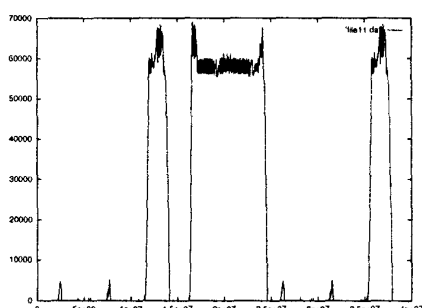

Fig. 7 - Buffer Occupancy with Ex_SCD

With No_RD, the buffer must be filled until the High Threshold is reached before to start elimination which leads to a greater mean CTD.

The difference of CTDs between different schemes increases with larger buffer size. For instance, with limited buffer size, the difference between random drop and preventive discarding schemes is small, whereas when Qmax increases, it becomes larger. This is explained by the fact that the preventive B-frame cells elimination approach works better when more buffer space are available. With limited buffer size, the space saved by dropping B-cells is limited and therefore it performs similarly to No_RD.

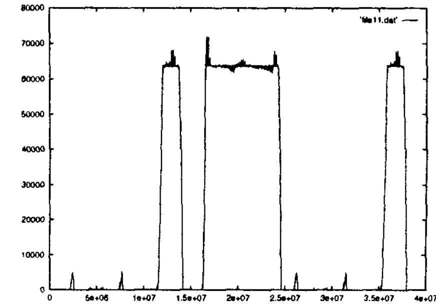

Fig. 8 - Buffer Occupancy with Ex_PSD

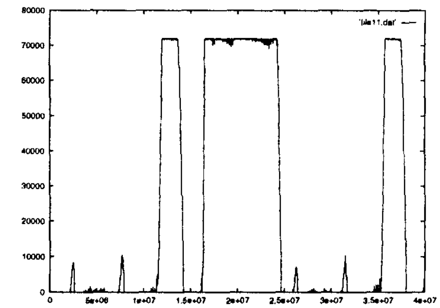

Fig. 9 - Buffer Occupancy with Dex_FEC_PSD

Intuitively it is expected that Dex_FEC_PSD has better performance at slice level. This is exhibited by figure 10, figure 11, figure 12, and figure 13. The proposed framework significantly improves the percentage of arrivals at the destination of non-corrupted video slices. Indeed, the aggregated Slice Loss Ratio (SLR) is reduced to achieve an upper bound of 6.8% of the total number of transmitted video slice. In comparison, No_RD, Ex-SCD and Ex_PSD reach 16.6%, 12.2% and 8.9% respectively.

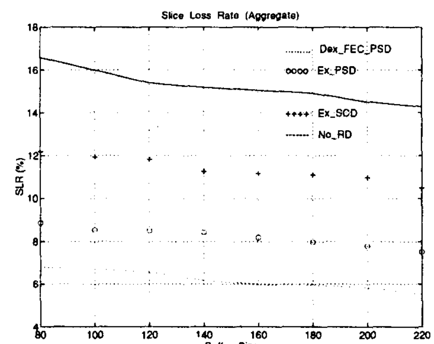

Fig. 10 - Slice Loss Ratio (Aggregate Stream)

Finally, the SLR per sub-flow is analyzed for the four approaches as follows. We observe that, Ex_PSD and Ex_SCD outperforms the other approaches by better protecting I-frames, though for aggregate SLR, our new scheme has the best performance Finally, the SLR per sub-flow is analyzed for the four approaches as follows. We observe that, Ex-PSD and Ex-SCD outperforms the other approaches by protecting I-frames, though for aggregate SLR, our new scheme has the best performance. This is consistent with the results obtained at cell level. There is a trade-off between fair distribution of cell discarding among the connections (i.e. VCs) and the speed of reactions to congestion. With P-frame and B-frame, Dex_FEC_PSD demonstrates the best SLR value. And performs similarly with I-frames. This further indicates the capability provided to protect data at the slice level by the FEC mechanism based on Parity [12] and Reed-Solomon [13] correction codes

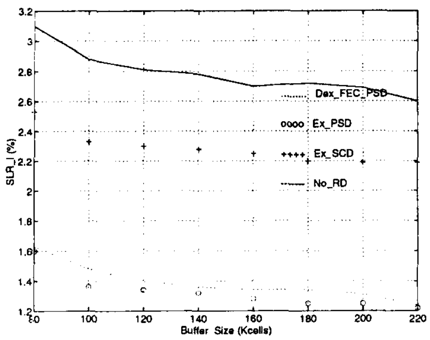

Fig. 11 - Slice Loss Ratio (I Frame)

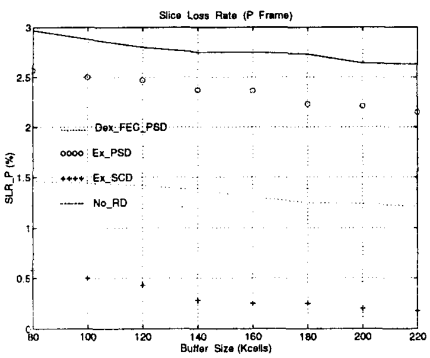

Fig. 12 - Slice Loss Ratio (P Frame)

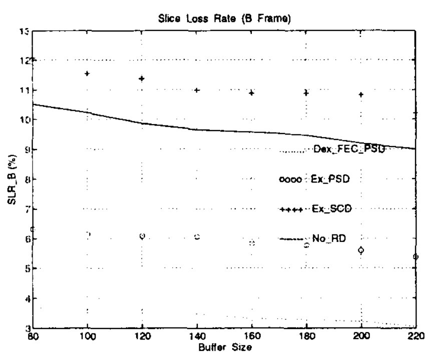

Fig. 13 - Slice Loss Ratio (B Frame)

V. CONCLUSION

In this paper, we proposed and evaluated an enhanced best-effort video delivery service based on UBR+, that takes into account the specific encoding and stochastic properties of MPEG2 video sources. This service is composed of three components: A new priority data partition and assignation technique called Dynamic Extended Priority Assignation Scheme (DexPAS), an intelligent packet video drop policy named FEC-PSD and an Audiovisual AAL5 SSCS with FEC.

By providing three different priority classes per-connection and the detection of video slice and FEC Control Block boundaries at the cell level, DexPAS permits accurate cell discrimination and progressive cell group discard and error recovery at the slice level. Compared to classical UBR+, our best effort video delivery service shown better performance in the transmission of non-corrupted video slices to the destination, which leads to graceful picture quality degradation and higher link utilization during network congestion.

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