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# An Adaptive Early Video Slice Discard (A-ESD) Scheme for Non Guaranteed ATM Services

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## Abstract

*A novel cell dropping mechanism named Adaptive Early Slice Discard (Adaptive-ESD) scheme is proposed to minimize video quality degradation in situation of losses due to buffer overflow. The mechanism runs at the video slice level and adaptively and selectively adjusts discard level to switch buffer occupancy and video cell payload types. To evaluate its performance, we have designed an Extended Priority Assignation Scheme (ExPAS) which permits the definition of up to three priority classes per virtual connection. In comparison with previous space priority techniques based on CLP mechanism, Adaptive-ESD associated with ExPAS shows better results in minimizing probability of reception of corrupted video slices, as well as a significant improve of the network effective throughput.*

**Keywords** : ATM, UBR, MPEG, QoS.

## 1. Introduction

The Unspecified Bit Rate (UBR) service defined by the ATM Forum [1] has no explicit congestion control mechanisms, no quality of service guarantee but is expected to be simple to deploy with a low usage cost. Although it is targeted for the delivery of non-real time applications (e.g. TCP/IP [2]), the inclusion of a Minimum Cell Rate (MCR) and the design of intelligent video-oriented drop policies make it an attractive and economical candidate for the transport of non-interactive video applications (i.e. video playback, video-based security, ...).

To save bandwidth, these audio-visual applications will widely use MPEG (Moving Picture Expert Group) compression techniques. MPEG coding organizes the video data in a hierarchical format in order of increasing spatial size : pixels Block, Macroblock, Slice, Frame, Group of Pictures and Sequence [3]. Two of them have significant impact on decompression and displaying process.

Slice is the main coding processing unit in MPEG. Coding and decoding of blocks and macroblocks are feasible only when all the pixels of a slice are available. Besides, coding of a slice is done independently from its adjacent slices, making it the smallest autonomous unit as well as the resynchronization unit in situation of data losses or corruption. Therefore, the smallest video transmission data unit to be considered by the transport service is rather slice than cell or system packet (e.g. Transport Stream or Program Stream [4]).

Frame or picture is the basic unit of display. Three types of pictures may be used in MPEG and differ from the coding method used : Intra-coded (I) picture, Predictive-coded (P) picture and Bidirectionally predictive-coded (B) picture. Non-available referenced pictures (I- or P-frames) lead on perceptible picture degradation. Indeed, due to error propagation I-frame impairments will affect all the subsequent frames on the same Group Of Picture (GOP). Similarly, the impairment of P-frames will affect the following P- and B-frames until the next I-frame. Only B-frame impairments have no adverse effects on other frames. Consequently, I- and P-pictures are essential and have to be preserved from corruption during transmission, whereas B-frames maybe preventively dropped in situation of congestion.

To address this problem of picture quality degradation in best effort networking environment, we propose, a new triggered threshold priority scheme. To work efficiently, this scheme is associated with an enhanced MPEG data source partitioning strategy previously introduced in [5]. The article is structured as followed. Section 2 is devoted to the description of the adaptive video slice-based discard mechanism and the associated source priority partition scheme. In Section 3, performance evaluations are performed using simulation and the results are discussed. Finally, we conclude and present directions for future works in Section 4.

# 2. An Adaptive Early Video Slice Discard Scheme with Multi-priority Support

## *2.1 Multi-priority Support*

In [5], a new source tagging mechanism is proposed to extend ATM prioritization capability. The scheme is called Extended Priority Assignation Scheme (ExPAS) and use a novel field located in the cell header referenced as Extended CLP (ExCLP). Actually, ExCLP comprises the classical CLP bit and the adjacent Payload Type Identifier ATM-User-to-ATM-User bit (PTI-AUU) [6]. This new definition of the CLP and the PTI-AUU bits permits a better utilization of the cell header. Using this ExCLP field, three priority services are now available in a single channel. Whereas the traditional approach restricts the number of priority to two and under utilize ATM capabilities.

| ***ATM Cell belonging to*** | ***CLP value*** | ***PTI-AUU value*** | ***Priority Level*** |
|---|---|---|---|
| Intra-frame | 0 | 0 | High |
| Predictive-frame | 0 | 1 | Medium |
| Bi-directional frame | 1 | 0 | Low |
| End Of video Slice | 1 | 1 | n/a |

Table 1 - MPEG data Mapping into ExCLP field

Table 1 presents the mapping of MPEG data frames into the ExCLP field. The PTI-AUU bit is currently used to specify ends of upper layer packets and used by various group discard techniques (e.g. Tail Drop, Early Packet Discard). To allow these policies to properly work with ExPAS, a similar End of Message flag is reserved in the ExCLP field. The last cell of the video slice has the PTI-AUU bit tagged to '1' and is referenced as End Of video Slice (EOS).

Statistically, low priority cells (e.g. belonging to B-frames) represents about 23 % of a MPEG encoded video stream. Here, we assume a Group Of Picture (GOP) pattern having the parameters N and M respectively equal to 12 and 2. Medium priority cells (e.g. belonging to P-frames) are about 24 % and high priority cells (e.g. belonging to I-frames) 53%.

With this video-oriented space priority scheme, network performance can be also significantly improved by dropping entire ATM Adaptation Layer (AAL) packets or higher messages before buffer overflow. This strategy is know as Early Packet Discard and can be performed with any packet-oriented application [7]. Since the smallest manageable video data unit is slice rather than MPEG2 Transport Stream or AAL packet, we propose to extend this policy to address the transmission of integral video slices. The enhanced scheme is referenced as Adaptive Early video Slice discard (Adaptive-ESD) and dynamically adjusts drop level to switch load variations.

In this paper, Adaptive-ESD scheme is associated with ExPAS but may easily be adapted and employed with any other cell prioritization strategy.

To allow the scheme to properly work with the highest efficiency, video slice boundaries have to be correctly managed. Three data structuring conditions have to be respected by the source before transmission and summarized in Table 2.

| ***Protocol Layer*** | ***Requirements*** |
|---|---|
| Transport Layer | Every MPEG-2 Transport Stream packet is composed with data from a single video slice. |
| ATM Adaptation Layer | An ATM Adaptation Layer packet is constituted with data from only one video slice. |
| ATM Layer | An ATM cell embeds data from only one video slice |

Table 2 - Video data encapsulation requirements

## *2.2 Scheme Parameters*

Adaptive-ESD scheme runs per-Virtual Connection and employs three state variables to control each video connection :

1. **S_DISCARDING** indicates whether the buffer is currently discarding (S_discarding = 1) this video slice or not (S_discarding = 0).
2. **S_PRIORITY** indicates the priority level of the current slice. The indicator is modified at the reception of the first cell of the slice in respect to its priority field (e.g. CLP or ExCLP). The switch is currently handling a high (S_priority =

0), a medium (S_priority = 1) or a low (S_priority = 2) priority slice.

3. **S_RECEIVING** indicates whether the switch buffer is currently receiving (S_receiving = 1) the slice or not (S_receiving = 0). Only the last cell of a slice (EOS) can change this indicator from receiving to not receiving. Other cells will only change the flag from not receiving to receiving.

As illustrated in Figure 1, Adaptive-ESD uses three buffer thresholds : Low_Threshold (LT), Medium_Threshold (MT) and High_Threshold (HT).

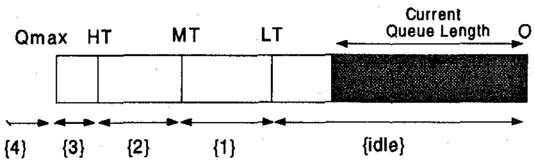


Figure 1 - Switch Buffer thresholds and Operation modes

### 2.3 *Scheme Operation Modes*

These thresholds define up to five operation modes depending on the used source priority assignation scheme (e.g. CLP-based or ExCLP).

1. **Mode {Idle}** : If the current switch buffer queue length (QL) is below Low_Threshold, no cells are discarded.
2. **Mode {1}** : If $LT \leq QL < MT$, newly incoming low priority slices (e.g. arrival of the first cell of the slice) are entirely discarded. Other slices are accepted in the buffer. That way, Adaptive-ESD reserves the remaining buffer space for low priority video slices that have already started to enter the buffer or slices having higher priority. It optimizes the probability of successful transmission of these slices. This mode stops when the queue length falls down below Low_Threshold.
3. **Mode {2}** : It is activated when $MT \leq QL < HT$. With CLP-based priority mechanisms (e.g. two-state priority), the scheme behaves like in mode {1}. With ExPAS, low and medium priority slices are both submitted to early elimination. The mode ends when queue length falls down to Medium_Threshold.
4. **Mode {3}** : If $QL > HT$, all newly incoming slices are entirely eliminated until the queue length drops below High_Threshold.
5. **Mode {4}** : If the buffer is full, e.g. the maximum queue size (Qmax) is reached, all cells are dropped and the scheme reacts like Tail Drop scheme. This mode ends when the queue length falls down to High_Threshold.

Except in mode {4}, the End Of Slice (EOS) cells are always preserved from elimination.

## 3. Performance Evaluation

### 3.1 *Simulation Model*

As depicted in Figure 2, we consider a network simulation model composed with an ATM switch with a finite capacity buffer and FIFO service discipline, an OC-1 (e.g. 55.1 Mbps) output link and three VBR MPEG sources . The distance between the sources and the ATM switch are constant and set to 0.125 miles (e.g. 0.2 km). The OC-1 link length is initialized to 310 miles (e.g. 500 km).

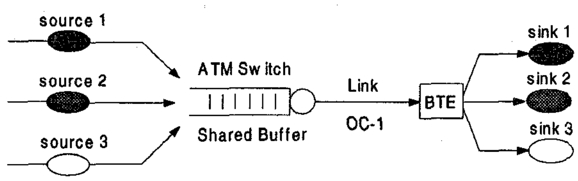


Figure 2 - Network Model

The VBR video connections are generated using three actual MPEG-1 frame traces from 'Star-Wars', 'Tennis' and 'Soccer' movies [8]. The main statistics of the video sequences are summarized in Table 3.

| | *Star Wars* | *Tennis* | *Soccer* |
|---|---|---|---|
| Mean Cell Rate (Mbps) | 0.36 | 0.55 | 0.63 |
| Peak Cell Rate (Mbps) | 4.24 | 1.58 | 2.29 |
| Peak/Mean ratio | 11.7 | 2.87 | 3.63 |

Table 3 - Statistics of the video sources

### 3.2 *Simulation Parameters*

All the video connections have the same Group Of Picture pattern but transmit at different starting times in the range of [0, 41.6 and 83.3 ms.]. Therefore for the three connections, the I-frame beginning the first GOP are desynchronized. In this paper, we assume one slice per frame and a simulation time of 1.43 min. We also assume that frames of each video streams are split into ATM cells and are uniformly distributed over a frame period. The level of congestion is measured by means of the three thresholds previously introduced (e.g. LT, MT and HT).

We carried out our simulations with seven switch buffer configurations. For each of them, the same method is applied to determine the values of the three thresholds. HT, MT and LT are respectively set to 1.0, 0.9, 0.8 fraction of the maximum queue size (Qmax). Qmax is varying in the range of 40 to 165 Kbits.

Table 4 and 5 respectively summarized the possible states of a cell crossing the network and the investigated performance parameters.

| *Data units* | *Definition* |
|---|---|
| Lost Cell | a cell dropped by Adaptive-ESD scheme |
| Dead cell | a cell received at the destination but belonging to a partially discarded slice |
| Late cell | a cell arriving at destination after an ended time-out. This time-out is triggered at the reception of every first cell of a picture. Its value is set to 1/N sec., where 'N' is the frame rate of the video sequence. In this paper, 'N' is equal to 24 |
| Correct cell | neither a lost, dead or late cell. |
| Correct slice | a slice received with only correct cells |

Table 4 - Data unit definitions

| *Performance Parameters* | *Definition* |
|---|---|
| I-frame Cell loss *ratio (CLR_i),*<br>P-frame Cell loss *ratio (CLR_p),*<br>B-frame Cell loss *ratio (CLR_b),* | number of lost and late cells belonging to I-frames from the three connections vs. the total number of transmitted I-cells. The same metric is applied for P- and B-frames. |
| Cell Bad Throughput *(CB)* | number of dead cells vs. the total transmitted cells. It is a performance parameter evaluated at the ATM layer. |
| Video Slice loss ratio *(SLR)* | number of corrupted slices vs. number of transmitted slices. |
| Mean cell transfer delay (Mean *CTD)* | time between the departure of cell $K$ from the source node $(t_{iK})$ and its arrival at the destination node $(t_{0K}): D_K = t_{0K} - t_{iK}$ [9] |

Table 5 - Performance Parameters Definitions

Video Slice Loss Ratio (SLR) is measured at the application layer and take into account decoding (e.g. lost and dead cells) and propagation (e.g. late cells) constraints.

During simulations, the processing delays at the ATM and AAL layer are not explicitly modeled. We assume that their contribution to the end-to-end delay experienced by the cell is relatively constant, and thus it can be omitted. Emphasis is on the variation of the mean-CTD for the aggregate stream composed of the three video connections.

### *3.3 Results Analysis*

In order to validate our proposed algorithm, we have completed some computer simulations to compare the performance of Adaptive-ESD with the two following discarding policies.

1. *Random Cell Discard* (RD) with every cells tagged with a high priority (e.g. CLP bit set to '0'). Cell elimination starts only when High_Threshold is exceeded. This hypothesis allows us to simulate a non-priority mechanism.
2. *Adaptive and Selective Cell Discard* (Adaptive-SCD) scheme with a static CLP-based cell priority assignation technique [5]. I- and P-frame cells are considered with a high priority and have their CLP bit set to '0', while B-frame cells are assigned a lower priority with CLP flag set to '1'.

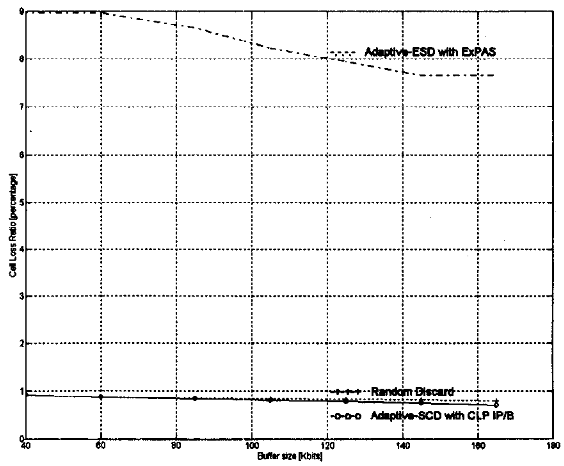


Figure 4 - (I)ntra-frame Cell Loss Ratio

Figures 4, 5 and 6 compare the variation of the cell loss rate for the different dropping policies. The percentage of lost cells are presented individually for each MPEG frame classes (e.g. Intra, Predictive and Bidirectional Predictive).

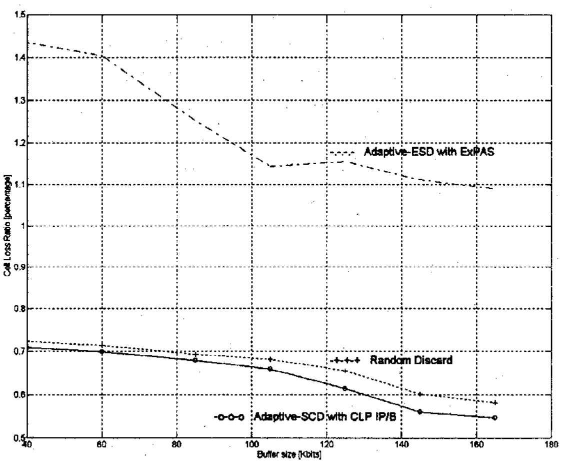


Figure 5 - (P)redictive-frame Cell Loss Ratio

Since Adaptive-ESD stops elimination only at the reception of an end of video slice (EOS) cell, it experiences the highest cell loss ratio regardless to the picture types. With Random Drop and Adaptive-SCD, *CLR_i* seems to be constant and independent to the buffer queue size. In the other hand with Adaptive-ESD, *CLR_i* decreases slightly when the thresholds values rise. As illustrated in Figure 6, Adaptive-SCD concentrates the loss within the B-frames and better protects high priority I- and P-frame cells from loss than Random Drop policy.

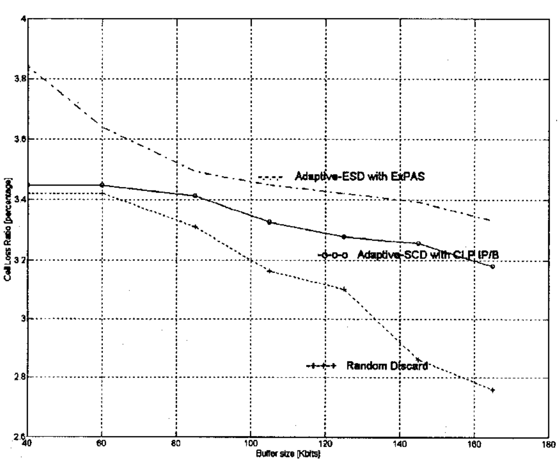


Figure 6 - (B)idirectional Predictive-frame Cell Loss ratio

As depicted in Figure 7 and 8, our slice-based delivery framework significantly improves the probability of reception of non-corrupted slices at destination. Indeed, the Slice Loss Ratio for the aggregate stream *(SLR_agg)* is reduced to achieve an upper bound of 8.6 % of the total number of transmitted video slices. In comparison, Random discard and adaptive-SCD reach respectively 13.1 and 13.4 %. Moreover, the cell badput *(CB)* crossing the network is dramatically minimized by a factor of four, e.g. from approximately 11 % to 3.15 %.

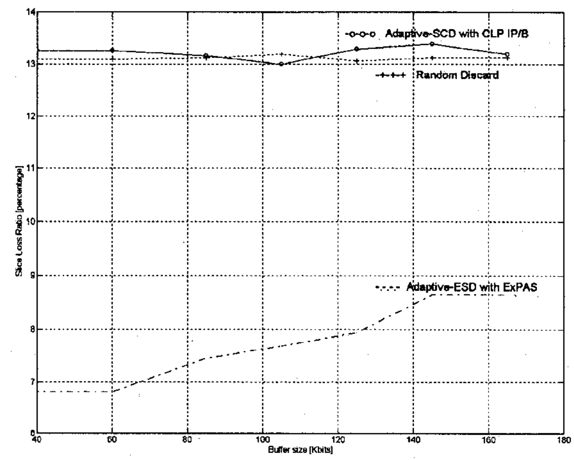


Figure 7 - Slice Loss Ratio for the aggregate stream

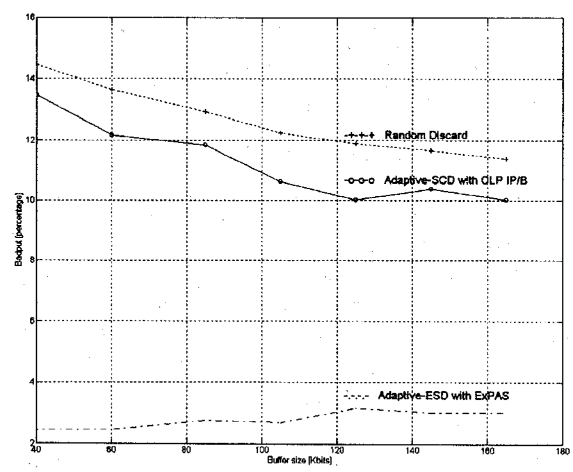


Figure 8 - Cell Bad Throughput

Finally, Figure 9 shows that the mean cell transfer *delay (mean CTD)* increases in order of magnitude of the buffer queue size regardless to the used technique. With limited buffer sizes (e.g. smaller than 110 Kbits), Adaptive-SCD performs similarly to Random Drop, whereas when 'Qmax' increases it demonstrates better results. This is explained by the preventive B-frame cells elimination approach applied by Adaptive-SCD when the current queue length reaches Low_Threshold. The average buffer occupancy is reduced and consequently also the mean cell service delay. However according to the simulation results, the lowest mean end-to-end cell transit delays are achieved by Adaptive-ESD with values in the range of 2.5 and 2.7 ms. This may be explained by two factors. First, similarly to Adaptive-SCD, Adaptive-ESD preventively discards low priority B-frame cells when LT is reached, but also includes progressively medium priority P-frame cells when MT is crossed. Secondly, Adaptive-ESD runs at the application level (e.g. video slice) and thus discard entire slice which dramatically reduce the average queue length.

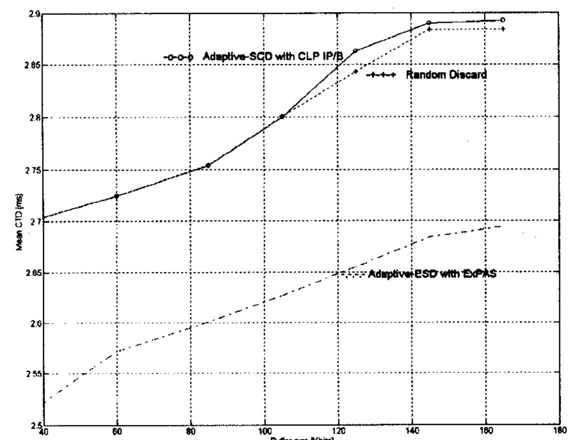


Figure 9 - Mean-Cell Transfer Delay for the aggregate stream

# 4. Conclusion

We have proposed in this paper an adaptive video slice-based dropping scheme, called Adaptive-Early video Slice Discard, to improve the performance of MPEG-encoded applications over best effort ATM services (e.g. UBR+, GFR). In association with an Extended Priority Assignation Scheme (ExPAS), the proposed mechanism aims to minimize loss probability of critical video data due to buffer overflow by applying a preventive and discriminative dropping strategy at the basis of video slice rather than cell.

In comparison with previous discarding techniques, our scheme has shown a significant reduction of the badput, a reduction of corrupted slices received at destination as well as the decrease of the mean end-to-end cell transfer delay. Finally, our objective is to design intelligent video-oriented congestion control schemes to ensure graceful and manageable picture quality degradation during transient network congestion in ATM best effort environment.

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