CCITT SGXV
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Experts Group for ATM Video Coding

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SOURCE : JAPAN
TITLE : COMPARISON BETWEEN SLIDING WINDOW AND LEAKY BUCKET AS A UPC MECHANISM
Purpose : Discussion

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1. Introduction

VBR support is one of the key features in ATM environments. Its expected merits for video coding are use of statistical multiplex gain, better picture quality, low coding-decoding delay, etc. However, VBR coding benefits largely depend on the UPC mechanism in the network by which the average bit rate of the source is monitored and the input cells are regulated.

This document compares two average rate monitoring methods, "sliding window" and "leaky bucket," assuming a simple source model for information generation.

2. Source and UPC models

2.1 Source model

We assume information generation of the source as modeled in Figure 1, which is a cyclic square wave of period D (frame time). There is a burst of information generation with bit rate of b (bits/frame) and duration of L (frame time) in the midst of base information generation a (bits/frame). Sequences for which VBR coding can outperform CBR coding are those containing scene changes and short time camera panning/zooming. The model in Figure 1 simplifies these situations with an assumption that such bursty information generation takes place periodically.

For simplicity, it is assumed here as follows;

- Encoding of a picture frame takes place instantaneously at the end of that frame.
- Declared peak rate is b (bits/frame), thus transmission delay is one frame time.
- Decoding finishes soon after the reception of complete coded bits for a frame, and starts to display decoded frame. Total delay from the start of the input frame to the coder and the start of the output frame from the decoder is 2 frame time in this assumption.

2.2 Sliding window as an average monitoring mechanism

Sliding window mechanism is characterized by its window size W (frame time) and declared average rate AV (bits/frame). See Annex. The network accumulates input number of bits in the previous W frame time. After the result reaches W*AVE, all the remaining cells are discarded by the network. The encoder should control its information generation not to violate this network restriction.

2.3 Leaky bucket as an average monitoring mechanism

Leaky bucket mechanism is characterized by its capacity BK (bits) and declared average rate AV (bits/frame). See Annex. Input bits from the terminal are fed into the bucket and read out at the rate AV. Once the bucket becomes full, the following cell is discarded. The encoder should control its information generation not to violate this network restriction.

3. Average rates to be declared

3.1 Sliding window

If we assume the window size W is smaller than the source cycle D, the maximum value of bit number accumulation is given as follows;

$$L*b + (W-L)*a$$

hence the average rate AVsw to be declared against the network should be

$$AVsw/a > 1 + (L/W)*(b/a - 1).$$

3.2 Leaky bucket

The total number of bits fed to the bucket during the cycle time D is

$$L*b + (D-L)*a.$$

Since this should be less than the number of bits read out at the declared average rate AVlb,

$$AVlb/a > 1 + (L/D)*(b/a - 1).$$

3.3 Observations

Actual average bit rate AVact for the source in Figure 1 is given as

$$AVact/a = 1 + (L/D)*(b/a - 1),$$

which equals to the lower boundary of the leaky bucket case.

Lower boundaries for AVsw and AVlb are shown in Figure 2. It is noted that AVsw is constant regardless of the duration D, which means that a larger value of average should be declared against the network with a sliding window mechanism.

Figure 3 shows an example of this transmission efficiency loss, where 2 second zooming with bit rate b (=4a) is assumed after 18 second stationary scene with bit rate a. If the window size is 20 second, there is no loss. If the window size is 10 second, however, 23% more average rate should be declared against the sliding window controlled network than the leaky bucket one.

4. Necessary sizes for the window and the bucket

From the above analysis, the window size for the sliding window mechanism should be close to the duration D.

For the leaky bucket case, the maximum bucket occupancy BOCmax is calculated as

$$BOCmax = L*(b-a)*(1-L/D) < L*(b-a).$$

Hence, the bucket size BK should be at least L*(b-a) for the source in Figure 1.

5. Conclusion

A very simple source model has been used for the comparison of sliding window and leaky bucket as UPC mechanism in the network. We can conclude that "leaky bucket" is a more suitable UPC mechanism for video coding at least from transmission efficiency.

The analysis method may be extended to a more sophisticated source model as combination of multiple simple sources with different parameters. Ease of coding control in the VBR coder may also support the leaky bucket. These points need further study.

END

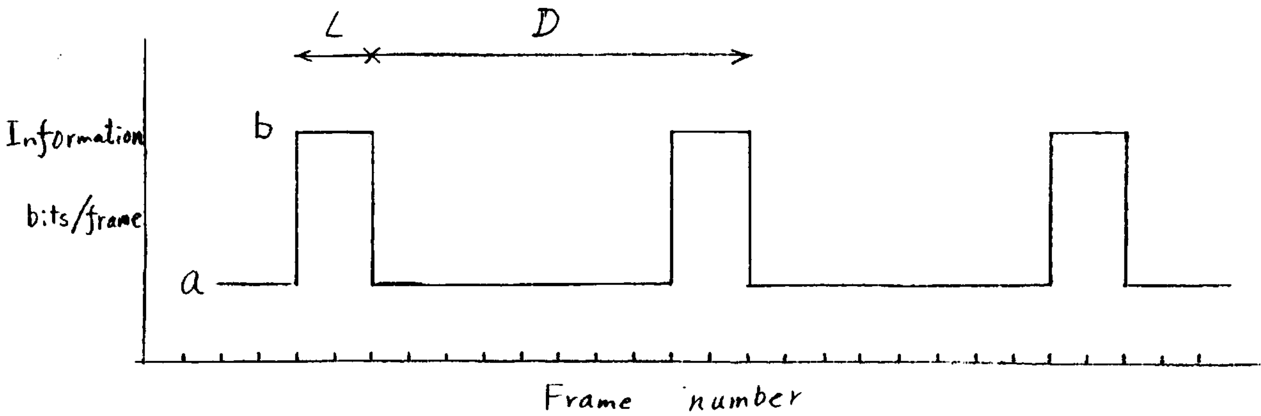


Figure 1 Source model

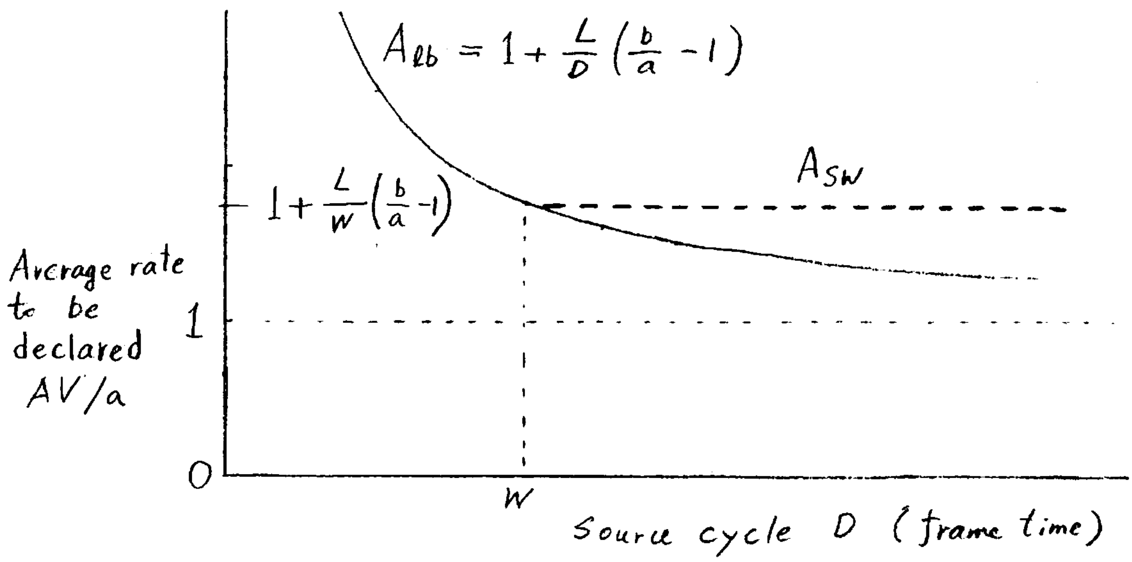


Figure 2 Average rates to be declared

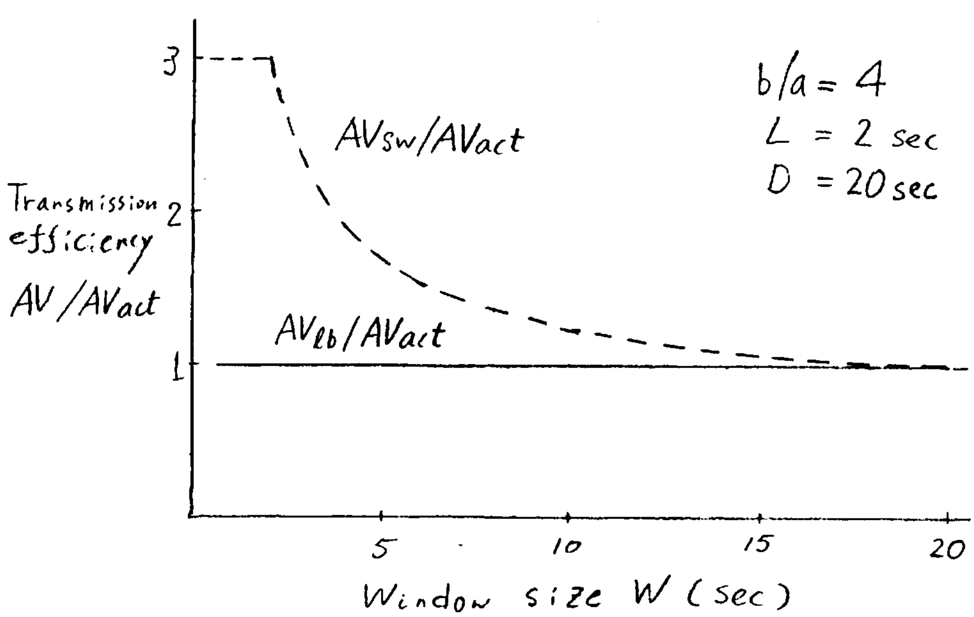
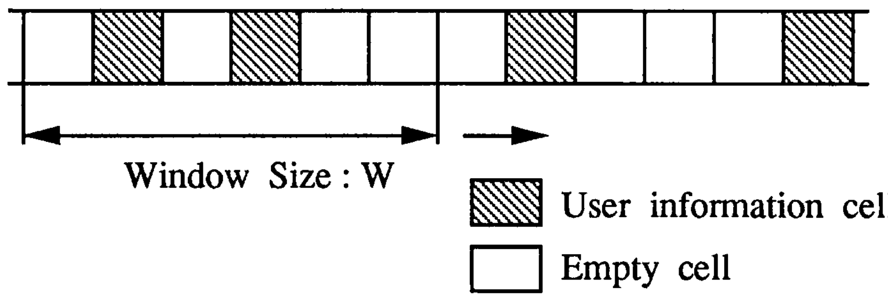


Figure 3 Example of transmission efficiency

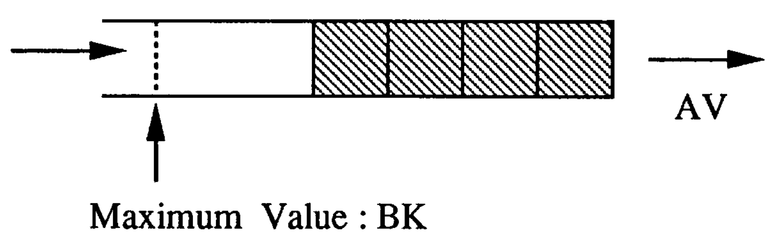
Annex : Sliding window and leaky bucket

Reference :
Netherlands, Germany, United Kingdom, France, Norway,Sweden, Portugal, Italy,Spain, Belgium : "COMPENDIUM ATM; Coding procedures," AVC-13, pp.16-21 (1990)



Sliding (Moving) window allows X arriving cells in an arbitrary time interval containing Y time slots.

(a) Sliding (Moving) Window



Leaky Bucket is based on a counter which is incremented every time a cell arrives and decreases with a constant rate. When the maximum of the counter value is reached, policing action takes place.

(b) Leaky Bucket

Fig. UPC Mechanisms