CCITT SGXV
Working Party XV/1
Experts Group for ATM Video Coding

Document AVC-272
16 June 1992

SOURCE : Japan
TITLE : Improvement of delay under average bit rate constraint
PURPOSE : Information

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1. Introduction

We discuss how transmission delay defers between CBR and VBR services using a simple information generation model under average bit rate constraint. Impacts of the Usage Parameter Control (UPC) mechanism in the network is analyzed assuming the same mechanism is applied to the coder for preventive policing.

2. Information generation model

For the transmission delay analysis purpose, information generation of the coded video signal is modeled here as shown in Figure 1. Initially the bit rate is lower than AVE (period 'a'), after that it steps up to AVE with a burst of bit rate HIGH and duration T_B (period 'c').

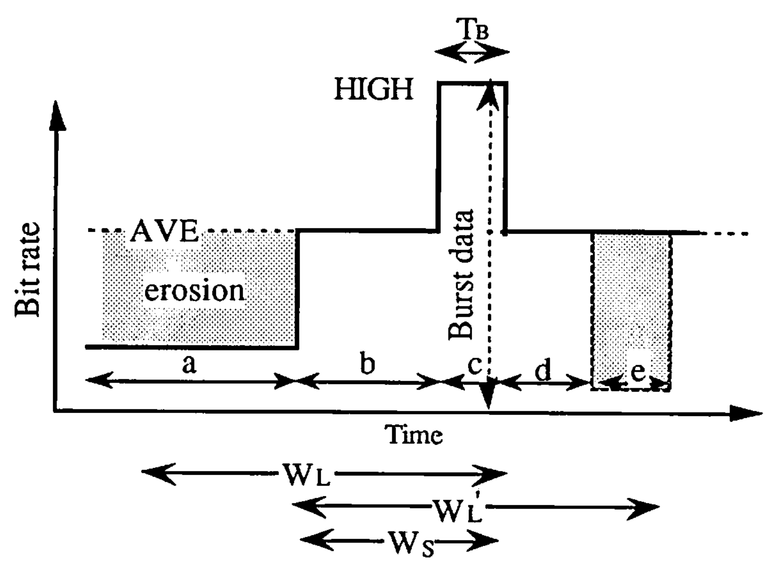

Fig. 1. Information generation model

3. CBR service

Transmission bit rate must be maintained at a constant declared value AVE at any time. Since actual information generation rate is lower than AVE in the period 'a', no transmission delay is involved even if stuffing should take place to make the transmission rate constant. During the period 'b', information generation of the coder balances with the transmission rate, thus again no transmission delay is involved.

During the period 'c' when a burst of information HIGH $\times T_B$ is generated, only AVE $\times T_B$ is transmitted and the difference (HIGH-AVE) $\times T_B$) remains to be transmitted at the end of the period 'c'. This causes the following transmission delay;

$$T_D(CBR) = (HIGH\text{-}AVE) \times T_B/AVE. \quad (1)$$

After the burst period 'c', information generation and transmission rate balance again, but the signal is subject to the above mentioned delay.

4. VBR service

We consider a case that VBR service is characterized by the two parameters which are declared by the user; peak rate PEAK and average rate AVE. Information generated by the coder is transmitted at the rate PEAK as far as the average is not higher than AVE, therefore VBR service inherently provides less transmission delay. Implication of the average rate to the coder is different with the UPC mechanism employed in the network. The coder should control its information transmission by emulating this mechanism so that no information is lost due to the UPC violation.

4.1 Leaky bucket

During the period 'a', the leaky bucket counter value is zero since information generation is less than AVE at which rate the counter decrements. During the period 'b', the counter value remains to be zero since increments and decrements balance. At the end of period 'c', the counter value becomes maximum; (HIGH-AVE) $\times T_B$. After the burst period 'c', the counter maintains this value because of the balance between the information generation and transmission rates. If the bucket size is larger than this, there happens no violation of the UPC, thus all the information can be transmitted at the peak rate. Transmission delay is calculated as follows for the leaky bucket;

$$T_D(VBR_{LB}) = (HIGH\text{-}PEAK) \times T_B/PEAK, \text{ if } HIGH > PEAK \quad (2)$$
$$= 0 \qquad , \text{ otherwise}$$

If the bucket size BUCKET is less than (HIGH-AVE) $\times T_B$, the difference remains to be transmitted at the end of period 'c' which should be transmitted at a rate AVE because the bucket is full. In this case, the transmission delay is given as follows;

$$T_D(VBR_{LB}) = \{(HIGH\text{-}AVE) \times T_B\text{-}BUCKET\}/AVE, \quad (3)$$
$$\text{if } BUCKET < (HIGH\text{-}AVE) \times T_B$$

Transmission delay improvement of the leaky bucket VBR service is calculated as difference between Equations (1) and (2),(3) for a sufficiently large bucket size;

$$\Delta T_{LB} = (HIGH/AVE - HIGH/PEAK) \times T_B \qquad ; HIGH > PEAK$$
$$= (HIGH/AVE - 1) \times T_B \qquad ; AVE<HIGH<PEAK$$

if BUCKET > (HIGH-AVE) × T_B
= BUCKET/AVE
if BUCKET < (HIGH-AVE) × T_B (4)

Figure 2 shows the relation between the delay improvement ΔT_{LB} and the necessary bucket size BUCKET.

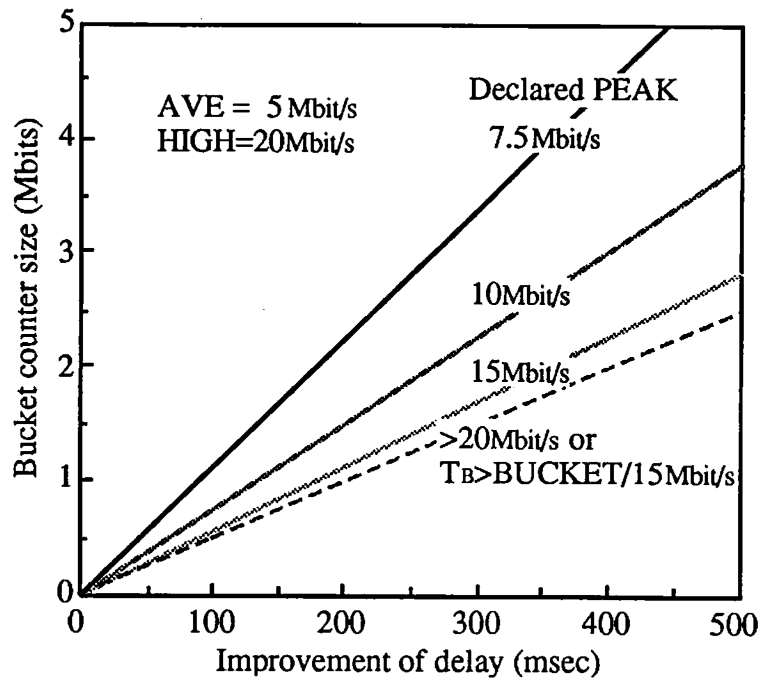

Fig. 2. Bucket counter size vs. improvement of delay

4.2 Sliding window

If the sliding window mechanism with its size W_L is applied to the source signal shown in Figure 1, the average over the window is kept below AVE as far as the 'erosion' area in the period 'a' (shadowed area) in Figure 1 compensates with the burst area in the period 'c'. In this case, all the information can be transmitted at the peak rate PEAK, thus the delay is equal to that of the leaky bucket as given by Equation (4). If the window is slided further as indicated W_L' in Figure 1 so that the window covers both the burst area and the area with bit rate AVE, the average restriction is violated however large the window size is. In this case, the overflow information (HIGH-AVE) × T_B remains to be transmitted at the end of the window period. Since this should be transmitted at the rate AVE, the worst case delay of the sliding window VBR service is equal to that of the CBR service as given by Equation (1).

As a conclusion, the sliding window does not provide improved transmission delay unless the burst is always accompanied by both preceding and following erosion periods. Generally, this condition can not be guaranteed for coded video signals in real time audiovisual communications. Therefore, we can not expect improvement of transmission delay in the sliding window VBR service.

A special case is that coded information is generated periodically. For example, MPEG-1 has been developed as a video coding algorithm for digital storage media adopts the periodical use of one frame intraframe coding for random access and causes periodical fluctuation on generated signals. Fig. 3 shows a model of periodical signal fluctuation. The transmission delay in the CBR services described as follows;

$$T_D(CBR) = (HIGH-AVE)\times T_B/AVE \qquad (5)$$

where $AVE=(T_B\times HIGH+(T_C-T_B)\times LOW)/T_C$

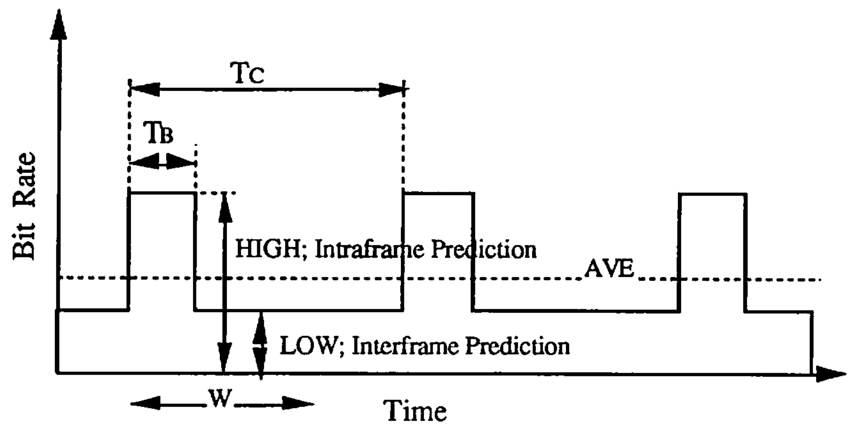

Fig. 3. Model of periodical information generation

If the burst duration time T_B is one video frame time (33 msec) as a realistic value, the relation between burst period T_C and transmission delay $T_D(CBR)$ is drawn in Fig. 4. If this type of periodical intraframe insertion is adopted for conversational services and if the bit generation period is long and/or HIGH/AVE is big, this delay is not negligible. In these periodically structured signals, a burst is always accompanied by its preceding and following erosion. Then the improvement of delay may be possible even when sliding window is used for UPC. To get the same improvement of delay as that of leaky bucket, the following AVE_{sw}' should be declared;

a) $n\times T_C<W<n\times T_C+T_B$:

$$AVE_{sw}'/AVE=\frac{\{LOW\times W+(HIGH-LOW)[n(T_B-T_C)+W]\}T_c}{[LOW\times T_C+(HIGH-LOW)T_B]W}$$

b) $n\cdot T_C+T_B<W<(n+1)T_C$:

$$AVE_{sw}'/AVE=\frac{[LOW\times W+(HIGH-LOW)(n+1)T_B]T_c}{[LOW\times T_C+(HIGH-LOW)T_B]W}$$

(6)

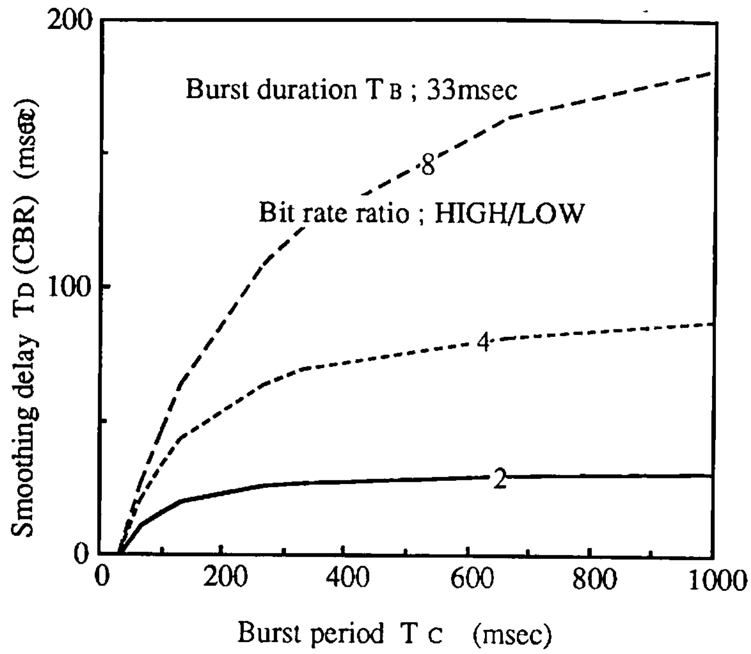

Fig. 4. Smoothing delay of periodical fluctuation in CBR transmission

Fig. 5 shows the calculated AVEsw'. When the window size W is equal to multiple of the information generation period, AVEsw' becomes equal to AVE. In other words, improvement of delay equivalent to leaky bucket can be achieved at the same average bit rate.

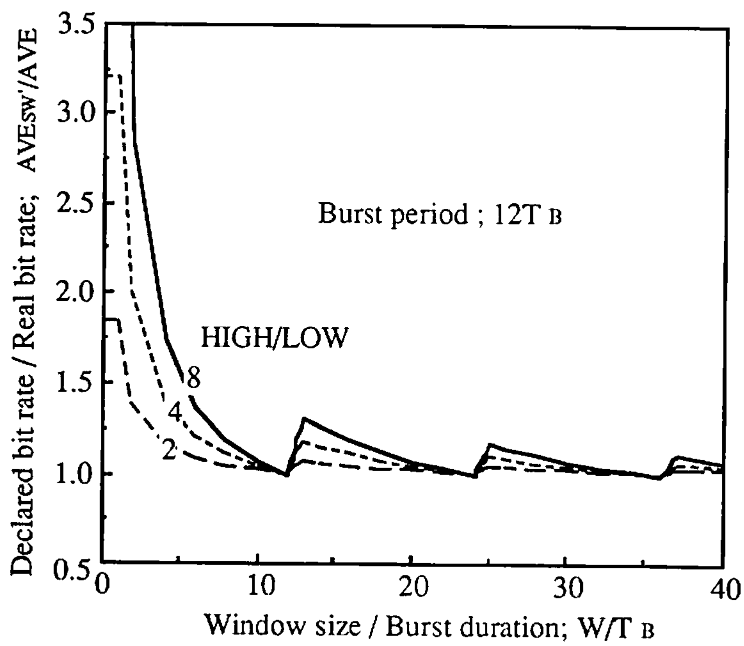

Fig. 5. Required declared value for average bit rate in sliding window

5. Conclusion

VBR video service has been compared with CBR service under the assumption that a new traffic descriptor for VBR service is average bit rate in addition to the peak bit rate. Improvement of transmission delay in VBR service is studied. Two types of

Usage Parameter Control methods are examined: one is leaky bucket and the other is sliding window. They have different implications to VBR video coding. Conclusions are as follows;

1) If leaky bucket method is adopted, shorter transmission delay than those of CBR can be expected.

2) If sliding window is adopted as UPC, this improvement is not promised except for a special case, in which fluctuation of generated information is periodical.

References

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