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Bandwidth Renegotiation Scheme for VBR Video Services

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Abstract

In this work we show how the existence of long term variability in Variable Bit Rate (VBR) video traffic imposes the need of bandwidth renegotiation. In particular, two simple scenarios with a fixed renegotiation interval are considered. Using a real MPEG trace the renegotiation scheme is evaluated to prove its benefits in terms of bandwidth gain and quality of service. The problem of renegotiation demonstrates the need of modelling long term variability in VBR traffic.

1. INTRODUCTION

In opposition to CBR (*Constant Bit Rate*) encoding schemes, VBR (*Variable Bit Rate*) encoding will offer a constant image quality and a better ratio quality/bandwidth as well as the possibility of benefiting from the statistical gain in asynchronous networks such as ATM. However, it has been proved [1] that VBR video traffic exhibits long term variations motivated by the existence of Long Range Dependences (LRD). These LRD are justified by the presence of long periods (scenes) with different levels of image complexity and degree of motion. The practical effect of these long term variations is that the signal converges to its mean bit rate very slowly

In this work we show that bandwidth renegotiation is essential to optimise the use of the network resources when transmitting a VBR video signal. In particular we propose a simple periodical renegotiation, which is able to significantly improve the bandwidth utilization, reducing the delay that a real MPEG video flow experiments

2. RENEGOTIATION ALGORITHM

In the case of off-line services in which the user accesses to video data bases (such as Video on Demand, servers of multimedia information, video-kiosks, ...), the evolution of the pre-recorded video signal is perfectly known. Present transmission schemes reserve a fixed bandwidth for the whole duration of the video transmission. To respect the QoS requirements, the required bandwidth must be dimensioned for the worst case, that is, the scene or period of time for which the traffic is more dense. This implies that the assigned bandwidth will be overdimensioned during the rest of the session. To overcome this problem we propose to periodically renegotiate the bandwidth. In ATM, bandwidth renegotiation is possible in the ABR (*Available Bit Rate*) service model, which has been proposed by the ATM-Forum and the ITU to convey MPEG streams via the AAL5 (ATM Adaptation Layer) [2]. This is also possible for real time services over IP networks, as in RSVP (*Reservation protocol*) the reservation state is dynamically refreshed. In this letter, we propose to renegotiate the bandwidth for each interval of duration *T*. As *T* decreases, the bandwidth reservation will be more accurate and close to the real needs of the video signal, but it must be also considered that each renegotiation includes a management cost and that a demand of more bandwidth may not be accepted by the network.

To show the benefits of renegotiation we consider two different scenarios:

1) In the first one, the bandwidth for each interval is assigned so that the mean channel utilisation (ρ) is fixed to be the same for all the intervals. So, the reserved bandwidth *C[k]* for the *k*-th interval is defined as follows:

$$C[k] = \frac{1}{\rho} \sum_{i=(k-1)\cdot\frac{T}{T_s}+1}^{k\cdot\frac{T}{T_s}} \frac{x[i]}{T} \cdot T_s; \quad for\ i \in [1, N_f] \qquad (1)$$

where *x[i]* is the bit rate of the *i-th* frame of the recorded video signal, N_f is the number of frames of the signal, T_s is the frame period (normally 1/30 or 1/25 s.) and T is the renegotiation period (chosen to be a multiple of T_s).

2) In the second scenario, the bandwidth for each intervals is individually assigned to respect the maximum delay (D_{max}) that the video service can tolerate. According to this method, the maximum delay that the signal experiments during the *k-th* interval is computed in a simulated queue.

Using a simple search algorithm, it can be computed the minimum $C_{min}[k]$ that guarantees that, for the *k-th* interval, the number of bits buffered in the queue ($Q[i]$) does not exceed a certain value B for which the delay would not be admissible:

$$\max_{(k-1)\cdot\frac{T}{T_s}+1\le i\le k\cdot\frac{T}{T_s}} \{Q[i]\} \le B = \frac{D_{max}}{C_{min}[k]}; \quad \forall\, k \in \left[1, \left\lceil N_f \cdot \frac{T_s}{T} \right\rceil\right] \qquad (2)$$

3. SIMULATION AND RESULTS

To evaluate both scenarios, an ATM node with an input buffer is simulated. The video signal is multiplexed in the ATM node. As a test series, we utilise a real video trace consisting in the film "Blade Runner" (N_f=156431 frames). The signal, with 30 frames per second in the NTSC format, was encoded under an open loop MPEG-1 scheme. The mean and the peak bit rate of the flow are 0.53 Mbps and 1.59 Mbps, respectively.

Considering the first scenario, Figure 1 shows that as the renegotiation period T decreases the quality of service (in terms of mean delay) is improved. In particular, for a value of T=1 min., which would just imply a slight overload due to the renegotiation management, the delay decreases in more than an order of magnitude, if we compare it with the case without renegotiation for the same channel utilization.

For the second scenario we consider three values of the maximum tolerated delay, ranging from D_{max}=0.1 s to D_{max}=0.001 s., which correspond to realistic QoS parameters of simplex and interactive video transmissions, respectively. We define the bandwidth gain G_{BW} as the ratio between the mean bandwidths (*BW*) required for a transmission without renegotiation and a renegotiated session under the same constraint of D_{max}.

In all cases (Figure 2) it is proved the efficiency of the renegotiation. For T=1 min and comparing with the absence of renegotiation, the bandwidth gain is about 3, while for T=10 s. the gain is about 4.

4. NEED OF MODELLING LRD

The previous results show the importance of reassigning resources when traffic with LRD properties is being transmitted. However, it has been asserted [3] that, for practical purposes, LRD could be neglected. In figure 3 it is shown the results of renegotiating the bandwidth with the traffic generated by two models adjusted to match the previous MPEG trace: a projected uncorrelated noise, which completely neglects LRD, and a FARIMA model, designed to fit the Hurst parameter of the signal, which entirely describes the LRD (see [4] for more details of the models). The figure shows that if we consider the uncorrelated noise as a valid representation of the real traffic, renegotiation would offer no significant advantages. Oppositely, the results for the FARIMA model present the same behaviour as the real trace. This implies that LRD must be taken into account for the design of controls in the long term time scale.

5. CONCLUSIONS

In this work we have shown that reserving a fixed bandwidth for a VBR video transmission can be very inefficient in terms of QoS and network utilization. Using a real MPEG trace, we have shown that with a simple periodical bandwidth renegotiation (with a period of about 1 min.) delay can be reduced in a order of magnitude or, otherwise, for the same QoS, network utilization can be improved by a factor of more than 2. In any case, the renegotiation problem demonstrates that LRD in video traffic cannot be completely neglected.

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FIGURE CAPTIONS

Figure 1. Mean delay as a function of the renegotiation interval and channel utilizatiom.

Figure 2. Maximum utilization and minimum required bandwidth under maximum delay constraints.

Figure 3. Effects of renegotiation on the traffic generated by an uncorrelated model and a LRD model.

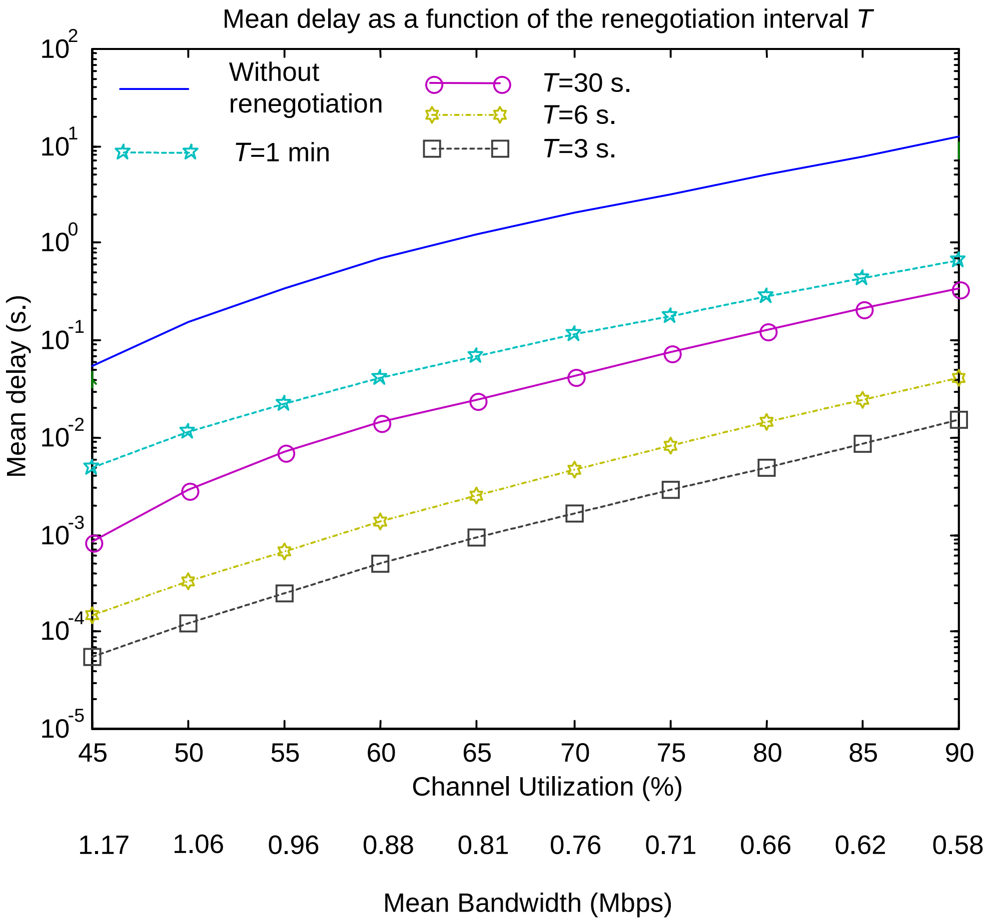
Mean delay as a function of the renegotiation interval *T*
Without renegotiation
T=1 min
T=30 s.
T=6 s.
T=3 s.
Mean delay (s.)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
45
50
55
60
65
70
75
80
85
90
Channel Utilization (%)
1.17
1.06
0.96
0.88
0.81
0.76
0.71
0.66
0.62
0.58
Mean Bandwidth (Mbps)

Figure 1

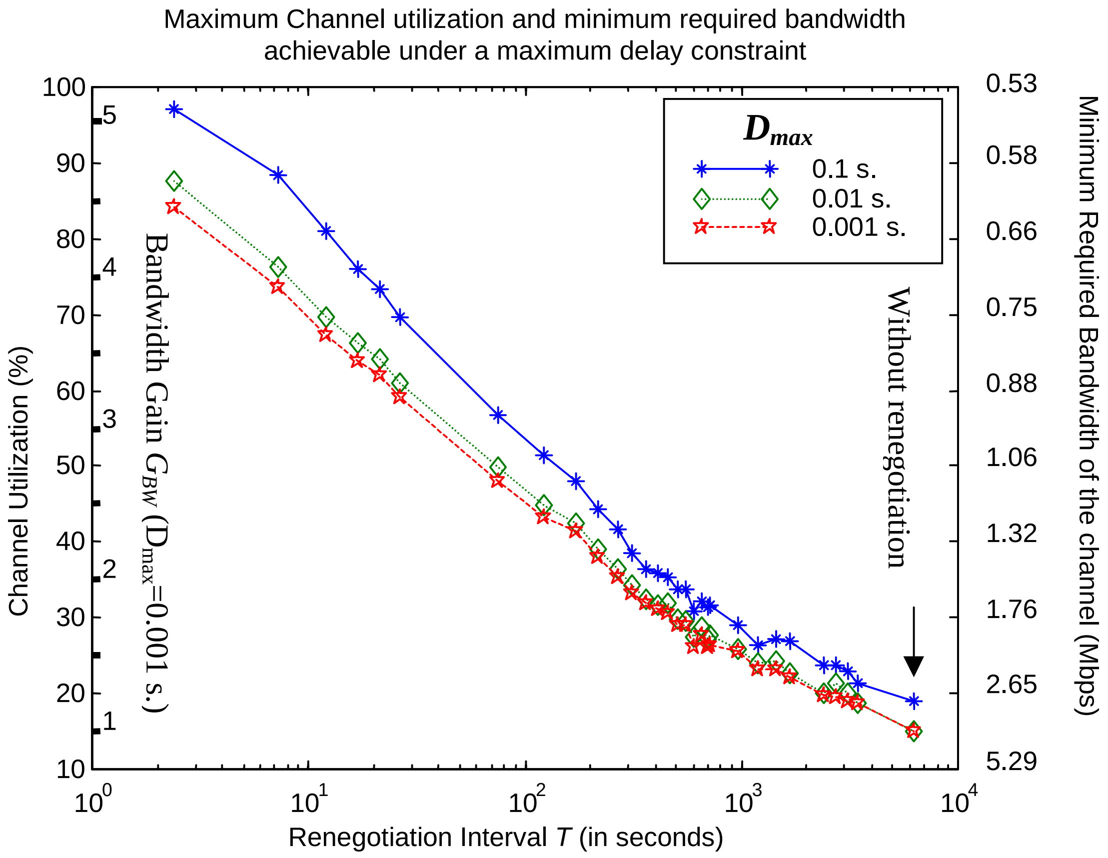
Maximum Channel utilization and minimum required bandwidth achievable under a maximum delay constraint
Channel Utilization (%)
100
90
80
70
60
50
40
30
20
10
5
4
3
2
1
Bandwidth Gain G_BW (Dmax=0.001 s.)
0.53
0.58
0.66
0.75
0.88
1.06
1.32
1.76
2.65
5.29
Minimum Required Bandwidth of the channel (Mbps)
Dmax
0.1 s.
0.01 s.
0.001 s.
Without renegotiation
10^0
10^1
10^2
10^3
10^4
Renegotiation Interval T (in seconds)

Figure 2

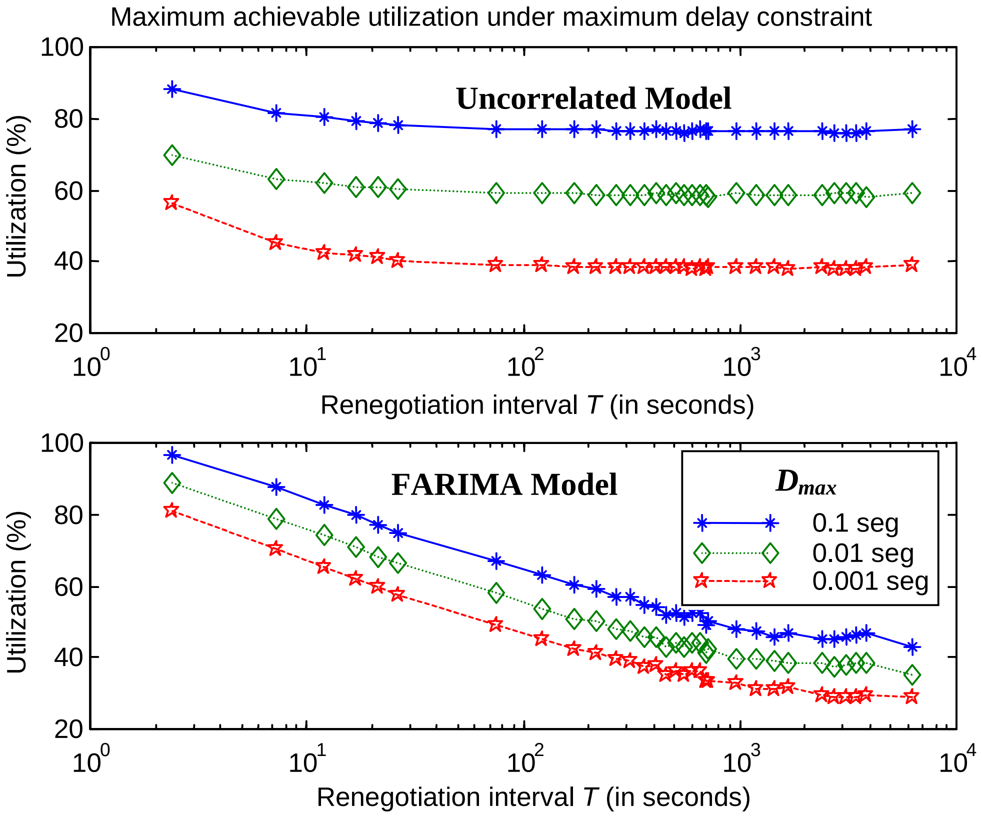
Maximum achievable utilization under maximum delay constraint
Uncorrelated Model
FARIMA Model
Utilization (%)
Renegotiation interval T (in seconds)
100
80
60
40
20
10^0
10^1
10^2
10^3
10^4
Dmax
0.1 seg
0.01 seg
0.001 seg

Figure 3