Effect and Analysis of Sustainable Cell Rate using MPEG video Traffic in ATM Networks

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ABSTRACT

The broadband networks inhibit the capability to carry multiple types of traffic – voice, video and data, but these services need to be controlled according to the traffic contract negotiated at the time of the connection to maintain desired Quality of service. Such control techniques use traffic descriptors to evaluate its performance and effectiveness. In case of Variable Bit Rate (VBR) services, Peak Cell Rate (PCR) and its Cell Delay Variation Tolerance ($CDVT_{PCR}$) are mandatory descriptors. In addition to these, ATM Forum proposed Sustainable Cell Rate (SCR) and its Cell delay variation tolerance ($CDVT_{SCR}$). In this paper, we evaluated the impact of specific SCR and $CDVT_{SCR}$ values on the Usage Parameter Control (UPC) performance in case of measured MPEG traffic for improving the efficiency**.**

Keywords: Asynchronous Transfer Mode, Variable Bit Rate, Peak Cell Rate, Sustainable Cell Rate, Cell Delay Variation.

1. INTRODUCTION

ATM networks generally use call level control schemes for traffic control. Such schemes employ a specific set of traffic parameters to admit or deny a connection using functions like connection admission control (CAC). As defined by ATM Forum [1], CAC is the set of actions taken by the network at virtual connection establishment in order to determine whether a connection can be accepted or should be rejected. Generally, CAC has to make the decision based on whether or not all connections (including both the existing ones and the new one) will be able to achieve their QoS, given limited network sources. A successful CAC strategy should achieve a good balance between user's desire for QoS guarantees and the network provider's desire for maximum revenue. Furthermore, it should be relatively simple to implement, suitable to a wide range of traffic types, and able to deal with time-varying traffic. With these values the UPC procedure monitors the conformity of cell streams with traffic characteristics negotiated at the time of connection set up. ATM forum has proposed PCR, SCR, MBS, MCR and CDVT as traffic parameters in ATM networks. Out of these parameters PCR and $CDVT_{PCR}$ [10] are mandatory traffic descriptors. Using these parameters it is easy to implement the traffic control mechanisms for example: PCR of VPC having a number of VCCs would be the sum of PCR for each VCC. Hence the control of whole VPC becomes easy. But the adverse effect is that it would result into peak allocation of resources and thus overbooking of the channel bandwidth. To avoid this statistical multiplexing can be applied using certain additional traffic descriptors. For effective utilization of resources, traffic control mechanisms using SCR and $CDVT_{SCR}$ is a solution with a combination of simplicity and efficiency. SCR is an upper bound on average rate of the conforming cells of an ATM connection over time scales that are long relative to those for which the PCR is defined. Enforcement of this bound by UPC could allow the network to allocate sufficient resources but less than those based on PCR and still ensure that the performance objectives can be achieved. The $CDVT_{SCR}$ is defined along with and is related to maximum number of consecutive cells that can be transmitted at peak cell rate that is, maximum burst size (MBS).

The block diagram in Fig. 1 shows a reference model according to ATM forum specifications describing the UPC at the public UNI. A similar model applies when UPC is implemented at private UNI. All traffic sources offering cells to a connection are put together in equivalent terminal. Each source generates request to send ATM cells at its own rate. All requests are multiplexed in a multiplexer before entering a Virtual Shaper. The virtual shaper reflects some smoothness in the cell flow offered to the connection. The minimal inter arrival time between two consecutive request is greater than equal to T which is the peak emission interval of the connection that is T= 1/PCR.

To define conformance with respect to traffic contract of the connection Generic Cell Rate Algorithm (GCRA) is used. GCRA is Virtual Scheduling algorithm or continuous-state Leaky Bucket Algorithm and defines relationship between PCR and CDVT, the relationship between SCR and Burst Tolerance (BT). The GCRA is defined with two parameters: the Increment (I) and the limit (L). The notation GCRA (I, L) means the Generic Cell Rate Algorithm with the value of increment parameter set equal to I and the value of the limit parameter set equal to L. The algorithm assures that the cells of a connection entering the network is spaced by a specific time interval I and that a maximum tolerance L is allowed (GCRA (I, L)). The PCR can be policed at public UNI using GCRA (T, τ_s) where T is peak emission interval of the connection and is inversely proportional to PCR, is the $CDVT_{PCR}$. Similarly for SCR, it can be represented as GCRA (T_s, τ_s), where T_s is inverse of SCR and s is the $CDVT_{SCR}$.

2. TRAFFIC CONTRACT PARAMETERS AND ANALYSIS

2.1. Dimensioning criteria for traffic contract

The traffic is characterized by PCR, $CDVT_{PCR}$, SCR, $CDVT_{SCR}$ the values of such parameter must be chosen in order to obtain the desired Quality of Service (QoS). The choice of SCR, BT is important since it is desirable related to resources allocation

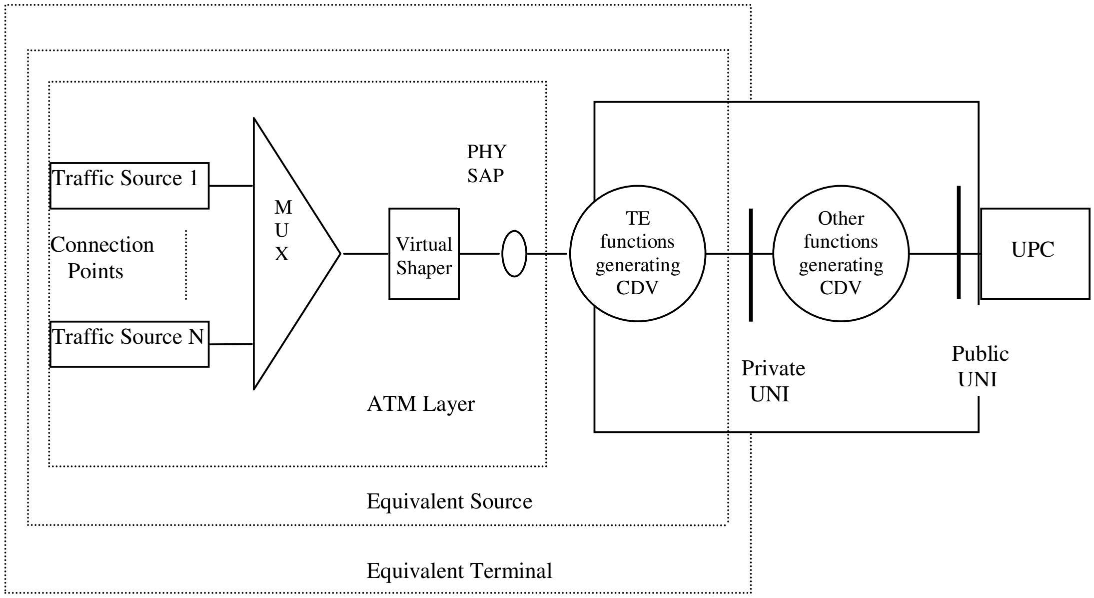

Fig. 1. PCR Reference Model

(bandwidth and buffer) and QoS (delay and cell loss). The problem is to determine SCR and BT when given a certain delay bound and cell loss ratio requirement that will satisfy the requirements and yet minimize the amount of resource allocations. In particular, the dimensioning of T_s and τ_s can be very difficult. The aim of this section is to assess quantitative criteria to dimension these parameters by focusing on the fraction of non-conforming cells Π.

GCRA (T, τ_s) can be modeled with queuing system characteristics as follows: (i) the 'users' are the user generated cells; (ii) the service time is deterministic and equals T_s (iii) the workload can never exceed $T_s + \tau_s$

2.2. MPEG Traffic

The digital video traffic is significant portion of VBR traffic in B-ISDN. The MPEG (ISO Moving Picture Expert Group) is expected to be the major compression algorithm to be used in video applications. The numerical presented in the Section were produced by using actual MPEG video sequences. The sequences are characterized by the number of cells generated for each frame. We assume that each ATM cell carries 48 bytes of coded video. The ATM cells produced by the video codec in a frame time are assumed to be uniformly spaced within the frame itself [11]. The experimental sequences analyzed are the Star Wars sequence [7] and 21 MPEG sequences [12]. Let us define the activity factor of a traffic stream, p, as the ratio between its average cell rate, ACR and its peak cell rate PCR. In the following we use normalized SCR, i.e. fraction η=SCR/PCR, with $p \leq \eta \leq 1$.

The Fig. 2 depicts a fraction of non-conforming cells Π as a function of fraction η for various values of τ_s. The sequence used in the experiment comprises of 174126 frames and each frame duration is 1/25 seconds. The PCR is 12075 cells/s = 4.6368 Mbit/s, while the ACR is 1028.025 cells/s ≈ 395 kbit/s and these values give p ≈ 0.085. The values of τ_s in Fig. 2 are normalized with respect to STM-1 cell emission time v ≈ 2.827 μs. The graph clearly indicates that the fraction of non conforming cells falls below a low threshold (for example 10^{-4}) for the values of SCR quite close to PCR (for example an SCR of about 80% of PCR must be assigned in case of $\tau_s = 1000$). Further increase in τ_s leads to lower values of Π, but it is important to note that very less fall in curve for the values of τ_s ranging from 0 to 500. The fraction of non conforming cells

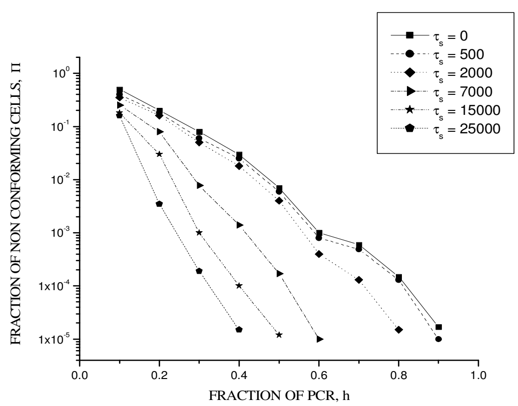

Fig. 2. Fraction of non conforming cells, Π, as a function of the normalized SCR (η=SCR/PCR) for various values of the $CDVT_{SCR}$

gives an average assessment of the policer performance, which can be inadequate when Π becomes very low. Hence, in spite of requiring a low value of Π, it could happen that the QoS is not satisfactory from the user point of view (e.g. a peak frame cloud be strongly affected by the UPC, severely affecting the QoS).

Another important characteristic of the MPEG traffic is the large difference between the values of Π experienced by the different sequences. Fig. 3 shows the minimum value of τ_s to guarantee a fraction of non-conforming cells equal to zero and the resulting value of MBS=1+[τ_s/[T_s(1-η)]], as a function of the normalized SCR. After a sharp decrease of the lower values of η, the τ_s decay quite slowly. In particular, for the values of

SCR higher than half of the PCR, the MBS sticks to the value 483 cells, this is exactly equal to the highest number of cells produced in single frame in entire Star Wars sequence. It should be noted that values of τ_s as high as those plotted in Fig. 3 could well be reasonable, if it is required that Π is very low (e.g. Π in the order of 10^{-9}). In fact, such a requirement is meaningless, unless the amount of cells emitted during the connection exceeds 10^9. Thus a strict requirement on Π can easily imply that no cell can be declared non-conforming, that is, they result in Π=0, when referring to real data sources.

3. ALLOCATION EFFICIENCY WITH THE SCR

In this Section we restrict ourselves to the consideration of N GCRA compliant cell streams multiplexed on a 150 Mbit/s

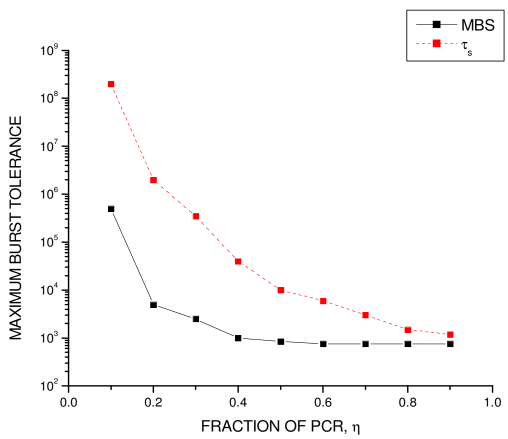

Fig. 3. Minimum value of τ_s (and the resulting MBS) to obtain a conforming cell stream vs. the normalized SCR η.

ATM link. We evaluate the maximum number of sources that can be allocated by using the SCR and its associated $CDVT_{SCR}$ under the constraints of no cell loss at the multiplexer in case of MPEG sources. We use the following property [12]:

Property: The multiplexing of N GCRA complaint cell streams with parameters $T_{s,i}$ and $\tau_{s,i}$, i=1,…,N, can be carried out with no cell loss, provided that the following inequalities are satisfied

$$N+\sum_{i=1}^{N}\frac{\tau_{s,i}-1}{T_{s,i}} \le B_{MUX} \quad \sum_{i=1}^{N}\frac{1}{T_{s,i}} \le 1 \qquad (1)$$

where B_{MUX} is the buffer size of the multiplexer.

This property shows that the CAC rules for GCRA compliant streams can be performed by means of simple additive formulas. In the rest of this section, we exploit (1) and the results of section 2 to evaluate the maximum number N_{SCR} of sources that can be allocated by using the SCR, under a no cell loss requirement at the access multiplexer; in addition, the GCRA parameters are chosen so as to reduce to zero the fraction of non-conforming cells. As discussed in section 2, this might well be equivalent to requiring $\Pi \le$ very low threshold (for example 10^{-9}). Finally the value of the multiplexer buffer size B_{MUX} is chosen so that the maximum delay at the multiplexer is no more than a specified quantity D_{max}.

These are strong requirements: one could consider a non null cell loss at the multiplexer and/or a buffer sizing based on a quantile of the delay instead of the maximum value. However, it is likely that such strong (and safe) constraints will be met at least in a first stage of deployment of the ATM B-ISDN. More relaxed constraints lead to many difficulties in their definition characterization, evaluation and implementation, even if they can result in non negligible resource savings. In the presented graphs we plot the SCR to PCR allocation ratio R, defined as the ratio of N_{SCR} and N_{PCR}, where the latter is the maximum number of connections that can be allocated by using the PCR only. Fig. 4 plots the ratio R vs. the normalized SCR η for two values of D_{max} in case of MPEG traffic (star wars sequence). With D_{max} 10ms, the optimal value of η is about 0.8 and the efficiency gain over the peak allocation is about 20% (35 admitted sources instead of only 29 sources). In case of Dmax = 1ms the best choice of SCR is SCR=PCR. This result is motivated by the strong constraints imposed in deriving the considered curve. In fact, requiring perfect GCRA compliance leads to large values of the $CDVT_{SCR,}$ unless SCR were close to PCR as indicated in Fig. 3; this in turn has a heavy impact on the buffer consumption according to the CAC rules (1), where B_{MUX} is determined by the maximum allowed delay.

The maximum value attained by the SCR to PCR allocation ratio obviously depends on the allowed maximum delay D_{max} at the multiplexer. The SCR concept can lead to very significant multiplexing gains, provided a relatively large value of D_{max} can be tolerated. As an example, if one frame delay can be allowed (D_{max}= 40 ms), the number of multiplexed MPEG streams according to the CAC rules (1) is doubled with respect to the peak allocation case.

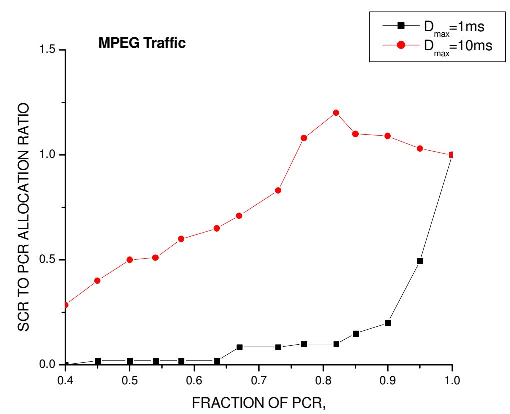

Fig. 4. SCR to PCR allocation ratio, R, as a function of the normalized SCR for two values of maximum allowed delay in the multiplexer (MPEG traffic)

4. CONCLUSION

In this paper, analysis of MPEG traffic using SCR and $CDVT_{SCR}$ shows that efficiency can be improved at the expense of a large increase of the values of τ_s. The higher values of τ_s of the order of 10,000 or greater, the SCR falls below half of PCR and the fraction of non conforming cells reduces below the threshold of 10^{-4}. In the last section, it is shown that for the smaller values of SCR to PCR ratio buffer constraints dominates as high values of $CDVT_{SCR}$ is needed to make the offered cell stream GCRA complaint, while the bandwidth constraint is the limiting factor at the high values of the ratio of SCR to PCR.

The balancing of these two factors leads to the appearance of an optimal value of SCR.

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