# End-to-End Simulation of VBR Traffic over ATM Networks using CIPP Network Traffic model

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**Abstract**

*In this paper, we model the background network traffic by CIPP in an ATM multiplexer while simulating the end-to-end transport of* real world *VBR traffic over ATM networks. CIPP has been proposed in [1] for modeling broadband teletraffic. In [1], it was shown that, an empirical relationship exists between the parameter $\rho$ of CIPP and estimated local Hurst parameter $H$. This feature is made use of here, to study the effect of degree of self-similarity of background network traffic on various performance measures. The modeling and simulation results show the effect of self-similarity of the background process (as measured by $\rho$ of CIPP) on various performance measures parameterised by ATM multiplexer buffer size and decoder buffer size.*
Keywords *CIPP, interarrivals, self-similarity, VBR traffic modeling.*

## 1 Introduction

The MPEG-2 standard (ISO/IEC 13 818) [2] assumes that the end-to-end delay from an MPEG-2 system's encoder to decoder is constant to ensure that the decoder buffer does not overflow nor underflow. But, an ATM network introduces jitter (variations in delay) while transporting the corresponding cells from source to destination, due to statistical multiplexing. Thus, the statistical characteristics of the output cell stream of the VBR video traffic under study, depends on the variability (or more precisely, self-similarity), of the background network traffic process, for the same mean rate of the background network traffic. To the best of our knowledge, until now, most studies, explore the decoder buffer behaviour without considering the ATM network jitter [3, 4, 5], except in [6] and [7]. In [7], the network is modeled as a black box which introduces jitter (approximated as truncated Gaussian) into the cells.

In this paper, we model the background network traffic by Correlated Interarrival time Poisson Process (CIPP), in order to justify the self-similar nature of the background network traffic, while simulating the end-to-end transport of *real world* MPEG video traffic over ATM networks with background traffic. CIPP was introduced by the authors in [8], where it is shown that the CIPP models well the broadband teletraffic. An empirical relationship between $\rho$, a parameter of CIPP and the estimated local Hurst parameter of corresponding CIPP trace and its ease to simulate on the computer are attractive features of CIPP. We model the ATM multiplexer as a single server FCFS queue with the superposition of *real world* VBR traffic and the background network traffic generated by CIPP. By doing so, we inherently introduce jitter into the cells belonging to video traffic under study. We study the effect of self-similarity of the background network traffic on the various performance measures parameterized by ATM multiplexer buffer size and decoder buffer size. We first generate MPEG transport stream (TS) packets by (deterministic) smoothing [7] the *real world* MPEG traffic. We then segment these TS packets into ATM cells. We simulate their transport over ATM networks by merging this cell stream with the background ATM cells generated based on CIPP model and feeding them into single server FCFS queue. Then, we segregate the cells belonging to VBR traffic under study, at the output. Finally, these cells are reassembled into TS packets at the destination, which are delivered into the upper layer TS packet decoder. We simulate the behaviour of the decoder buffer under the real-time requirement. We show the interactions among ATM multiplexer buffer size, decoder buffer size, the degree of self-similarity of background traffic process in the network and the various performance measures including packet loss ratio. The rest of the paper is organized as given below: in Section II, we give a brief account of CIPP process. In Section III, we give the end to end simulation of MPEG transport streams over ATM network. In Section IV, simulation results for the decoder behaviour and the statistical multiplexer are given.

## 2 Correlated Interarrival Time Poisson Process (CIPP)

The CIPP, a stationary increment counting process, is parameterized by a correlation parameter '$\rho$' which represents the degree of correlation in adjacent interarrivals in addition to '$\lambda$' the intensity of the process. We briefly define CIPP as below. For more formal derivation and for other details regarding CIPP, please see [1]. Let $P_n(t) \triangleq Pr\{N(t) = n\}$, be the probability that the number of arrivals in the interval $(0, t]$ is $n$. CIPP with parameter $\lambda$ and $\rho$ has the distribution,

$$P_n(t) = \begin{cases} (1+\rho-(1-\rho)\alpha_n) \\ \sum_{j=0}^{n} \frac{\alpha_j \prod_{k=0}^{n}[\alpha_j - \rho\alpha_k]}{(\rho(\alpha_j+1)-\alpha_n+1)(\alpha_j-\alpha_n+1)(\alpha_j-\rho\alpha_n)\prod_{k=0,k\neq j}^{n}[\alpha_j-\alpha_k]} e^{-\frac{\lambda t}{\alpha_j}} & 0 \leq \rho < 1 \end{cases} \quad (1)$$

for $n = 0, 1, 2, \ldots, \lambda > 0, \; t \geq 0,$ and $\alpha_j = \sum_{i=0}^{j} \rho^i$
We give the following remarks: **Remark 1** It has been shown in [1] that, as $\rho$ increases, the estimated local Hurst parameter $(0.5 < H < 1)$ increases. **Remark 2** We contend here that, the introduction of correlation in the interarrival sequence is more appropriate, rather than to introduce correlation in the count sequence in the context of modeling broadband teletraffic (as done in [9]). **Remark 3** It is worth mentioning that, CIPP is *not* a special case of Neuts process [10].

## 3 End-to-end simulation of MPEG transport streams over ATM networks

**Source-side modeling of MPEG transport stream:-** The MPEG system first packetises elementary streams (compressed video sequences) to produce packetised elementary streams (PES) packets. PES packets are further combined with system information to form TS's. The TS packet has a fixed length of 188 bytes. We use MPEG *terminator* movie sequence for our study. The coding parameters used are $M = 3$ (M is the space between anchor frames) and $N = 12$ ( N is the space between I frames), which yield the following fixed frame pattern within each group of pictures (GOP): IBBPBBPBBPBB. Deterministic smoothing is done as in [7]. The simulation parameters are as in [7] while transporting MPEG TS packets over ATM.

**Transporting MPEG TS packets over ATM networks** We consider the transport of MPEG TS packets over ATM networks using AAL5 PDU. In this scheme, MPEG TS packets are mapped into AAL5 PDUs, each containing 2 TS packets. Each PDU is then converted into eight ATM cells. At the destination, eight ATM cells are reassembled into an AAL5 PDU, which is then decomposed into two adjescent TS packets. These TS packets are then delivered to the upper layer TS packet decoder.

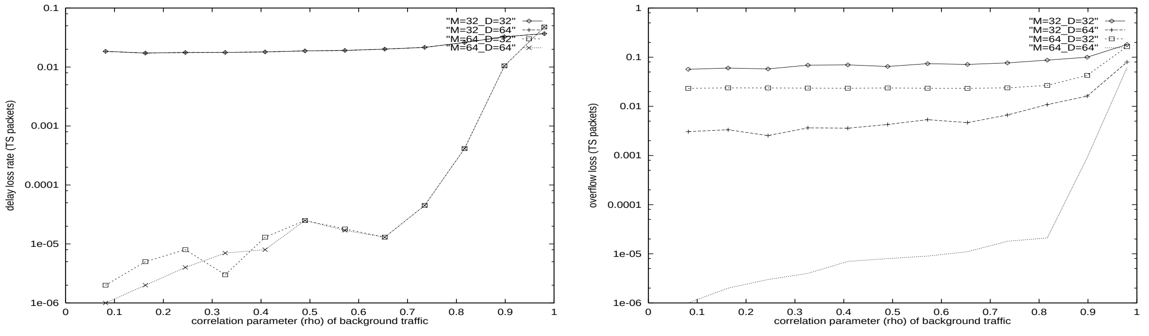
**ATM multiplexer with background network traffic process** After the cells are formed at the source, they are merged with the CIPP traffic which is independently generated. This merged traffic is fed into the FCFS queue which models an output queue in an ATM multiplexer. In this study, we set the rate of CIPP generator as 80% of mean arrival rate of the VBR traffic under study. We study the effect of precariousness of the network traffic on the performance of decoder buffer and ATM multiplexer buffer. We also study the interactions among decoder buffer behaviour and multiplexer at various values of the correlation parameter.

**Decoder buffer system definition** MPEG video TS packets enter the T-STD decoder buffer after they are reassembled from ATM cells. We model the decoder buffer operation based on the MPEG TS system target decoder (T-STD) [2]. For detailed information about the operation of T-STD, the reader is reffered to [2]. In our study we consider a simplified version of the T-STD in which decoding is performed at regular intervals (1/R s). Packet losses occur when the buffer is full. In our simulations, at every frame interval of 1/R secs, we check whether the TS packets for one video frame have arrived completely. If all the packets have arrived, they are removed from the decoder buffer instantly. Otherwise, we wait for one more frame interval (1/R sec) to see whether the data for this frame is complete. After this extra frame interval, the arrived data for this frame are removed from the decoder buffer even though they may be incomplete. The late PDUs are counted as lost PDUs in our packet loss ratio calculation (in addition to those PDUs lost due to decoder buffer overflow). We believe that even with this simplified decoder, the salient features of the MPEG decoding mechanism still remain and the overall performance would not change any significant way. Also, simulation results based on this simplified model give us the worst case scenario and provide an upper bound on the decoder buffer requirements. The following are the performance measures, we consider for our study: (i) Probability of loss of TS packets due to delay (delay loss rate), (ii) Probability of loss of TS packets due to cell losses in the ATM multiplexer (network loss rate), (iii) Probability of loss of TS packets due to decoder overflow (overflow loss rate) and (iv) Cell delay variation while cells transiting ATM buffer (cdv).

# 4 Simulation results

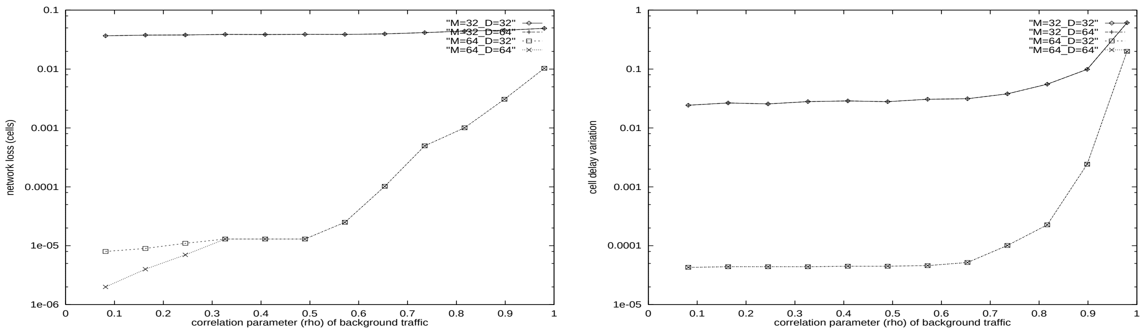
Let us denote the multiplexer buffer size and decoder buffer size by $M$ and $D$ respectively. Note that $M$ is in cells and $D$ is in TS packets. In order to study the effect of precariousness of the network traffic on the performance of decoder buffer and ATM multiplexer buffer we design the experiment as follows. First we fix the buffer capacity of ATM multiplexer ($M$) and decoder buffer size ($D$). The experiment is carried over $\rho$. The results are depicted in Figures 1 and 2. We would also like to study the interactions between the ATM multiplexer buffer size ($M$) and decoder buffer size ($D$) for fixed $\rho$. Hence, for the second set of results, we fix the $\rho$ of CIPP and buffer capacity of ATM multiplexer ($M$). We study the effect of decoder buffer size ($D$) on the performance measures. We repeat the experiment for various combinations of $\rho$ and $M$. Thus we get, the second set of measurements (see Figures 3 and 4). Our third experiment is designed to explore the effect of ATM multiplexer buffer size $M$ on the performance measures, parameterized by $\rho$ and $D$. The results are illustrated in Figure 5.

**Effect of precariousness of background traffic process:-** As one may see from Figure 1 (a), delay loss rate increases as $\rho$ increases initially slowly, but increases sharply as $\rho$ approaches 1. This is due to the monotonic non-linear empirical relationship between $\rho$ and the estimated Hurst parameter $H$ as given in [1]. Note that the curves corresponding to $D = 32$ and $D = 64$ merge. This intuitively makes sense, since the delay losses are independent of $D$. One may also note that, losses are high for the parameterization $D = 32$ and $M = 32$. Figure 1 (b) gives our result of overflow loss rate. Again queueing performance degrades as $\rho$ increases. Overflow loss rate rises sharply as $\rho$ approaches 1. Overflow losses are high for the parameterization $D = 32$ and $M = 32$. Network loss rate and cell delay variation (*cdv*) (Figure 2 (a) and Figure 2 (b) respectively) show the same behaviour as delay loss rate. Note that, the curves corresponding to parameterization of $D = 32$ and $D = 64$ merge similar to the situation as we observed in Figure 1 (a).




(a) Delay losses (b) Overflow losses.

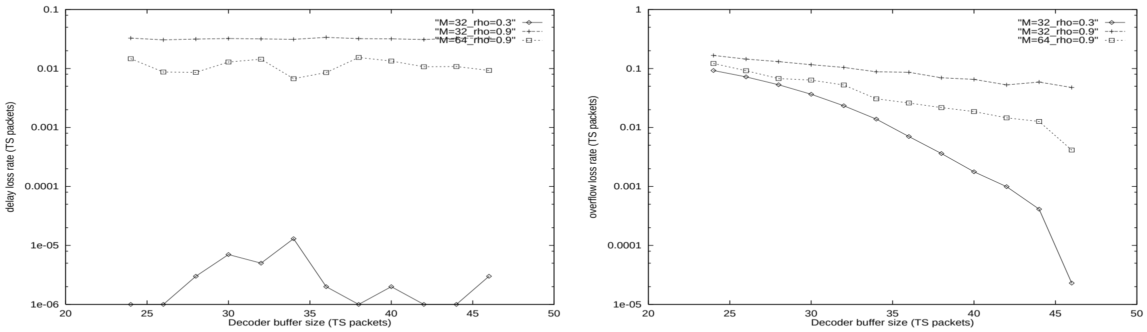
**Figure 1. Decoder performance measures versus $\rho$**




(a) Network losses (b) cdv.

**Figure 2. Decoder and multiplexer performance measures versus $\rho$**

**Effect of Decoder buffer size $D$:-** As one may see from Figure 3 (a), the delay loss rate is independent of $D$. This intuitively makes sense. One may also note that, delay losses are high for $\rho = 0.9$. Figure 3 (b) gives our result for overflow losses. As $D$ increases, loss rate decreases. Losses are high for the parameterization $M = 32$ and $\rho = 0.9$. Figure 4 (a) depicts that fact that the network losses are independent of $D$. Here, also one may see that higher $\rho$ corresponds to more losses. Cell delay variation follows the same behaviour, which is depicted in Figure 4 (b).




(a) Delay losses (b) Overflow losses.

**Figure 3. Decoder performance measures versus $D$**

**ATM multiplexer buffer size $M$:-** Figure 5 (a) depicts that fact that the network losses decreases as $M$ increases. Here, also one may see that higher $\rho$ corresponds to higher losses. Cell delay variation follows the same behaviour, which is depicted in Figure 5 (b). Note that the curves corresponding to $D = 32$ and $D = 64$ merge.

## 5 Conclusions

From our simulations using CIPP it is seen that as $\rho$ increases, both the ATM multiplexer buffer and the decoder buffer performance degrades. We believe that, the simulation approach proposed in this paper, will be a useful tool in supporting real-time ATM network traffic management. Currently we are working on the theoretical study incorporating the queueing theory results for CIPP [11] to the above problem.

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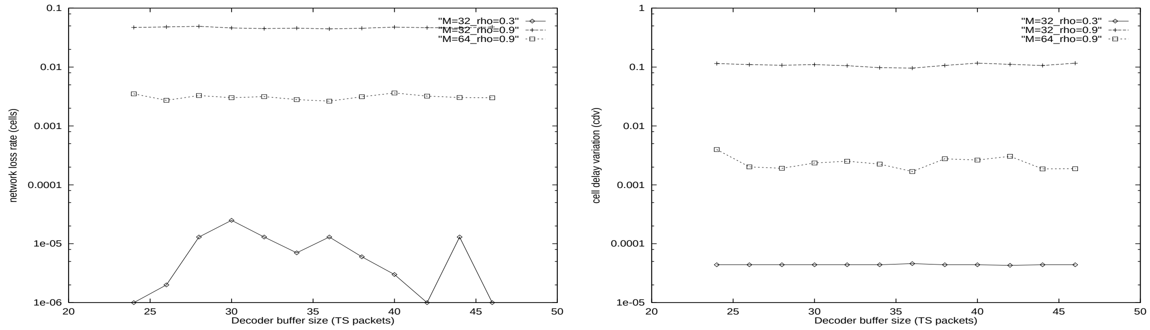
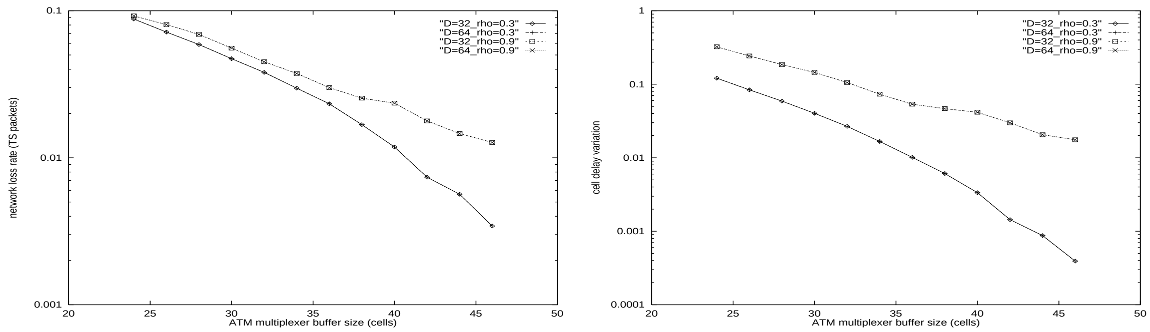



(a) Network losses (b) cdv.

**Figure 4. Decoder and multiplexer performance measures versus $D$**




(a) Network losses (b) cdv.

**Figure 5. Decoder and multiplexer performance measures versus $M$**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