The CIPP and the Performance Modeling of VBR Video Traffic by CIPP/M/1/K Queue

R. Manivasakan, U. B. Desai and Abhay Karandikar

SPANN Lab., Department of Electrical Engineering, Indian Institute of Technology - Bombay, Powai, Mumbai - 400 076. INDIA.

Telephone : +91-22-579 0651, Fax : +91-22-578 3480 E-mail : {mani, ubdesai, karandi}@ee.iitb.ernet.in

Abstract

Correlated Interarrival time Process (CIPP) has been proposed in [1], for modeling both the composite arrival process of packets in broadband networks and the individual source modeling. The CIPP - a generalization of the Poisson process - is a stationary counting process and 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. In this paper, we undertake the performance modeling of more realistic finite buffered statistical multiplexer with smoothed VBR video traffic input using CIPP/M/1/K queue. Queueing performance measures considered here are, packet loss probability and conditional packet loss probability. The buffer occupancy distribution in a queue with real-world MPEG-1 VBR video traffic is compared with that of its “best fit” CIPP/M/1/K. The above simulation results show that, the correlation in interarrivals degrades the queueing performance in the finite capacity queue case also. (In [2], we have shown analytically that the (positive) correlation in interarrivals in a CIPP/M/1 queue degrades the queueing performance). Finally, we consider the fluid-flow approximation of queues with CIPP arrivals to study the behavior of statistical multiplexer with VBR video traffic input. Comparisons with other models like, Markov chain, histogram model are also undertaken.

1 Introduction

There are enough empirical evidence that, the individual source traffic namely, voice and video have non-zero correlation [3], (for non-zero lags) in their rate or (counts) process (in fact, they exhibit long-range dependence (LRD) or self-similar behavior). This is true for composite traffic also [4]. Thus, Poisson model is ruled out, despite its analytical simplicity. Hence, researchers were looking for models, which have correlations in increments on the one end, and on the other hand, are analytically tractable. The correlation in increments could be brought in a number of ways, namely, considering correlations in the count sequence by say a discrete autoregressive (DAR(1)) model, or by considering correlations in rate process by an autoregressive (AR) model or by introducing correlations by modulating Markov chain or finally by considering correlations in the interarrival sequence itself. In literature, researchers have considered models which capture correlation in the counts sequence given as cells per unit time (as in DAR(1) model [5]), or in the (traffic) rate process (as in AR model [3] or self-similar models [4, 6]) or the correlation introduced by the modulating Markov chain as in Markov modulated models [7]. Note that, it has been observed by Paxson et al. [8], that there is correlation in interarrivals in Ethernet traces. (We reproduce below the exact sentence, given in page 229 of [8]. “... If we require fixed rates only over 10 minutes intervals, then SMTP and FTPDATA burst arrivals are not terribly far from Poisson, though neither is statistically consistent with Poisson arrivals, and consecutive SMTP interarrival times show consistent positive correlation”). All of the models addressed in literature, are intended to capture the correlation in the increment, by considering correlation in count sequence or in rate process or introducing correlation in the modulating Markov chain.

In light of the above, we contend that, a model capable of capturing the correlation in the interarrival sequence is a more appropriate candidate in the context of modeling teletraffic data. We argue as given below: We know that correlations in interarrivals necessarily imply correlations in the number of counts; however converse of this statement is not necessarily true. A good example would be a renewal process. Hence, a model capable of capturing the correlation in the interarrival sequence is a more appropriate candidate in the context of modeling teletraffic data. Moreover, the interarrival correlation plays a major role in exhibiting the self-similar behavior in increments of the corresponding counting process. Thus, we are motivated to define a process, whose interarrivals are correlated.
In [1], we proposed a model for broadband teletraffic, namely the Correlated Interarrival time Poisson Process (CIPP). The CIPP, a stationary counting process is parameterized by correlation parameter \( \rho \) which represents the degree of correlation in adjacent inter-arrivals in addition to \( \lambda \), the intensity of the process. It is shown in the above paper that the CIPP does exhibit self-similarity over a range of time scales of interest although it may not be mathematically a pure self-similar process. Infinite capacity queues with CIPP input is considered in [2]. In this paper, we undertake a simulation based performance modeling of statistical multiplexer with VBR video traffic input using the CIPP/M/1/K queue. Here the output buffer of the statistical multiplexer is assumed to have finite capacity in order to take into account the finite storage capacity of all realistic systems. We resort to simulation study, since the analysis of finite capacity queue, with CIPP input, seems analytically intractable.

The paper is organized as below. In Section 2, we give a brief account of CIPP process. Section 3, provides the fitting procedure based on autocorrelation function, which we use in this paper. The simulation methodology for our performance modeling study is given in Section 4. The simulation study of the finite capacity CIPP queue is considered in Section 5. Section 6 gives cell loss simulation results for fluid flow approximation for CIPP queues. Conclusions and future work are indicated in Section 7.

2 CIPP - A Brief Introduction

In this section, we will give a brief introduction about the Correlated Interarrival time Poisson Process (CIPP) as introduced by the authors [1]. For \( t > 0 \), let \( N(t) \) be the number of arrivals that have occurred in the half-open interval \((0,t]\). Let \( P_n(t) \equiv P \{ N(t) = n \} \), be the probability that the number of arrivals in the interval \((0,t]\) is \( n \).

CIPP with parameter \( \lambda \) and \( \rho \) has the distribution,

\[
P_n(t) = \begin{cases} \frac{(1+\rho-(1-\rho)\alpha_n)}{\sum_{i=0}^{n} A(j,n) e^{\frac{-\lambda t}{j}}}, & 0 < \rho < 1 \\
0 & \text{otherwise}
\end{cases}
\]

(1)

where, \( A(j,n) = \frac{\alpha_j \prod_{k=0}^{j-1} (\alpha_k + \rho a_j)}{B(j,n)} \) and \( B(j,n) = (\rho (\alpha_j + 1) - \alpha_j + 1)(\alpha_j - \alpha_{n} + 1)(\alpha_j - \rho a_n) \) for \( n = 0,1,2,\ldots \), \( \lambda > 0 \), \( t \geq 0 \), and \( \alpha_j = \sum_{j=0}^{\infty} \rho^j \).

For derivation of the above distribution and other details about CIPP, please see [1].

**Remark 1:** The interarrivals in CIPP forms the first order Markov chain [9] as described below. Let \( X_n \) be the interarrival time between the \( n^{th} \) arrival instant \( (T_n) \) and \( (n-1)^{th} \) arrival instant \( (T_{n-1}) \). Then,

\[
X_{n+1} = \rho X_n + \epsilon_{n+1} \quad 0 \leq \rho < 1 \quad n = 1, 2, 3, \ldots
\]

(2)

where, \( \{\epsilon_n\}_{n=1}^{\infty} \) is an iid sequence, with \( \epsilon_n \), \( n > 1 \), being a product of Bernoulli random variable \( (B) \) with parameter \( \rho \) and exponential random variable \( (V) \) with parameter \( \lambda \). \( B \) is statistically independent of \( V \). \( \{X_n\} \) forms a stationary sequence with the exponential distribution characterized by parameter \( \lambda \). Note that, \( X_1 = T_1 - T_0 \) where, \( T_0 \) is the 0th arrival instant.

**Remark 2:** As the limit \( \rho \to 0 \) in (1), we obtain the Poisson case. Thus, the Poisson distribution is approached continuously from the CIPP distribution.

3 Fitting Procedure

Digital video communications (like video phone, video conferencing, television distribution etc.) are the major class of services provided by broadband networks. The multiplexing gain of a statistical multiplexer is restricted by quality of service (QoS) guarantees which are basically bounds on queueing performance measures introduced in Section ?? . Accordingly, the performance modeling of variable bit rate (VBR) traffic receives much attention in light of modeling and analysis of traffic generated by video communications in broadband networks. In this context, there are two issues, which are worth mentioning here: first, to come up with a process, which models well the real-world data (statistical modeling part) and second, to evaluate how closely the behavior of a queue with this model as input, approximates the queueing behavior of a queue with real-world traffic data as input (performance modeling part). Although, the main focus of this paper is on the performance modeling of a statistical multiplexer with VBR video traffic input using CIPP queues, the parameters of CIPP are evaluated by 'fitting' the CIPP to the traffic data. In the following, we give the fitting procedure we used.

3.1 Fitting the CIPP Model to Real Traffic Data

In order to show that CIPP models well the data, we have to "fit" the CIPP model to the data. This requires the parameters of CIPP be estimated such that this "best fit" CIPP in some sense behaves closer to the data (with respect to some statistical measures). This fitting procedure usually involves the estimation of first/higher order statistics of data and matching this with the corresponding moments of CIPP to get the parameters of CIPP. Note that, here in CIPP case, one may use the elegant method of estimating the parameters (namely \( \rho \) and \( \lambda \) as given in [9]. But, here, we would like to mention that, we are more interested in capturing the LRD of the real-world data. Hence, we use autocorrelation measure for our fitting procedure.

3.1.1 Autocorrelation of Counts Sequence \( \{u_T(i)\} \)

Let \( \{u_T(i)\}_{i=1}^{\infty} \) denote the number of arrivals in \( i^{th} \) slot on the positive real axis where each time slot is of equal length, \( T \) time units. The sequence \( \{u_T(i)\}_{i=1}^{\infty} \) is called
as counts sequence\(^1\). Then the correlation coefficient (denoted by \( \psi_T(k) \) for lag \( k \)) for counts sequence \( (u_T(.)) \) is defined by,

\[
\psi_T(k) = \frac{E(u_T(i)u_T(i+k)) - E^2(u_T(i))}{\text{var}(u_T(i))}
\]

Note that for Poisson process \( \psi_T(k) = 0 \) for all \( k \neq 0 \).

We fit a CIPP to the VBR video traffic, by using the following algorithm:

**Fitting procedure**

1. Segment the bits in each frame into packets by smoothing. (See Section 4.1). We then have the counts sequence \( u_T(i) \) of packets.

2. Estimate the correlation coefficient of this counts sequence of packets. Note that the we consider the sequence of number of packets in a group of pictures (GOP) (denoted by \( u_{\text{GOP}}(i) \)) for our fitting procedure. The correlation coefficient \( \psi_{\text{GOP}}(.) \) corresponding to data, to which we intend to match the correlation coefficient of the CIPP model.

3. **Algorithm to estimate parameters of CIPP**: Set the rate \( \lambda_{\text{opt}} \) of CIPP equal to \( E(u_{\text{GOP}}(i))/T_{\text{GOP}} \).

   **Algorithm to estimate \( \rho_{\text{opt}} \) of CIPP**: begin
   
   \[
   \begin{align*}
   \text{min} &= 99999999.9 \\
   \text{step} &= 0.0001 \\
   \rho &= \text{step} \times i \\
   \text{estimate the correlation coefficient} \\
   \psi_{\text{GOP}}(.) & \text{ for CIPP by reasonably large realizations.} \\
   \text{compute the mean square error (P)} \\
   \text{between} \psi_{\text{GOP}}(.) \text{ and} \psi_{\text{data}}(.) \\
   \text{if} (\text{min} < P) \text{ then} \\
   \text{min} &= P \\
   \rho_{\text{opt}} &= \rho \\
   \psi_{\text{GOP}}(.) &= \psi_{\text{data}}(.) \\
   \text{endif} \\
   \text{end}
   \end{align*}
   
4. **Simulation Methodology**

   In this section, we discuss the simulation methodology for performance modeling and related techniques which will be used in subsequent sections to handle the real-world MPEG-1 VBR video traffic data for our simulation purposes.

   There is a problem (discussed in detail in Section 4.1) in simulating the several multiplexed video sources with same frame periods. In literature, smoothing is used to get around this problem. But, conventional smoothing gives only fixed size packets. Here, since our study includes variable length packets (to account for the real world situation), we use geometrical packet sizes and are reasonable though. This calls for a method of smoothing which gives the variable sized packets (owing to the deterministic service nature of a broadband switch). In light of the above, we propose a variation of the deterministic smoothing which gives geometrically distributed packet sizes. This is explained in Section 4.2.

   The smoothed packet stream is then fed to an infinite buffer single server queue with exponential service (here, exponential service times are approximated by the ratio of geometrical packet lengths (which we generated earlier while smoothing) to the link capacity). Then, the queueing measures are estimated from simulations. We thus get the experimental results corresponding to data.

   Since, the finite capacity CIPP queue is analytically intractable, we resort to simulation based performance modeling. We first fit the CIPP to video trace data by autocorrelation matching (given in the previous section). We then use this "best fit" CIPP to simulate the CIPP/M/1/K queue and estimate the queueing performance measures. We repeat the experiment with various link utilization factors to get the plot of queueing performance measures versus link utilization factor.

4.1 **Smoothing of VBR Video Traces**

   As mentioned earlier, there is a problem in simulating the several multiplexed video sources with same frame periods. If the multiplexed video sources are synchronized, they all begin their burst at the same instant for every frame, overloading the multiplexer's buffer. However, if the traffic is smoothed (for simulations) the sensitivity to synchronization is eliminated. Mathematically, smoothing gives an equivalent arrival process (equivalent in a statistical sense) specified by interarrival sequence \( (T_i)^{\infty}_{i=0} \), from the given sequence of number of arrivals \( (u_T(i)) \), in a fixed length \( (T_f) \) of adjacent intervals. In deterministic smoothing [10], in every frame of the real-world traffic, all the packets in the VBR trace are accommodated at equally spaced intervals. Thus, packet interarrivals are deterministic.

   In this paper, we use a variation of deterministic smoothing, which generates geometrical sized packets. In the following, we explain the deterministic smoothing with geometrical packet sizes.

4.2 **Deterministic Smoothing with Variable Packet Sizes**

   Given a real-world VBR video traffic trace, the bit stream in the \( i \)th frame of size \( u_T(i) \) is segmented into \( N_T(i) \) packets, such that \( N_T(i) \) is the maximum number of packets whose cumulative size does not exceed \( u_T(i) \), while the packet sizes are geometrically

\(^1\)Many approaches can be used to describe packet arrival process: through the counting process \( N(t) \) or through the sequence of arrival instants \( (T_i)^{\infty}_{i=0} \) or through the counts sequence \( u_T(i) \). Here, we would like to mention that the first two descriptions are well defined and the counts sequence \( u_T(i) \) can be derived from them for a given \( T \).
distributed (see (3)). Then, all the packets in the ith frame interval \(N_T(i)\) are accommodated with equal intervals within the frame interval. The ratio of this geometrical packet sizes to the link capacity is used as service intervals, when we simulate queues with smooth video traffic. We use the above procedure as an approximation for exponential service\(^2\).

The whole process of deterministic smoothing with variable sized packets is given below with more mathematical clarity.

### Problem:
Given the frame size sequence \(\{u_T(i)\}_{i=1}^{N}\) (denoting the frame size of the ith frame interval in bits), generate the sequence of packet arrival instants \(\{T_j\}_{j=1}^{N}\) with packet sizes \(S(j)\) for \(1 \leq S(j) \leq N\) where \(N\) is the total number of frame intervals in the frame size trace and \(n\) is the total number of arrival of (variable sized) packets after smoothing.

### Methodology:

**Step 1:** During the ith frame interval, generate the geometrically distributed packet sizes \(V(i)\) for any \(N_T(i)\) such that,

\[
N_T(i) = \max_{k} \{ k \mid \sum_{j=1}^{k} V(j) < u_T(i) \} \tag{3}
\]

Here, \(N_T(i)\) denotes the number of packets generated in the ith frame interval \(T_f\).

**Step 2:** Generate \(\{T_k\}\) such that,

\[
T_k = (i - 1)T_f + \frac{N_T(i)}{T_f} 1 \leq j \leq N_T(i) \tag{4}
\]

where, \(k = j + \sum_{i=1}^{j-1} N_T(i)\) for \(2 \leq i \leq N\) and \(k = j\) for \(i = 1\).

**Step 3:** Packet sizes are given by,

\[
S(j + \sum_{i=1}^{j-1} N_T(i)) = V(i) 1 \leq j \leq N_T(i) \tag{5}
\]

for \(2 \leq i \leq N\) and

\[
S(j) = V(i) 1 \leq j \leq N_T(i) \tag{6}
\]

for \(i = 1\).

## 5 Finite Capacity Queue with CIPP Input

In this section, we undertake the performance modeling of finite capacity statistical multiplexer with VBR video traffic using CIPP/M/1/K queue. We use the queuing performance measures packet loss probability and conditional packet loss probability for our performance modeling study. Since the CIPP/M/1/K queue is analytically intractable, we use the simulation approach. We first demonstrate by simulations that, in finite capacity queue with MPEG-1 VBR video input, the buffer occupancy distribution exhibits peaks at empty state and fully occupied state. This is consistent with the results observed by earlier workers. In this section, we consider the ‘race’, ‘dino’ and ‘MrBean’ MPEG-1 encoded VBR video sequences [11] for our experiments.

### 5.1 Buffer Occupancy Distribution

An intriguing feature of the buffer occupancy distributions of a finite capacity queue with highly correlated arrivals is that, they exhibit peaks at empty state and fully occupied state, particularly at high utilizations. This means that, the buffer spends most of its time either almost empty or almost full. (This is in sharp contrast with the conventional M/M/1/K queue, wherein the distribution is geometrically decaying with respect to the buffer occupancy). This behavior has also been noted by Lazar et al [12] on the MAGNET II network and by Skelly et al [10] on video conferencing traces. Before we start investigating the performance modeling of VBR video traffic, we show that, the above feature is true for finite capacity CIPP queue. For the purpose of simulations, we consider the CIPP with \(\rho = 0.97\) and same \(\lambda\). We take \(K = 12\). The result is shown in Figure 1. As one can see, CIPP/M/1/K queue exhibits peaks at empty and fully occupied states. Note that, the buffer occupancy distribution is geometric in the M/M/1/K queue case.

![Figure 1: Buffer occupancy distribution in a CIPP/M/1/K queue and the corresponding behavior in an M/M/1/K queue](image-url)

We next present the performance results of VBR video traffic by CIPP/M/1/K queue. Figure 2 illustrates our simulation results for the buffer occupancy distribution for a queue with ‘race’ and ‘MrBean’ MPEG-1 video sequences and their corresponding ‘best fit’ CIPP/M/1/K and M/M/1/K queues. We have considered \(K = 64\) packets. Note that the distribution peaks at the empty state and fully occupied state for both the data and the VBR video traffic. From Fig-
Figure 2: Buffer occupancy distribution of a queue with VBR video sequence input and that of the approximating CIPP/M/1/K and M/M/1/K queues (a) race (b) MrBean. Buffer capacity considered here is 64 packets.

Figure 2, it is also seen that CIPP models reasonably well the queueing situation with real-world MPEG-1 VBR video traffic. One can see that the distribution for both the CIPP/M/1/K and queue with real-world VBR video traffic are drastically different from the M/M/1/K queue case. This is another manifestation of the observation (by Paxson [8]) that the Poisson process models the broadband teletraffic poorly.

5.2 Packet Loss Probability

In this section, we concentrate on the performance measure of packet loss probability. We consider a buffer capacity of 96 packets for our simulation purposes. Figure 3 depicts our results for the video sequences race and MrBean. From the figure, one can see that, the CIPP makes a good approximation to the performance of finite buffer statistical multiplexer with real-world MPEG-1 video traffic.

5.3 Conditional Packet Loss Probability (CPLP)

Often, the packet loss probability is not an appropriate indicator of performance of packet loss. In particular, for video sources using interframe and intraframe redundancy to achieve compression, if the sufficient number of consecutive packets are lost in a single video connection, it could lead to the loss of the whole block of image data at the receiver while decoding and hence suffer QoS degradation. Simulation [13] and analytical studies [14] show that even if the overall packet loss of the superposition is small, individual sources may experience the loss of a string of consecutive packets, sufficient enough to lead to the above phenomena. This consecutive packet loss has two origins: first, there may be temporal overload situation due to the fact that the number of active users exceeds the capacity of the system and second, due to the periodical nature of the arrival process, a call losing a packet is likely to lose a string of packets. Here, in the case of individual VBR source, the latter situation is of much relevance. Moreover, we note that, CPLP is of prime importance, in particular, in the guaranteed services like video services wherein, a consecutive packet loss of compressed...
stream may lead to a loss of block of data after decoding. We will see that CIPP with high \( \rho \) is able to capture this behavior of consecutive packet loss.

![Figure 4: Conditional packet loss for a queue with the MPEG-1 VBR video sequences and the approximating CIPP/M/1/K and M/M/1 queues (c) MrBean (Part (a) and (b) of Figure 4 are shown above.)](image)

with the conventional models. The main advantage of this method is that it allows one to use the real-world traces as they are thus, avoiding the need for smoothing. Moreover, fluid-flow approach has another attractive feature, namely, negligible computational overhead. Throughout this section, we will use the term 'cell' to denote fixed size packet.

Here, we present the cell loss simulation results that are used to compare the present model with the conventional models. We have simulated on frame level assuming a constant video transmission rate for each frame. The frame level results are essentially equivalent to the cell level results, if we assume that each video source spreads the cells belonging to a frame over the whole frame duration.

![Figure 5: Cell loss probability for a buffer of 100 cells](image)

The multiplexer has a link rate of 10 Mbps. Buffer sizes of 100, 1000, 10000 and 100000 cells were considered. The multiplexer load is determined by the number of video input sources, ranging from 5 (load of about 0.4) to 40 (load of about 3). We have scaled down the link rate to 10 Mbps because we wanted to

6 Fluid Flow Approximation of Queue with CIPP Arrivals

In this section, we use the fluid-flow approximation of CIPP queues for performance modeling of VBR traffic. In particular, we present the cell loss simulation results which are used to compare the present model with the conventional models. The main advantage of this method is that it allows one to use the real-world traces as they are thus, avoiding the need for smoothing. Moreover, fluid-flow approach has another attractive feature, namely, negligible computational overhead. Throughout this section, we will use the term 'cell' to denote fixed size packet.

Figure 4 illustrates the conditional packet loss probability for the queue with real-world MPEG-1 VBR video sequences namely, race, dino and MrBean as input and their corresponding 'best fit' CIPP/M/1/K queue. Also shown are the corresponding results for the M/M/1/K queue case. One can see from the figure that, the CPLP corresponding to M/M/1/K queue decays very fast, while the decay (with respect to length of consecutive packet loss \( k \)) is slow for the CIPP/M/1/K case. For CIPP with high \( \rho \), this trend of 'slower' decay is highly pronounced. This is the consequence of high correlation in the arrival stream.

![Figure 4: Conditional packet loss for a queue with the MPEG-1 VBR video sequences and the approximating CIPP/M/1/K and M/M/1 queues (c) MrBean (Part (a) and (b) of Figure 4 are shown above.)](image)

Figure 4: (a) race (b) dino

The multiplexer has a link rate of 10 Mbps. Buffer sizes of 100, 1000, 10000 and 100000 cells were considered. The multiplexer load is determined by the number of video input sources, ranging from 5 (load of about 0.4) to 40 (load of about 3). We have scaled down the link rate to 10 Mbps because we wanted to

![Figure 5: Cell loss probability for a buffer of 100 cells](image)

The multiplexer has a link rate of 10 Mbps. Buffer sizes of 100, 1000, 10000 and 100000 cells were considered. The multiplexer load is determined by the number of video input sources, ranging from 5 (load of about 0.4) to 40 (load of about 3). We have scaled down the link rate to 10 Mbps because we wanted to
obtain realistic cell loss results in spite of the fact that the empirical data set has a bit rate of only 5 to 10 high quality full-screen MPEG video sequences.

Figure 5 shows the cell loss results for the histogram, MC, CIPP models [15] and race data set for a buffer size of 100 cells. The CIPP models better than the histogram and MC models. For a buffer size of 1000 cells (see Figure 6), the situation remains the same. Increasing the size to 10000 cells (see Figure 7) shows that the CIPP and MC models show the best approximation quality, whereas the estimates of the histogram are becoming more and more optimistic.

For very large buffer size of 100000 cells (Figure 8), the CIPP model underestimates the cell loss probability, however, for buffer sizes of up to 10000 cells, CIPP shows marginal overestimate. This is desirable since, for network dimensioning purpose, it is more convenient to use a model which marginally overestimates the traffic.

7 Conclusions

In this paper, the performance modeling of VBR video traffic is studied using CIPP/M/1/K queue. The results of our study are summarized as below:

1. Buffer occupancy distribution for finite capacity CIPP queue traces exhibit peaks at the empty state and fully occupied state, in particular, at high utilizations. This is a feature of a queue with highly correlated arrivals. This behavior is consistent with that of the earlier workers [12], [10]. Also, we noted a similar behavior for buffer occupancy was exhibited by the finite capacity queue with real-world MPEG-1 VBR traces.

2. For low values of $k$ (denoting the length of consecutive packet loss), the CPLP for VBR trace data was found to be higher than the value predicted by CIPP, whereas, for high value of $k$, the CPLP for CIPP was found to be high. This is due to the fact that CIPP arrivals with high $\rho$ is nearly periodic.

3. The correlation in interarrivals degrade the queueing performance even in the finite capacity CIPP queue case also. (Note that the authors have shown analytically that for the infinite capacity CIPP queue, the correlation in interarrivals degrades the queueing performance [2]).

In short, the results demonstrate that, CIPP/M/1/K queue approximates well the queueing situation encountered by the real-world VBR video traffic in a finite buffered statistical multiplexer. The main contribution in this paper is that, we have demonstrated that considering models which capture the interarrival correlation from the real-world data is more appropriate is not only in the modeling context, but also in the performance modeling aspect. Future work will involve the priority queues with CIPP arrivals.

References


