# TECHNICAL RESEARCH REPORT

## A Software Facility for the Performance Analysis of a Finite-Buffer ATM Transmission Link

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CENTER FOR SATELLITE & HYBRID COMMUNICATION NETWORKS
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University of Maryland Institute for Systems Research

# A Software Facility for the Performance Analysis of a Finite-Buffer ATM Transmission Link

# A Preliminary Report

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**Abstract**

We develop a software facility for the performance analysis of an ATM transmission link. The link is modeled by a discrete-time single server queue with a FIFO finite buffer. This software facility is capable of providing the probability of cell loss due to buffer overflow and average delay of a cell in the buffer, when fed by statistically multiplexed traffic. Such a source of traffic is modeled by a class of stochastic processes. In particular, we represent a source of multiplexed traffic by a Discrete-time Batch Markovian Arrival Process (D-BMAP). Given samples of a cell stream from an unknown source, we approximate the performance measures of the ATM link using an estimated Markov process as a source. This approach is motivated by our analytical results. We then verify the usefulness of this approach through numerical results.

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# 1 Introduction

The Asynchronous Transfer Mode (ATM) is a transport mode that has been adopted for Broadband Integrated Services Digital Networks (B-ISDNs). In an ATM network, information is transmitted in the form of fixed-size cells of 53 bytes on slotted ATM links. The strength of ATM lies in the fact that an ATM link can support cells generated by voice, data and video sources. These sources, in general, have different characteristics and quality of service requirements. To multiplex cell streams from such sources onto an ATM transmission link, buffering is needed to avoid excessive cell loss which can seriously affect quality of service. On the other hand, for certain sources, e.g., voice, extensive cell buffer delay is unacceptable owing to stringent real-time delay constraints. Therefore, the probability of cell loss due to buffer overflow and average delay of a cell in the buffer are important indicators of quality of service. The performance analysis of an ATM transmission link with a finite buffer thus plays a critical role in the design and evaluation of any ATM network. Such an analysis is also applicable to an output port of an output-buffered ATM switch.

The main objective of this effort is to develop a software facility for an efficient performance analysis of an ATM transmission link carrying a multiplexed cell stream. The software facility uses stable recursive procedures to compute performance measures of the system carrying a cell stream generated by a given traffic source. We also provide a capability to simulate a multiplexed cell stream from some specific traffic sources. This is developed on the OPNET[1] package. The capabilities of this software include the following.

- We provide the evaluation of the probability of cell loss due to buffer overflow and average delay of a cell in the buffer by using both analytical as well as simulation techniques, when the multiplexed cell stream is generated by a specific traffic source. In particular, we consider a Discrete-time Batch Markovian Arrival Process (D-BMAP) which has been proposed as a good source model to represent a multiplexed cell stream [1].

- Often the parameters of a D-BMAP used to represent the multiplexed cell stream are not known. In this case, we would seek to estimate such parameters from samples of a cell stream in order to assess performance. Since parameter estimation in a D-BMAP environment is computationally prohibitive, and, in general, is unsuitable for ATM networks, our approach entails approximating the D-BMAP by an appropriate Markov process with finite memory. The theoretical foundation of this approach is provided by our work in [3] establishing that the performance measures of the system using a D-BMAP as a source can, under suitable conditions, be closely approximated by the performance measures using a *matched* Markov process with finite memory. We have included in our software facility the capability to estimate, on the basis of samples of a cell stream, parameters of the approximating Markov process, and their subsequent use in obtaining good approximations of performance measures.

[1] OPNET is a product of MIL 3, Inc.

## 2 Description of System

We briefly describe our approach below; details can be found in [3]. Fig.1 is a schematic block diagram of this work. We model an ATM link by a discrete-time single server queue with a finite buffer employing the FIFO service discipline. The service time of a cell is assumed to be constant and equal to the transmission time of the cell on a link (fig.2).

The multiplexed cell stream is modeled by a D-BMAP, which is a doubly stochastic process with the arrival process making transitions among a finite numbers of states according to a Markov chain. The generation of the number of arrivals in any arbitrary slot is determined by the state in which the process resides. If parameters of the D-BMAP are given, our software facility can provide the probability of cell loss due to buffer overflow and average delay of a cell in finite buffer, by using analytical technique presented in [2] and by simulation.

Next, given a D-BMAP with known parameters, we determine its best Markov approximation by means of *parameter matching* [3] to obtain a sequence of matched Markov processes with finite memory $k$. The latter can then be used as substitute sources, for the purpose of performance analysis, to get performance measures $PF_{M(k)}$. The proximity of $PF_{M(k)}$ to the performance measures of the D-BMAP, $PF_{D-BMAP}$, with increasing k is borne out by our analytical results. Furthermore, our numerical results indicate that only a relatively small value of $k$ is needed to yield a good approximation of the true performance measures. A numerical example is provided to illustrate the usefulness of the Markov approximation for a restricted system in fig.3. (Work is currently under way to extend the capability of this software facility to more practical environments.)

The strength of our approach is seen when parameters of the D-BMAP used to model the source are not known. In this situation, parameters of the approximating Markov process are far easier to estimate than those of the D-BMAP, given the samples of a cell stream. Furthermore, the performance measures $PF_{E(k)}$ corresponding to the *estimated* Markov process with memory $k$ approaches $PF_{D-BMAP}$ as $k$ increases. Indeed, our numerical results show that for typical sample sizes, the performance measures of the system using an estimated Markov process with a relatively small memory are good approximations of the true performance measures. An example of this is provided in fig.4.

### References

[1] C. Blondia and O. Casals, "Statistical multiplexing of VBR sources: A matrix-analytic approach," *Performance Evaluation*, 16(1), pp. 5-20.

[2] T. Takine,T. Suda and T. Hasegawa, "Cell Loss and Output Process Analyses of a Finite-Buffer Discrete-Time ATM Queueing System with Correlated Arrivals," in *Proc. IEEE INFOCOM'93*, pp. 1259-1269.

[3] N. Rananand and F.M. Pal, "Approximation Techniques for the Performance Analysis of a Finite-Buffer ATM Transmission Link," under preparation.

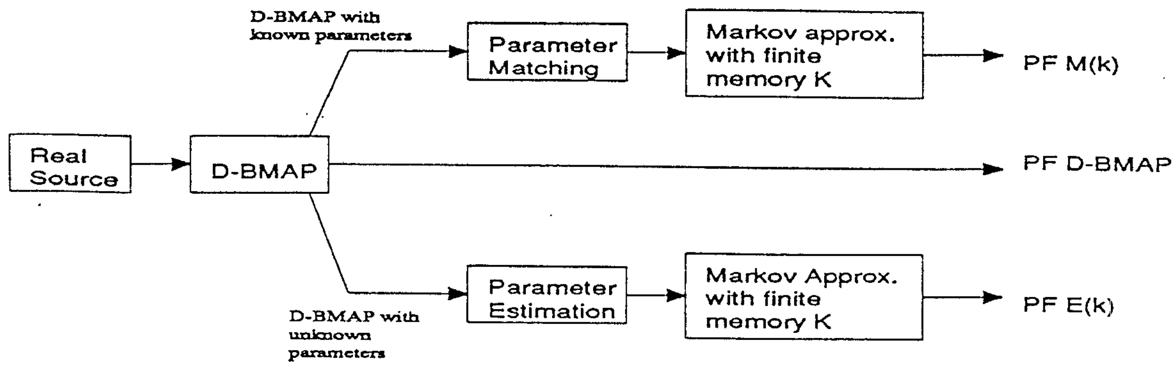


Fig. 1: Block diagram of the approach

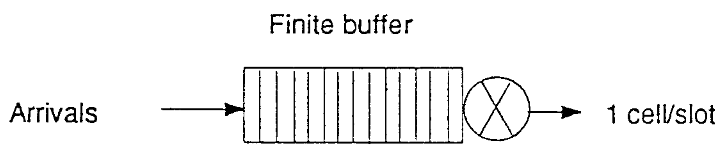


Fig. 2: The queuing system

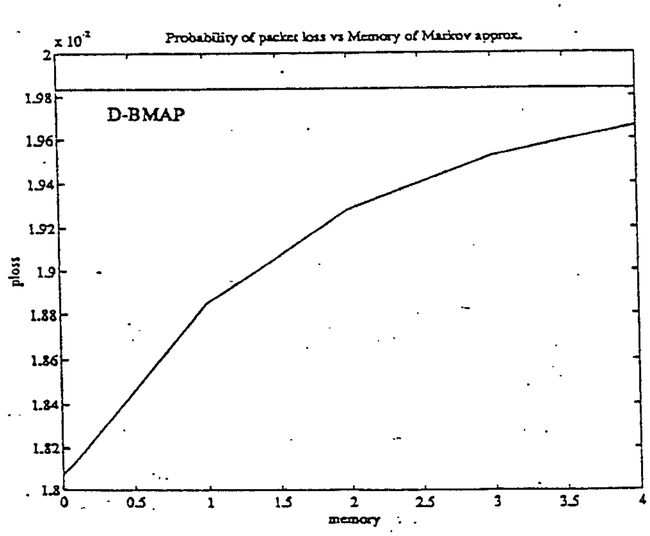


Fig. 3: Prob. of cell loss vs.
Memory of markov approx.
(Buffer size = 5, Max. arrivals = 2)

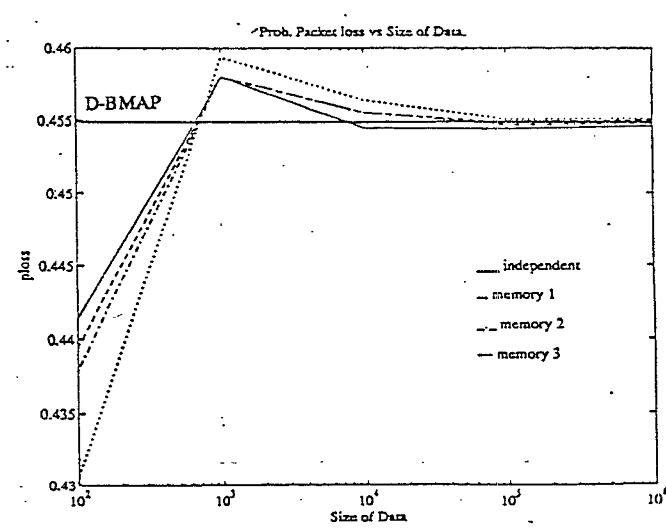


Fig. 4: Prob. of cell loss vs.
Size of data (slots)
(Buffer size = 1, Arrivals = 0 or 1)