ATM Traffic Analysis: Burst Scale Probability Function

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[1]***Abstract* - The paper presents the analysis and results of traffic measurements in the 155 Mbit/s real working ATM backbone network. The traffic is described as an ordered sequence of real–time cells. In this paper we analyze two timescales in which some form of a stochastic process is taking place: cell scale and burst scale. We present another way to describe the cell flow in ATM networks by definition the function, designed to be the probability of the burst of length *l* in *n* sequential slots.**

Index terms - **ATM technology, traffic statistics, Markov chains.**

1 Introduction

ATM is popular now because of its high QoS characteristic, despite its high price and complexity. Acquisition of high-speed statistics is a critical issue in the world of data communications. The comprehension of ATM traffic characteristics is of particular importance for the future of ATM networks in the areas of network protocols, architecture design, congestion control and performance modeling. To manage the traffic implications of all types of connections, we should return to the basic principles of traffic statistics. There are two basic modeling approaches: simulation and analysis. Simulation models are very useful in investigating the detailed operation of an ATM system. A simulation is usually much more accurate than analysis, but can become a formidable computational task when trying to simulate the performance of a large network. Analysis can be less computationally intensive, but is often inaccurate.

Realistic source and switch traffic models are not currently amenable to direct analysis. The results presented in different publications provide only approximations under certain circumstances. Such approximate methods may have large inaccuracies, which can only be ascertained by actual tests [1].

Investigation of cell flows in ATM networks is an actual problem. An appropriate statistics is a basis for developing the probabilistic models of ATM switching nodes and end-to-end connections. The traditional data flow models of Bernoulli or Poisson type appear to be not realistic in ATM networks. This has been extensively studied in recent years, and there is a large volume of published work on the subject [2-3]. New more realistic models can be structured on the basis of tests performed on the working network. A number of such models have been developed recently for a mesh-oriented topology of an ATM network. Such models are based on the concepts of Markov modulated Bernoulli process and Markov modulated Poisson process. Markov processes are popular in modeling because they can model processes with memory and their theory is well developed. However, up to now there is lack of experimental cell flow statistics referring to the backbone ring topology of ATM network.

In this research we are interested in different timescales in which some form of a stochastic process is taking place. The advantage of analyzing traffic over different timescales is that each timescale gives information on the validity of the assumptions used at a shorter timescale [4].

The timescales at which we can find stochastic processes that are important to our understanding of the traffic are cell scale and burst scale. Cell scale is the timescale that considers the multiplexing of cells using a first-in-first-out queuing buffer, which is at the heart of every ATM switch. At the burst scale, we are interested in phenomena that can cause modulation of the cell rate over short time periods.

The paper is organized as follows. In Section 2 we present the network topology of the real working ATM network, the organization of experiments and the Markov model for cell flows. In Section 3 we demonstrate the results of the experiments.

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2 ORGANIZATION OF EXPERIMENTS AND CALCULATIONS

As noted above, there is a lack of experimental data on ATM cell flows. In order to obtain statistics on data flows and to process it, we used an ATM backbone network that is installed at Bar-Ilan University. The topological state of the ATM network is presented in Figure 1. There are connections from LAN hosts to external WANs. The various types of connections with LANs and WANs are performed by means of ATM switches. The University ATM network incorporates a number of Ethernet LANs which are allocated in different buildings on campus. To obtain statistics from a real working ATM network we used the RADCOM PrismLite.

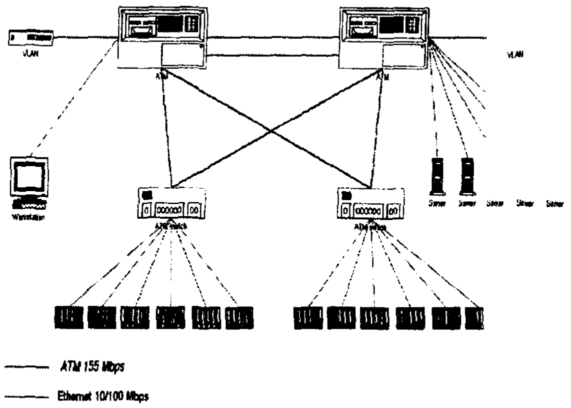

Figure 1. Network topology

The following values form a sample of real ATM traffic:

$$10^{14}10^{5}10^{17}1010...$$

The exponents are run lengths; i.e., 0^{14}denotes a run of 14 consecutive slots, and 1 denotes the cell.

The first step in the evaluation of the statistical behavior of the cell arrival process will be the building of the *k*-order *(k = 2)* Markov chain that is characterized by the probability transition matrix:

$$P = \begin{bmatrix} p_{00} & p_{01} \\ p_{10} & p_{11} \end{bmatrix},$$

where p_{11} is the probability that there was another cell after the cell, p_{00} is the probability that there was an empty slot after an empty slot, p_{01} is the probability that there was a cell after an empty slot and p_{10} is the probability that there was an empty slot after the cell.

Another way to describe the cell flow in ATM network is by bursts. We process the sequence of cells-slots, searching for a specific burst (for example, burst *"0001"*, *where 1 is cell and 0 is slot*). So, we have the sequence of *"burst, no-burst"* of the original cells-slots sequence. We define the probability transition matrix for burst scale:

$$Q = \begin{bmatrix} q_{00} & q_{01} \\ q_{10} & q_{11} \end{bmatrix},$$

where q_{11} is the probability that there was a burst after the burst, q_{00} is the probability that there was an empty slot after an empty slot, q_{01} is the probability that there was a cell after an empty slot and q_{10} is the probability that there was an empty slot after the cell.

We define the function *P(i, n)* as the probability of *i* cells in *n* sequential slots and $P^*(i,n)$ as the cell distribution based on the Markov model. The Markov model is a powerful tool for modeling stochastic random processes. This model is general enough for modeling with high accuracy a large variety of processes and is relatively simple allowing us to compute analytically many important parameters of the process that are very difficult to calculate for other models. Another advantage of using the Markov model is the existence of powerful algorithms for fitting them to experimental data and approximating other processes. Many papers use the Markov models to model channels with memory. We use the model of Gilbert that initiated the study of the Markov models for real communication channels. His model is popular because of its simplicity [10]. The analysis of cell distribution based on experimental data, and the analysis of cell distribution based on the Markov model, are presented in [6]. Now, we define the function *Q(l, n)*, as the probability of the burst of length *l* in *n* sequential slots and the function $Q^*(l,n)$ as the cell distribution based on the Markov model.

We define the function *Q(l, n)* as the probability of *l* cells in *n* sequential slots by the formula [7]:

$$Q(l, n) = [q_{01}/(q_{01}+q_{10})]\, G(l, n) + [q_{01}/(q_{01}+q_{10})]\, B(l, n).$$

The functions *G(l, n)* and *B(l, n)* are calculated by the recursive formulas:

$$G(l, n) = G(l, n-1)\, q_{00}k + B(l, n-1)\, q_{01}k + G(l-1, n-1)\, q_{00}k' + B(l-1, n-1)\, q_{01}k',$$

$$B(l, n) = B(l, n-1)\, q_{11}h + G(l, n-1)\, q_{10}h + B(l-1, n-1)\, q_{11}h' + G(l-1, n-1)\, q_{10}h',$$

$$G(0, m)=k, \qquad B(0, m)=h,$$
$$G(1, m)=k', \qquad B(1, m)=h',$$

$G(l, n) = B(l, n) = 0$, *if* $l<0$ *or* $l>n$.

The function $B(l, n)$ defines the probability of l bursts in n slots with the condition that in the first m slots there was a burst. The function $G(l, n)$ defines the probability of l bursts in n slots with the condition that the first m slots are not the burst. Using equations, we can write:

$$G(0, m)=1, \quad B(0, m)=0,$$
$$G(1, m)=0, \quad B(1, m)=1.$$

Obviously, these are the final states of the recursions.

3 Results

In this section we present some of the results that we have received in our experiments in the real working ATM network. For example, the Markov matrices of the cell scale presentation of the traffic in our experiments and the Markov matrices of the burst scale presentation of the ATM traffic are:

$$P = \begin{bmatrix} 0.999852421934 & 0.000147578066 \\ 0.999643678533 & 0.000356321467 \end{bmatrix},$$

$$Q = \begin{bmatrix} 0.002850848775 & 0.997149151225 \\ 0.000294424877 & 0.999705575123 \end{bmatrix}.$$

Table 1 presents the numerical presentation of the distribution functions $P(i, n)$, $P^*(i,n)$, $Q^*(l,n)$ and $Q(l, n)$, when the number of slots is *2390503672132*, $n = 2091$ and l = *"100000"*.

i, l	$P(l, n)$	$P^*(i,n)$	$Q(l, n)$	$Q^*(l,n)$
0	0.97076	0.969625	0.74191	0.73512
1	0.02798	0.029905	0.23086	0.22566
2	0.00101	0.000465	0.01742	0.03518
3	0.00016	0.000048	0.0046	0.00371
...	...	...	...	...

Table 1: Numerical presentation of $P(i, n)$, $P^*(i,n)$, $Q^*(l,n)$ and $Q(l, n)$.

Figures 2-5 presents the $P^*(i,n)$ function, the function $Q^*(l,n)$ and the experimental functions $P(i, n)$ and $Q(l, n)$. We compared the experimental and theoretical distributions on the basis of the omega-squared criteria [6].

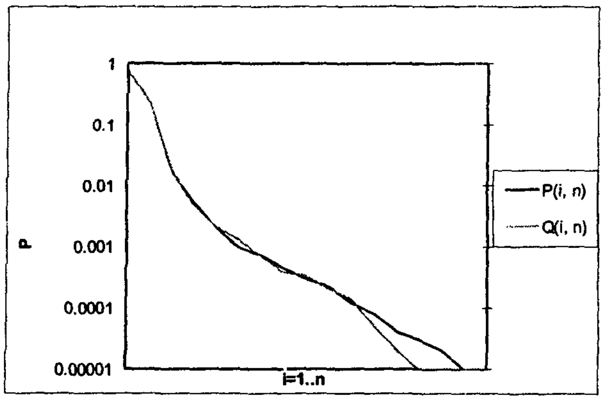

Figure 2: Graphical Representation of $P(i, n)$ and $Q(l, n)$, *l="000"*.

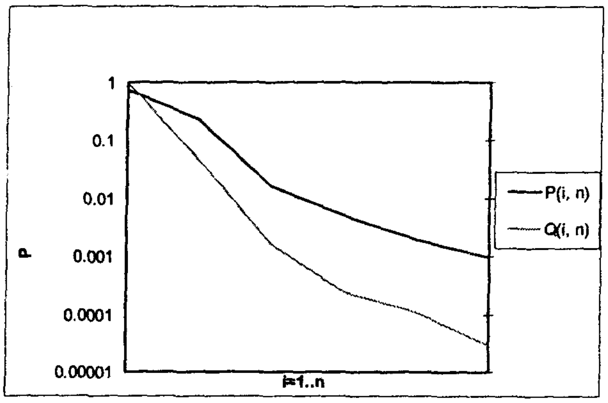

Figure 3: Graphical Representation of $P(i, n)$ and $Q(l, n)$, *l="100000"*.

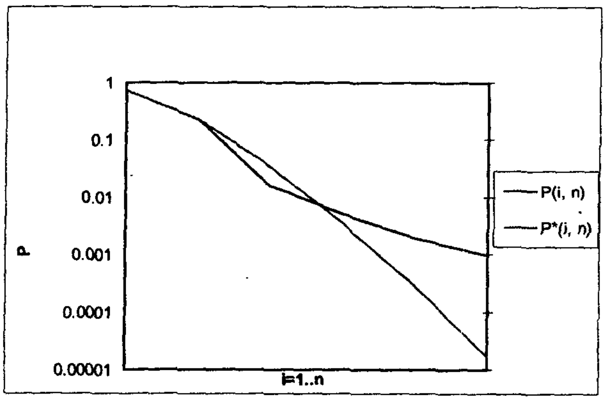

Figure 4: Graphical Representation of $P(i, n)$ and $P^*(i,n)$.

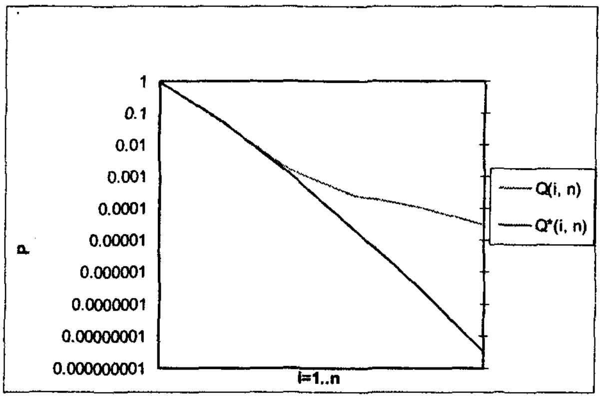

Figure 5: Graphical Representation of $Q(l, n)$ and $Q^*(l,n)$, l="100000".

Figure 2 shows that the distributions based on the cell and the burst scales are similar. The reason for this is the little size of the burst that was chosen for the experiments. On the other hand, on the Figure 3 we can see that the distributions based on the cell scale and the burst scale are not close enough. The reason is that the actual burst size is hard to predict. This makes it difficult to produce any reliable model using this technique.

The cell distributions based on the experimental data, and cell distributions based on the simple Markov model in the cell and burst scales are not close (see Figures [4-5]). It means that there is a need for an experimental algorithm with a more complicated process of theoretical definition of $P(i, n)$ and $Q(l, n)$.

4 CONCLUSIONS

The results of traffic measurements in the 155 Mbit/s ATM backbone network were presented and analyzed. The traffic was presented as a collection of real-time cell sequence. The evaluation of cell flow characteristics in a real working ATM network was presented as well. The cell distributions based on experimental data and the cell distributions based on the simple Markov model were analyzed and presented in two timescales: the cell scale and the burst scale. The complex Markov chain model must be further developed to structure ATM cell flow in the backbone network. As more information about the traffic characteristics are obtained, these should be fed back into the modeling effort. For this reason, modeling has a close relationship to the performance measurement aspects of network management.

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