Characterization of the Cell Flow Using Burst Scale Probability Algorithm

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***Abstract* - The paper presents the analysis and results of traffic measurements in the 155 Mbit/s ATM backbone network. The traffic is described as an ordered sequence of real–time cells. We present an evaluation of cell flow characteristics in a real working ATM network, analysis of cell distribution based on experimental data, and analysis of cell distribution based on the Markov model. We also present another way to describe and check the cell flow in ATM networks by definition of the function $Q(l, n)$, designed to be the probability of the burst of length l in n sequential slots.**

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

1 INTRODUCTION

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 must 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, which can lead to key insights into equipment, network, or application design. 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.

While theoretically optimal, detailed source modeling can be very complex and [1]usually requires computer-based simulation. Often this level of detail is not available for the source traffic. Using source traffic details and an accurate switch and network model will result in the most realistic results. When either traffic or switch and network details are not available, approximations are the only avenue that remains. Approximate modeling is usually simpler, and can often be done using only analytical methods.

There is also a philosophical aspect related to how accurate the traffic model should be. As would be expected, the more complicated the model, the more difficult the results are to understand and calculate. The accuracy of the switch and network model should be comparable to the accuracy of the source model traffic. If we only know approximate, high-level information about the source, then an approximate, simple switch and network model is appropriate [11].

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.

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. 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 that are based on the concepts of Markov modulated Bernoulli process and Markov modulated Poisson process. 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 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.

The timescales at which we can find stochastic processes that are important to our understanding of the

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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 concentrator or switch. At the burst scale, we are interested in phenomena that can cause modulation of the cell rate over short time periods [9].

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 results of real traffic measurements in the 155 Mbit/s ATM backbone network are presented and analyzed in this paper. The traffic is described as a collection of real-time cell sequences with the keeping order of cells. The evaluation of cell flow characteristics in a real working ATM network is also presented.

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. Specifically, the University ATM network incorporates a number of Ethernet LANs which are allocated in different buildings on campus. In addition, 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.

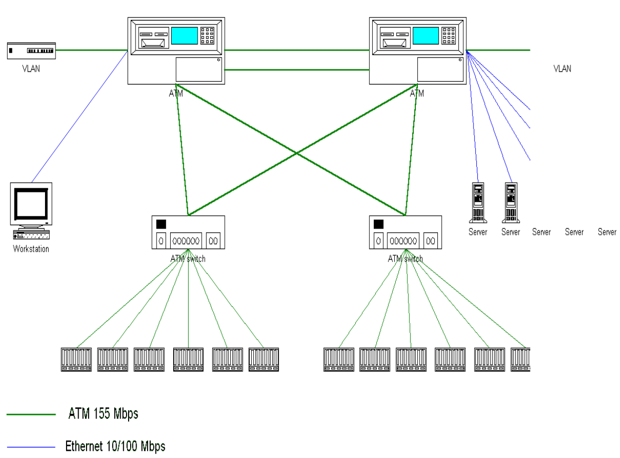

Figure 1. Network topology

The following digits form a sample of real ATM traffic:

$10^{14}10^{5}10^{171}1010...$

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 *100001011*, 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:

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

where q_{11} is the probability that there was a burst after the burst.

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 analysis of cell distribution based on experimental data, and the analysis of cell distribution based on the Markov model, are presented in [*3*]. 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 [5]:

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

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

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

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

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

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

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

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

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:

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

$$Q = \begin{bmatrix} 0.999853851993 & 0.000146148007 \\ 0.998823529412 & 0.001176470588 \end{bmatrix}.$$

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(i, n)*	$P^*(i,n)$	*Q(l , n)*	$Q^*(l,n)$
0	0.74143	0.734468	0.92814	0.926415
1	0.23189	0.226633	0.06816	0.0706579
2	0.01657	0.0349962	0.00286	0.00284457
3	0.00518	0.00360585	0.00065	8.02E-05
…	…	…	…	…

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

Figures 3-5 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].

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. It means that there is a need for an experimental algorithm with a more complicated process of theoretical definition of $P(i, n)$ and $Q(l, n)$.

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.

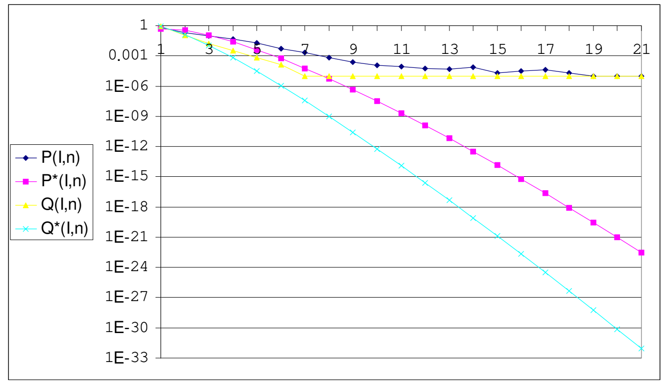

Figure 3: Graphical Representation of $P(i, n)$, $P^*(i,n)$, $Q^*(l,n)$ and $Q(l, n)$.

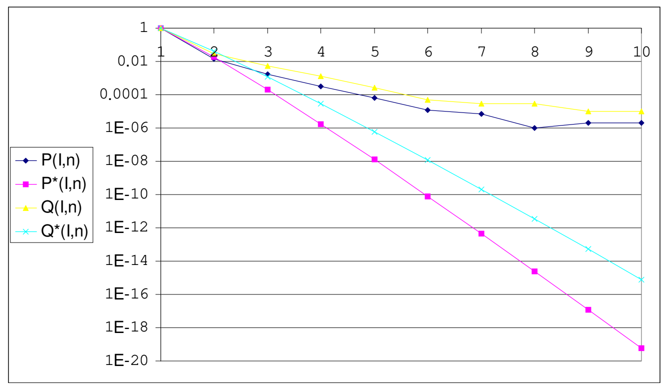

Figure 4: Graphical Representation of $P(i, n)$, $P^*(i,n)$, $Q^*(l,n)$ and $Q(l, n)$.

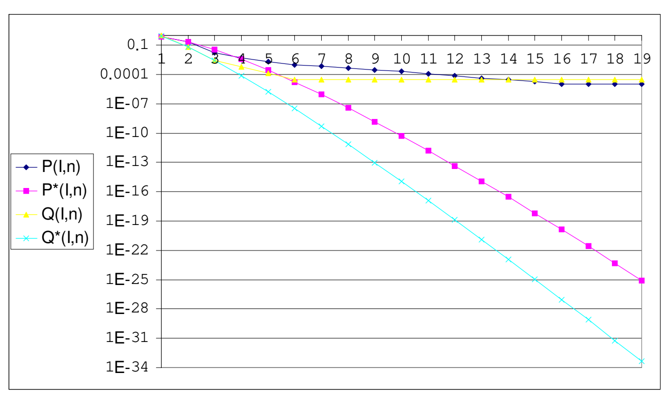

Figure 5: Graphical Representation of $P(i, n)$, $P^*(i,n)$, $Q^*(l,n)$ and $Q(l, n)$.

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.

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. We intend to expand our results for formulating and solving the problem of optimal resource allocation in the ATM networks. This problem, very actual now in ATM networking, can be solved only on the basis of concise traffic characterization in the ATM links. The complex Markov chain model must be further developed to structure ATM cell flow in the backbone network.

5 ACKNOWLEDGMENTS

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