An Integrated Block-Oriented Simulation Model for Estimating Cell Loss Rate in ATM Networks.

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ABSTRACT

It has always been desired to simulate a network so as to be able to study its different performance characteristics under various operating conditions. This work presents an integrated MATLAB® based simulation model capable of evaluating cell loss rate which is an important QoS parameter in multimedia networks such as ATM networks. The integrated model combines both the simulation and analytical model in the same environment. The analytical model is fed directly from results obtained from the simulation model; the advantage of this arrangement is that the statistics generated during simulation gives the exact description of cells activities at the transmission buffer. The variation of cell loss rate with buffer capacity for a single source at a given bandwidth was obtained from this model within reasonable simulation time.

(Keywords: asynchronous transfer mode, cell loss rate, buffer, bandwidth, MATLAB, Simulink)

INTRODUCTION

The asynchronous transfer mode (ATM) is a networking technology that provides the capability to transport voice, data, video, and images [3]. It is a communications technology designed to overcome the constraints associated with traditional voice and data networks. To provide these multimedia services laid down standards for certain quality of service such as cell loss rate, delay/jitter must be met.

This work presents an integrated simulation model, which comprises a fusion of an analytical model and computer simulation model, to study the behavior of ATM networks. The need for the integrated model stems from the fact that it has been shown that computer simulation alone cannot be used to effectively evaluate this parameter. For instance a rather very high simulation time would be required to determine cell loss say in the region of 1×10^{-11} as specified for video services, as 100 billion cells will be required to pass through the buffer. Another critical factor is that computer simulation model can predict zero cell loss during simulation even though cells could probably be lost if a higher number of cells are produced. Ani and Halsall [1] showed the advantages of this approach and successfully implemented it in a BONeS simulation environment for an isolated ATM node. The aim of this work is to extend the concept of the integrated simulation model and operate it in the block-oriented MATLAB® simulation environment.

MATERIALS AND METHODS

The methodology used involves the studying of the basic characteristics and components of an ATM network and representing them by suitably configured subsystems with the respective attributes using Simulink blocks.

Before considering the integrated model we will first look at its constituent parts; the simulation model and analytical model. These models will be considered for the case of a single source of ATM traffic.

Simulation Model

The model of an ATM switching node can be deduced from the integrated model shown in Figure 1; it consists of the traffic source module, a buffer and a server.

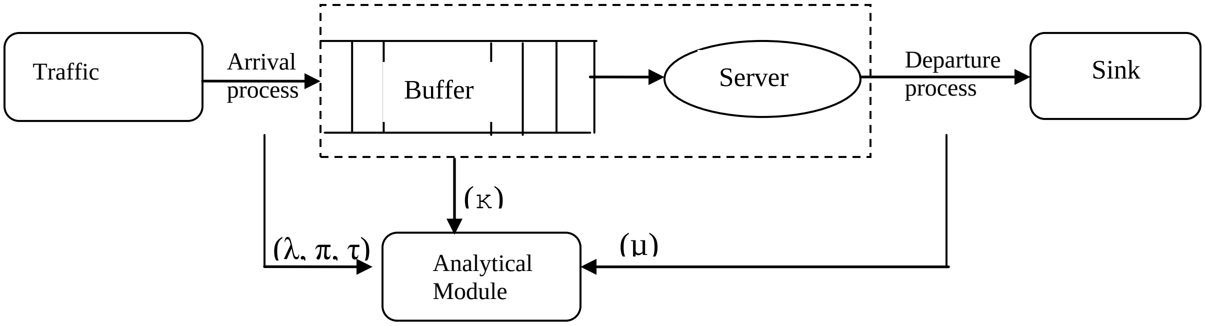

Figure 1: An Integrated Model of an ATM Switching Node.

The source module generates traffic at a peak rate of π cells/seconds, mean rate of λ cells/second as a sequence of bursts and silent periods which are represented by a two-way Markov process; this is known to give a true approximation of ATM networks [3].

The buffer is a FIFO (first-in-first-out) queue which has the capacity to hold arriving cells awaiting service. The single server determines the queue service rate of the model while the sink absorbs cells that have finished being served.

The cell loss rate (CLR) of the simulation model can be evaluated for a specific buffer size, transmission capacity and service rate from Equation 1 [2].

$$CLR = \frac{Number\ of\ cells\ rejected}{Number\ of\ cells\ through\ queue + Number\ of\ cells\ rejected} \qquad (1)$$

Analytical Model

The cell loss rate for the analytical model is evaluated from Equation 2 [2].

$$\mathrm{CLR} = \psi * exp - (\varphi) \qquad (2)$$

ψ is usually approximated to unity while Cell loss rate, φ, is as given in Equation 3.

$$\varphi = \frac{\pi(\mu - \lambda)\kappa}{\tau\mu(\pi - \lambda)(\pi - \mu)} \qquad (3)$$

where, π = *peak cell rate*
λ = mean cell rate
μ = service rate
k = buffer capacity
τ = burst period

Equation 3 is the analytical model for the ATM network and it can be modeled using Simulink as shown in Figure 2.

Integrated Simulation Model

Figure 3 depicts the integrated simulation model which comprises the simulation model with the addition of the analytical model shown in Figure 2. The analytical model is fed directly from results obtained from the simulation model; the advantage of this arrangement is that the statistics generated during simulation gives the exact description of cells activities at the transmission buffer.

To implement this model other parameters such as the cell inter-arrival period, α, and time interval between cell departures, β, are defined. The maximum buffer occupancy, κ, and the queue is served at the rate of μ cells per second. The parameters of equations 4 – 7 are gotten from the simulation model and are fed directly into the analytical model to obtain the cell loss rate. T_S in (6) is the average traffic silent period.

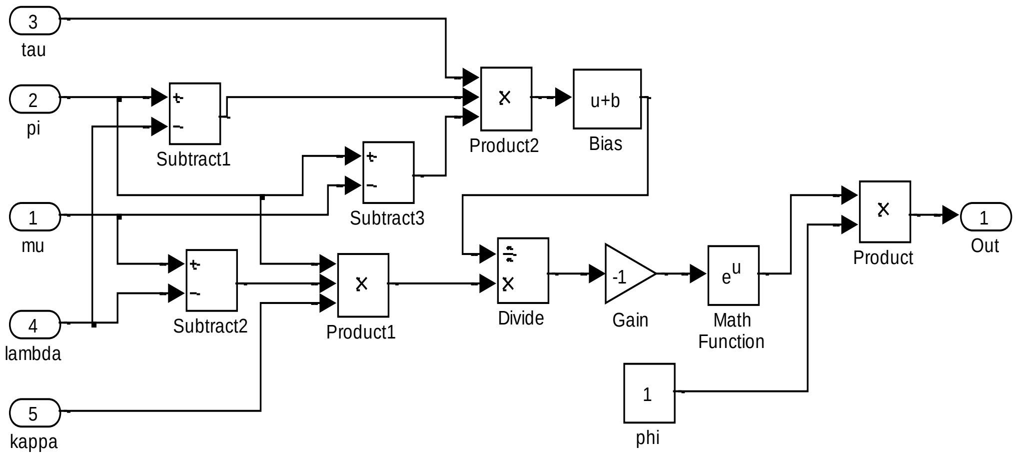

Figure 2: Simulink Analytical Model for Cell Loss Rate in ATM Network.

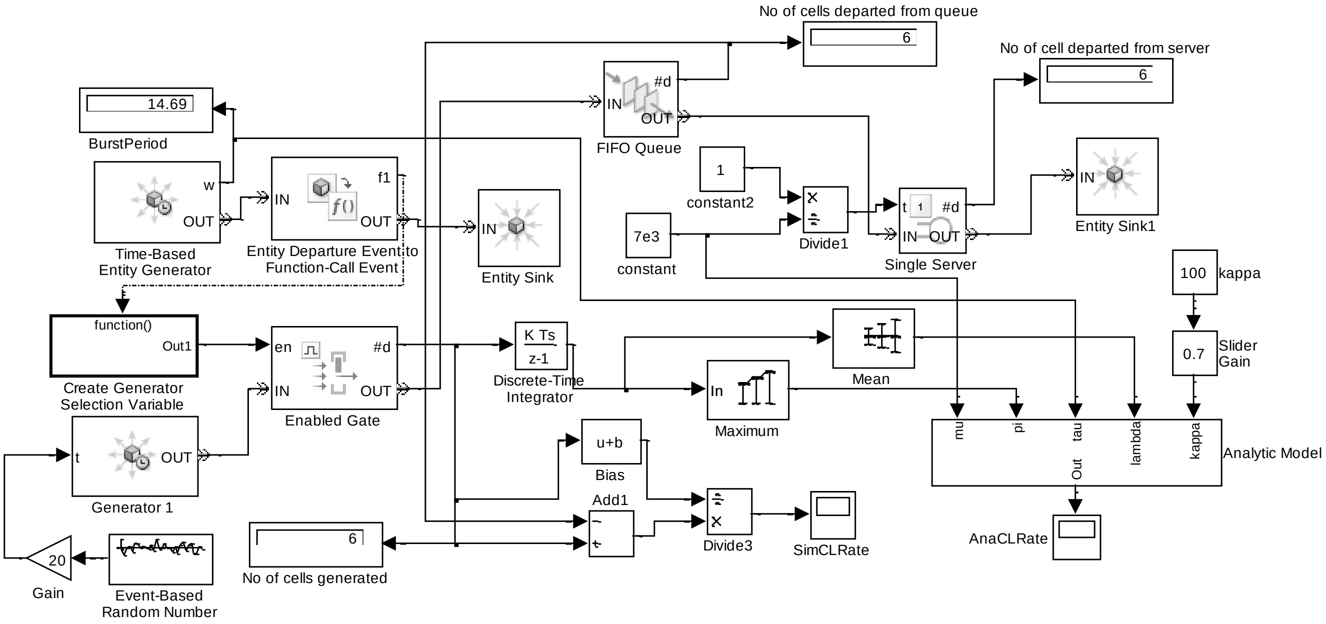

Figure 4: Integrated Simulation Model for Cell Loss Rate in ATM Network.

$$\lambda = \frac{\left(\begin{matrix} Number\ of\ intervals, \alpha, \\ within\ a\ simulation \end{matrix}\right) + 1}{Duration\ of\ simulation} \tag{4}$$

$$\pi = \frac{1}{Minimum\ value\ of\ \alpha} \tag{5}$$

$$\tau = \frac{\lambda * T_s}{\pi - \lambda} \tag{6}$$

$$\mu = \frac{1}{Minimum\ value\ of\ \beta} \tag{7}$$

RESULTS AND DISCUSSION

The simulation of the models depicted in Figures 2 and 3 are done using the same simulation parameters used in [2]. The peak cell generation rate, π = 10Mbps, the mean cell generation, λ = 2Mbps, the buffer capacities, κ, are between 1 to 80 cells, and the service rate, μ, of 5Mbps and 7Mbps, the average burst length is 10 cells.

Simulation Model Results

Figures 5– 8 show the effect of varying simulation time, T, on cell loss rate. A close observation reveals that increase in simulation time increases the number of cells generated. As such for a given buffer size and service rate, the cell loss rate is an integral function of the cell generation rate. Another noticeable trend is that increase in simulation time leads to decrease in cell loss rate.

Analytical Model Results

The results obtained from the analytical model of Figure 2 for differing buffer capacities and service rate is presented in Table 1.

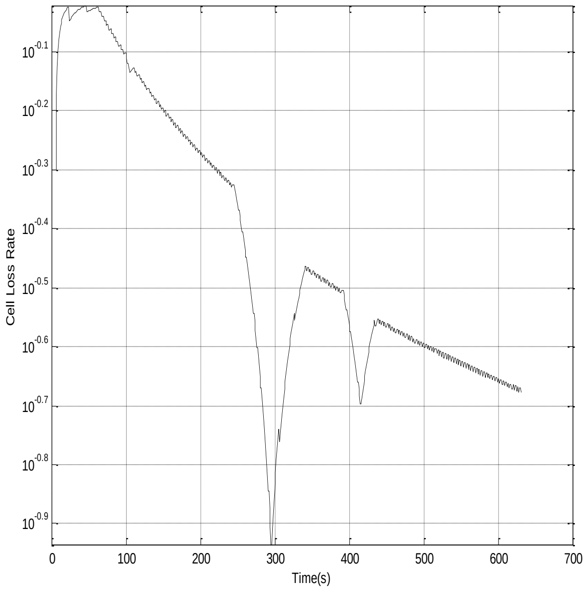

Figure 5: Cell Loss Rate for T = 50.

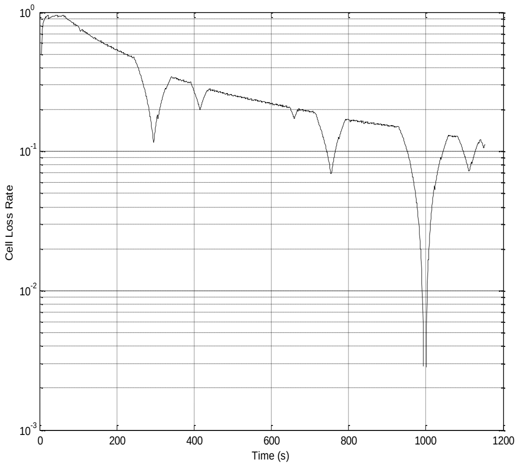

Figure 6: Cell Loss Rate for T = 100.

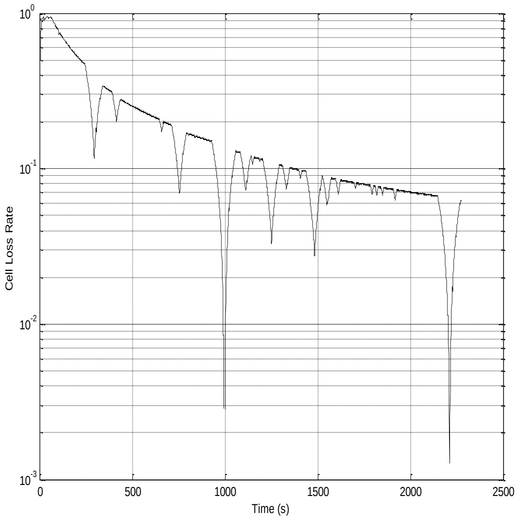

Figure 7: Cell Loss Rate for T = 200.

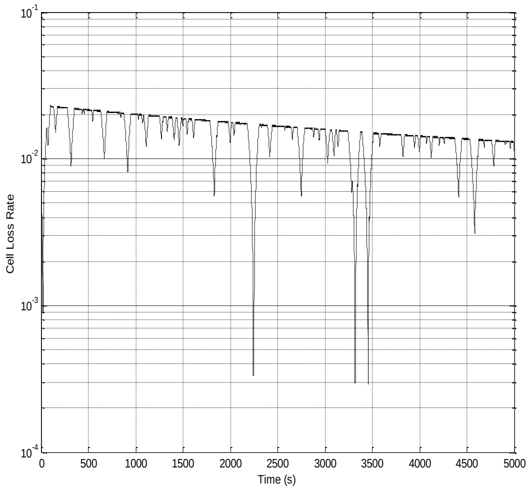

Figure 8: Cell Loss Rate for T = 1000.

Table 1: Cell Loss Rate for given Buffer Capacities and Service Rates.

Buffer capacity, k	Cell Loss Rate	
	5Mbps	7Mbps
0	1	1
5	6.873E-1	3.529E-1
10	4.724 E-1	1.245E-1
15	3.247 E-1	4.394E-2
20	2.231 E-1	1.550E-2
25	1.534 E-1	5.471E-3
30	1.054 E-1	1.930E-3
35	7.224 E-2	6.812E-4
40	4.979 E-2	2.404E-4
45	3.422 E-2	8.484E-5
50	2.352 E-2	2.993E-5
55	1.616 E-2	1.056E-5
60	1.111 E-2	3.727E-6
65	7.365 E-3	1.315E-6
70	5.248 E-3	4.64E-7
75	3.607 E-3	1.637E-8
80	2.479 E-3	5.778E-8

The results in Table 1 show that as the buffer capacity increase, the cell loss rate decrease considerably tending towards zero. A notable trend is observed for service rate 7Mbps, with buffer size 80, the cell loss rate is in the region of 5E-8. This amount of cell loss is not easily obtained from the simulation model as a large amount of time will be needed for the source to produce 500 million cells.

CONCLUSION

This work presented the block-oriented simulation model that can be used for the estimation of cell loss rate in ATM networks. Further extension beyond this point will be to implement the integrated model using Simulink and to further extend the whole process for multiple sources of ATM traffic.

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