Analysis of Access Network in ATM Networks

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Abstract – **This paper is a part of ATM access network analysis implemented with an ATM multiplexer. The ATM multiplexer on ATM layer is a buffer. The aim is to define: buffer overflow probability for different incoming streams and cell loss ratio with variable queue length, multiplexing gain and number of sources.**

Keywords – **ATM, multiplexing, overflow, queue**

I. Introduction

Planning and designing of Asynchronous Transfer Mode - based (ATM) networks is a challenge in the view of heterogeneous services, statistical multiplexing and additional logical layer that manages virtual paths. Describing ATM as multiplexing and switching modes defines both ATM multiplexer and ATM switch as underlying components in Broadband Integrated Services Digital Network (B-ISDN). They consist of a physical ATM link with a buffer. Since packet switching networks are based on queuing model, their efficiency is bound up with the serving queue ones.

II. Principles of Multiplexing

The main feature of ATM multiplexer is multiplexing into one and the same outgoing ATM line. If there is multiplexing of cell streams generated by separate sources the multiplexer is called primary. On the other hand the multiplexer is called secondary if the flows come from great number of incoming ATM lines [3].

The above mentioned division of ATM multiplexers is strongly related to the nature of incoming heterogeneous traffic. In that sense the stream has specific quality of services requirements. On ATM layer, from traffic point of view the multiplexer is a buffer [4]. The multiplexer may implement different queue disciplines or scheduling policies. In this paper we assume first in first out (FIFO) discipline. The cell transfer rate depends on the outgoing line speed and transfer time of each cell is constant due to its fixed length (fig. 1).

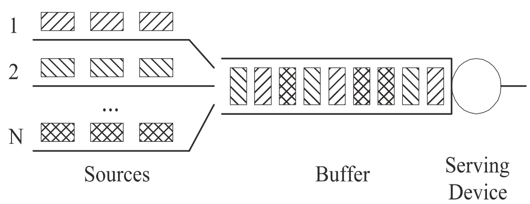

Fig. 1. ATM multiplexer

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The queue length and the incoming traffic intensity could lead to the loss of cells originating from different sources. Cell losses are due to cell delay or lack of queuing positions.

III. Buffer Overflow Probability

A. Constant bit rate (CBR) streams multiplexing

Buffer occupancy state for any fixed set of streams is a periodic process of period T. To render the probability of this occurrence less than a target level (say, 10^{-9}), the multiplexer buffer may be dimensioned so that, for a random incoming traffic, the probability of buffer overflow $Q(B)$ (where B is buffer capacity in cells) in an arbitrary instant is less than the target value [1].

For the small probabilities generally considered, $Q(B)$ can be likened to the saturation probability of a buffer of capacity B. An approximate formula which gives good order of magnitude estimates at load (N/D) greater than 0.8 is [2]:

$$Q(B) = \exp\Big\{ -2B\Big(\frac{B}{N} + \frac{D-N}{N}\Big)\Big\}. \quad (1)$$

For the very small probabilities of interest, $Q(B)$ constitutes a tight upper bound on the cell loss ratio. In general, the streams do not have the same rate. In this case, the calculation of the buffer overflow probability $Q(B)$ proves complicated.

The $M/D/1/m$ system may be used as a tool for worst-case dimensioning, without restriction of number of multiplexed connections. The results of this traffic model provide conservative estimate of buffer requirements and constitute a good approximation when the number of sources is high and the multiplexer load is not too close to 1. An accurate approximation for the queue length is [2]:

$$Q(B) \approx Ce^{-rB} \quad (2)$$

where $C = (1-\rho)/(\rho e^r - 1)$ and r is the solution of the equation and ρ is multiplexer load.

$$\rho(e^r - 1) - r = 0. \quad (3)$$

The assumption of Poisson arrivals corresponds to a worst-case traffic model for any superposition of periodic streams (homogeneous or heterogeneous) having the same overall average arrival rate in the sense that all quantiles of the delay distribution are greater [1].

In particular, the Cell Loss Ratio (CLR) estimated by Q(B) is greatest for Poisson arrival (Fig. 2).

The Eq. (2) can be used to estimate the buffer saturation probability for corresponding batch arrival systems on replacing B by B/k. For example, the buffer saturation probability when cells arrive in batches of k according to a Poisson process (the $M^{(k)}/D/1$ queue) may be estimated by

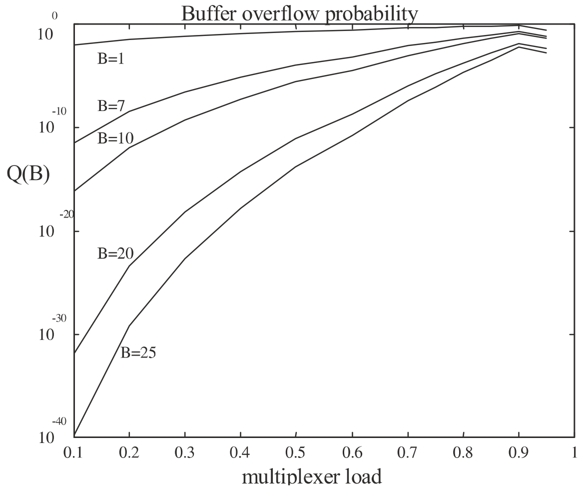

Fig. 2. $Q(B)$ for Poisson arrival process

$Q(B/k)$ where $Q()$ is given by Eq. (2). An example is given in Fig. 3.

B. *Variable bit rate (VBR) streams multiplexing*

Variable bit rate steam called on/off stream allow statistical multiplexing, it can be performed by assuring that the combined instantaneous input rate is not greater than the multiplexer service rate.

The purpose being to keep the cell arrival rate within the limit defined by the service rate is referred to as Rate Envelope Multiplexing (REM) [1].

Cell loss ratio (CLR) is decomposed at into "burst-scale" and "cell-scale" components. The first, CLRbs corresponds to losses due to rates greater than multiplexer capacity and second CLRsc corresponds to a correction term.

When the rate of multiplexed traffic streams is defined with negligible cell delay variation with respect to a k-batch Poisson process the "burst-scale" component may be sufficiently approximate with buffer overflow probability given

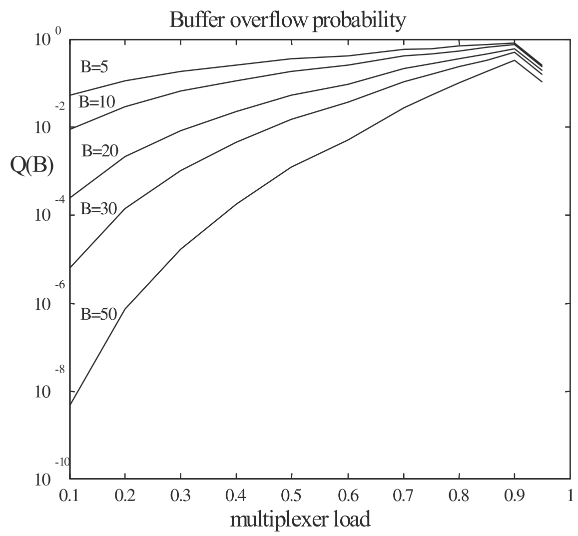

Fig. 3. $Q(B)$ for $M^{(k)}/D/1$ queue

with Eq. (2):

$$CLR_{CS} + Q(B/k). \quad (4)$$

When N identical on/off sources of peak rate p and mean rate m are multiplexed on a link of capacity c. CLR_{bs} is then estimated by:

$$CLR_{bs} = \sum_{ip>c'} (ip-c) \binom{N}{i} \left(\frac{m}{p}\right)^{i} \left(1-\frac{m}{p}\right)^{N-i} \frac{1}{Nm}. \quad (5)$$

IV. Results and Analysis

The buffer overflow probability as a function of buffer length is displayed in Fig. 4 (Eq. 1). In this case the multiplexer load is fixed at 0.9 and the number of CBR sources is variable. It is shown that the buffer overflow probability becomes smaller when the queue length increase. When queue length is greater than 20 $Q(B)$ is negligible.

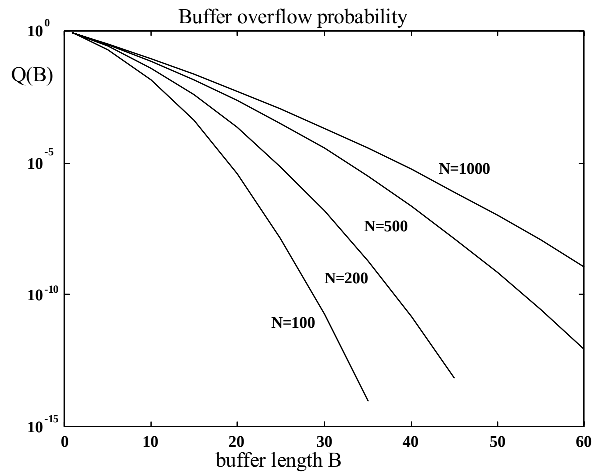

Fig. 4. $Q(B)$ at multiplexer load 0.9

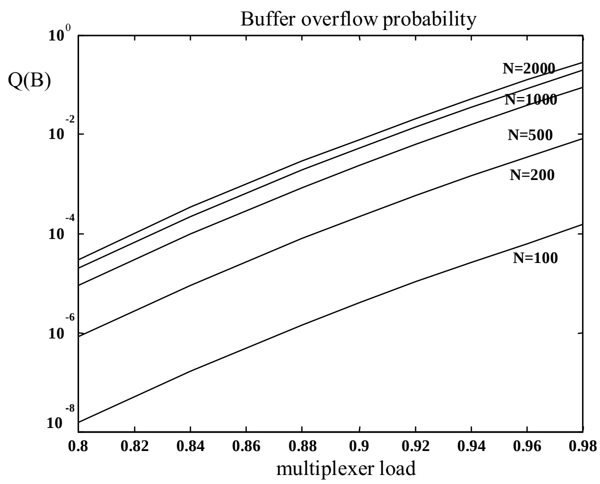

Fig. 5. $Q(B)$ at buffer length equal to 20

The buffer overflow probability as a function of multiplexer load is shown in Fig. 5. It shown that, as much the number of streams increases as the difference between $Q(B)$ decrease.

V. Conclusion

The results of this investigation may be used for the multiplexer dimensioning. The CLR or $Q(B)$ requirements (around 10^{-6} or 10^{-9}) are achieved by a queue length with capacity over 20-50 cells.

References

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