SUBMISSION TO CAC METHODS USED IN ATM

Peter Kvačkaj Ivan Baroňák
e-mail: kvackaj@ktl.elf.stuba.sk *e-mail: baronak@ktl.elf.stuba.sk*
Slovak University of Technology, Faculty of Electrical Engineering and Information Technology, Department of Telecommunications, Ilkovičova 3, 812 19 Bratislava, Slovakia

Key words: Asynchronous Transfer Mode, Connection Admission Control, statistical CAC methods

ABSTRACT

Connection admission control is a traffic control function, which satisfies both conflicting needs: the network operator wants high link utilization and the user wants guaranty on QoS parameters (e.g. peak cell rate). Many CAC schemes are proposed to satisfy this needs, in this paper are presented the intensive and weak properties of three CAC methods: Gaussian, effective bandwidth and diffusion approximation.

I. INTRODUCTION

Connection admission control (CAC) is a traffic control function, which decides whether or not to allow new connection into multiplex in ATM network. The decision is based on the current ATM node and network load, on the available network resources (output link bandwidth capacity, buffer size), on the values of traffic parameters and required Quality of Service (QoS) characterization of the new connection and the existing connections. The traffic parameters are e.g. Peak Cell Rate (PCR), Sustainable Cell Rate (SCR) and Maximum Burst Size (MBS). To provide the guaranteed QoS, a traffic contract is established during connection setup, which contains a connection traffic descriptor and conformance definition between the network and the user. The QoS is often formulated in the terms of network performance parameters: Cell Loss Ratio (CLR), Cell Delay Variance (CDV) and Maximum Cell Transfer Delay (MaxCTD). In this paper, CAC methods in the case of the new connection acceptance are bound with CLR estimation. Our assumption is that CDV and MaxCTD will be satisfied with proper method of buffer allocation [1, 2].

II. CAC METHODS

Main CAC function is realized by using properly created CAC method. In CAC method's acceptance decision, these must be taken into account:

- CAC methods are dependent on the ATM node architecture. For proper CAC functionality, buffer size, cells queuing method in buffer, number of input and output links, etc. must be taken into account [1, 2].
- There are many services in ATM, so they are divided into five categories: Constant Bit Rate (CBR), Variable Bit Rate (VBR) in real time or non-real time, Available Bit Rate (ABR) and Unspecified Bit Rate (UBR) [10]. Each category has different requirements on QoS.
- Typical ATM source can transmit at any cell rate due to the selected category, in the traffic flow there can be cell burstiness and fluctuations in cell rate. Traffic source's description is related with the traffic parameters and a traffic model specification. The basic traffic models are with constant, variable and on-off traffic [2, 11].

III. CLASSIFICATION OF CAC METHODS

CAC methods are based on many principles and approximations e.g. stationary, effective bandwidth, fluid flow methods etc [7]. Some of the CAC methods exploits on-line traffic measurements or analyzes buffer load status. The task of CAC is common and can be formulated as follows: Suppose that there are N connections in multiplex, output link bandwidth capacity is C. Probability, that current cell rate of N connections exceeds link capacity C, is lower than ε value. If $r_i(t)$ is the current cell rate for ith connection, then CAC task is given by

$$P\left(\sum_{i=1}^{N} r_i(t) \geq C\right) < \varepsilon \,. \qquad (1)$$

The common classification of the CAC methods is shown in ***figure 1***. First basis is whether CAC method takes into account buffer effect. Methods in which the buffering effect is considered are called rate-sharing multiplexing (RSM) methods. . If we consider RSM method, we need to model an appropriate queuing method at the output link buffer. They are high efficient, but require a fair amount of processing power. Those in which the buffering effect is not considered are called rate-envelope multiplexing (REM) methods. The output link buffer does not need to be considered. When the total cell rate of all connections is higher than output link capacity, excess cells are discarded immediately.

The second basis for classification is whether we evaluate CLR (CLR method) or effective bandwidth (EB method). In the former case, if requested CLR in QoS objective is higher than evaluated CLR, the connection is accepted; otherwise it is rejected. The strength is their precision in estimation. Its weakness is fair amount of processing. In the case of EB method, if sufficient bandwidth exists to support the effective bandwidth, the connection is admitted; otherwise it is rejected. The strength of EB method is simplicity in the case of admission decision.

The third basis is whether a method uses declared traffic descriptor (traffic descriptor based method) or uses on-line measurement as well (measurement based method). The strength of traffic descriptor method is that it can guarantee the declared QoS in traffic descriptor. Its weakness is that efficiency can be low, because user declares upper bound of parameters in traffic descriptor (e.g. mean SCR and peak cell rate PCR). In the case of measurement based method, we can not directly measure CLR. CLR value is very small and measurement requires a fair amount of transferred cells (approximately 10^{12} cells or more). Therefore we measure the cell stream and calculate the CLR. The strength of measurement based method is that it does not require an accurate traffic model beforehand.

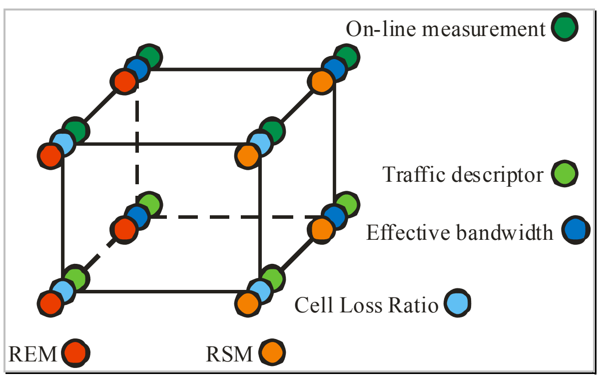


Figure 1. Classification of CAC methods.

IV. CAC METHODS

The following two principles are the most used ones – equivalent bandwidth and Gaussian approximation. Third investigated CAC method is method of diffusion approximation. These methods can be found in [5]. The paper will follow with short overview of mentioned CAC methods. Connection as on-off source (transmits at rates of PCR or 0 value only) is characterized with ordered triplet (R, r, b) where R is source peak cell rate, r is the source's average (equivalently sustainable) cell rate, both in cells/sec (or bit/sec) and b is the average on (burst) period in seconds (or equivalent cells). Output link capacity is C cells/s, buffer size is set to B cells and for simplicity all connections request CLR equal to ε. All terms in this paper will be measured in cells, cells/second and seconds except as otherwise stated.

EQUIVALENT BANDWIDTH

This method is quite simple but highly conservative, when buffer size is small or moderate. Equivalent bandwidth C_i for ith source for the buffer size B is defined as

$$C_i = R_i \frac{y_i - B + \sqrt{(y_i - B)^2 + 4 y_i a_i B}}{2 y_i}, \tag{2}$$

where

$$y = (-\ln \varepsilon)\left(\frac{1}{\beta_i}\right)(1 - a_i) R_i , \tag{3}$$

where R_i is source peak rate, $b_i = \beta_i^{-1}$ is average source length of the "on" (burst) period and a_i is source activity factor

$$a_i = \frac{\theta_i}{\theta_i - \beta_i}, \tag{4}$$

where θ_i^{-1} is average length of the "off" period. This method gives equivalent bandwidth for source in isolation and fails to account for the statistical multiplexing gain. A compromise was made in such a way that required bandwidth for N sources equals

$$\min\{C_e, C_g\}, \tag{5}$$

where

$$C_e = \sum_{i=1}^{N} C_i \text{ and } C_g = \lambda + \sigma\sqrt{-2\ln\varepsilon - \ln 2\pi}\ , \tag{6}$$

where λ is total mean rate and σ^2 is total variance given by ***equation (7)*** and ***(8)***.

GAUSSIAN APPROXIMATION

This approach is based on zero length buffer assumption; the buffer's capacity to absorb traffic bursts is ignored. Resulting bandwidth can be excessively conservative, when number N of multiplexed sources is small. If the number of sources N is sufficiently large, the aggregate traffic can be approximated by a Gaussian process with total mean rate and total variance

$$\lambda = \sum_{i=1}^{N} \lambda_i, \quad \sigma^2 = \sum_{i=1}^{N} \sigma_i^2 , \tag{7}$$

where

$$\lambda_i = r_i R_i, \quad \sigma_i^2 = \lambda_i (R_i - \lambda_i). \tag{8}$$

Using the Gaussian approximation we can estimate overflow probability and upper bound to cell loss probability (equivalently CLR)

$$P_{overflow} = P(R(t) \geq C) \approx \frac{1}{\sqrt{2\pi}} e^{-\frac{(\lambda - C)^2}{2\sigma^2}},$$
$$P_{loss} = \frac{E\left[(R(t) - C)^+\right]}{\lambda} \approx \frac{\sigma}{\lambda\sqrt{2\pi}} e^{-\frac{(\lambda - C)^2}{2\sigma^2}}, \tag{9}$$

where *R(t)* is instantaneous cell arrival rate.

DIFFUSION APPROXIMATION

This method uses statistical bandwidth obtained from a closed-form expression based on the diffusion approximation models. When number of multiplexed connections is small and the ratio of burst length to buffer size (both in cells) is significantly long, statistical bandwidth tend to over estimate the required bandwidth.

For N on-off sources we have total mean rate and total variance using ***equation (7)*** and ***(8)***. Instantaneous variance of cell arrival process α is

$$\alpha = \sum_{i=1}^{N} \lambda_i CV_i^2, \tag{10}$$

where

$$CV_i^2 = \frac{1 - (1 - \beta_i T_i)^2}{(\beta_i T_i + \theta_i T_i)^2} \text{ and } T_i = \frac{1}{R_i}, \beta_i = \frac{1}{b_i}, \tag{11}$$

where $b_i = \beta_i^{-1}$ is the mean "on" period and θ_i^{-1} is the mean "off" period of ith source. Then we get two expressions (one for Finite Buffer and the other for Infinite Buffer model respectively) for statistical bandwidth

$$C_{FB} = \lambda - \delta + \sqrt{\delta^2 - 2\sigma^2\omega_1},$$
$$C_{IB} = \lambda - \delta + \sqrt{\delta^2 - 2\sigma^2\omega_2} \tag{12}$$

where

$$\delta = \frac{2B}{\alpha}\sigma^2, \quad \omega_1 = \ln\left(\varepsilon\sqrt{2\pi}\right) \tag{13}$$

and

$$\omega_2 = \ln\left(\varepsilon\lambda\sqrt{2\pi}\right) - \ln(\sigma) \tag{14}$$

As the worst case estimate of the statistical bandwidth it is possible to take

$$\max\{C_{FB}, C_{IB}\}. \tag{15}$$

V. SIMULATION RESULTS

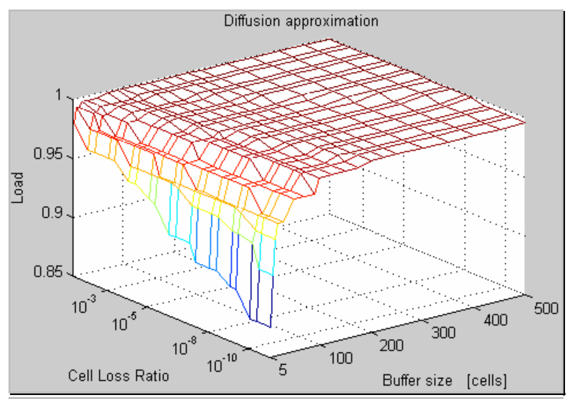
First simulation compares the estimation's precision in the case of effective bandwidth and diffusion approximation methods and eventually their dependency on parameters:

- ***Buffer size B:***
  20 values from interval $\langle 5{,}500 \rangle$ cells).
- ***CLR parameter:***
  20 values from interval $\langle 5 \cdot 10^{-2}, 10^{-11} \rangle$.

Output link capacity is set to 155 Mbit/s, there are 100 on-off connections in multiplex. Their peak cell rate is uniformly distributed, for ith connection we get

$$PCR_i = \frac{C}{N} k, \tag{16}$$

where N stands for number of connections and k is constant set to exceed output link capacity when aggregating connections altogether. Burstiness (or the ratio of the peak to the average rate) varies in range from 1,1 to 10 due to SCR_i value for ith connection.



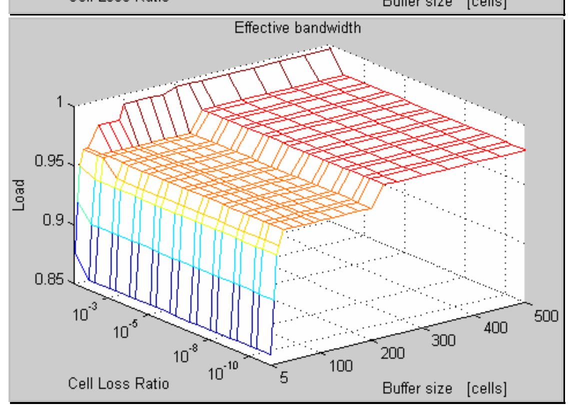


Figure 2. CAC method simulation:
a) Diffusion approximation b) Effective bandwidth

The result (see ***figure 2***) plot the real load which is admitted with concrete CAC method. The traffic on-off model is same in both cases; we can only see method's admission dependency on the *B* and *CLR* request. Comparing these two methods we can see that the estimation of effective bandwidth method is more conservative. Moreover, the effect of buffer size is the most significant; we can also see low link utilization in the case of very small buffer size.

In the case of Gaussian approximation, this CAC method is proposed for buffer less switching architecture only. Second simulation tries to catch method's dependency on the number of connections *N* and the requested *CLR*. Two traffic models are used: the on-off and a variable bit rate traffic model (VBR source transmits at various rates ranging from 0 to PCR).

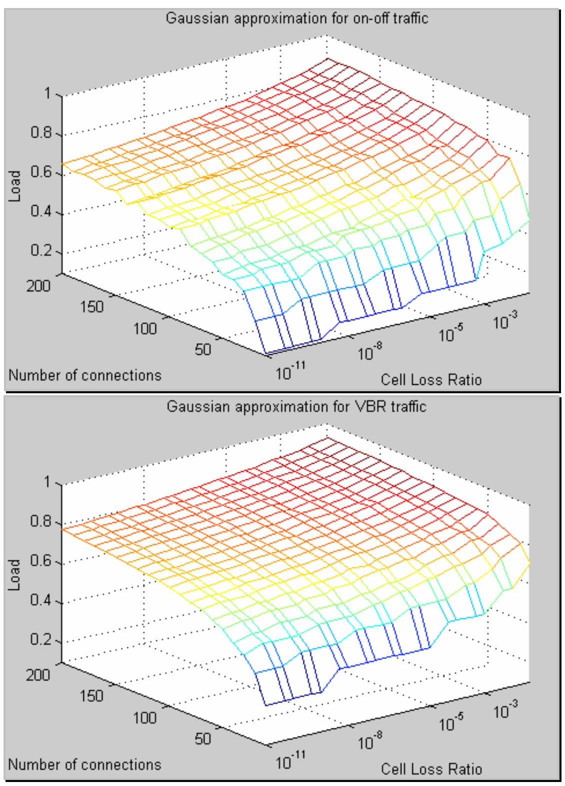


Figure 3. Gaussian approximation for:
a) On-off traffic b) VBR traffic

As we can see (***figure 3***), Gaussian approximation method is more conservative in policing of on-off traffic sources. Traffic aggregation in the case of VBR traffic sources gets the Gaussian probability distribution of cell rates sooner as in the case of on-off traffic sources. In both cases, the effect of *N* and *CLR* is clear: the more connections we have in multiplex, the better link utilization; if the QoS requirements are higher (lower CLR), the higher statistical bandwidth the connection needs.

VI. CONCUSION

In this paper, the simulation (in MATLAB) is efficient and precise tool for the CAC method evaluation. Sometimes it is the only way, how to verify CAC method before it is launched in real network environment due to the technical complexity and costingness.

A properly created abstract traffic model enables to visualize results obtained from simulation. By means of the results we can assume whether the CAC method is suitable for given environment or not. In real systems the choice of a suitable CAC method is a strategic point for effective exploitation of link capacity and QoS guaranty.

REFERENCES

1. **Baroňák, I., Kajan, R.:** *Quality of ATM services and CAC methods*, FEI STU Department of Telecommunications, Bratislava, 1999 (in Slovak).
2. **Kvačkaj, P.:** *CaC methods for traffic control used in ATM*, Diploma work, FEI STU Department of Telecommunications, Bratislava, December 2004 (in Slovak).
3. **Shiomoto, K., Yamanaka, N., Takahashi, T.:** *Overview of Measurement-based Connection Admission Control Methods in ATM Networks*, IEEE Communications Surveys, First Quarter 1999.
4. **Marzo I Lazaro, J. L.:** *Enhanced Convolution Approach for CAC in ATM Networks, an Analytical Study and Implementation*, ISBN 84-8458-106-53, Girona, 1996.
5. **Gelenbe, E., Mang, X., Onvural, R.:** *Diffusion Based Statistical Call Admission Control in ATM*, Performance Evaluation 27-28, 1996, p. 411-436.
6. **Baroňák, I., Kvačkaj, P.:** *Submission to CAC*, Communications, Scientific Letters of the University of Žilina, volume 6, 4/2004, pp 80-83.
7. **Baroňák, I., Kvačkaj, P.:** *Connection Admission Control (CAC) in ATM Systems*, International Conference "Applied Electronics 2004", Pilsen, Czech Republic, September 8-9, 2004, pp 134-137.
8. **Baroňák, I., Kvačkaj, P.:** *QoS and CAC methods in ATM networks*, International Conference "Telecommunication and Signal Processing 2004", Brno, Czech Republic, September 1-2, 2004, pp 25-29.
9. **Kvačkaj, P.:** *CAC Method of Effective Bandwidth*, International Competition STUDENT EEICT 2004, section Telecommunications, Bratislava, May 27, 2004, pp 232-237.
10. **The ATM Forum:** "*Traffic Management Specification Version 4.0*", af-95-0013R13, Letter Ballot, April 1996.
11. **Engel, R.:** *Design and Implementation of a New Connection Admission Control Algorithm Using a Multistate Traffic Source Model*, Department of Computer Science, Washington University St. Louis, 1996.