COMPARISON OF A DETERMINISTIC AND A HEURISTIC APPROACH TO CAC[1]

J.-L. Marzo[a], M. Ramalho[b], R. Fabregat[a], E. M. Scharf[b], J. Sole-Pareta[c], J. Domingo[c]

Abstract

Two approaches to Connection Admission Control (CAC) in ATM networks are presented and their relative performances are assessed. The two CAC methods are, respectively, the enhanced convolution approach (ECA), an optimised algorithm based on the deterministic convolution method and the Fuzzy CAC (FCAC) approach, a heuristic method based on a combination of fuzzy logic and genetic algorithms.

1. Introduction

Connection admission control (CAC) is a traffic control function which decides whether or not to admit a new connection into an ATM network. The decision is based on the current network load, on the values of the characterisation parameters (e.g. mean and peak rates), on the available network resources (link bandwidth capacity and output buffer size) and on the required Quality of Service (QoS) of the existing connections and the new connection. QoS requirements are often formulated in terms of the constraints placed on the following network performance parameters: queueing delay, delay variation and cell loss. In this paper, cell loss will be the QoS parameter considered. It is assumed that cell delay requirements can be satisfied by an appropriate buffer dimension method.

The CAC decision making process relies on an accurate knowledge on the traffic behaviour of the connections multiplexed in an ATM link. The specific properties of ATM (fixed size packets and bandwidth on demand) require statistical source models different from those used for traffic in existing circuit or packet switched networks. ATM source models need to

---

a Institut d'Informàtica i Aplicacions. Universitat de Girona

[b] Dept. of Electronic Engineering, Queen Mary & Westfield College, U. of London

[c] Dept. D'Arquitectura de Computadors. Universitat de Politècnica de Catalunya

[1] This work has been supported jointly by the CICYT (Spanish Education Ministry, TIC95-0982-CO2-02) and the British Council, Ref. 162 - B.

be accurate, simple, and generally applicable. Considering this, the On-Off traffic model [1] is the source model adopted in these studies for source characterisation purposes.

The required time to perform the CAC decision has to be reasonable. This requirement is particularly difficult to fulfil when the network is heavily loaded in terms of the number of multiplexed connections or when the multiplexed connections have different characteristics in terms of bit rates and burstiness. In this case the complexity of the calculations required to predict a cell loss value increases enormously.

Various CAC approaches have been proposed in the literature: Hui [2] presents a CAC approach based on a traffic model in three levels (cell, burst and call level), Guerin et al [3] proposes a CAC approach based on the notion of 'equivalent capacity', Iversen [4] studied the performance of CAC algorithms based on the convolution approach. Given the before mentioned, the authors have proposed two CAC approaches that satisfy the requirements for CAC methods but are based on two different methodologies. Hence, the CAC approach proposed by Marzo et al [5] (ECA) is based on an analytical model, the convolution algorithm, and the CAC approach proposed by Ramalho et al [6] (FCAC) is based on fuzzy logic techniques. The main objective of this paper is not to present in detail the above mentioned CAC methods but rather to compare them in terms of: i) accuracy of the cell loss prediction, ii) facility of development of each of the two CAC approaches, and iii) optimisation of the use of network resources in terms of the number of admitted connections.

2. The proposed CAC methods

2.1 Enhanced Convolution CAC

CAC aims to maximise the statistical multiplexing gain, then cells could be lost when the instantaneous rate is greater than the link bandwidth. Stationary models are accurate enough for CAC traffic modelling purposes. This is also the case for network environments with small output buffer size and bursty traffic. The most accurate method based on stationary models is the convolution approach, which determines the exact distribution of the aggregated bit rate on an ATM link.

The convolution algorithm assumes that the traffic behaviour of each of the multiplexed connections is independent of each other. The convolution algorithm does not take into account the burst length of each connection, though. Convolution methods allow to calculate the rate distribution of the multiplexed traffic, and therefore, the probability of congestion (PC), the average cell loss ratio (CLR) and the CLR per connection can be also calculated.

This approach is based on the well known expression of the convolution procedure denoted by: Q = Y * X

which is evaluated by the following expression:

$$P(Y+X=b)=\sum_{k=0}^{b} P(Y=b-k)P(X=k)$$

where **Q** is the bandwidth requirement of all established connections including the new connection; **Y** is the bandwidth requirement of the already established connections; **X** is the bandwidth requirement of a new connection, and **b** denotes the instantaneous required bandwidth. In fact, the convolution approach obtains a probability density function for the offered link load, expressed as the probability that all traffic sources together are emitting at a given rate **b**.

Clearly, we should carry out N-1 convolutions to obtain the global distribution. In order to overcome this drawback, an Enhanced Convolution Approach (ECA) has been proposed by Marzo et al [7] . In the following a brief overview of the method is presented.

First, only one class of traffic is assumed, which are emitting in **T** possible states. P(state s_0 occurs n_0 times, ... , state s_{T-1} occurs n_{T-1} times) is

$$\frac{N!}{n_0!n_1!\ldots n_{T-1}!} \quad p_0^{\,n_0} \cdot p_1^{\,n_1} \cdots p_{T-1}^{\,n_{T-1}}$$

this is the probability corresponding to the Multinomial Distribution Function. This expression allows the direct evaluation of the corresponding probability to each possible state of the link. When there are different classes of sources j (heterogeneous traffic), it is necessary to convolute between all source classes. The evaluation of CLR based on ECA can compute the corresponding CLR for each class (as it is explained in [8]).

Using ECA for CAC implementations additional reduction of the evaluation complexity can be achieved. The complete calculation of PC is not always necessary and those link states corresponding to a non-congestion situation may be skipped. Moreover, an upper bound for the admissible PC in the link may be pre-set based on the CLR requirement. If the cumulative PC value reaches the admissible PC value, the evaluation process stops and the new connection is rejected. Complementary programming techniques may be also applied to improve the implementation performance. All the previously referred mechanisms to improve the performance of ECA can be used simultaneously.

2.2 Fuzzy Logic CAC

CAC requires a simple but accurate traffic model that can easily adapt to new traffic patterns generated by ATM services introduced in the future. Considering this, CAC approaches such as the neural network based CAC [9], neuro-fuzzy CAC [10] and the fuzzy logic based CAC (FCAC) further presented are based on data (knowledge) modelling techniques rather than on analytical traffic models. The subjacent technique (neural network, fuzzy logic) provides a mechanism for clustering data obtained from ATM traffic measurements in a structure that constitutes the traffic model by itself, that is: i) a net structure composed of a set of neurones and respective connections for neural networks, and ii) a rule structure composed of a set of “if-then” variable associations in the case of fuzzy logic systems.

Worster [11] points out the training requirements imposed by a neural network approach do not map conveniently the CAC fast response requirement due to the time consuming training phase. A fuzzy logic based system requires a less lenghty set up (training) phase than a neural network and the data is expressed in “if-then” rules, easy to understand by a human operator.

The application of fuzzy logic to CAC envisages to predict the maximum cell loss ratio per connection when a candidate connection is added to a background traffic scenario. The fuzzy logic based CAC (FCAC) uses the mean and peak bit rates and mean burst length to describe the traffic behaviour of each of the multiplexed connections on a node-to-node basis.

The fuzzy rule base in FCAC is automatically designed using a method of learning from examples based on the work done by Herrera et al [12]. This learning method has been explained in detail in previous studies (see also Ramalho et al.[13] and [14]) and it allows to define (a) the fuzzy sets for the fuzzy variables in the antecedent and consequent of each fuzzy rule and (b) a finite set of fuzzy rules able to reproduce the input-output system behaviour. The learning method can also be used on-line, every time a new set of traffic examples is available, so allowing FCAC to adapt to changes in the traffic patterns.

3. Experiments

3.1 Homogeneous scenarios

In the following, a set of experiments is presented for traffic scenarios with identical traffic sources (homogeneous traffic) and for different link configurations expressed in terms of the link capacity, *C*. The output buffer size, *K*, is equal to 50 cells. Data traffic has a peak rate equal to 10 Mbit/s, the mean rate is equal to 1 Mbit/s and the mean burst length equal 339 cells. For Voice traffic the corresponding values are 64 Bbits/s, 22 Kbits and 58 cells.

ECA and FCAC are going to be compared with an analytical method proposed by Yang and Tsang [15] to estimate the cell loss probability in an ATM multiplexer loaded with homogeneous traffic. This method, in the following referred as the (M+1)-MMDP approximation, uses the *Markov Modulated Deterministic Process* (MMDP) to approximate the actual arrival process and models the ATM multiplexer as an MMDP/D/1/k queuing system. The results obtained were also checked using an ATM cell rate simulator, LINKSIM, developed by Pitts [16].

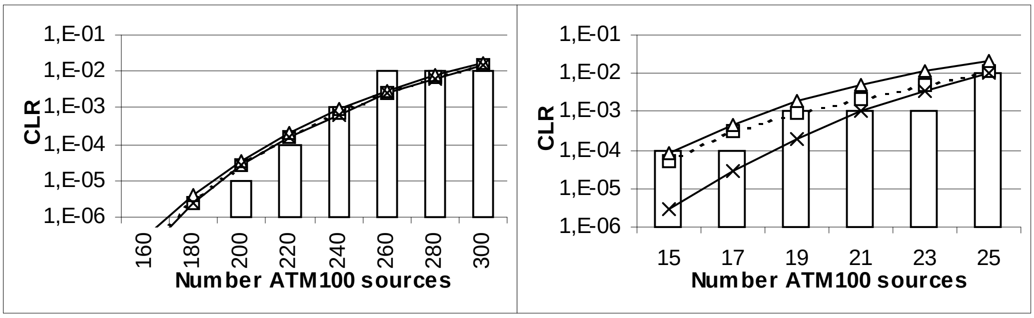
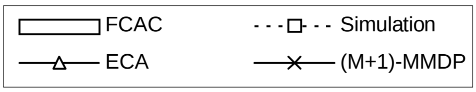


Figure 1. *Data* (C = 350 Mbit/s) .... **Figure 2:** *Voice* calls (C = 0.7 Mbit/s and K=50)



The ECA prediction provides an upper bound for the average cell loss probability for the traffic scenarios plotted in figures 1 and 2. ECA is conservative in this scenario being more accurate when the number of sources increases. The FCAC prediction conforms with the cell loss value given by the simulation.

The ECA prediction for both figures is below the average cell loss curve obtained via simulations but the difference is not enough to classify the prediction given by ECA as optimist. The same behaviour can be observed for the prediction given by the (M+1)-MMDP approximation in Figure 1, but it is quite optimistic in cell loss predictions in Figure 2. The FCAC prediction conforms with the cell loss value given by the simulation. Note that the rounding to the next power of ten can sometimes mislead the observer to think that the approach is either pessimist or optimist for a particular traffic study.

3.2 Heterogeneous scenarios

This set of experiments allows to compare the average cell loss results obtained from on-line measurements in the Exploit ATM test-bed in Basel [17] with the cell loss predictions given by both the ECA and FCAC approaches for heterogeneous traffic scenarios.

Traffic Class	Peak Rate Mbit/s	Mean Rate Mbit/s	Burst L. cells
A	31.1	6.22	1467
B	7.78	0.39	183
C	1.94	0.97	229

Table 1 Characteristics of the traffic sources.

In table 1 the traffic sources used for the comparison experiments are described. The link capacity considered is 155.52 Mbit/s. Considering that the buffer size is small (27 cells), it is not surprising that the cell loss predicted by the convolution approach is so close to the cell loss measured values.

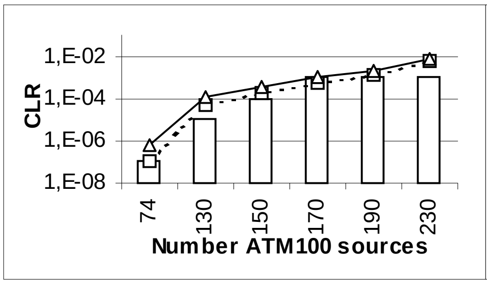


Figure 3. CLR (2 A, variable # B)

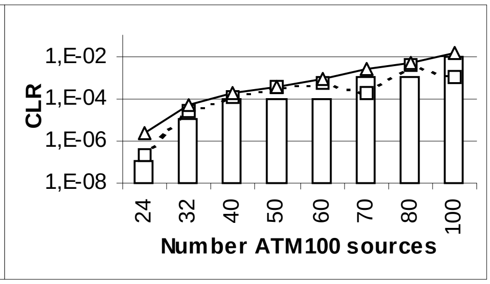


Figure 4. CLR (4 A, variable # C)

FCAC — ECA - - - Simul

It can be observed that the cell loss prediction given by FCAC is close to the one obtained from measurements. The fact that the cell loss predictions given by FCAC can be more optimistic than predictions given by ECA, for some traffic scenarios, has to do with the fact that the rounding-off error to the closest negative power of ten.

Overall, the FCAC predictions obtained for each of the eight heterogeneous traffic mixes shown previously approximate the measurements curve and the FCAC prediction is never less optimistic and generally more optimistic than the ECA prediction.

4. Conclusions and Further Work

The cell loss predictions obtained by FCAC and ECA measurement are in agreement with the cell loss reference values obtained via on-line measurements and using simulations, although the cell loss ratio prediction given by ECA is generally conservative and the FCAC prediction is generally optimistic. The conservatism of the prediction given by ECA is related with the bufferless assumption. The optimism observed in the prediction given by FCAC is mainly related to the round-off error when rounding a floating point value of the measured cell loss ratio to the nearest negative power of ten.

Future research is required to test both ECA and FCAC approaches on-line regarding the speed of the calculations, the accuracy of the cell loss ratio predictions and the optimisation of the use of the ATM link. This paper has used as much as possible results obtained from on-line measurements but the set of obtained results is not enough to make very broad conclusions. The authors regret that there isn't a common set of ATM traffic scenarios used among ATM researchers to compare CAC approaches.

5. References

[1] R.O. Onvural, "Asynchronous Transfer Mode Networks: Performance Issues", Artech House, Boston, London, 1994.

[2] J.Y.Hui, "Resource Allocation for broadband networks", IEEE J. on Sel. A. in Com., vol. SAC-6, no.9, pp. 1598-1608, Dec. 1988.

[3] R. Guerin, H. Ahmadi, M. Naghshineh, "Equivalent capacity and its application to bandwidth allocation in high-speed networks", IEEE J. on Sel. areas in com., vol. 9, no.7, Sept. 1991.

[4] V.B. Iversen and Liu Y., "The performance of convolution algorithms for evaluating the total load in an ISDN system", 9th Nordic Teletraffic Seminar, Norway, pp. 14, Aug. 1990.

[5] J.L.Marzo, R. Fabregat, J. Domingo, J. Sole. "Fast Calculation of the CAC Convolution Algorithm, using the Multinomial Distribution Function". Tenth UK Teletraffic Symposium, pp.23/1-23/6, 1993.

[6] M. F. Ramalho and E. M. Scharf, "Developing a Fuzzy Logic Tool using Genetic Algorithms for Connection Admission Control in ATM Networks", Proc. of the 6th Int'l Fuzzy Systems Association World Congress, Vol. 1, pp. 281-284, S. Paulo, 22-28th July 1995.

[7] R.Fabregat-Gesa, J. Sole-Pareta J.L.Marzo-Lazaro, J. Domingo-Pascual, "Bandwidth Allocation Based on Real Time Calculations Using the Convolution Approach", Globecom 1994.

[8] R.Fabregat-Gesa, J.L.Marzo-Lazaro and Pere Ridao, "Resource dimensioning aspect of heterogeneous traffic with different service requirements: integration versus segregation" Twelfth UK Teletraffic Symposium, Windsor.

[9] T. Takahashi, A. Hiramatsu, "Integrated ATM traffic control by distributed neural networks", in Proc. ISS '90, Stockholm, vol. 3, pp. 59-65, 1990.

[10] M. Fontaine and D.G. Smith, "A neuro-fuzzy approach to connection admission control in ATM networks", 13th UKTS, Glasgow, 1996, session 1, paper 2, pp. 2/1 to 2/8.

[11] T. Worster, "Neural network based Controllers for Connection Acceptance", 2nd RACE Workshop on Traffic and Performance Aspects in IBCN, Aveiro, Portugal, Jan., 1992.

[12] Herrera F., Lozano M., Verdegay J., "A learning process for Fuzzy Control rules using Genetic Algorithms", Dept. of Computer Science and Artificial Intelligence, Univ. Granada, Spain, Technical Report #DECSAI-95108, February 1995.

[13] M. F. Ramalho and E. M. Scharf, "Fuzzy Logic Tool and Genetic Algorithms for CAC in ATM Networks" in Electronic Letters, vol. 32, no. 11, pp. 973-974, 1996.

[14] M. F. Ramalho and E. M. Scharf, "The application of Fuzzy Logic Techniques and Genetic Algorithms for Connection Admission Control in ATM Networks", in: Genetic Algorithms and Soft Computing, F. Herrera, J.L. Verdegay (Eds.), Physica-Verlag (Studies in Fuzziness, Vol. 8), pp. 615-640, 1996.

[15] T. Yang, D.H.K. Tsang, "A novel approach to estimating the Cell Loss Probability in an ATM Multiplexer loaded with Homogeneous On-Off sources", IEEE Trans. on Communications, vol. 43, no.1, pp. 117-126, January 1995.

[16] Pitts J.M., "Cell-rate simulation modelling of Asynchronous Tranfer Mode Telecommunications Networks", Ph.D. Thesis, Queen Mary and Westfield College, July 1993.

[17] EXPLOIT-RACE2061/EXP/SW3/DS/P/028/B1, "Results of Experiments on Traffic Control using Real Applications", 31 December 1994.