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COMMUNICATIONS

CAC — CONNECTION ADMISSION CONTROL IN ATM NETWORKS

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CAC is defined as a set of actions executed by the network in the phase of connection setup if VP/VC connection should be accepted or denied. The request for a new connection is accepted only if there is enough capacity in the network for creation of the new connection with requested QoS and QoS of the existing connections in the network is saved. If a new connection is accepted, then a traffic contract between the network and user is signed. The network will keep the signed QoS and the user connection will keep the traffic contract parameters.

K e y w o r d s: CAC (Connection Admission Control), ATM, Networks

1 INTRODUCTION

CAC is the first protection of the network against redundant overload (preventive function) and it has to reduce the number of connections in the network as each connection should receive the requested QoS. CAC makes estimation consequence of the accepted connection for QoS of all existing connections in the network and also for QoS of a new accepted connection. First CAC evaluates the bandwidth needed for QoS requests of the new connection. If QoS requests of the new connection can be guaranteed, the request of the new connection is accepted, else it is denied. If the connection is cancelled, CAC frees the bandwidth used by the connection in the network.

2 CAC ALGORITHM

At present, a lot of methods and modifications exist which are usable as CAC functions. Part of these methods are based on mathematical models which use the theory of probability and mathematical statistics. An important part of CAC algorithms is statistical estimation of the bandwidth requested by the set of connections and keep QoS of each connection. In other words this problem can be explained so that for N multiplexed connections a total bandwidth C is determined. The probability that the bit rate of N connections is higher than bandwidth C is lower than ε. If $r_i(t)$ is the actual bit rate of connection i, then this possibility can be written as:

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

3 GAUSSIAN APPROXIMATION METHOD

The Gaussian approximation method is an easy and fast method for specification of the required bandwidth, cell loss probability and buffer overflow probability. This method is based on the central limited theorem, where the number of connections is close to infinity, no connection is dominant. Traffic approximation in the network is based on the Gaussian distribution function. Each connection i is described by two basic parameters: mean bit rate λ_i and standard bit rate deviation σ_i. For a large number of connections N there are valid the following expressions for the mean arrival bit rate $\lambda = \sum_{i=1}^{N} \lambda_i$ and arrival bit rate variation $\sigma^2 = \sum_{i=1}^{N} \sigma_i^2$. If the value of N is too small, these expressions are not valid.

Analysis of the Gaussian approximation method led to the buffer overflow probability estimation

$$P_{overflow} = P\left[\left(\sum_{i=1}^{N} r_i(t)\right) \geq C\right] = \frac{1}{\sqrt{2\pi}} e^{-\frac{(\lambda-C)^2}{2\sigma^2}} \tag{2}$$

and upper boundary cell loss probability

$$P_{loss} = \frac{E\left[\left(\sum_{i=1}^{N} r_i(t)\right) - C\right]^{+}}{\lambda} \leq \frac{\delta}{\lambda\sqrt{2\pi}} e^{-\frac{(\lambda-C)^2}{2\sigma^2}}\,, \tag{3}$$

where $r_i(t)$ is the actual bit rate of connection i [5].

This method is valid only if we suppose a large number of connections. In other case this method is not too accurate and results are too similar. All connections are considered as equal in cell loss requirements and when calculating the cell loss probability, the model is based on a system without a buffer.

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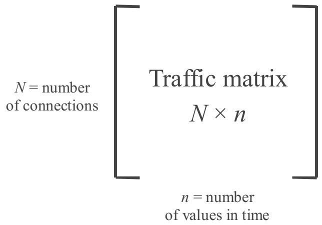

Fig. 1. Traffic matrix

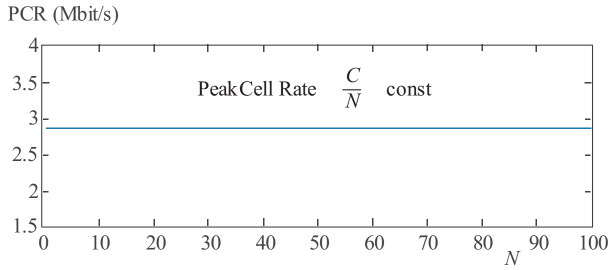

Fig. 2. PCR of each connection in the first case

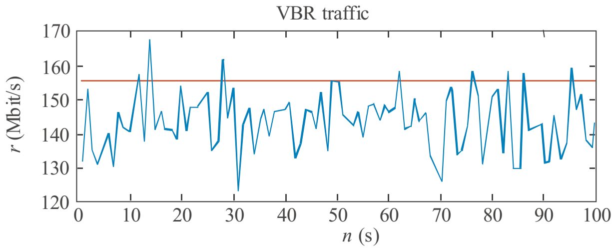

Fig. 3. VBR traffic in the first case

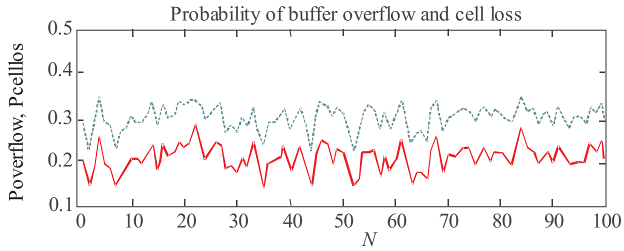

Fig. 4. VBR probabilities in the first case

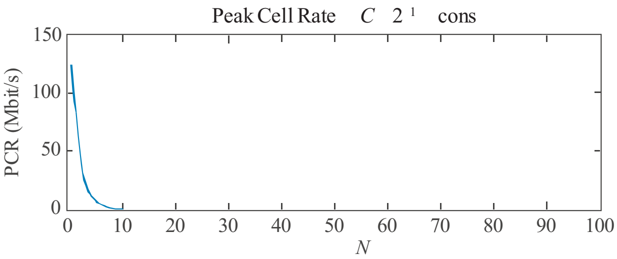

Fig. 5. PCR of connections in the second case

4 SIMULATIONS

For simulation of the chosen method it was necessary to prepare a traffic model which provides traffic values in real time in ATM network. ATM traffic model was defined through traffic parameters **PCR** of each connection. An important part of this model is also the link capacity C, the number of connections N and the number of traffic values n in unit time generated for each of N connections. The result of this traffic model is the *traffic matrix* $N \times n$, where N rows of the matrix are N connections and n columns are n traffic values in time for each connection.

This simulation deals with the case when $N = 100$ independent connections exist in the network and for each of these connections there were generated $n = 100$ traffic values in time dependent of PCR for each of connections. The link capacity was specified to be $C = 155$ Mbit/s.

In the first case, PCR is equal for each connection $PCR = \frac{C}{N} \times \text{const}$, where the constant is specified because of random overload of the link capacity. In this case the constant value was set to 1.85. In Fig. 2, PCR of each connection is generated, on x-axis there is index of connection and on y-axis the PCR value.

For these specified PCR values the VBR traffic was randomly generated and then the probabilities were calculated using the Gaussian approximation method. Results are graphically visualized in the following figures.

Figure 3 shows VBR traffic generated by the traffic model which was described before. On x-axis there are time values and on y-axis there is traffic generated by the traffic model, sum of bit rates of each connection in any time instant. The dotted line represents the link capacity 155 Mbit/s, the solid line the VBR traffic in time.

Figure 4 shows the probabilities computed by the Gaussian approximation method. On the x-axis there is index of each connection and on y-axis there are computed probabilities. The probability of buffer overflow is depicted with the dotted line and the probability of cell loss by the solid line. This is the resulting graph and it is possible to specify which connections should be denied by using some decision rule.

In the second case there are various values of PCR for each connection, where PCR of connection i is $PCR_i = C \times 2^{-i} \times \text{const}$, where $i = 1, \dots, N$. It means that the first connection allocates one half of link capacity, the second connection one quarter of link capacity *etc*, so the bandwidths distributed between connections are very different. The constant was specified because of random overload of the link capacity and its value was set to 1.65 in this case. In the next figure, PCR generated for each connection is shown, on x-axis there is index of connection and on y-axis the PCR value.

As in the first case, there is randomly generated VBR traffic for these specified PCR values and probabilities computed by the Gaussian approximation method. Results are graphically visualized in Figs 6 and 7.

Figure 6 shows VBR traffic generated by the traffic model. On x-axis the time values are depicted and on y-axis there is traffic generated by traffic model, sum of bit rates of each connection in any time instant. The dotted line represents the link capacity 155 Mbit/s, the solid line is the VBR traffic.

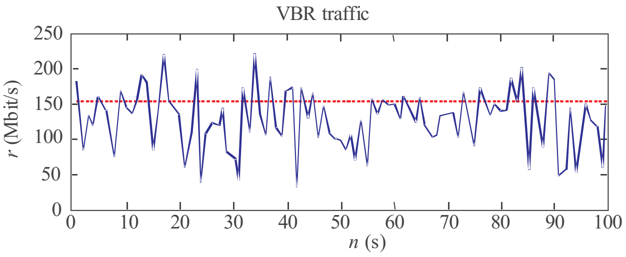

Fig. 6. VBR traffic in the second case

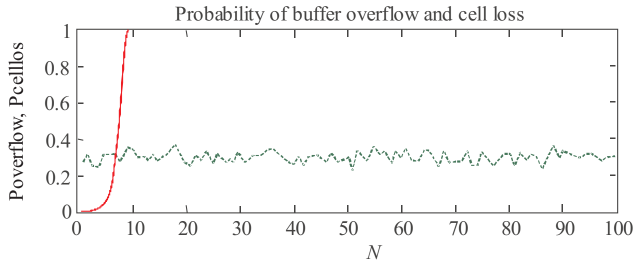

Fig. 7. VBR probabilities in the second case

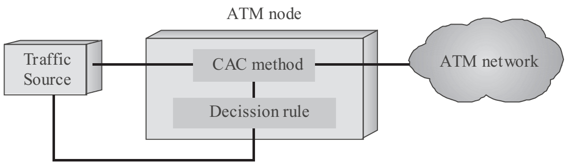

Fig. 8. Example of CAC method realization in ATM network

Figure 7 shows the probabilities computed by the Gaussian approximation method for this simulation. Index of each connection is on the x-axis and the computed probabilities are on y-axis. The probability of buffer overflow is plotted using the dotted line and the probability of cell loss is the solid line. It is possible to specify which connections should be denied by using some decision rule. It is interesting in this case to compare Fig. 4 and Fig. 7. PCR values of the first 10 connections in Fig. 4 are considerable. In Fig. 7, there is cell loss probability 1 (100 % of cell loss) for the 9th and next connections. It means that the first 8 connections allocate the full link capacity and for the next connections there is almost 100 % probability of link capacity overload.

5 CONCLUSIONS

The decision rule in this simulation experiment was described just like a hint, but in a real system a real decision rule must be implemented to decide which connection should be denied. In the next figure there is an example of CAC method realization in ATM network.

The traffic source values are input values for the implemented CAC method. The results of CAC method are input to the decision rule which by feedback control decides which connections should be denied as a protection against link capacity overload at ATM node output.

In realization of the Gaussian approximation method as CAC method in ATM node, formula (1) could be implemented as a decision rule, where ε value could be substituted with QoS parameter CLR. Generally it can be expected that the Gaussian approximation method, despite its simplicity, will fulfil the traffic control requirements only for larger sets of connections [5]. It can be seen also in our graphs that the results for a limited number of connections cannot describe the process of connection admission control with adequate accuracy.

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