CaC in ATM – the Diffuse Method

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Connection Admission Control is an element in the of preclusive mechanisms of ATM management. Its main task is to prevent overloading of the network and to ensure the required quality of service. This means that it has to predict the service of the network and according to its state it can manage both existing and new connections. This paper deals with the diffuse method, a CAC method that enables us to obtain the required results.

Keywords: ATM, QoS, CaC – the diffuse method.

1 Introduction

ATM technology arose as the basic communication code for B-ISDN worldwide broadband communication network. The ATM philosophy is based both on fast switching of very tiny cells of fixed length, and also on effective usage of bandwidth transmission. ATM enables us to realize transmissions with guaranteed quality of service for all services provided in broadband networking. If we want a setting with a large number of services to be effectively supported, we need an ATM control mechanism that will accept different quality requirements of particular services. This is called traffic management.

2 ATM traffic management

The main task of traffic management is to protect the network and end systems from overloading in such a way that efficiency goals are achieved and the given quality of services is retained. If overloading of the network occurs, the next task of traffic management is to eliminate this overloading. An additional function is to increase the effective usage of network resources. Reaction management responds to network overloading when it happens, i.e. it reduces the consequences of overloading to an acceptable level. It regulates the operative flow at the entry points on the basis of the current level of operation in the network with the help of management through feedback. Preventive management provides a fair allocation of the communication area in such way that during high load in the network it ensure that the operative flow stays within the specified range acceptable for the particular service. The chief idea of preventive management is to prevent overloading of the multiplex the entry point to the network in the process of connection building.

3 Call admission control

Call admission control is the basic function of preventive management, which is defined as the series of acts done by the network during the phase of connection building in order to define whether the connection will be accepted or refused. The operation contact is made between the customer and the network at the time of connection building, which specifies the properties of the ATM connection on the UNI and NNI interfaces, that it goes through. The network will undertake to support the operation on a given level and the customer agrees not to overrun the given efficiency parameters. Maintenance of the given QoS is important for ATM services with reference to fulfilling the operation contract. The given QoS is on to a great extent dependent on rationing the network devices, and this is what CaC determines. For CBR (Constant Bit Rate) services, for rt-VBR (real time-Variable Bit Rate) and also for nrt-VBR (non real time – Variable Bit Rate), CaC is compulsorily applied as the preventive function of traffic management. Judged on the basis of the operative parameters, PCR (Peak Cell Rate) is defined as the maximum rate of cell broadcasting for an individual ATM connection SCR (Sustainable Cell Rate) is measured over a long time period in respect of the T value, where $PCR = 1/T$ and others. ABR (Available Bit Rate) and UBR (Unspecified Bit Rate) services characteristically use abundant network devices. To secure the QoS mechanism, ABR uses feedback control as a reactive function of traffic management. UBR does not have QoS or assigned network devices secured by the network.

4 The diffuse method

The diffuse method [2] is based on two statistical formulations of the required bandwidth. In the first case, it is based on the cell loss ratio for a finite series

$$P_{FB} = \frac{1}{\sqrt{2\pi}} e^{\frac{2B(\lambda - C)}{\alpha}} * e^{-\frac{(\lambda - C)^2}{2\sigma^2}} \tag{1}$$

derived from the model of an ATM multiplexor with finite capacity. Relation (1) is based on the ratio of the line capacity overflow set by the Gaussian method

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

and on the exponential function

$$e^{-\frac{2B(\lambda - C)}{\alpha}} \tag{3}$$

which represents the usage of the capacity of buffer store B according to the of diffuse method. The time of operation of buffer store cells of fixed size has a specified constant value. In dependence on the load of the line capacity, the time of operation of the buffer store can vary. The contrast $\lambda - C$ represents the immediate average rate of cell access into the buffer store (drift), where

$$\lambda = \sum_{i=1}^{N} \lambda_i \tag{4}$$

is the central bit rate of cell access into the buffer store and C is the general line capacity (multiplexor). Parameter α determines the immediate variance of cell access into the buffer store, and is defined as

$$\alpha = \sum_{i=1}^{N} \lambda_i * c_i^2, \tag{5}$$

where

$$c_i^2 = \frac{1-\left(1-\frac{1}{R*b}\right)^2}{\left(\frac{1}{R*b}+\frac{1}{R*p}\right)^2} \tag{6}$$

is the variance coefficient of cell access (average time of active status b and average time of inactive status p).

In the second case, we deal with the application of the cell loss ratio for an infinite series

$$P_{IB} = \frac{\sigma}{\lambda\sqrt{2\pi}} e^{\frac{2B(\lambda-C)}{\alpha}} * e^{-\frac{(\lambda-C)^2}{2\sigma^2}} \tag{7}$$

derived from the ATM multiplexor model when the infinite capacity is considered. Relation (7) is determined from the account of the top cell loss ratio

$$P_{\text{loss}} = \frac{E\left[\left(\sum_{i=1}^{N} r_i(t)\right)-C\right]^+}{\lambda} \le \frac{\sigma}{\lambda\sqrt{2\pi}} e^{-\frac{(\lambda-C)^2}{2\sigma^2}}, \tag{8}$$

where $r_i(t)$ is the immediate connection bit rate $_i$ and

$$\sigma^2 = \sum_{i=1}^{N} \sigma_i^2 \tag{9}$$

is the central quadratic diversion of the bit rate. Relation (3) is also derived from the exponential function. Let ε represent the maximum accepted cell loss ratio. Consequently, two statistical formulations of the required bandwidth marked as C_{FB} and C_{IB} can be derived. C_{FB} denotes the statistical bandwidth derived from the diffuse model of a system with finite series for an ATM multiplexor. From relation (1) we obtain the quadratic equation

$$(\lambda - C)^2 - 2\delta(\lambda - C) + 2\sigma^2\omega_1 = 0, \tag{10}$$

where for the account we use artificial variables

$$\delta = \frac{2B}{\alpha}\sigma^2 \tag{11}$$

and

$$\omega_1 = \ln(\varepsilon\sqrt{2\pi}). \tag{12}$$

If $C = C_{FB}$ is valid than

$$C_{FB} = \lambda - \delta + \sqrt{\delta^2 - 2\sigma^2\omega_1}. \tag{13}$$

C_{IB} marks the statistical bandwidths gained from the diffuse model of a system with infinite series for an ATM multiplexor. In the same manner as for C_{FB} we can derive C_{IB}, during which time we start from relation (8), and we get

$$C_{IB} = \lambda - \delta + \sqrt{\delta^2 - 2\sigma^2\omega_2}, \tag{14}$$

where the artificial variable is determined

$$\omega_2 = \ln(\varepsilon\lambda\sqrt{2\pi}) - \ln(\sigma). \tag{15}$$

This formulation of two statistical bandwidths contains the usage of the cell loss ratio selected by the user, the general characteristics of the operation and also the available size of the buffer store. They also define the acceptable range for different types of connection on the basis of their operation descriptors for different types of buffer stores. The statistical bandwidth for the diffuse method C_{df}, which is needed for the particular connection, can be determined from the relation

$$C_{df} = \max(C_{FB}, C_{IB}). \tag{16}$$

5 Simulation of the diffuse method

By simulating the diffuse method we tried to ensure the required bandwidth for the connections. When simulating the CAC method we had to define the model of the ATM service for the CBR, VBR and ON/OFF service. We dealt with the case that there exist $N = 100$ independent connections in the network, and for each connection $n = 100$ values of service in time are generated in dependence on the PCR of the individual connections. The size of the line we had chosen was $C = 155$ Mbit/s. We chose a constant size of the PCR parameter for all models of service CBR, VBR and ON/OFF, according to the formula

$$PCR = k * \frac{C}{N}, \tag{17}$$

where a supply constant occurs. When simulating the CAC method it is appropriate to generate the service in the network in such a way that the link capacity is accidentally overrun and the QoS of a few connections is corrupted. The constant $k = 1.95$ is defined for this purpose. The parameter of the cell loss ratio is represented by CLR on the whole line, and we chose its value at $CLR = 1.10^{-6}$. Buffer store $B = 1$ Mbit/s.

5.1 CBR service

Fig. 1 shows the dependability of the cell loss ratio for finite series P_{FB} and for infinite series P_{IB} for the diffuse method in CBR service. Both probabilities show zero values. Because the diffuse method is derived from the Gaussian method, this caused by the central quadratic derivation the of bit rate, which at the same immediate bit rate approaches zero. Thereby dividing by zero occurs in formulae (1) and (7).

The statistical bandwidth obtained from the diffuse model with finite series C_{FB} and with infinite series C_{IB} for an ATM multiplexor in CBR service, and also the consequential bandwidth of the diffuse method C_{df}, is shown in Fig. 2. The figure shows that for individual connections N both statistical bandwidths extend with increasing connections and with equal estimated values, and therefore they are stated as the consequential bandwidth of the diffuse method C_{df}. The 97$^{\text{th}}$ connection overruns the line capacity C. In comparison with the case when for every new connection we reserved its maximal value PCR of required bandwidth C_{pcr}, the overrun of line capacity would already come by the admission of the 52$^{\text{nd}}$ connection. Here we have to take into account that the standard deviation σ is zero in CBR service. It follows that after substitution to formula 13 and 14, the bandwidths for C_{FB} and C_{IB} are determined only by the central bit rate, and therefore they are equal. In a real ATM this would cause a big derivation of delay, which cannot be accepted. For this reason the diffuse method is not appropriate for CBR service.

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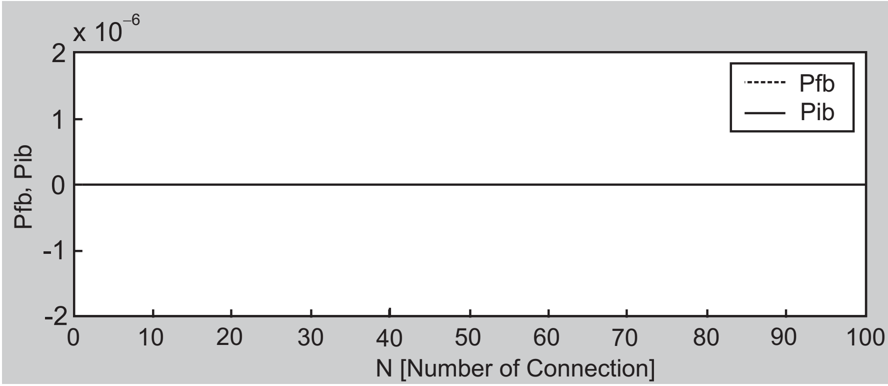

Fig. 1: The cell loss ratio for finite and infinite series of the diffuse method in CBR service for constant *PCR*

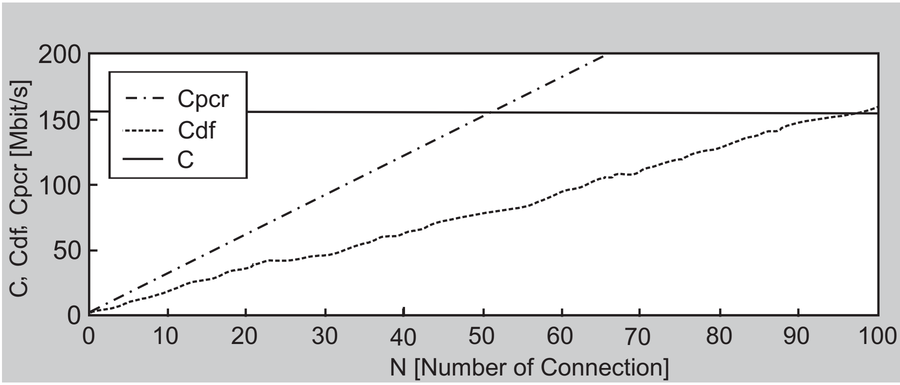

Fig. 2: The bandwidth estimated by the diffuse method in CBR service for constant *PCR*

5.2 VBR service

Fig. 3 shows the dependability of the cell loss ratio for finite series P_{FB} and for infinite series P_{IB} for the diffuse method in VBR service. In comparison with CBR service there are changes of values in both probabilities. Up to the 72nd connection, their values are about zero. After the 72nd connection both probabilities increase, which reflects the close-up of several connections in the ATM network. An overflow of line capacity occurs in the network. After the admission of the 78th connection the overflow of line capacity for finite series P_{FB} and after the admission of the 80th connection, for infinite series P_{IB} (Fig. 4) the line capacity overflows (Fig. 4). Fig. 3 shows that the line capacity overflow occurred at the set value of the cell loss ratio parameter on the lines *CLR* on $1 \cdot 10^{-6}$.

The Statistical bandwidth obtained from the diffuse model of the system with finite series C_{FB} and with infinite series C_{IB} for the ATM multiplexor in VBR service, and also the resultant bandwidth of the diffuse method C_{df}, are shown in Fig. 4.

The figure shows that for individual connections N both statistical bandwidths with increasing connections expand, during which time the estimated values with finite series C_{FB} are greater than the estimated values with infinite series C_{IB}. For this reason the C_{FB} values are stated as the resultant bandwidth of the diffuse method C_{df}. During the development of the 78th connection for C_{FB}, or let us say the 80th connection for C_{IB}, the line capacity C is overrun. In comparison with the case when, for each of the new connections, we reserved its maximum value *PCR* of required bandwidth C_{pcr}, the line capacity overrun would occur already at the admission of the

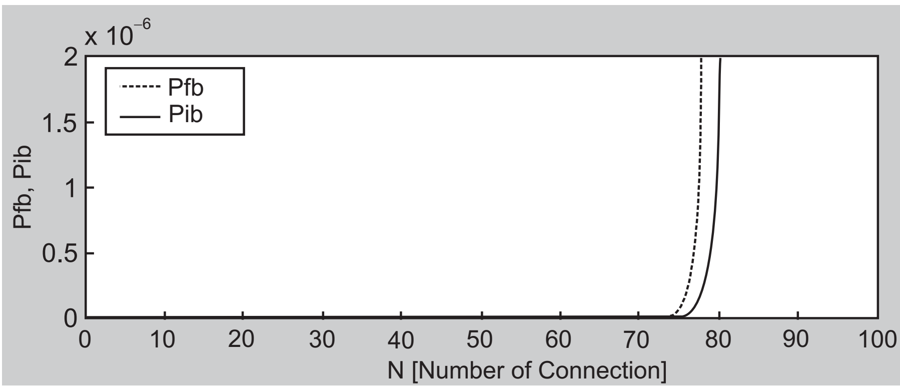

Fig. 3: The cell loss ratio for finite and infinite series of the diffuse method in VBR service for constant *PCR*

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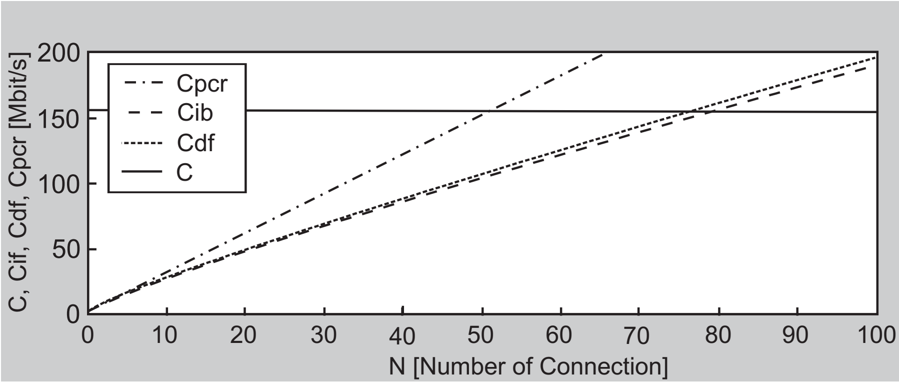

Fig. 4: The bandwidth estimated using of the diffuse method in VBR service for constant *PCR*

52nd connection. In this way we can enter more connections by using of the diffuse method. For this reason, the diffuse method is appropriate for VBR service.

We can enter more connections than are shown in Fig. 4 by using the diffuse method. We can achieve this with the use of greater buffer stores *B* in the network or, we can increase the cell loss ratio *CLR* parameter on the line.

Figs. 5 and 6 shows the influence on possible accepted connections due to changes of the buffer store capacity *B* or the parameter of cell loss ratio *CLR*. When the *CLR* parameter changes, Fig. 5 shows that, at low values of buffer store capacity *B* 0.1 till 1 Mbit/s, the number of possible accepted connections is aliasingly greater and greater with increasing *CLR*.

With a buffer store size of 10 Mbit/s we can see very similar aliasing growth and even 89 connections can enter. Fig. 6 shows changes, this time in dependence on the change of the buffer store capacity *B*. During the initial reflections it does not matter if we use a buffer store 0.01 or 0.6 Mbit/s in size, as the number of possible accepted connections is the same. Little improvement occurs at 1 Mbit/s. Sharp improvement occurs when the buffer store is over 10 Mbit/s in size. This means that if we change the buffer store size above $B = 10$ Mbit/s, the change in possible accepted connections increases linearly. For this reason we have to choose values like these when creating the layout of the ATM service. The change in the *CLR* parameter, and also the change in *B* cause sharp changes in the number of possible accepted connec-

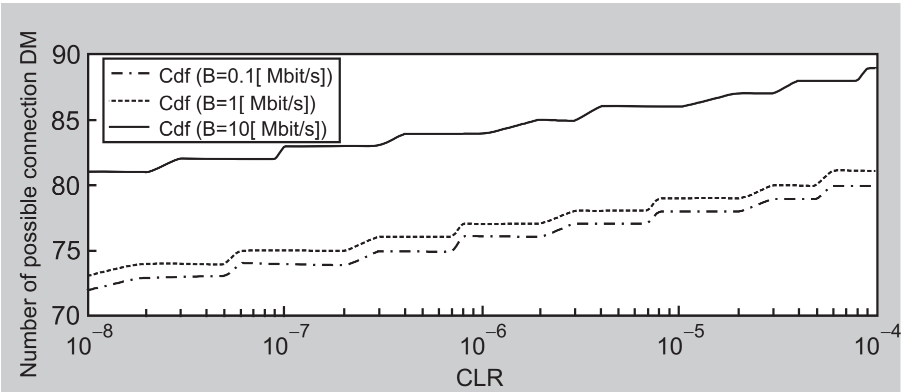

Fig. 5: The number of possible accepted connections of the diffuse method with the change of *CLR* in VBR service for constant *PCR*

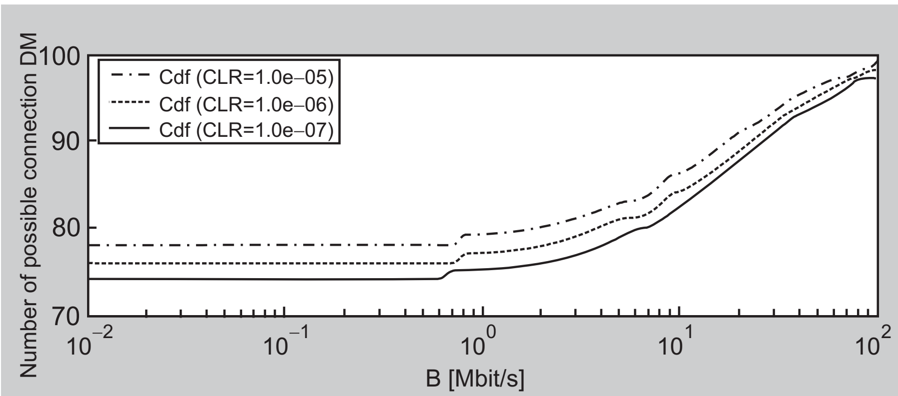

Fig. 6: The number of possible accepted connections of the diffuse method with the change of *B* in VBR service for constant *PCR*

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tions. The best combination is to use the greater possible cell loss ratio *CLR* as possible and as great buffer store size *B*. However in reality these parameters are influenced by many other factors.

5.3 ON/OFF service

Fig. 7 shows the dependability of the cell loss ratio for finite series P_{FB} and for infinite series P_{IB} for the diffuse method in ON/OFF service. Up to the 70th connection their values are about zero. After the 70th connection both probabilities increase, which reflects the entry of several connections in the ATM network. Line capacity overflow occurs in the network. After the admission of the 74th connection the line capacity overflows for the finite series P_{FB} and after the admission of the 76th connection it overflows for infinite series P_{IB} (Fig. 8) as well. Fig. 7 shows that line capacity overflow also occurred at a set value of the cell loss ratio parameter on the whole line *CLR* at $1\cdot 10^{-6}$.

The statistical bandwidth obtained from the diffuse model of the system with finite series C_{FB} and with infinite series C_{IB} for the ATM multiplexor in ON/OFF service as well as the resultant bandwidth of the diffuse method C_{df} is shown in Fig. 8.

The figure shows that for individual connections *N* both statistical bandwidths with increasing connections expand, during which time the estimated values with finite series C_{FB} are greater than the estimated values with infinite series C_{IB}. For this reasons values C_{FB} are stated as the resultant bandwidth of the diffuse method C_{df}. During the development of the 74th connection for C_{FB}, or let us say the 76th connection for C_{IB}, *the line capacity C* is overrun.

In the case when for each of the new connections we reserved its maximum value *PCR* of required bandwidth C_{pcr}, the line capacity overrun would occur already at the admission of 52nd connection. In this way we can enter more connections with the use of the diffuse method. However we have to take into account the fact that with a few entered connections bandwidth C_{FB} as well as C_{IB} is slightly greater than if we had reserved its maximum capacity C_{pcr} for the connection. This factor can be eliminated with the use of greater buffer stores *B* to allow a greater cell loss ratio *CLR* on the line. The diffuse method is also appropriate for ON/OFF service, but with the use of few connections it can be ineffective. For this reason we have to focus on the proper arrangement of the service.

Also in this case we can enter more connections than are shown in Fig. 8 when we use greater buffer stores *B*, or we can increase the cell loss ratio parameter *CLR* on the line.

Fig. 9 and 10 show the influence on possible accepted connections due to changes in buffer store capacity *B* or the cell loss ratio parameter *CLR*.

When the *CLR* parameter changes, Fig. 9 shows that at low values of buffer store capacity *B* 0.1 till 1 Mbit/s the number of possible accepted connections grows with increasing *CLR*. With a buffer store size of 10 Mbit/s we can see very similar growth and as many as 95 connections can enter. Fig. 10 shows changes, this time in dependence on the change in buffer store capacity *B*. During initial reflections it does not matter if we use a buffer store 0.01 or 0.1 Mbit/s in size, as the number of possible accepted connections is the same. A sharp improvement occurs when the size of the buffer store rises above 10 Mbit/s. This means that if we change *B* about

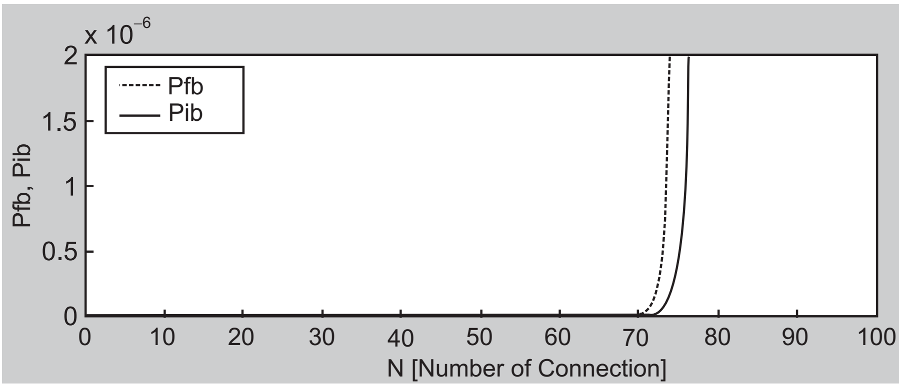

Fig. 7: The ratio of line capacity overrun for finite and infinite series of the diffuse method in ON/OFF service for constant *PCR*

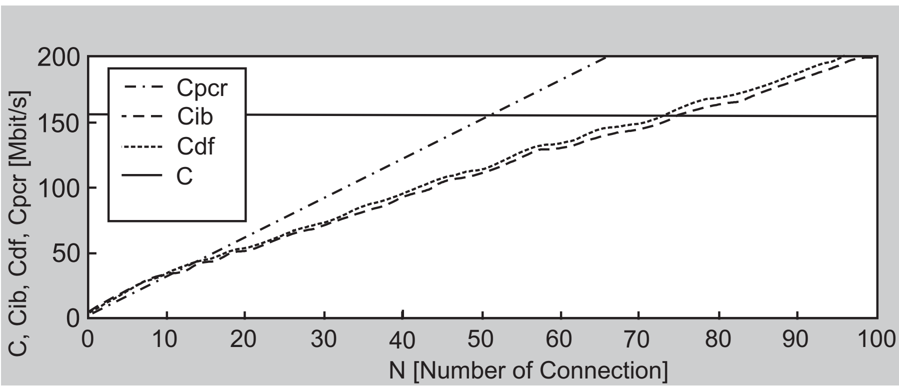

Fig. 8: The statistical bandwidth estimated using of the diffuse method in ON/OFF service for constant *PCR*

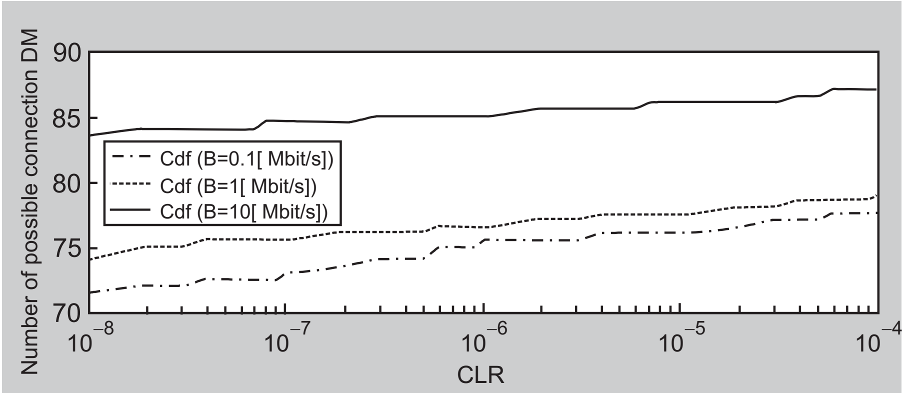

Fig. 9: The number of possible connections of the diffuse method with the change of *CLR* in ON/OFF service for constant *PCR*

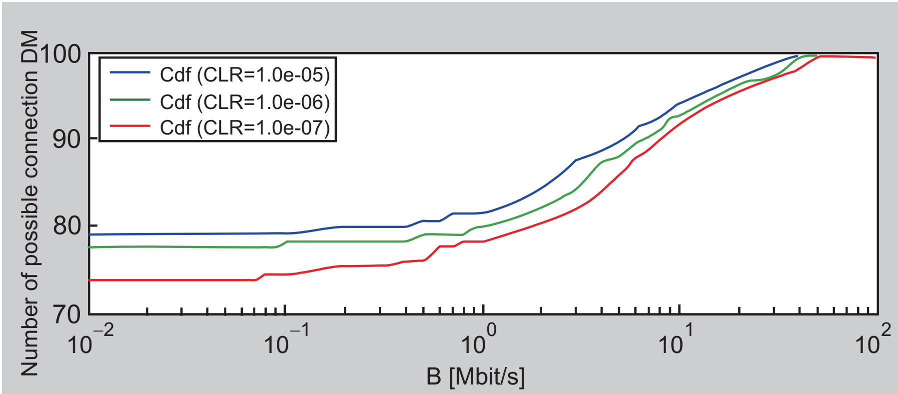

Fig. 10: The number of possible connections of the diffuse method with the change of *CLR* in ON/OFF service for constant *PCR*

10 Mbit/s, the change of possible accepted connections increases linearly. An absolute decay occurs at about 60 Mbit/s. This is why we have to choose of the buffer store values of about 10 Mbit/s when creating the layout of the ATM service. The change in the *CLR* parameter as well as the change in *B* cause sharp changes in the number of possible accepted connections. The best combination is to use the greatest possible cell loss ratio *CLR* and buffer store size *B* about 10 Mbit/s.

6 Conclusion

The diffuse method cannot be used in CBR service because the central quadratic derivation of bit rate $\sigma^2_\cdot$ approaches zero in equal immediate bit rate, i.e. dividing by zero occurs in formulae (1) and (7).

Afterwards the bandwidths for C_{FB} and C_{IB} are determined only by the central bit rate. In the real ATM service this could cause big derivation delays, which cannot be accepted.

For this reason the diffuse method is not appropriate for CBR service. In VBR and cluster ON/OFF service the method can be used effectively.

In both models of the service the results were much better than if we were to reserve for each of new connections its maximal value of *PCR*. In the diffuse method, an even greater number of connections can enter than was shown in the figures with the use of greater buffer stores *B* in the network or we can expand the cell loss ratio *CLR* parameter on the line.

In comparison with other methods, the diffuse method maintains the values of the cell loss ratio during which it is more effective during allocation of the required bandwidth. It is appropriate for homogeneous and also for heterogeneous type of service.

In comparison with classic models, the account of this method is effective. It is easily employable as a CAC algorithm.

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