Call Admission Control for ATM System using Fuzzy Control Approach

H. El-Madbouly and M. Hamdy

Abstract—**In estimating Cell Loss Probability (CLP) and mean cell delay which are often specified to be less than 10^{-9} and less than 10 μsec respectively. Fuzzy based control techniques have been introduced to be more promising over crisp statistical techniques. In this paper a novel fuzzy logic algorithm has been proposed to estimate CLP and the mean cell delay in the real time for self-similar ATM networks. The proposed fuzzy approach is validating by comparing the estimated values of CLP and delay with the theoretical values. The new approach not only estimates accurate real time CLP and delay, but also achieves it by using fewer theoretical data.**

I. Introduction

The Asynchronous Transfer Mode is considered as the appropriate transmission technology for both local and wide area broadband communication networks (B–ISDN). The most important attraction of ATM is its support for a number of different types of applications and services with widely varying degrees of traffic characteristics and performance QoS requirements. ATM requires adequate and flexible traffic control schemes to meet the QoS requirements of these services and applications. The statistical multiplexing of the traffic flows improves the utilization of the bandwidth. To guarantee a certain QoS in terms of delay, and Cell Loss Probability CLP, suitable traffic control is required. If the network has no proper policing mechanism, the access traffic random fluctuation can lead to serious congestion problem.

Effective control mechanisms are necessary to maintain a balance between the QoS and network utilization both at the time of call setup and during the progress of the calls across the ATM network. The control mechanism allocating resources and judging rejection or acceptance of the connection is usually called Call Admission Control (CAC). The control mechanism monitoring and smoothing the rate of the traffic during the call setup phase is called Policing or Usage Parameter Control (UPC). Policing is used to ensure that sources stay between the declared rate limit, thus do not affect the performance of the network. If the source does not obey its contract, the network provider may complete blocking the source or selectively dropping packets by tagging packets which will be dropped if necessary.

CAC is a sophisticated control mechanism whose specific goal is to maintain a fine balance between the two contradictory objectives of maximizing network utilization and delivery of QoS performance guarantees to connections in progress. CAC is the first control step in the provisioning of network resources to connections.

Manuscript received October 26, 2006.

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It is basically a decision algorithm which on receipt of a new connection request determines whether not to admit the connection based on the current usage of network resources. The new connection is admitted only when there are sufficient resources available to meet the QoS requirements of all the existing connections as well as new connection. While CAC should seek to maximize the number of admitted connections it must not jeopardize/ isolate the performance guarantees to existing connections. Generally the problem of the CAC lies in the limitation to acquire complete or accurate statistics of the input traffic. As result it is not easy to determine the effective resources that will be needed by the call. There is always the chance of under provisioning or over provisioning for a call. In the case of over-provisioning, the user is paying for resources he is not using and if under-provisioned he would suffer QoS loss. In this paper we propose a new fuzzy decision maker.

Over the past years significant progresses have been made in the theory [1-8] and practice of ATM CAC. However, there are still some issues remain to be resolved. Full understanding of traffic characteristics and properties which is essential in exploiting statistical multiplexing in order to maximize the utilization of ATM networks is to be made. Most of the present day CACs are based on complex queuing models and are known to have large processing demand. Alternative adaptive methods derived from Artificial Intelligence (AI) can play an important role towards the development of fast intelligent CAC. These should be able to learn from the actual traffic behavior to which they are subjected to and thus relieve the model based dependency which otherwise affects queuing or stochastic theoretical solutions. Development of a performance framework is also of paramount importance. A benchmark suite for testing of CAC performance under various trying scenarios is also required to test the robustness, flexibility, efficiency and effectiveness of CAC schemes.

In the present work, we propose a novel fuzzy logic system to predict real time CLP and mean cell delay for ATM networks at different buffer sizes. In the proposed fuzzy approach, a learning algorithm based on construct membership function of the input and output variables. All the training data required for the system are computed from the mathematical expressions derived for ATM traffic model. This fuzzy learning algorithm has a higher average classification ratio and generates fewer rules than the existing algorithms.

Section 2 deals with the Connection Admission Control and conventional Call Admission Control, section 3 deals with Fuzzy based Call Admission Control, section 4 deals with simulation results and Conclusion has been introduced in section 5.

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II. CALL ADMISSION CONTROL

The call admission control CAC mechanism is used during traffic contracting in order to decide whether a call request is to be accepted or not.

CAC procedures determine if sufficient resources are available in the network to support the requested call.

They also ensure that the performance of existing connections is not degraded by accepting the new one. If sufficient resources are not available or the acceptance of connections may endanger the QoS guarantees of the existing connections, the network rejects the call [9-10]. Conventional CAC schemes use either equivalent capacity estimation or buffer threshold method. The necessity to obtain complete detail about the traffic makes it difficult to implement these methods in real-time environment. The previously suggested methods thus force the network to take decision according to incomplete information.

A. *Requirements from a CAC Algorithm*

There are many factors that are required from a good CAC algorithm. Amongst a plethora of these factors, three important ones are mentioned below

1. Minimum Processing Complexity

ATM switch operates in real-time and requires that connection establishment and release requests be served with minimum latency. Under such circumstances, a CAC algorithm that requires lot of processing time and power may reduce the number of SVCs that can be handled by the switch.

2. Model Independence

Accurate modeling of source traffic is a nontrivial task. Thus, it is better that the CAC algorithm be model independent. Model independence here implies that the CAC algorithm should be applicable even if the model used to characterize the source behavior is altered.

3. Balance between Cell Loss and Link Utilization

Cell loss is a performance measure that concerns the user; link utilization is a factor that is important from the network's point of view. Low link utilization and greater bandwidth allocation leads to lower cell losses and vice-versa. Thus, the CAC algorithm should strive to achieve a balance between the orthogonal measures.

4. Maximum Cell Transfer Delay

The delay experienced by a cell between the instance the first bit of the cell is transmitted by the source and the instance the last bit of the cell is received by the destination. Maximum Cell Transfer delay (max CTD) and Mean Cell Transfer Delay (mean CTD) are normally used

B. *Conventional CAC*

The conventional CAC algorithm involves the use of piecewise linear functions in order to estimate the degradation in the network resources as well as the QoS of the existing connections. The algorithm utilizes the bandwidth estimation of the new call and compares with the existing bandwidth. The connection is established if the QoS parameters remain unaffected.

The algorithm may be described as follows

STEP 1: The initial values for the network parameters are got from the user.

STEP 2: The descriptor values are thereby initialized as required.

STEP 3: The parameters for a new call are accepted.

STEP 4: The bandwidth required is calculated from the input parameters.

STEP 5: Verify if the QoS parameters are satisfied.

STEP 6: Accept the call if QoS is unaffected else reject the call

C. *Limitations of Conventional CAC*

Conventional CAC suffer from some fundamental limitations like difficulty of obtaining complete statistics on input traffic to a network. Hence it is not easy to accurately determine the equivalent capacity for multimedia high-speed networks in bursty traffic flow conditions.

Besides, the conventional schemes provide optimal solution only under steady state conditions. A control scheme that dynamically regulates traffic flows according to changing network conditions requires understanding of network dynamics. The rationale and principles underlying the nature and choice of the capacity estimation are unclear. Hence networks are forced to make decisions based on incomplete information. Thus because of unpredictable statistical fluctuations of the system, these control schemes are always subject to decision errors which degrade performance.

III. FUZZY LOGIC CONTROL

The limitation faced by the conventional method is mainly due to its incapability to predict the traffic of the high-speed networks and thus adapting to it. This may be overcome by the use of a fuzzy model to predict the behavior of the traffic input. The Fig.1 shows the basic block diagram of a fuzzy operation.

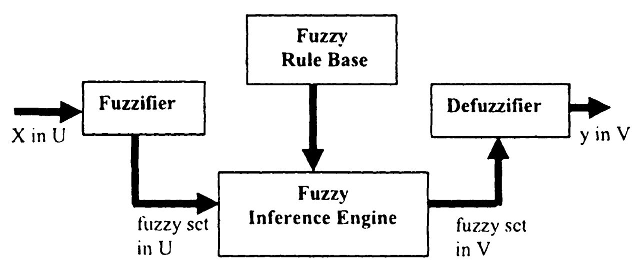


Fig. 1 The basic block diagram of a fuzzy operation.

The use of fuzzy implicates the conversion of crisp (non-fuzzy) inputs to fuzzy based inputs. The fuzzifier interface consists of the following operation [11]:

1. Compute the input variables (crisp values of inputs).
2. Perform the fuzzification strategy that converts input crisp data into suitable linguistic variable, which may be viewed as labels of fuzzy sets.

Using three linguistic variables such as: small, medium, and large to represent the fuzzy values of the inputs and output of the controller.

The fuzzy inference mechanism involves the following two functions:

1. Determine for any fuzzy inputs which rules are applicable.
2. Terminate the fuzzy outputs action by using fuzzy reasoning type Mamdani's minimum operation [12].

The defuzzifier interface consists of the following operations:

1. Defuzzification strategy that converts the fuzzy outputs action into a crisp values.
2. Perform a scale mapping that converts this crisp values form universe of discourse into suitable ranges to be applied to the CAC system

The overall fuzzy block diagram for call admission control is shown in Fig.2.

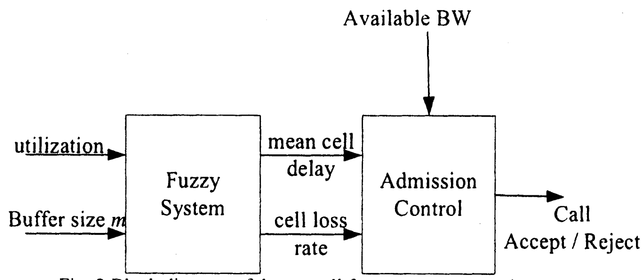


Fig. 2 Block diagram of the overall fuzzy system operation.

A. The Fuzzy Controller Rules & Membership Functions

The fuzzy control system designed for process has two inputs, utilization and the buffer size and two outputs mean cell delay and cell loss rate. It is therefore a Multi-input Multi-output (MIMO) fuzzy control system.

The range of utilization set to be [0.1, 0.9], and the buffer size range set to be [10, 100]. The fuzzy subsets of utilization and the buffer size are small, medium, and large. The Gaussian shaped is introduced to represent the membership functions of the linguistic variable as shown in Fig. 3 for utilization whereas Fig. 4 represents the membership function definitions of the buffer size.

The range of mean cell delay is restricted to be [0,100] μsec and the range of cell loss rate is restricted to be [0, 0.01].The fuzzy subsets mean cell delay and cell loss rate are small, medium, and large. The outputs membership functions are given in Fig. 5 and Fig. 6.

The dynamic behavior of a fuzzy system is characterized by a set of conditional statements, which form a set of decision rules.

If a fuzzy system has n-inputs and m-outputs, then its fuzzy rules can be of the following general format:

R_j: If X_1 is A_{1i}, AND X_2 is A_{2i} AND X_3 is A_{3i}, ..., X_n is A_{ni} THEN Y_1 is B_{1i}, AND Y_2 *is* B_{2i} AND Y_3 is B_{3i} ,..., Y_m is B_{mi}.

where Aij are the fuzzy sets of the input linguistic variable X_j, and B_{ik} is called the set of the output linguistic variable Y_k.

In the present work, we can consider $n=m=2$, then its fuzzy rules can be of the following general format:

R_j: If X_1 is A_{1i}, AND X_2 is A_{2i} THEN Y_1 is B_{1i}, AND Y_2 is B_{2i}.
($i=1,2$ and $j=1, ..,M$)

where M is the number of the rules, we assume that X_1 represent utilization, X_2 represent the buffer size, Y_1 represent mean cell delay, and Y_2 represent the cell loss rate.

The fuzzy controlled rule base is composed of nine fuzzy IF-THEN rules:

1. IF X_1 is small and X_2 is small THEN Y_1 is small and Y_2 is small
2. IF X_1 is small and X_2 is medium THEN Y_1 is small and Y_2 is small
3. IF X_1 is small and X_2 is large THEN Y_1 is small and Y_2 is small
4. IF X_1 is medium and X_2 is small THEN Y_1 is small and Y_2 is small
5. IF X_1 is medium and X_2 is medium THEN Y_1 is small and Y_2 is medium
6. IF X_1 is medium and X_2 is large THEN Y_1 is small and Y_2 is medium
7. IF X_1 is large and X_2 is small THEN Y_1 is large and Y_2 is large
8. IF X_1 is large and X_2 is medium THEN Y_1 is medium and Y_2 is large.
9. IF X_1 is large and X_2 is large THEN Y_1 is medium and Y_2 is large

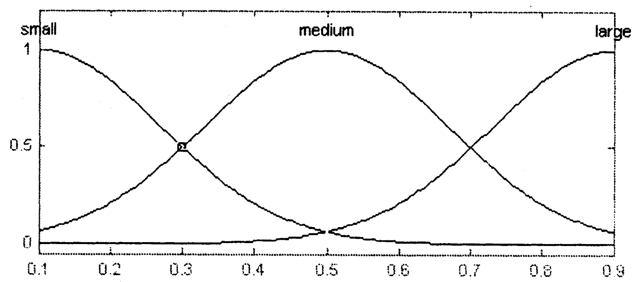


Fig. 3 Membership functions of utilization.

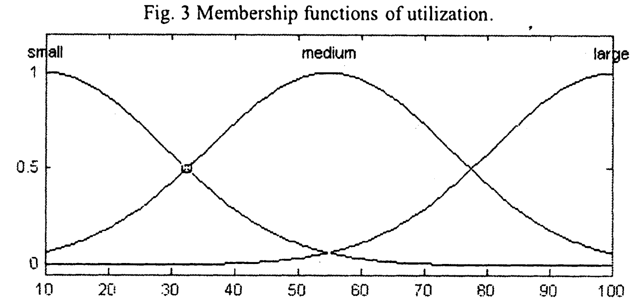


Fig. 4 Membership functions of the buffer size.

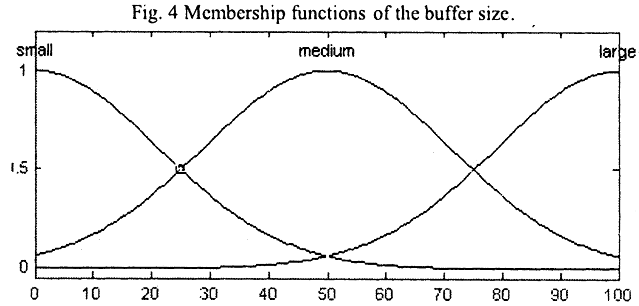


Fig. 5 Membership functions of mean cell delay.

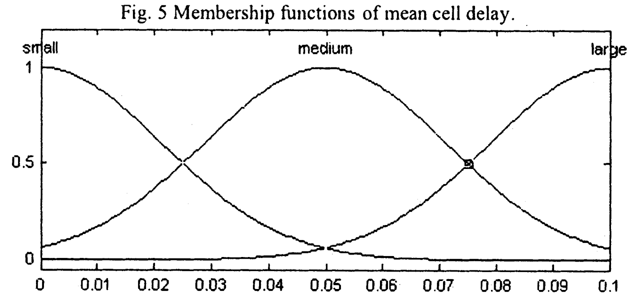


Fig. 6 Membership functions of cell loss rate.

B. Admission Control

The information regarding the bandwidth and congestion is fed into the admission control block. It then compares the bandwidth required with the available bandwidth and computes the remaining bandwidth. The available bandwidth, congestion state and the cell loss ratio together are used to decide whether to accept or reject the new call. The call is accepted if the admission controller output is greater than the acceptance threshold.

IV. NUMERICAL RESULTS AND DISCUSSION

For the self similar traffic in ATM networks considered here, the buffer size is varied for 4 to 100 and the arrival rate is varied from 0.1 to 0.9 to obtain the analytical CLP and delay values.

It is observed that is self similar traffic model, the CLP varies linearly with small buffer size, whereas at larger buffer size the CLP does not decrease significantly in the burst region. Further it is also observed that when occupancy of buffer size in the range of 32-60. There is a change in the fuzzy estimated CLP and delay values.

The fuzzy system deals with most condition of traffic including overload. The system depends on the queuing model of the ATM system. In case of the light and medium traffic load many models are proposed such as M/D/1 or M/M/1 and in case of high traffic load the MPP/D/1 model is used [13].

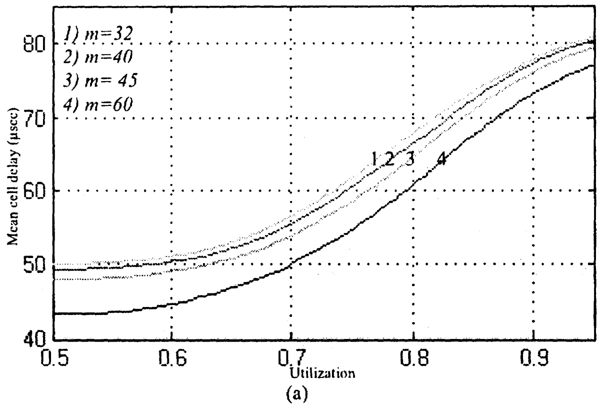
In Fig. 7 (a) shows the utilization-delay relationship, the utilization values changes from 0.5 to nearly 1 for different values of buffer size, it is cleared that the delay increases by increasing of the utilization and decreasing by increasing the buffer size and visa versa.

In Fig. 7 (b) shows the utilization-cell losses rate relationship, the utilization values changes from 0.5 to nearly 1 for different values of buffer size, it is cleared that the cell losses rate increases by increasing of the utilization and decreasing by increasing the buffer size and visa versa.

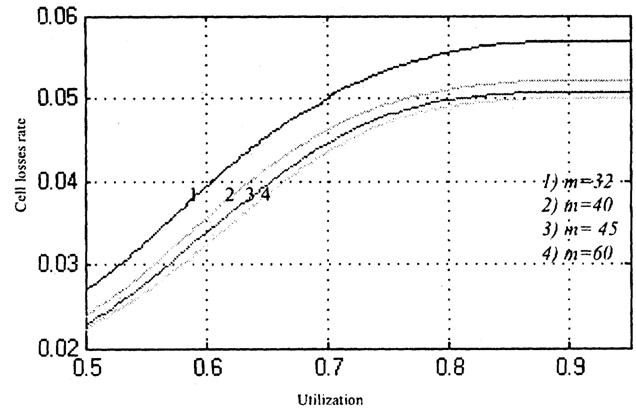
By comparing the results deduced by the fuzzy system and that by the calculation from the other systems, the proposed results show reliable and accurate results and the fuzzy system is simple, faster, and can operate accurately in online mode in the time of setup of the call.

V. CONCLUSION

In this paper, we have presented a CLP and mean cell delay prediction method for ATM networks using a novel fuzzy learning algorithm. In this work, the CLP and mean cell delay are predicted using fuzzy system based on constructing the membership functions of the fuzzy variables without any considering of the statistical type of the input traffic or queuing model of the ATM system. The membership functions and the fuzzy rules are automatically derived from expert training data. The advantages of the proposed algorithm are used to predict the CLP and mean cell delay with different buffer sizes requirement, it can be worked online, simple, more accurate in case of high traffic values.



(a)



(b)

Fig. 7 (a) Mean cell delay (b) Cell loss rate with different buffer sizes *m=32, 40, 45, and 60* respectively

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