Fuzzy Traffic Control of ATM Networks

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Abstract: - In this paper, we will use the benefits of fuzzy logic to design a high performance traffic controller of Asynchronous Transfer Mode (ATM). In the proposed fuzzy traffic controller, the actual mean cell rate of traffic source is estimated and the traffic controller is adjusted so its loss load is equal to generated excessive load. In order to improve the channel utilization, the proposed controller uses a feedback from network to decide passing, marking or discarding the input cells. Simulation results show that the proposed fuzzy traffic controller can outperform the traditional Usage Parameter Control (UPC) mechanisms. Also, the proposed controller improves the channel utilization and demonstrates a low cell loss probability.

Key-Words: - ATM networks, traffic control, fuzzy control.

1 Introduction

Asynchronous Transfer Mode (ATM) is a new technology to support wide variety of services including Constant Bit Rate (CBR), Variable Bit Rate (VBR), Unspecified Bit Rate (UBR) and Available Bit Rate (ABR). The traffic control includes traffic parameters and the requested QoS. Traffic parameters such as peak cell rate, maximum burst size and minimum cell rate are used to describe the inherent characteristics of a traffic source. At the network side, Connection Admission Control (CAC) [1-4] is responsible to describe the acceptance or rejection of the new requested connection. That is accepted if the network has enough resources and also the acceptance of new connection does not impress the QoS of existing connections. If traffic source violates from its traffic contract and generates excessive cells, then too many cells will exist in intermediate nodes and congestion may occur. When congestion happens, the number of input cells to the network increases, because of cell loss in intermediate nodes, the number of delivered cells to the destination wick decrease and the network performance will be degraded. So, in order to protect network resources from any misbehavior of traffic source, the input traffic stream must be monitored by a proper policing algorithm. This policing function is performed by UPC at the edge of network. A UPC mechanism must avoid inappropriate control actions on a traffic steam generated by well behavior sources. An ideal UPC mechanism must be capable to detect any illegal traffic situation (high selectivity) in real time (high responsiveness). Some of the most popular UPC mechanisms can be found in [5-8].

During the past years, the fuzzy control has found many applications in telecommunications networks [9-12]. A survey of recent advances in fuzzy logic in telecommunication applications including queuing, buffer management, distributed access control, load management, routing, call acceptance, policing, congestion mitigation, bandwidth allocation, channel assignment, network management and quantitative performance evaluation in networks is presented in [13]. In this work, a high performance Fuzzy Traffic Controller (FTC) for ATM networks is presented. In the proposed FTC, the excessive load of traffic source is estimated and the traffic controller is adjusted so that its loss load is equal to the generated excessive load. The proposed FTC uses a network congestion indicator to decide passing, marking or discarding the input cell. Simulation results show that the proposed FTC has better selectivity and responsiveness than traditional UPC mechanisms, e.g., Leaky Bucket (LB), Exponentially Weighed Moving Average (EVMA) and Jumping Window (JW). It is observed that the proposed FTC improves channel utilization and demonstrates low cell loss probability.

2 Fuzzy traffic controller

In this section, the proposed FTC is described. Fig. 1 shows an ATM multiplexer where a number of incoming cells are directed towards the same output link. Before entering the network, every source is forced by the proposed FTC. The basic block diagram of FTC is shown in Fig. 2. The proposed FTC consists of two fuzzy controllers, an excessive load estimator and a loss load estimator. The Fuzzy Controller 1 (FC1) monitors the input traffic steam to detect any possible violation from traffic contract. The output of FC1, V, demonstrates the violation rate of traffic source. The Fuzzy controller 2 (FC2) is responsible to decide to accept, market or discard the input cells. The FC2 is a two-input-single-output fuzzy controller with the following inputs:

- The number of cells in the multiplexer buffer, K.
- The violation rate of traffic source (the output of FC1).

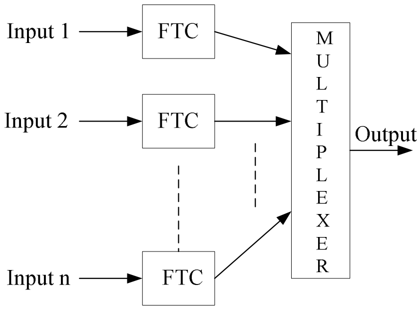

Fig. 1. An ATM multiplexer.

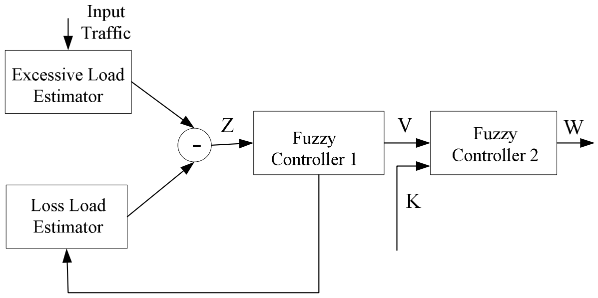

Fig. 2. Basic block diagram of the proposed FTC.

2.1 Mean cell rate estimation

Two methods are proposed to estimate the normalized actual mean cell rate σ of the traffic source. In the first method, the number of input cells in a constant time window T_o is counted. The new time window starts immediately at the end of preceding window. If N_k represents the number of input cells in the k^{th} time window, then the normalized actual mean cell rate, σ_k, is calculated by the following recursive formula

$$\hat{\sigma}_k = \frac{k-1}{k}\hat{\sigma}_{k-1} + \frac{N_k}{kT_o m_o}$$

where m_o is the negotiated mean cell rate.

In the second method, in each burst/silence period, the number of input cells in the burst phase and also the length of silence are measured. The number of input cells in the k^{th} burst and the length of k^{th} silence are represented by two random variables X_k and S_k, respectively. By using the Maximum Likelihood Estimation (MLE) method and assuming the geometric distribution for mean number of input cells in the burst phase and also experimental distribution for silence phase, the mean number of cells in the bust phase, $E(X_k)$, and the mean silence length, $E(S_k)$, are estimated by the following formula

$$E(X_k) = \frac{\sum_{i=1}^{k} X_k}{k}, E(S_k) = \frac{\sum_{i=1}^{k} S_k}{k}$$

At the end of k^{th} burst/silence period, the normalized actual mean cell rate of traffic source is determined as

$$\hat{\sigma}_k = \frac{E(X_k).\Delta.b_o}{\left(E(X_k).\Delta + E(S_k)\right)m_o}$$

where Δ, m_o are the cell inter-arrival time during a burst and the peak cell rate of traffic source, respectively.

2.2 Fuzzy Controller 1 (FC1)

An ideal UPC mechanism has a zero detection probability up to the negotiated parameter and a detection probability corresponding to the percentage of excess cells beyond the negotiation parameter point. So, the detection probability P_d of an ideal UPC mechanism can be calculated as $P_d = (\sigma - 1)/\sigma$. If the traffic source violates from its traffic descriptor, then σ will be greater than one and the source has generated an excessive load equal to $\sigma - 1$. The loss load ρ of an ideal UPC mechanism must be equal to the generated excessive load of traffic source. We define a random variable Z as $Z = \hat{\sigma} - \hat{\rho} - 1$, where $\hat{\sigma}$ and $\hat{\rho}$ are the estimated values of σ and ρ, respectively. The main responsibility of FC1 is to control the random variable Z near zero. The fuzzy conditional rules corresponding to the membership functions depicted in Fig. 3 are as follows

1. IF Z is Negative, then V is Zero.
2. IF Z is Zero, then V is Low.
3. IF Z is Positive, then V is High.

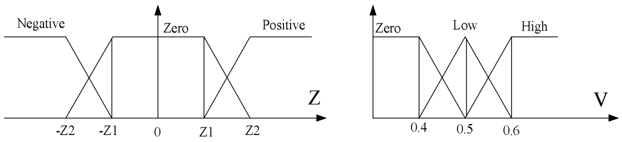

Fig. 3. the membership functions of FC1.

2.3 Fuzzy Controller 2 (FC2)

One of the most important problems of the traditional UPC is that the input cells may be discarded even if the output multiplexer link is underutilized. To remove this problem, the FC2 uses a feedback via the multiplexer buffer to improve the channel utilization. The FC2 in a two-input single-output fuzzy controller, which uses the state of multiplexer buffer and the violation rate of traffic source (the output of FC1), as two linguistic inputs. By using the knowledge stored in the rule base and according to the values of linguistic inputs, the FC2 decides to pass, mark or discard the input cells. The fuzzy conditional rules according to the membership functions showed in Fig. 4 are as follows

1. If *V* is Low and *K* is Low, then *W* is Pass.
2. If *V* is Low and *K* is Medium, then *W* is Pass.
3. If *V* is Low and *K* is High, then *W* is Mark.
4. If *V* is High and *K* is Low, then *W* is Pass.
5. If *V* is High and *K* is Medium, then *W* is Mark.
6. If *V* is High and *K* is High, then *W* is Discard.

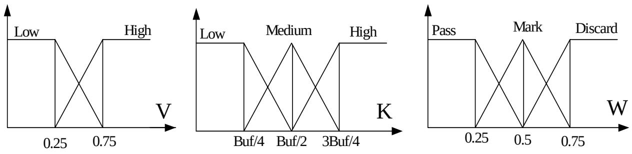

Fig. 4. The membership functions of FC2.

3 Simulation results

In this section, the performance of the proposed FTC is evaluated and compared with those of traditional UPC mechanisms including LB, JW and EWMA. Two voice traffic sources, with traffic characteristics shown in the TABLE I, are used to derive the system. The number of cells per burst has a geometric distribution with a mean of *E[x]* and the silence phase has an exponential distribution with a mean of *E[s*]. The traffic parameters are based on ADPCM with a 64 bytes information fields [14]. In both the FC1 and the FC2, the mamdani's interface method and center of gravity difuzzification technique are used [15]. An ATM multiplexer with N independent ON/OFF input voice sources is simulated. The multiplexer is modeled as a finite queue served by a single server with First-In First-Out (FIFO) service discipline. The output link of multiplexer is a T1(1.544 Mbps) pipe. We assume that the multiplexer does not add any overhead to the input cells. All simulations are carried out using MATLAB. As mentioned above, the actual mean cell rate of traffic source is estimated by two methods. For each method 1 and 2, the corresponding FTC is called Fuzzy1 and Fuzzy2, respectively. All UPC mechanisms are dimensioned to achieve a detection probability less than 10^{-6} at the nominal cell arrival rate. The time window T_o is set to 10Δ. The flexibility factor of EWMA mechanism, γ, is selected as $\gamma = 0.91$. For the traffic source 1, the values of parameters are selected as follows

$$C_{LB} = 1.2, C_{JW} = 1.77, C_{EWMA} = 1.2,$$
$$N = 1100, Z1 = 0.12(0.06), Z2 = 0.5(0.5).$$

where *N* and *C* represent the counter size and the over-dimensioning factor of UPC mechanism, respectively.

For the traffic source 2, the values of parameters are selected as

$$C_{LB} = 1.45, C_{JW} = 2.5, C_{EWMA} = 1.3,$$
$$N = 670, Z1 = 0.112(0.07), Z2 = 0.6(0.5).$$

The values of Z1 and Z2 shown in the parenthesis are the corresponding values for Fuzzy2. The selectively curves of the proposed FTC and the other traditional mechanisms for two traffic sources 1 and 2 are shown in Figs. 5-a and 5-b, respectively. As it can be seen, the proposed FTC has a detection probability which is very close to the ideal controller specially Fuzzy2. For example, when traffic source1 generates 10% excessive load, the violation probability of Fuzzy2 is improved about 3.2,2 and 1.5 order of magnitude in comparison with JB, LB and EWMA, respectively.

TABLE I Traffic characteristics of two voice sources.

Traffic characteristics			
Source	**b_o(bps)**	**m_o(bps)**	**E(X)**
1	32000	11200	22
2	64000	22000	58

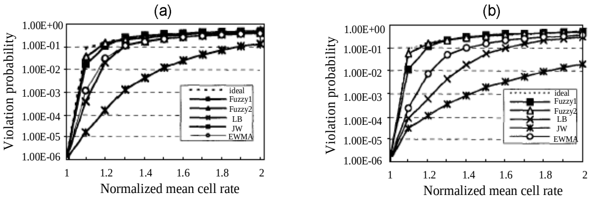

Fig. 5. (a) Selectivity curve of FC2 for traffic source 1, (b) Selectivity curve of FC2for traffic source 2.

In Fig. 6, the dynamic behavior of FTC is compared with that of LB. In this case, the traffic source 2 generates 50% overload by increasing the mean number of cells during the burst phase. In order to improve the dynamic behavior of LB, the bucket size is set to 300. as shown in Fig. 6, the proposed Fuzzy2 starts detecting violation after only 500 and its violation probability grows very fast so that after emitting 1500 cells the violation probability grows slowly.

For the FC2, the fixed threshold A and B are set to 0.3 and 0.7, respectively, in Fig. 7-a, the system cell loss of the proposed FTC is compared with that of LB and EWMA mechanisms. In this case, 40 voice sources (64 kbps) with an actual mean cell rate 50% higher than the negotiated one, have been connected to the inputs of multiplexer. This figure shows the both the Fuzzy1 and Fuzzy2 have a lower system cell loss probability than the LB and EWMA mechanisms. Fig. 7-b shows the link utilization versus the number of connected sources. The multiplexer buffer size is set to 35 cells. As shown in this figure, both the Fuzzy1 and Fuzzy2 achieve better system utilization than LB and EWMA mechanisms. It is found that for a multiplexer with 50 connected sources, the system utilization is effectively improved by 3% and 10% in comparison with LB and EWMA mechanisms, respectively.

In order to observe the efficiency of the proposed controller, the number of input sources of multiplexer is reduced to 2.5. In this case, the output link of multiplexer is always underutilized. Figs. 8-a and 8-b show the system cell loss probability and the link utilization, respectively. As it can be seen from Fig. 8-a, the system cell loss probably of both Fuzzy1 and Fuzzy2 is less than traditional UPC mechanisms. Fig. 8-b shows that for a multiplexer with 30 connected sources and a buffer size equal to 25 cells; the system utilization is effectively improved by 3% and 8% in comparison with LB and EWMA mechanisms, respectively.

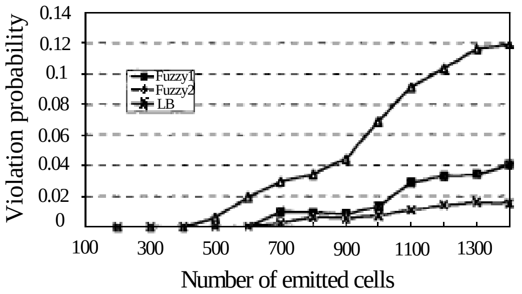

Fig. 6. Dynamic behavior of FTC and LB.

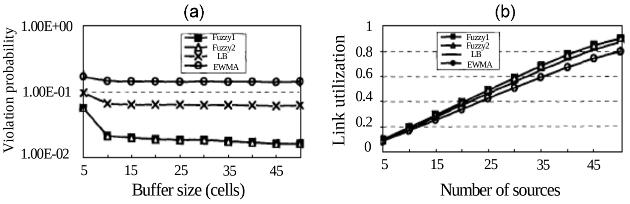

Fig. 7. (a) Cell loss probability versus buffer size, (b) Link utilization versus number of sources.

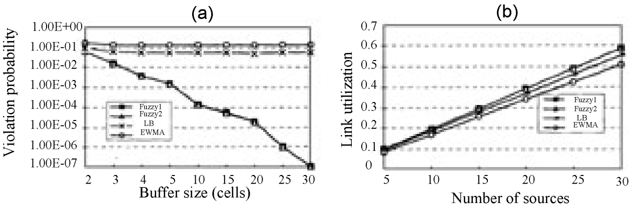

Fig. 8. (a) Cell loss probability versus buffer size, (b) Link utilization versus number of sources.

4 Conclusions

In the article, a high performance fuzzy traffic controller for ATM networks was proposed. In the proposed model, the mean cell rate of traffic sources was estimated by two different methods. The fuzzy traffic controller was adjusted in such a manner that its loss load is equal to excessive load generated by the traffic source. In order to achieve a high utilization, the proposed fuzzy traffic controller used a network congestion indicator via the state of multiplexer buffer. This network congestion feedback enables the proposed fuzzy traffic controller to decide passing, marking or discarding the input cells. The performance of the proposed model was evaluated through several simulations and compared with those of traditional UPC mechanisms including Leaky Bucket, Jumping Window and Exponentially Weighted Moving Average. Simulation results showed that the proposed fuzzy traffic controller demonstrates much better selectivity and effectiveness than the other conventional UPC mechanisms. It was also observed that the proposed model, duo to the optimum using of network resources, improved the link utilization and cell loss probability of the multiplexer.

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