A Modified Asynchronous Transfer Mode Fuzzy Policer

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ABSTRACT: A Modified Fuzzy policer for Asynchronous Transfer Mode is introduced. In a preceding fuzzy policer model the time window (time interval where ATM cells are accepted in the policer) is not synchronized with the source activity. In the proposed one, the time windows are not consecutive but are triggered by the first arriving cell. The modified policer gives good improvement to the selectivity, and minimizes the congestion over the path. This improvement can be significant for multiple channels.

KEYWORDS: Fuzzy Logic, Asynchronous Transfer Mode, Usage Parameter Control.

1. Introduction

The basic characteristics of Asynchronous Transfer Mode (ATM) networks (De Prycker, 1993) are the provision of broadband user access interfaces, packet-oriented information transfer without flow control between the user and the network, and the use of statistical multiplexing. Due to these properties, a call can, in principle, exceed the negotiated traffic parameters up to the maximum capacity of the User Network Interface (UNI) (Rathgeb, 1991).

One of the advantages of ATM compared to other networking technologies is the support of various service qualities (De Prycker, 1993). ATM layer traffic control is designed to avoid network congestion by preventative traffic management. Network congestion is a state when the network cannot meet the negotiated network performance objectives for established connections or for new connection requests. The goal of traffic control is to protect the network, and other users of the network, so that everyone receives the performance that they pay for and depend on (Hewlett-Pakard, 1995). In order to achieve a guaranteed service quality QoS, the user has to commit to a specific traffic contract during connection setup. The service provider should guarantee the parameters of this traffic contract. They will be one of the main factors a potential customer will be charged for. On the other hand, the service provider needs to control if the customer's cell stream entering the network really behaves compliant to the negotiated traffic contract. If not, the network equipment has to take appropriate measures to protect the network from intentionally or accidentally misbehaving users. These so called policing functions are well defined in the ATM and B-ISDN specifications under the category "Usage Parameter Control" (UPC) (Catania *et al.*, 1996).

This paper presents a new fuzzy policer mechanism. A full study and evaluation of the existing fuzzy policer mechanism published in (Catania *et al.*, 1996) is performed. Then a proposed modification to this fuzzy mechanism is introduced and implemented. In section one we describe the traffic source that was used in the comparison and the evaluation of the mechanisms. In section two we simulate the existing fuzzy policer mechanism, described in (Catania *et al.*, 1996) and compare the results with the published one. In section three we propose a modification to this fuzzy mechanism, which improve the performance of the policer. In section four a comparison between the Leaky bucket mechanism, the existing fuzzy policer mechanism, and the modified fuzzy policer mechanism was done through a software simulation for the three mechanisms. In the last section we concluded our results and recommended some points for further study.

2. Traffic Source Model

The two-phase burst/silence model shown in Figure 1 has been used for the comparison of the various mechanisms. This model has been used in earlier publications (Rathgeb, 1991). It allows the relevant parameters, namely maximum cell rate, mean cell rate, and mean burst duration to be varied independently of each other. The number of cells per burst is assumed to have a geometric distribution with mean E [X]; the duration of the silence phases is assumed to be distributed according to an exponential distribution with mean E [S], and the cell interarrival time during a burst is given by t_c

With

$$\alpha^{-1} = E[X] \text{ x } t_c \tag{1}$$

and

$$\beta^{-1} = E[S] \tag{2}$$

The mean cell rate λ is defined as

$$\lambda = \frac{1}{t_c + \frac{\alpha t_c}{\beta}} \tag{3}$$

3. Study of the Fuzzy Policer Mechanism (Catania *et al.*, 1996)

A software simulator using MATLAB (MATLAB, 1997) was implemented and used to validate the results for the fuzzy policer mechanism (Catania *et al.*, 1996). The Figure of merit considered is the selectivity of the mechanisms. We used the source described in the above section with the same statistical parameters as in (Catania *et al.*, 1996) in order to compare the results. Therefore we assumed a voice source with a peak bit-rate 32 Kb/s, cell inter-arrival time t_c of 12 ms, E [X] = 29 cells (mean burst duration 350 ms), and E [S] =650 ms. From equations (1), (2), and (3), taking into consideration the ATM cell size is 53 bytes, the negotiated mean cell rate $\lambda_n = 29$ cells/s.

The membership functions for the fuzzy sets are shown in Figure 2, where A_{oi}, A_i, N_i, and ΔN_{i+1} are defined as follows: A_{oi} the average number of cell arrivals per window since the start of the connection, A_i the number of cell arrivals in the ith window, the threshold N_i in the ith window indicating the current degree of tolerance the mechanism has over the source, and ΔN_{i+1} represents the variation to be made to the threshold N_i in the i+1 window (Figure 3). N is equal to the expected value of cells per window (N= T λ_n), MAX equals the maximum number of cells that can arrive in a window (T/t_c), where t_c is the cell inter-arrival time during a burst, $N_{i-max} =9N$ indicates the upper bound value for the N_i variable, and $N_1= 3.5$ N which is the value to be attributed to N_i at the beginning of the connection.

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Choosing T=3 seconds in the simulation gives, N=87 cells, MAX=250 cells, N_{i-max} = 783, N_1=300.

If P_d represents the probability that the policer mechanism detects a cell excessive, the ideal behavior would be that P_d is zero with the mean cell rate up to the nominal one, and $P_d = (\sigma - 1)/\sigma$ for $\sigma > 1$ for $\sigma > 1$, where σ is the long-term actual mean cell rate of the source normalized to the negotiated mean cell rate.

In order to obtain the curve P_d versus σ, we assume that a variation in the cell rate is due to a change in the average number of cells per burst E (X), while the average silence time is assumed to be constant (E(S)= 650 ms). Also, in order to evaluate the capabilities of the mechanisms to react to different kinds of violations, we made the mean cell rate vary by decreasing the average silence time E(S), and keeping the number of cells per burst constant (E(X)=29 cells).The chosen generated traffic source duration is about 3 minutes, which is enough for P_d to go to the steady state.

The following table1.gives the results of the simulation compared to the existing results.

Table 1: Comparison between simulation results and existing results for the fuzzy policer mechanism.

σ	Existing fuzzy policer. [E(X)const.] P_d	Simulated. fuzzy policer. [E(X) const.] P_d	Existing fuzzy pol. [E(S) const] P_d	Simulated. fuzzy pol. [E(S) const.] P_d	Ideal Behavior $(\sigma -1)/\sigma$ for $\sigma >1$ P_d
0.95	0	0	0	0	0
1.0	$<10^{-8}$	$<10^{-6}$	$<10^{-8}$	$<10^{-6}$	0
1.05	0.031090	0.022	0.033753	0.02	0.04762
1.1	0.078306	0.066	0.087029	0.087	0.09091
1.2	0.135768	0.13	0.155668	0.154	0.16667
1.3	0.18623	0.185	0.211353	0.206	0.2307
1.4	0.248756	0.239	0.278909	0.26	0.2857
1.5	0.283214	0.278	0.310451	0.31	0.3333
1.6	0.327301	0.321	0.342940	0.338	0.375
1.7	0.372404	0.372	0.378184	0.375	0.4117
1.8	0.418008	0.41	0.411373	0.407	0.44444
1.9	0.457541	0.445	0.444393	0.435	0.47368
2.0	0.492144	0.4855	0.476444	0.47	0.50

Figure 1. Two-phase burst/silence source model.

Membership functions for the A_{0i} and A_i input

Membership functions for the N_i input variable

Membership functions for the ΔN_{i+1} output variable

Figure 2: Membership functions for the existing fuzzy policer mechanism.
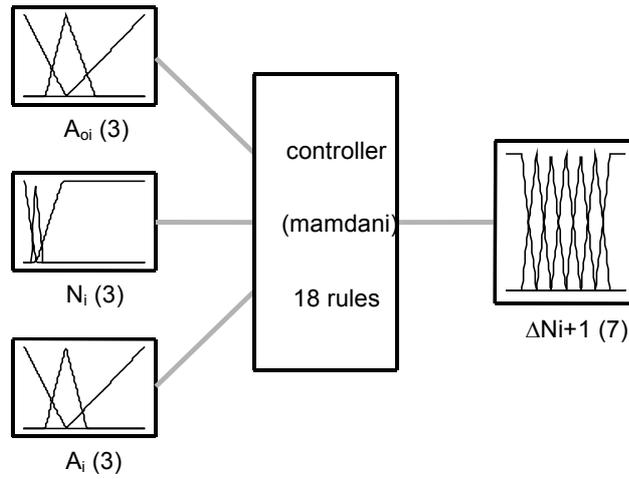
Figure 3. System controller: 3 inputs, 1 output.
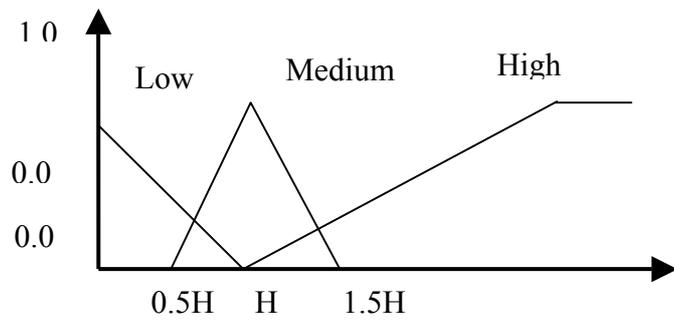
Membership functions for the A_{0i} and A_i input variables
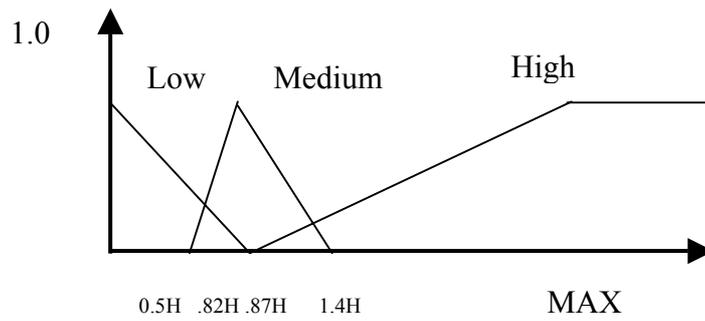
Membership functions for the N_i input variable
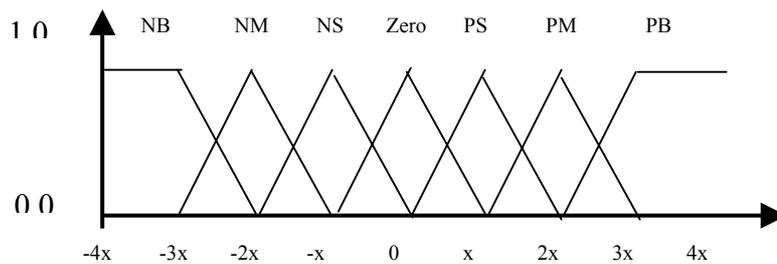
Membership functions for the ΔN_{i+1} output variable (x= H/22)

Figure 4. Membership functions for the modified fuzzy policer mechanism.

It is clear from the above table that the simulation results almost coincide with the published ones for the same traffic source model. This validates the simulated mechanism and the existing results. Since our simulation is justified so we can compare these results with the results from other policer such as the one proposed in the next section.

4. Modified Fuzzy Policer Model

In the preceding fuzzy policer model the time window is not synchronized with the source activity. In the proposed fuzzy policer mechanism the time windows are not consecutive but are triggered by the first arriving cell.

Table 2: The simulation results for E(s) constant.

σ	Leaky Bucket C=1.42 [E(S) constant] P_d	Existing fuzzy policer [E(S) constant] P_d	Modified fuzzy policer [E(S)constant] P_d	Ideal behavior $(\sigma -1)/ \sigma$ for $\sigma >1$ P_d
0.95	0	0	0	0
1.0	0	$<10^{-6}$	$<10^{-6}$	0
1.05	0	0.02	0.03	0.04762
1.1	0	0.087	0.085	0.0909
1.2	0	0.154	0.155	0.166666
1.3	0	0.206	0.212	0.2307
1.4	0.01	0.26	0.265	0.2857
1.5	0.045	0.31	0.325	0.3333
1.6	0.1	0.338	0.369	0.375
1.7	0.1552	0.375	0.408	0.4117
1.8	0.2017	0.407	0.435	0.44444
1.9	0.2472	0.435	0.469	0.47368
2.0	0.28	0.47	0.495	0.50

We used the same input and output for the fuzzy controller. The membership functions chosen for the fuzzy sets of this modified controller was obtained through trial and error until it reached a level of performance considered to be adequate as shown in Figure 5.4. *H* represents the average number of cells arrival per trigger window for an ideal source, MAX is the maximum number of cells that can arrive in a window *(T/t_c)*, $N_{i\text{-}max}$ is equal to *9H* ,and the value for the beginning of the connection is $H_1 = 3.5 H$.

5. Performance Evaluation

In this section, we compare the performance of the three mechanisms [Leaky Bucket, existing fuzzy policer, and the modified fuzzy policer]. The Figure of merit considered is the selectivity of the mechanisms. To assess the performance of the three mechanisms a simulator is implemented using MATLAB to generate the traffic source and evaluate the three mechanisms. The traffic source model used here is the same as the one used in section 3, whose statistical parameters are those typical to a real packetized source. Considering a peak bit-rate of 32 Kb/s and a cell interarrival time t_c of 12 ms the traffic parameters are typically E [X] = 29 cells (mean burst duration 350 ms) and E [S] =650 ms.

It is worth pointing out that for this kind of source, traditional policing methods proved to be inefficient. To achieve a low false alarm probability, it is necessary to have either a high value for the counter limit, N, which means a poor dynamic response, or a high value for the over dimensioning factor C>2, which reduces the capability to detect a violation.

For the Leaky Bucket N=45, C=1.42 where N is the counter limit and C is a over dimensioning factor (Catania *et al*., 1996).
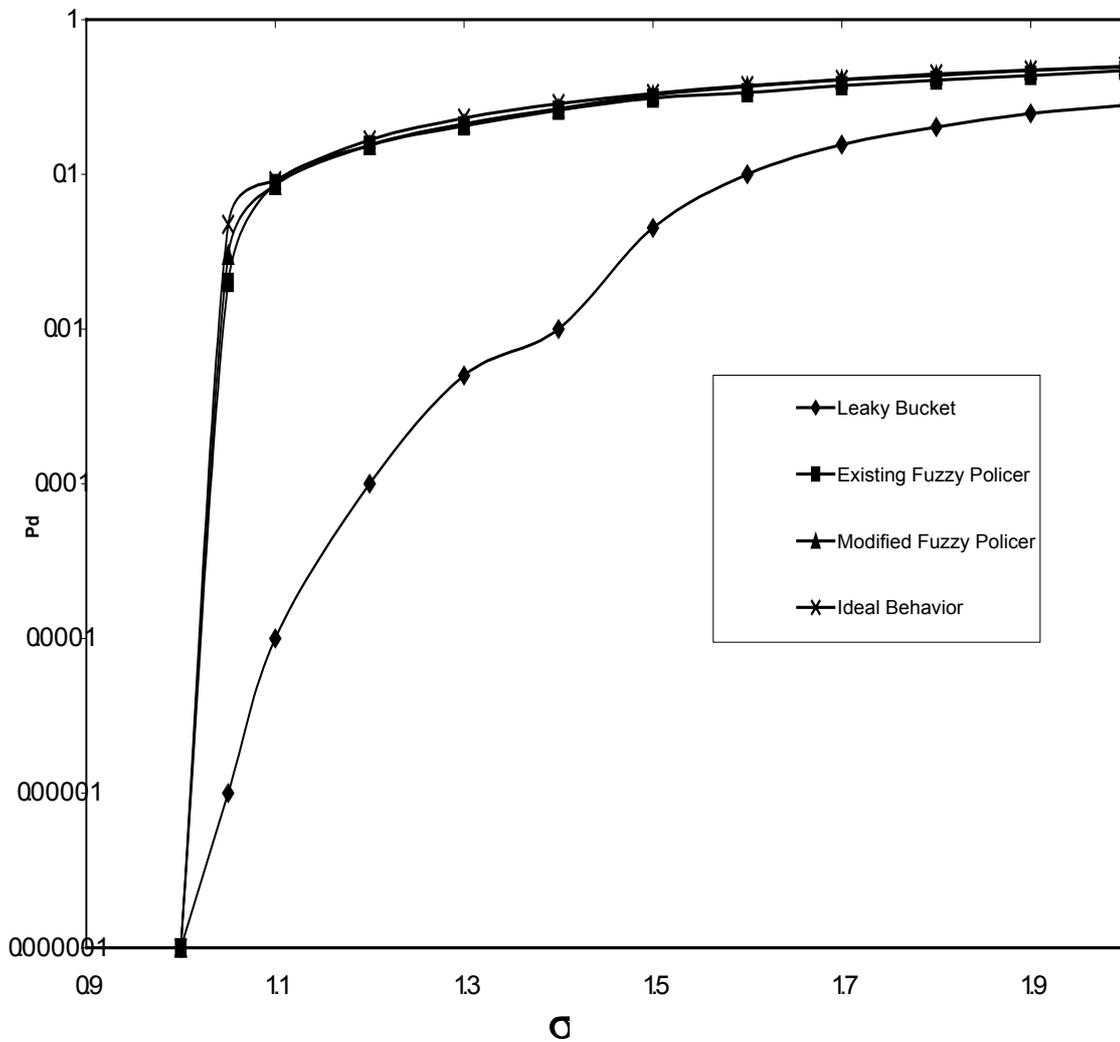
Figure 5. Selectivity for a packetized voice source E(S) constant.

For the fuzzy policer mechanism we choose a window size T=3 s (about three burst/silence) so N=87 cells and N_1 = 300 (Catania *et al.*, 1996).

For the modified policer mechanism a window size of T=4 s (about four burst/silence) showed a better performance compared to the existing mechanism , this gives H=129 cells and H_1 = 400.

Table 3: The simulation results for E(X) constant.

σ	Leaky Bucket C=1.42 E(x) constant P_d	Existing fuzzy policer [E(x) constant] P_d	Modified fuzzy policer [E(x) constant] P_d	Ideal behavior $(\sigma -1)/ \sigma$ for >1 P_d
0.95	0	0	0	0
1.0	0	$<10^{-6}$	$<10^{-6}$	0
1.05	0	0.022	0.015	0.04762
1.1	0	0.066	0.055	0.0909
1.2	0	0.13	0.12	0.166666
1.3	0	0.185	0.182	0.2307
1.4	0.005	0.239	0.221	0.2857
1.5	0.037	0.278	0.2783	0.3333
1.6	0.095	0.321	0.333	0.375
1.7	0.155	0.372	0.392	0.4117
1.8	0.18	0.41	0.426	0.44444
1.9	0.245	0.445	0.46	0.47368
2.0	0.3	0.4855	0.4995	0.50

As discussed in section 3, in order to obtain the curve P_d versus σ, we assume that a variation in the cell rate is due to a change in the average number of cells per burst E (X), while the average silence E(S)=650ms time is assumed to be constant. It is shown from Figure 5, which compares the selectivity performance versus cell rate variation for the three mechanism, that the modified fuzzy Policer and the existing fuzzy Policer give an improvement for P_d compared to the Leaky Bucket in table 2.

From the numerical values we can conclude that the modified fuzzy mechanism give an improvement to P_d for σ greater than 1.5 as compared to the existing fuzzy mechanism.

In order to evaluate the capabilities of the mechanisms to react to different kinds of violations, we made the mean cell rate vary by decreasing the average silence time E(S), and keeping the number of cells per burst constant (E(X)=29 cells).

As expected, the modified fuzzy policer and the existing fuzzy policer give an improvement for P_d compared to the leaky bucket mechanism (Figure 6). From table 3, the modified fuzzy policer gives an improvement to P_d for σ greater than 1.5 as compared to the Fuzzy Mechanism.
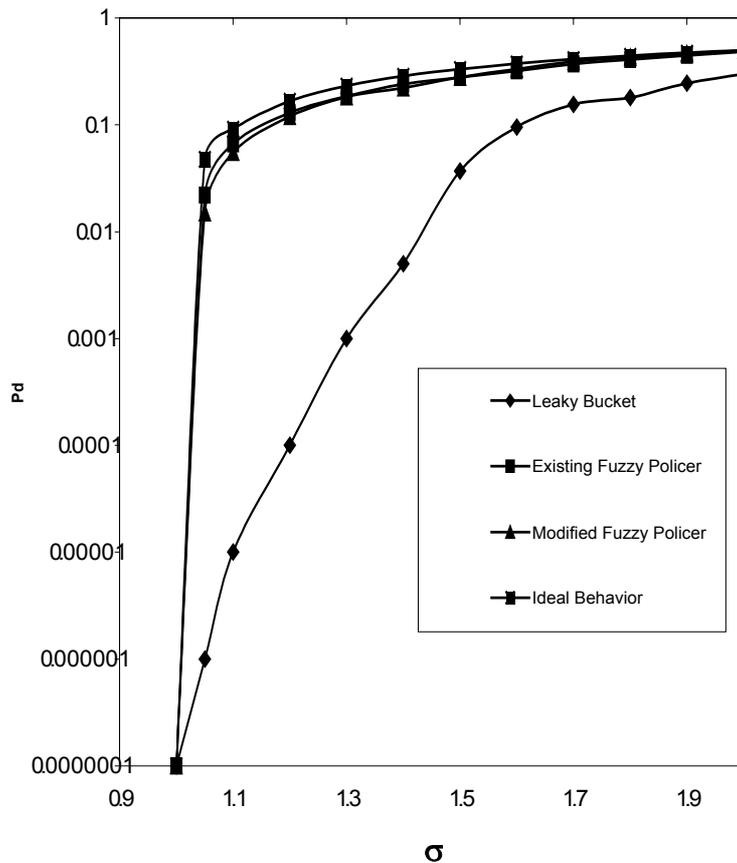
Figure 6. Selectivity performance for a packetized voice source E(X) constant.

6. Conclusions

We can conclude from the given results that in general the intelligent mechanisms give a good improvement to the selectivity over traditional mechanisms, and the proposed modifications to the existing fuzzy policer give an improvement to the selectivity for value of σ greater than 1.5 which in turn minimize the congestion over the path. This improvement can be significant for multiple channels.

Also, an important conclusion is that the number of windows processed by the modified fuzzy policer mechanism is reduced by a factor of 2/3 compared to the existing fuzzy policer mechanism for the same source and the same duration of the connection. This in turn leads to a reduction in the processor time.

We recommend the following points for further study. First optimization of the membership function for a given traffic model. Second using the modified fuzzy policer mechanism to test different traffic sources, such as video on demand, and adjust the needed variations in the membership functions.

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