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ATM Traffic Shaper with Neural Control

ABSTRACT

In this paper, a new traffic shaping mechanism for congestion control in ATM network, is studied. Performance measures such as the burstiness reduction factor and the mean cell waiting time of the proposed shaper are discussed. In this current exploratory stage of the study, the shaper is used to shape the different mixes of multimedia traffic as well as self-similar LAN-LAN traffic.

INTRODUCTION

Various frameworks have been proposed for the ATM traffic control, but it is not easy to build an efficient traffic control system because of the diversity of multimedia bursty traffic characteristics. Bursty traffic is inevitable in ATM networks and is known to have adverse effect on network performance [1-2]. There is no universal measure of burstiness [3]. It is sometimes measured by the ratio of peak bit rate to average bit rate [2]. It is sometimes characterized by the average burst length [2]. It can also be measured by the cell jitter ratio which is the variance-to-mean ratio of the cell interarrival times [3]. Other definitions are done by [4].

Shapers or cells spacers have been proposed as a means to reduce the burstiness of a bursty traffic. The idea in shaping a bursty traffic is basically to buffer the incoming traffic and output them at a lower rate, i.e., to have the traffic smoothed.

In this paper, the framework of shaping function is described as an example of neural-network-based control scheme for mobile ATM networks. The rest of the paper is organized as follows. Section 2 describes the traffic shaper with neural control. Section 3 gives informations about some additional functions of the proposed shaper. Section 4 presents simulation results, and Section 5 summarises the paper.

THE TRAFFIC SHAPER WITH NEURAL CONTROL

The traffic shaper proposed in this paper is aiming at substantially reducing both burstiness and the buffer requirement. The basic concept is to send the cell into the network with a rate which is the function of the occupancy of the shaping buffer. In order to prevent cell loss, the cell departure rate is set equal to the peak cell input rate when the shaping buffer becomes full. That is, the normalized cell output rate l follows

$$\lambda = f(B) \qquad (1)$$

where l is the ratio of the cell departure rate to the peak cell arrival rate, *B* is the normalized buffer occupancy i.e. ratio of the actual buffer occupancy to the shaper buffer size, and *f* is some (may be nonlinear) function.

Figure 1 illustrates the block scheme of proposed implementation of traffic shaper with neural control

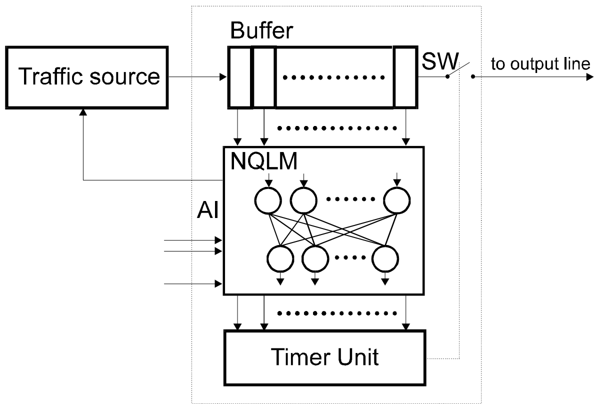

Figure 1. Block scheme of neural shaper

As shown in Figure 1, the proposed shaper consists of an input buffer, *Neural Queue Length Monitor (NQLM)* and a interdeparture time controller. According to (1), the cell departure rate from the shaper depends on the input buffer occupancy. The buffer occupancy is monitored by NQLM which has one input neuron per each buffer location. Everytime a cell arrives at the buffer or a cell leaves the buffer, the output state of NQLM is changed according to the desired characteristic (1) which is implemented in the neural network training phase. The inter-cell time interval is computed by neural network and set in the output lines which controls the *Timer Unit* (TU). TU is the functional element which automatically counts time and in the appropriate instant opens the output of the shaper. In this moment, the cell is passed through the closed *Switch* (SW) and quiets the system.

Special purpose group of the NQLM's input lines is signed in the Figure 1 as the *Additional Information lines* (AI). These lines are used by the *Traffic Management Function* to control the cell flow among the classes of traffic controlled by *Binary Feedback Schemes*. In the proposed system the state of AI lines reflects the actual traffic situation in the neighbouring switching node.

NQLM neural network are backpropagation neural networks. In simulation experiments several neural networks were implemented using the California Scientific Software *BrainMaker*. The training tolerance, additive noise present during training, and the network learning rate were varied. A 3% tolerance was found to produce a good compromise between decision accuracy and the ability of the network to converge during training. The learning rate and momentum term were fixed to 0.3 and 0.7, respectively. The example results are given below:

- For a 256 neurons in the input layer and 8 hidden neurons, after 3800 lessons, all states of the buffer were classified accurately. The learning process took about 15 min. using the TMS 320C25/20MHz- based accelerator card.
- For a 1024 neurons in the input layer and 10 hidden neurons, the learning process took about 2 hours on the accelerator.
- For a 4096 neurons in the input layer and 12 hidden neurons, the learning process took about 9 hours on the accelerator.

The time-domain results of the training phase would be significantly improved in future by applying the most powerful, i860-based accelerator.

ADDITIONAL FUNCTIONS OF SHAPER UNIT

The ATM protocol was developed to perform in environments with very low bit error rates, on the order of 10^{-9}. Also ATM was intended to be used in high speed communications, with very low delay (and low CDV) characteristics. In contrast, the battlefield environment is comprised of relatively low-speed communication links. Moreover, because mobile communication equipment is made to perform in hostile environment, much of the equipment has built-in error correction and other special processing features that further reduce the real data. In results, the neural shaper proposed in the paper has built-in additional functions which can improve the utilization of the tactical network resources. These additional, useful function are as follows:

- nonlinear throughput characteristics which can be used accordingly to the actual traffic situation in tactical ATM system;
- possibility to take cell dropping action at the frame level (the term "frame" refers to the AAL protocol data unit).

Both presented above functions are proposed under assumption that shaper unit will be connected to the *generic ATM switching node* without possibility to take any sophisticated actions when congestion occurs in rest of the system.

Non-linear throughput characteristics

As mentioned earlier, the neural network implemented in NQLM is used as a compact nonlinear throughput curve generator. Figure 2 illustrates the characteristics used in experiments.

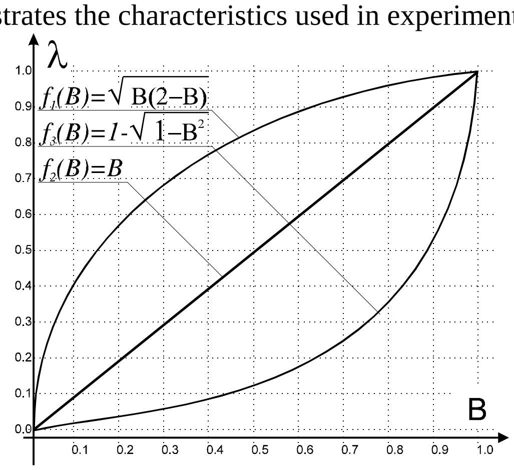

Figure 2. Output-rate characteristics used in experiments

The f_1 characteristic is foreseen for this situation when the buffers in neighbouring node are empty and as consequence data served in *best effort* mode may be transmitted with high rate.

The linear function f_2 is used in normal traffic situations. In this case equality (1) can be rewritten simply as l = B.

Last characteristic (f_3) is strongly restrictive. They is useful when congestion occur in neighbouring node. In this case transmission of ABR traffic is stopped by shaper which additionally increases the time interval between consecutive cells from real-time classes of traffic.

The front dropping scheme

There is the possibility that congestion may occur in buffer of the shaper. Congestion state is detected by NQLM and first signalised by the set in the active level appropriate output line which is connected to the traffic source (voice codec or MPEG codec for example) in the subscriber's terminal. At this way NQLM throttles the output rate of the traffic source at the appropriate level. Next, when the buffers come to overflow the NQLM takes dropping action at the cell level or frame level.

Cell dropping is one mechanism used to relieve congestion in ATM networks. The *Congestion Control* (CC) function is implemented in the buffered elements of the system to discard "violation tagged" cells in the face of network congestion, corresponding to traffic that exceeds the negotiated traffic parameters. In the classic ATM systems, the CAC, CC and UPC mechanisms are sufficient to avoid congestion, but in mobile systems the following unpredictable factors may occur:

- the capacity of some radio links may temporarily decrease or these links may be blocked by enemy jamming;
- due to traffic situation changes, high volume of traffic may be suddenly generated by high level priority sources.

In a multimedia ATM system, if a network element needs to discard cells from the overflowed buffer, it is in many cases more effective to discard at the frame level rather than at the cell level. The proposed implementation of shaper detects the frame boundaries by examining the SDU-type in the payload type field of the ATM cell header. In our simulation experiments the frame discarding model has been compared to the cell discarding model. In Figure 3, the average waiting times for different discarding models are presented.

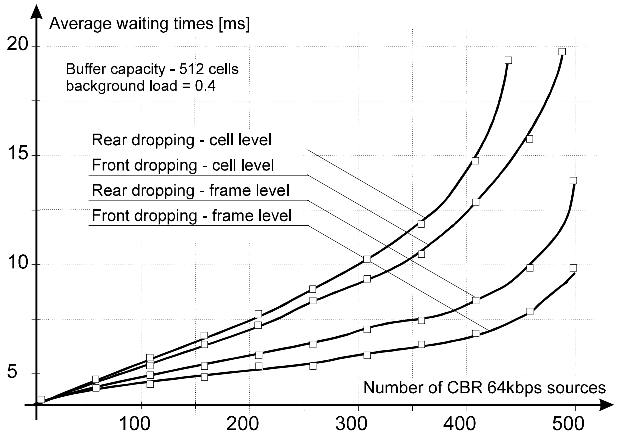

Figure 3. Average waiting times

Plots from Figure 3 show that the average waiting time of cells dropped from the front of the queue is much longer than that of those not discarded. This statement is true for both the cell and frame dropping methods. The plots illustrate that front dropping effectively discards long delayed cells and frames from the queue.

SIMULATION RESULTS

The former definitions of burstiness proposed by different researchers are relatively easy to handle mathematically, but it may not be accurate enough and sometimes misleading. The reason is quite simple that different traffic may have the same burstiness but with significantly different characteristic. The latter reflect reality better but may not be easy to obtain since the output departure process should be characterized before the output burstiness can be obtained. In our work we use a new definition of burstiness proposed first by [6]. In this definition the burstiness b may be written as follows

$$\beta = \frac{VAR[cell\_rate(t)]}{E^2[cell\_rate(t)]} \qquad (5)$$

The performances of the proposed shaper architecture have been checked in terms of the *Burstiness Reduction Factor (BRF)* which we define as

$$BRF = \frac{\beta_i}{\beta_o} \qquad (6)$$

where b_i is the burstiness of the input traffic and b_o is the burstiness of the output traffic respectively.

.In simulation experiments ABR background traffic $r_{ABR} = 0.3$ as well as CBR background traffic $r_{CBR} = 0.25$ has been used to obtain a close reality experiment environment.

The traffic under test consists of a number of MPEG2 2 Mbps streams (VBR) The MPEG data used in experiments was collected from the standard reference files *dino*, *lambs* and *race* from *Bellcore* ftp server. In each of the following experiments, the behaviour of the proposed shaper was examined for f_1, f_2 *and* f_3 throughput functions which are depicted in Figure 2.

Figure 4 illustrates the input burstiness b_i and the output burstiness b_o vs. number of MPEG 2 Mb/s sources in system under study.

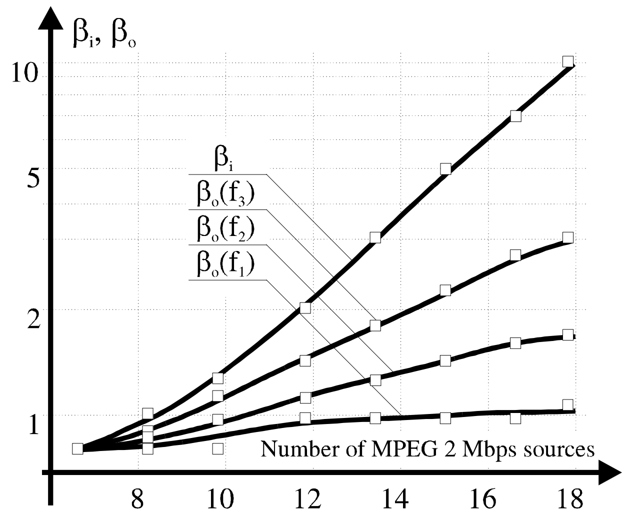

Figure 4. b_i and b_o vs. number of MPEG sources

As depicted in Figure 4, the dependency of the burstiness on the number of MPEG sources increases. One interesting phenomenon is that the $b_o(f_1)$ vs. offered load may be tread as stable.

CONCLUSIONS

A neural implementation of traffic shaper for mobile ATM networks, is proposed in this paper. The shaper is easy to implement since only simple components are required. Analysis of the burstiness reduction factor and CDV parameter is conducted among main traffic classes using the files from working ATM networks.

The proposed output-rate characteristics of the shaper with neural control minimizes an overall cost function of storage the ATM cells in the buffer. The simplicity and fast running time of proposed shaper unit make the solution a good candidate for efficient practical implementation

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