ATP: A NOVEL ADAPTIVE THRESHOLD-BASED BUFFER MANAGEMENT POLICY FOR ATM ACCESS NODES

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I INTRODUCTION

Asynchronous Transfer Mode (ATM) technology with its advanced quality of service (QoS) capabilities has been deployed worldwide as an infrastructure for backbone networks. With the tremendous growth of the Internet, followed by emerging of applications that require various types of QoS guarantees, it seems important to network operators to integrate Internet protocols and the mature ATM QoS technology.

The most widely used ATM QoS framework is described in the ATM Forum’s Traffic Management Specification [1]. This framework defines six service categories and a set of parameters for each one to describe both the traffic submitted to the network, and the QoS which is required of the network. A set of traffic and congestion control functions is also specified, including connection admission control (CAC), usage parameter control (UPC), traffic shaping, frame discard, etc.

For the Internet QoS architectures, two major frameworks have been established: (1) Integrated Services (IntServ) [2], based on a per-flow approach and (2) Differentiated Services (DiffServ) [3], which is a per-class based approach.

In QoS-enabled access network devices, the three principal mechanisms for resource control should be applied: (1) traffic regulation, (2) buffer management and (3) packet scheduling [4]. Buffer management is a fundamental mechanism for providing QoS under the bursty traffic. The most common classification of buffer management policies in shared-memory packet switches, for both switch and port levels, includes threshold based and push-out schemes [4, 5].

In this paper, considering the port level, we have proposed a novel buffer management scheme - Adaptive Threshold Policy (ATP). We have compared ATP with the well-known Static Threshold Policy (STP) by computer simulation method. Both policies use per-VC queuing with per-VC accounting in order to achieve QoS guarantees. Simulation has been conducted assuming a realistic model of an access IP-over-ATM device.

II TRAFFIC MANAGEMENT MODEL

We consider a scenario in which IP traffic is converted to ATM cells stream within the Interworking Function (IWF) entity, which also performs mapping of the IP to ATM traffic descriptors. Traffic control is further related with the generated ATM traffic. A model of the traffic management at the IP-over-ATM access node (see Fig. 1) is adopted considering [3-4] and [6]. We assume N independent IP flows, described by the traffic specification $T_{Spec_i} (1 \leq i \leq N)$, [7]. $T_{Spec_i}$ is expressed by token bucket parameters (a depth $b_i$ and a bucket rate $r_i$), a peak rate $p_i$, a minimum policed unit $m_i$, and a maximum policed unit $M_i$. The rates $p_i$ and $r_i$ are measured in bytes per seconds, while the values $m_i$, $M_i$ and $b_i$ are measured in bytes. Although our analysis deals with a single IP service class, the model can be extended to support different QoS classes.

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Figure 1. A traffic management model

A. Interworking Scenario

IntServ-over-ATM—The IWF entity is responsible for establishing an ATM virtual connection (VC) for each IP flow and computing traffic descriptors for that VC, based on the parameters of the IP flow. IWF entity generates a cell stream and forwards it to the ATM traffic policing entity. We assume that each IP flow requires guaranteed service (GS) class, which is mapped to real-time variable bit rate (rt-VBR) ATM service category. All generated cells should have CLP bit set to “0”, because of GS class requirements [8].

DiffServ-over-ATM—The IP Packet Classifier/Marker entity identifies packet flows according to specific policy rules, allocates packets to the appropriate traffic class and marks them according to the predefined class assignment. Each QoS profiled packet should be forwarded to the IWF entity. DiffServ Assured Forwarding (AF) [9], which supports traffic bursts by queuing mechanism, should be suitable for mapping to ATM VBR services.

B. ATM Traffic Control at the Access Node

The call admission control (CAC) entity is responsible for configuring the traffic policing, buffer management and scheduling entities during each call set-up, according to the negotiated QoS and traffic parameters.

The traffic policing entity allows conforming cells to pass to the next stage, while violating cells are either discarded or tagged by the use of cell loss priority (CLP) bit, causing tagged cells to be discarded when the network is congested.

The buffer management entity decides about cells accepted or dropped.

The scheduler allocates bandwidth between VCs. In order to allow guaranteed bandwidth for several VCs that share the...
III BUFFER MANAGEMENT POLICIES

We consider that the overall memory space, shared between N VCs, equals B cells. The input to a buffer is a cell stream from the traffic policer, that is, a superposition of CLP=0 and CLP=1 streams. Per-VC thresholds and per-VC accounting should be applied for CLP=0 cells because of QoS requirements, while for CLP=1 cells, a common threshold should be used. Although we are dealing with tagging and dropping at the cell level, all presented concepts may be easily extended with any of the well-known packet discard mechanisms.

A. Static Threshold Policy: STP Algorithm

Static Threshold Policy (STP) assumes existing of N separate per-VC static thresholds T1, T2, ..., TN, indicating criterions for CLP=0 cells discarding on individual VCs. Per-VC accounting is performed by means of a set of variables Q1(t), Q2(t), ..., QN(t), denoting the number of CLP=0 cells stored for individual VCs, at the instant t. The common static threshold L denotes the overall buffer occupancy level which triggers discarding of arriving CLP=1 cells. A global variable Qtot(t) represents current total number of cells (CLP=0+1) stored for all VCs.

The principal advantage of STP is a low implementation complexity, while its main drawback is the inflexibility to adapt to variable traffic conditions.

B. A Novel Adaptive Threshold Policy: ATP Algorithm

We suggest a novel method, namely Adaptive Threshold Policy (ATP), in which per-VC thresholds for CLP=0 cells, T1(t), T2(t), ..., TN(t), and the common threshold L(t) for CLP=1 cells may vary as a function of time t, depending on the current per-VC buffer occupancies, Q1(t), Q2(t), ..., QN(t), and the overall buffer occupancy Qtot(t). The objective is to achieve an optimal and fair buffer allocation under the various traffic loads. The adaptive threshold for the VCi, Tt(t), should be calculated from the following expression:

\[ T_i(t) = T_i(0) * \theta_i(t), \]

where T(0) is the constant initial threshold assigned to a VC, \( \theta_i(t) \) denotes a dynamic scaling factor for that VC, \( \theta_i(t) \) should be determined from the current buffer load \( Q_{tot}(t) \) and the current number of CLP=0 cells \( Q(t) \), stored for VCi:

\[ \theta_i(t) = \begin{cases} \frac{Q(t)}{Q_{tot}(t)}, & Q_{tot}(t) \neq 0 \text{ and } Q(t) \neq Q_{tot}(t) \\ 1, & Q_{tot}(t) = 0 \text{ or } Q(t) = Q_{tot}(t) \end{cases} \]

Since 0<\( \theta_i(t) \leq 1 \), for i=1,2, ..., N, dynamic factors determine relative partitioning of the available buffer space between individual VCs, pertinent to the initial threshold \( T_i(0) \). Thresholds are further reduced in accordance with the relative current per-VC buffer load. If there is only one active flow, i.e., \( Q_i(t) = Q_{tot}(t) \), it is allowed to accommodate the burst up to \( T_i(0) \).

The common adaptive CLP=1 threshold \( L(t) \) should linearly depend on the normalized current free buffer space:

\[ L(t) = L(0) * \Delta B(t) / B = L(0) * [B - Q_{tot}(t)] / B, \]

where \( L(0) \) is the initial common threshold value, at the moment t=0. An improved throughput of CLP=1 cells should be provided under the lighter loads of CLP=0 cells, while keeping CLP=0 cells QoS guarantees, under the heavy load.

An important feature of ATP is that it does not introduce any significant additional implementation complexity, in comparison with STP. Considering relations (1)-(3), it is sufficient to compute only one threshold, related to the submitted cell, at the cell arrival instant.

C. Determining of Optimal Thresholds

In order to accommodate traffic bursts and to accomplish rate guarantees, the amount of the reserved buffer space should correspond to the maximum burst size for CLP=0 cells, MBS0i, allowed by the traffic policer for the VCi. The scheduling entity is primarily responsible for achieving delay guarantees [10].

STP— Static per-VC threshold \( T_i \), should be set according to MBS0i, with some reserve for CDVT. Assuming the worst case with N simultaneously active and bursty flows, the overall buffer size should be \( B \geq \sum_{i=1}^{N} T_i \). Such complete partitioning approach may lead to underutilization of the buffer most of time, especially if N is large. For that reason, the sum of individual thresholds is usually set larger than the buffer size B. However, if the values of \( T_i \) are too high, several bursty flows may occupy the whole buffer. Low values of \( T_i \) may cause unnecessary losses, e.g., when a very few flows are bursty.

The choice of the common threshold L for CLP=1 cells should depend on the possibilities to meet QoS requirements for CLP=0 cells, that is, the ratio B/MBS0i and B/N. However, under the variable traffic load conditions, this may lead either to violating of CLP=0 cells transmission or to underutilization of the available buffer space for CLP=1 cells accommodation.

ATP — In this case, considering relations (1) and (2), the value of the initial per-VC threshold \( T(0) \), for i=1,2,..., N, should exceed MBS0i. The value of \( T(0) \) should be chosen with regards to the ratio B/MBS0i and taking into account number of flows N. A choice of high \( T(0) \) may lead to a fast exhaustion of the overall buffer space, and consequently, to unfairness between individual VCs. If \( T(0) \) is too low, this may lead to fast reducing of the adaptive threshold \( T_i(t) \), and, consequently, to unnecessary cells discarding.

Similar findings stand for L(0): high L(0) may increase delay and cell drop probability of CLP=0 cells, while the choice of low L(0) may lead to unnecessary loss of CLP=1 cells.

IV SIMULATION AND RESULTS

A. Simulation Model

We assume the IntServ-over-ATM interworking scenario. The event driven simulation method is applied and implemented as a sequential simulator, called Event Processor.

Traffic Sources — IP traffic sources are modeled by means of “on-off” model with “on” and “off” time duration distributed according to Bounded Pareto (BP) [11]. BP is a variation of the Pareto distribution, which is widely used for describing of self-similar processes. BP is characterized by the three parameters: the exponent of the power law, \( \alpha \), and the smallest and the largest values of random variable, \( k \) and \( p \), respectively. The probability mass function for the BP \( k, p, \alpha \) is:
IP packets are generated only during the “on” periods, with exponentially distributed interarrival times and packet lengths. IP to ATM conversion takes place at some internal rate (PR). ATM cells belonging to one packet are spaced by the fixed time interval, depending on the PR and the pre-allocated bandwidth.

Traffic Policing — The ATM Forum’s conformance definition VBR.3 [1] is applied, because of the cell tagging option. It encompasses the two consecutive GCRA (generic cell rate algorithm) policers. First of them, GCRA (1/PCR, CDVT), defines cell delay variation tolerance (CDVT) in relation to the peak cell rate (PCR) of the aggregate CLP=0+1 stream. Second GCRA (1/SCR, BT portion of bandwidth has been allocated to each flow, i.e., the 1500 bytes, 100 bytes and 3000 bytes, respectively. The same p=10. Mean, minimum and maximum IP packet sizes are probability.

The choice of simulation parameters was a compromise between the demand to simulate realistic situations and the need to obtain measurable cell loss probabilities with reliable confidence intervals during a reasonable simulation time. For different sets of parameters, the quotient B/MBSk (with respect to number of VCs) is a basic measure for cell drop probability.

A 10Mbits shared bandwidth has been assumed in all cases. BP distribution parameters are: $\alpha_{ON}=0.9$, $\alpha_{OFF}=1.5$, $k=1$ and $p=10$. Mean, minimum and maximum IP packet sizes are 1500 bytes, 100 bytes and 3000 bytes, respectively. The same portion of bandwidth has been allocated to each flow, i.e., the same weights have been assumed for all queues. Besides, we assume that ATM part does not introduce any jitter (CDVT=0).

In the first scenario, we have assumed 10 identical sources with the following TSpec: $p=250$kBps, $r=100$kBps and $b=30$kB. With the selected parameters, mean ATM burst size equals $MBS_{B0}=630$ cells. Per-VC processing rate equals 2Mbits, while the server utilization factor $r_i$ (the ratio of the arrival and server rate) equals 0.95. With the selected parameters no cells tagging occurs at the VBR.3 policer. Simulation results are obtained for various buffer size B. For STP, simulation has confirmed previous results [1], [5], in the sense of optimal behavior with per-VC thresholds set to the allowed burst size (MBSk). Fig. 2. represents mean per-VC cell drop probability of conforming cells for ATP, as a function of the initial adaptive per-VC threshold normalized to $MBS_{B0}$.

![Figure 2. CLP=0 cell drop probability as a function of the normalized initial per-VC threshold for ATP with various B.](image)

From this scenario, we can conclude the following: (1) it is possible to find optimal $T_i$ for STP and $T_i(0)$ for ATP, except for the very small buffer and (2) both policies with properly chosen thresholds, demonstrate a similar behavior.

Next, we assume that N/2 sources are conforming, with moderate traffic loads (utilization factor $r_i=0.5$). The other N/2 sources are not controlled by the policer, with $r_i$ varying in the range {0.5, 10.0}. Fig. 3. depicts average per-VC CLP=0 drop probabilities of conforming flows as a function of the $T_i$ and $T_i(0)$, normalized to $MBS_{B0}$, with B=2700 cells and N=10.

![Figure 3.](image)

For STP, different optimal $T_i$ were obtained for different loads of non-conforming flows. Optimal $T_i(0)$ for ATP were obtained in the range from 1.7*MBS_{B0} to 2.1*MBS_{B0}, for all utilization factors $r_i$. This result corresponds to one obtained in the first scenario, with $r_i=0.95$. For a given $r_i$, lower cell drop probabilities were obtained with ATP than with STP.
Finally, we consider N uniform traffic sources, but nonconforming to the second policer, GCRA (1/SCR, BT + CDVT), thus generating a portion of tagged cells. The following parameters were assumed: B=2700 cells, N=10 and \( r_i=0.95 \). Various percentages of tagged cells were simulated by varying token bucket rate and depth parameters \( r_i \) and \( b_i \), thus keeping the overall amount of generated cells approximately constant. For STP, \( T=\text{MBS}_{0i} \) was assumed, while for ATP, \( T(0)=2^{*}\text{MBS}_{0i} \) was assumed. Fig. 4. depicts mean per-VC CLP=0 and CLP=1 cell drop probabilities, as a function of the portion of tagged cells, for various L and L(0). STP with the highest threshold (0.9B) shows the best performance for CLP=1 cells, but at the expense of CLP=0 cell drop probability. STP with the lowest threshold (0.3B) shows good performance for CLP=0 cells, but the worst one for CLP=1 cells.

ATP with L(0)=0.7B behaves similarly as STP with L=0.5B for CLP=1 cells, but with better performance for CLP=0 cells, because of earlier discarding of CLP=1 cells for larger \( Q_{c}(t) \). ATP with L(0)=0.9B provides an acceptable level of CLP=0 cells dropping and a good performance for CLP=1 cells. From this scenario, we can conclude that the choice of L and L(0) should be a compromise between the QoS requirements and a potential to improve throughput of low priority level cells. Again, ATP with its adaptive capabilities should be a better solution to meet the aforementioned objectives.

V CONCLUSION

In this paper, a novel buffer management scheme, ATP, based on adaptive thresholds, has been proposed and compared with the well-known static policy, STP. The simulation analysis has been relied on the traffic management model at an IP-over-ATM access node.

The simulation study has confirmed that, with properly chosen thresholds, both policies behave similarly under the nominal traffic loads. However, unlike STP, it is possible to determine optimal per-VC thresholds for the suggested ATP scheme, depending on: (1) the ratio of the overall buffer size and the maximum negotiated burst size for the particular VC, and (2) the maximum number of VCs that should provide service guarantees. Besides, ATP is superior in comparison with STP, under the different and variable loads of the independent VCs.

Tuning of the initial threshold for CLP=1 cells should be a compromise between meeting the QoS requirements for transmission of CLP=0 cells and a potential to improve the throughput of CLP=1 cells.

REFERENCES


Sadržaj: U radu je predložen novi metod za upravljanje baferima (ATP) u ATM pristupnim vodoravima, zasnovan na adaptivnim pragovima. Ra-unarskom simulacijom, pretpostavljaju realističan “IP-over-ATM” model, ispitane su performanse ovog metoda i uporedene sa metodom zasnovanim na statičkim pragovima (STP). Rezultati simulacije pokazuju da ATP omogućava određivanje optimalnih pragova i pokazuje bolje performanse od STP u uslovima različito dobraopterećenja.

ATP: NOVI METOD ZA UPRAVLJANJE BAFERIMA U ATM PRISTUPNIM VOROVIMA, Stojanović M., Petrović Z., Željković N.