A New Queue Control Function Family to support Differentiated Services over ABR

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Abstract-- *A new queue control function family adopted in the Simple ER Identification Congestion Avoidance (SERICA) scheme, already used for the regulation of the ABR traffic flow in an ATM network, is derived and discussed. The resulting algorithm, called SERICA_ω, monitors both the load and buffer occupancy on each link and determines the load and the buffer occupancy rate factors, the available capacity, and the number of currently active virtual channels. The optimization parameters used are adjusted automatically, and thus, various quantities are determined on the switch. The new queue control function family improves the original SERICA scheme in the approximation of the ER field of the BRM cell, which will be sent by the switch to explicitly advise the sources about the rates at which they should transmit. Extended simulations on a simple network configuration showed that the achieved throughput is greater than 79% of the initially generated cells at the source and that the queuing delay is minimized. As it appears, the SERICA_ω algorithm succeeds on its purpose that is to increase throughput, preserving the queue threshold of the switch buffer at about O(*$\tau\sqrt[\omega]{PCR}$ *).*

Index Terms—SERICA_*ω* algorithm, SERICA algorithm, ERICA algorithm, TCP over ATM, ABR.

I. Introduction

As it is well known, among all the ATM service schemes, only the ABR service is able to guarantee for an adjusted to a feedback, end-to-end, flow control algorithm. This characteristic makes ABR appropriate for the TCP, which is a connection-oriented protocol, using an end-to-end, adjusted to a feedback window based mechanism. However, today's challenge is to support integrated Internet based applications, known as Differentiated Services over the ABR service and therefore a problem arises due to the unpredictable feature of the ABR traffic. Note that in order to serve all kind of traffic, the network administrator has to guarantee that the maximum Cell Transfer Delay (max*CTD*) and the deterministic part of the traffic flow, namely the Sustainable Cell Rate (*SCR*), are taking some predefined values. This last property gives rise for the Differentiated Services environment to be supported as a continuous scaling of the different Types of Services (ToS) through the extended ABR service and the extended ABR traffic descriptor set of parameters (Mousadis & Tsiligirides, 2002). The above framework requires a suitable flow control mechanism to auto-adjust the service rate fluctuations of the switches, and thus, to operate safely with almost 100% utilization, like the floater control valve. This controller should provide a globally stable feedback mechanism, which uses a queuing delay threshold in order to prevent buffer overflows.

The ATM Forum has adopted the Explicit Rate (ER) based scheme to control the ABR service. Feedback is carried via the Resource Management (RM) cells, in the Forward (FRM cells) and in the Backward (BRM cells) direction. To avoid congestion the hop-by-hop strategy has been proposed, which is used in conjunction with the Virtual Source / Virtual Destination (VS/VD) property (ATM Forum, 1996). According to the VD requests, the ER field (ERF) of the BRM cell is used in order to control the VS emission rate. An interesting ER-based scheme, which is also stable, is the ERICA algorithm (Kalyanamaran, 1997; Kalyanamaran et.al., 2002).

The stability of the ERICA algorithm is obtained by simulation using some artificial parameters, in order to ensure target utilization with a predetermined bandwidth level. ERICA and its extension ERICA+ algorithms are suited to provide max-min fairness with Minimum Cell Rate (MCR) criterion. Nevertheless, these algorithms are not able to guarantee for a specific Sustainable Cell Rate (*SCR*), and thus, they cannot support the extended ABR service. The queue control function $f(q(t_n))$, or simply $f(q)$, introduced in the ERICA and the ERICA+ schemes calculates the desirable *ERF* value of the BRM cell taking into account the level of the buffer occupancy (or, the queuing delay), at the VD. Nevertheless, the SERICA, a recently introduced algorithm achieves a stable focus equilibrium point, in O(1) calculations (Mousadis, 2001; Mousadis & Tsiligirides, 2002). SERICA is simply the SERICA_1 algorithm, i.e., the SERICA_ω when ω=1. It optimizes some auto-adjusted parameters and it is able to guarantee for a specific *SCR*, in accordance with the resources available in the network. The VS may accept more than one BRM cells, presiding better its emission rate, according to the finally arrived information of congestion. SERICA algorithm establishes a connection with a queue length of $O(\tau * PCR)$ in each buffer, whereas its extension, the SERICA_ω algorithm, establishes a connection with a queue length of $O(\tau\sqrt[\omega]{PCR})$ (Mousadis et.al., 2002). In addition, the queue control function $f\_\omega(t_n)$, or simply f_ω, of the SERICA_ω algorithm attempts to produce the most throughput, by leading the set of the VS-VD (the hop) in some predetermined levels of VS emission rates and VD buffer occupancies, whereas the queue control function *f(q)* of the ERICA/ERICA+ algorithms cannot determine a priori the average queuing delay during the connection negotiations. The key point of this work is to derive a new family of queue control functions f_ω, using the SERICA_ω scheme as a basis. In steady state, and for ω=1, 2 this function achieves throughput nearly 100%, whereas in the non-steady state the achieved throughput does not drop from 79%. Finally, one of the main benefits of using the function f_2 is that when the network administrator accepts a new session the allocation of the memory per switch is less than O(*PCR*), something which increases the network operability.

The organization of this paper is as follows. Section II presents in brief the new queuing control function family. Section III presents some interesting numerical and simulation results. Finally, the conclusions are presented in Section IV.

II. The new queue control functions family

The core of the ERICA and ERICA+ algorithms is the queue control function $f(q(t_n))$, which is based on the relation $ERF(t_n) = f(q(t_n)) * ACR(t_n)$ (Kalyanamaran, 1997). This assumption is extended (Mousadis & Tsiligirides, 2002) and the new function $f(t_n)$ is derived as follows:

$$ERF\left(t_n\right) = f\left(q\left(t_n\right), q_{st}, MACR\left(t_n\right), ACR\left(t_n\right)\right) * ACR\left(t_n\right) = f\left(t_n\right) * ACR\left(t_n\right), \qquad (1)$$

or, $f\left(t_n\right) = ERF\left(t_n\right) / ACR\left(t_n\right)$

The worst case of traffic assumes that the source is able to transmit at the requested rate i.e., $ERF(t_n) = MACR(t_{n+1})$. The above function is included in the SERICA (or SERICA_1) algorithm and generally, one may derive the following analytical form of the control function $f\_\omega(t_n)$ for the SERICA_ω algorithm (Mousadis et.al., 2002).

$$f\_\omega(t_n) = z(t_n) + h \begin{cases} T_0, & \text{if } q\text{pr} = 0 \wedge MACR(t_n) < ACR(t_n) \\ T_0 - \dfrac{z(t_n)-1}{\tau}, & \text{if } q\text{pr} = 0 \wedge MACR(t_n) \geq ACR(t_n) \\ \left[T_0 - T\text{pr}_n^{\omega}\right] - \dfrac{z(t_n)-1}{\tau}, & \text{if } \begin{cases} 0 < q\text{pr} < q\max, \text{ or} \\ q\text{pr} = q\max \wedge MACR(t_n) \leq ACR(t_n) \end{cases} \\ \left[T_0 - T\max^{\omega}\right], & \text{if } q\text{pr} = q\max \wedge MACR(t_n) > ACR(t_n) \end{cases} \quad (2)$$

In the above, T_0 is the target queuing delay, $z(t_n) = MACR(t_n)/ACR(t_n)$ is the load factor and $T\text{pr}_n = q(t_n)/ACR(t_n) + (z(t_n)\text{-}1)h/\tau$ is an estimation for the queuing delay of the next time instant t_{n+1}; $t_{n+1} = t_n + h$. In addition $T\max = q\max(t_n)/ACR(t_n)$ is the maximum queuing delay. In the extended ABR this queuing delay may be approximated by the difference max*CTD* – FRTT (*FRTT* is the Fixed Round Trip Time), whereas in the non-extended ABR is approximated by the parameter *CDVT*.

As it appears, starting with an initial buffer $q(t_0)$ and an initial $MACR(t_0)$ and taking into account the equations (1) and (2), the procedure derives the $ERF(t_0)$. This value is used to calculate the new buffer $q(t_1)$ (presented in the algorithm as *qpr*), which is then used to produce the new $ERF(t_1)$ and so on. More details may be found in (Mousadis & Tsiligirides, 2002; Mousadis et.al., 2002).

III. Simulation Results

The new function family is tested using the simulator proposed in (Mousadis & Tsiligirides, 2002). A simple network configuration consisted of two hops in tandem (namely a VS ABR switch, two VS/VD ABR switches and a VD ABR switch) and using a single VC is assumed. The ABR traffic descriptor parameters are: PCR = 36 cells/τ, MCR = 1 cell/τ, $q\max = 2h*PCR$ and $CDVT = 2h$. To simplify the simulation process the parameters h and τ are taken equal to 1. Finally the cells are generated through an on-off process, over a period of 1000τ.

Using the above simulator a comparison test has been carried out for the functions $f(q)$, f_1 and f_2 of the ERICA/ERICA+, SERICA_1 and SERICA_2 algorithms (ω = 1 and 2), respectively. The simulation results (Table 1) present the number of the non-conformed cells per switch buffer, the queuing delay of the switch_1 and the throughput in each session. Since the overflow rate is zero, this case is not presented. The simulation shows some interesting results concerning the overall performance of the functions f_ω, by means of the higher throughput achieved. In particular, as one may observe f_1 gives always better throughput than f_2 and $f(q)$. Interesting to note that f_2 achieves better throughput than the $f(q)$ in cases where p takes moderate values. Overall, using SERICA_ω the throughput achieved is always greater than 79%. Interesting to note that in case the probability p is "varied" (namely, p varies from slot to slot during a session), f_1 performs better than f_2, whereas f_2 performs better than $f(q)$. This case may correspond to the unpredictable ABR traffic environment, in which sudden changes of the input rate in the source causes unexpected behavior in the system performance. However, in terms of the queuing delay f_2 seems to achieve very low values for all p. Finally, although f_1 is always better than f_2 in terms of throughput, there are cases where f_2 should be preferred, particularly when the buffer availability is low and a new session is established.

p	Cells generated at Source	Non-conformed cells counted on buffer									Average queuing delay in the buffer of the switch_1			Throughput %		
		VS			switch_1			switch_2								
		*f*_2	*f*_1	*f*(*q*)	*f*_2	*f*_1	*f*(*q*)	*f*_2	*f*_1	*f*(*q*)	*f*_2	*f*_1	*f*(*q*)	*f*_2	*f*_1	*f*(*q*)
0.9	32427	4401	894	3114	2	0	0	0	0	0	.00002	.00006	.11788	86	97	90
0.8	28830	5079	868	3726	1	0	0	0	0	0	.00003	.00013	.18781	82	97	87
0.7	25084	4668	667	3901	13	0	0	0	0	0	.00005	.00022	.25275	81	97	84
0.6	21458	3840	610	4116	15	14	0	0	8	0	.00007	.00032	.23776	82	97	81
0.5	17786	2971	235	4096	14	143	0	0	103	0	.00009	.00043	.24376	83	97	77
0.4	14235	2394	31	4095	68	351	0	2	269	0	.00013	.00051	.24575	83	95	71
0.3	10736	1814	0	3960	76	408	0	21	352	0	.00018	.00050	.24176	82	93	63
0.2	7118	993	0	3582	185	467	2	86	303	0	.00029	.00054	.14785	82	89	50
0.1	3614	159	0	2332	370	437	3	233	282	1	.00049	.00055	.06094	79	80	35
varied	18661	3836	700	10667	111	359	82	0	146	11	.00008	.00020	.58541	79	94	42

Table 1: The 2 hop, single VC model, in non-WCT (τ=100 μsec, Link Rate = 155.52 Mbps)

IV. Conclusions

In this work we derived and tested a new family of queuing control functions $f\_\omega(t_n)$ for the SERICA_ω algorithm. Simulations on a simple network configuration proved the robustness of the new family of functions i.e., that the achieved throughput has always been greater than 79% of the initially generated cells at the source and that the queuing delay has been minimized. Thus, SERICA_ω may support the unpredictably varied ABR traffic, as well as, the predictable VBR traffic. In addition SERICA_2 may be preferred than SERICA_1 in cases when there is not enough buffer to establish a new session.

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