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PROPOSED A RATE-BASED SCHEME FOR ATM FLOW CONTROL

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ABSTRACT

ATM is representative of the connection-oriented resource provisioning class of protocols. The ATM network is expected to provide end-to-end Q_oS guarantees to connections in the form of bounds on delays, errors and/or losses. Performance management in ATM network depend upon different parameters. ABR flow control is one of the important parameter for performance management. In this paper, we shall focus on the ABR flow control. Available Bit Rate (ABR) service is becoming more and more important in Asynchronous Transfer Mode (ATM) networks because it can be used to fill in the bandwidth slack left by the scheduling traffic. Recently, two flow control scheme for ABR traffic were under active discussion. They are credit-based flow control scheme and rate-based flow control scheme. Credit-based flow control scheme can completely avoid cell loss. However, its main drawback is the per-VC large buffer requirement. On the other hand, rate-based flow control, requires less buffer. Unfortunately, the rate-based schemes are generally slow in response to congestion. Worst still, these schemes are usually unfair. In this paper, a rate-based flow control scheme called the Max- Min scheme is introduced. The scheme can rapidly achieve the max-min fairness allocation and reduce the peak queue lengths of the bottleneck switches. To solve the problem of different source-to-switch separations for different connections, another rate-based scheme, called the Max-Min Scheme with Delay Adjustment, is proposed. With this, the peak queue lengths at the switches are further reduced.

KEYWORDS

ATM, ABR, QoS.

1. INTRODUCTION

Many criteria are used to evaluate the different rate based flow control schemed. One of them is fairness. It is because the problem link best down problem [1] is highly undesirable. While many different definitions of fairness may be conceived, the ATM forum has converged toward a particular definition called the max-min fairness [2,3]. However, some of the proposed schemes cannot always achieve the max-min fairness allocation. Even if max-min fairness can be reached, the schemes may take a long time to do so. In this paper, a new rate-based switch mechanism called Max- Min scheme, which aims to rapidly achieve max-min fairness allocation, is proposed. The basic idea is to divide the connections at each switch into two groups: constrained and unconstrained. With the used of the Resource Management (RM) cells, the bottleneck bandwidths for different constrained connections can be made known to the switches along the path. Bandwidth is allocated to the constrained connections based on the bottleneck information on the RM cells. The leftover bandwidth is then evenly distributed among all the unconstrained connections. It is shown through simulations that the proposed scheme can significantly reduce the transient response times as well as the pack queue lengths. Besides, the scheme is very simple and does not require any parameters to set.

II. MAX-MIN FAIRNESS

Before explaining the Max-Min scheme, the idea of max-min fairness [2,3] needs to be introduced. It provides the maximum possible bandwidth to the source receiving the least bandwidth among all contending sources and it can be shown to lead to the maximization of total throughput. Connections competing for bandwidth at a node can be divided into 1) *constrained* connections, which cannot achieve their fair share of the bandwidth available at other nodes along its route and 2) *unconstrained connections*, whose access to higher bandwidth is limited by the bandwidth available at the considered node (the bottleneck). The key ideas behind max-min fairness are:

- Each connection must have at least one bottleneck node along its route.

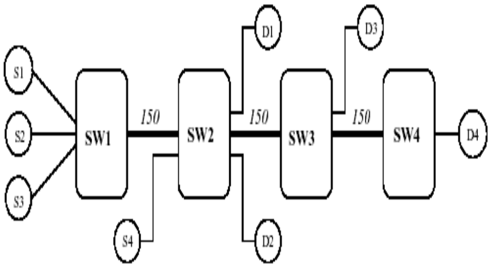
- Rates allocated to unconstrained connections at anode should be equal and given by the fair share A

$$A = (\text{Available\_Bandwidth} - \Sigma_{\text{constrained\_connection}}\, CA(k))/N\text{-}M \qquad (1)$$

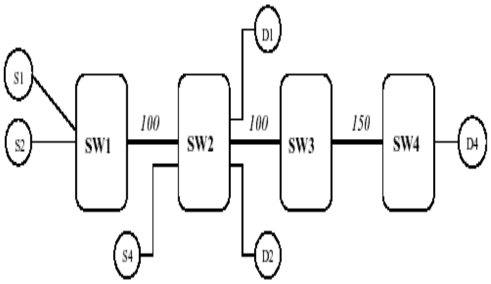
Where available Bandwidth is the link capacity available for the Available Bit Rate (ABR) traffic, CA(k) is the rate achievable by constrained connection k ($CA(k) < A$ for all k), N is the total number of connections, and M is the number of constrained connections at the considered link.The following example illustrates the idea of the max-min fairness. Figure 1.(a) shows a network with four switches connected via three 150Mbps links. Firstly we divide the link bandwidth fairly among contending sources. On the link between SW1 and SW2, S1, S2, and S3 can each get 50Mbps. On the link between SW2 and SW3, we would give 75Mbps to both sources S3 cannot use its 75Mbps share at the second link since it is constrained by the first link. Therefore, we give 50Mbps to S3 and construct a new configuration shown in Figure 1.(b), S3 has been removed and the link capacities have been reduced accordingly. Next, we can divide the link bandwidth fairly among contending sources again. S1 and S2 can each get 50*Mbps* at the first link. At the second and third link, S4 can get all the remaining 100*Mbps* and 150*Mbps*, respectively. Therefore, the allocation vector for this configuration is (50, 50, 50, 100) and this is known as the max-min fairness allocation.

III. MAX-MIN SCHEME

The aim of this scheme is to quickly achieve max-min fairness allocation when the network condition has changed. This can be done by using the information carried in the RM cells. Each switch maintains an information table for all active Virtual Circuits (VCs) that pass through it (Table 1). VCI denotes the identifier. ER_*f* and ER_*b* denote the Explicit Rate (ER) value of the most recent RM cell received in the forward and backward directions, respectively.



a) sample configuration



b) configuration after removing S3

Figure 1. Sample configuration for max-min fairness

CA is the current allocation for the VC at the switch. Constrained is a Boolean variable, when it is 1, the connection is a constrained one [4] and cannot achieve its fair share of bandwidth at that node because of the constraints imposed by its Peak Cell Rate (PCR) or by the limited amount of bandwidth available at other nodes along its path. Similarly when constrained =0, the bandwidth of the connecting is only limited by the bandwidth available at the considered node. Denote N as the total number of active connections and M as the number of constrained connections. When the RM cell comes out from the source, its ER is set to PCR as depicted in Figure 2. When the switch receives a forward RM cell of VC j with ER field equal to ER_RM, the switch will do the following:

```
i. IF ER_RM = ER_f(j) THEN GOTO step ix
ii      ER_f(j) = ER_RM
    iii.    IF min (ER_f(j), ER_b(j))≤ CA(j) THEN
constrained(j) = 1 and CA(j) = min(ER_(j), ER_b(j))
ELSE
constrained(j) = 0
iv. For all unconstrained connections i, let CA(i) = A, where,A = (Available_Banwidth - $\Sigma_{conatrained\_connection}$ CA(k))/N-M
                v.      changed = 0
                vi.     For all unconstrained connections I
IF min(ER_f(i), ER_b(i)) ≤ A THEN
constrained(i) = 1, CA(i) = min(ER_f(i), ER_b(i)) and changed=1
                vii.    For all constrained connections k
IF min(ER_f(k), ER_b(k))> A THEN
constrained(k) = 0 and changed = 1
viii. IF changed = 1 GOTO step iv
    x.      END
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Table 1. Information table for Max-Min scheme

VCI	ER_f	ER_b	CA	Constrained
X	f1	b1	c1	0/1
Y	f2	b2	c2	0/1

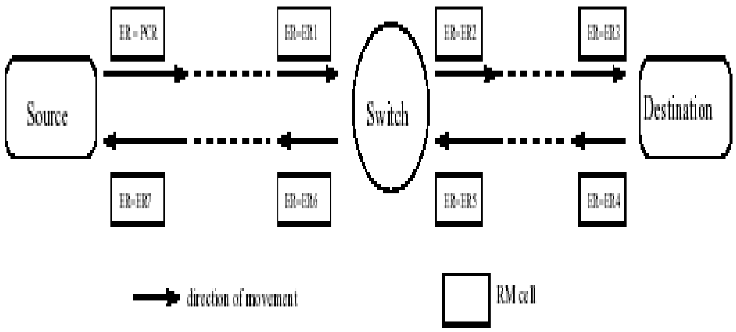

Figure 2. Flow of RM cells

This algorithm works as follows: when a forward RM cell with ER = ER_RM for VC j arrives at the switch checks whether ER_f(j) is equal to ER_RM. If they are equal (step i), nothing needed to bone for this RM cell. Otherwise, ER_f(j) is set to ER_RM (step ii). If the minimum of the new ER_f(j) and ER-b(j) is less than CA(j), this implies that the bottleneck of VC j is elsewhere along its path. Therefore, CA(j) is reduced to the minimum of ER_f(j) and ER_b(j), and constrained is set to 1. Otherwise, constrained is set to 0 (step iii). For all unconstrained connections i, CA (i) is updated to A (step iv) as in (1). Here, A is the new current allocation for all unconstrained connections and CA(k) is the current allocation for connection k. For all unconstrained connections i , A is compared to the minimum of ER_f(i) and ER_b(i) (step vi). If a larger, constrained (i) is set to 1 and CA(i) is set to the minimum of ER_f(i) and ER_b(i). It is because if A is larger, the bottleneck is in fact elsewhere and thus the connection should be classified as a constrained one. The change in A is due to either the change in the available bandwidth at some switch or the hang in the number of active VCs in the network. Similarly, if the minimum of ER_f(k) and ER-b(k) is larger than A for some constrained connection k (i.e., the bottleneck for the VC is not elsewhere but the current switch), constrained is then set to 0 (step vii). If changed = 1 after steps vi and vii, further calculation of A is necessary because of the change of some VC's constrained status. Therefore, steps iv to viii are repeated until changed is 0 at the end of step vii. Note that the computation of the term can be more efficiently performed by considering the changes only. It is therefore not necessary to sum up CA(k) every time when (4.1) is invoked. The update of the ER field is now discussed. As depicted in Figure 4.2, let ER1 be the ER value in the RM cell when arrived at the switch and CA be the current allocation for the VC at the switch. The new ER value for the outgoing RM cell, ER2, is computed as follows:

$$ER2 = \min\{iax\{ES,CA\},ER1\} \qquad (2)$$

Here, FS is the fair share allocation with Target Cell Rate being equal to the total available bandwidth. We take the maximum of FS and CA because FS is the minimum fair share allocation for each VC at the switch. When the RM cell reaches the destination, it is turned around and the ER value of the returning RM cell is reset to the minimum of PCR and the destination's supported rate (i.e., ER4 in Figure 2). Procedures similar to the pseudo code are done when a backward RM cell is received at the switch, except that ER_f(j) is replaced by ER_b(j) in steps i and ii. When the source receives the RM cell, it will set its ACR to the ER value in the received RM cell (i.e., ER7 in Figure 2). The resetting of the ER value in the RM cells allows more up-to-data bottleneck information from both forward and backward directions to reach the switches quicker and hence can improve the response times of the sources. When either the number of active VCs or the available bandwidth at the switch changes, steps iv to viii of the pseudo code must also be executed in order to determine the new max-min fairness allocation. When a VC is terminated, its entry in the information table at the switches involved must be deleted. On the other hand when a new VC is established, a new row in the information table at the switches involved is needed to be created. The initial values of ER_f and ER_b are set to PCR while the initial constrained status is set to 0. The values of CAs for all VCs passing through the switches are recomputed using steps iv to viii in the pseudo code.

VI. PERFORMANCE OF MAX-MIN SCHEME

In this section the performance of Max-Min scheme to that of CAPC (Congestion Avoidance using Proportional Control), ERICA(Explicit Rate Indication For Congestion Avoidance) and MIT schemes. Figure 3 shows the simulation mode [8] that is implemented by using simulation package BONeS [5,6]. In this network, there are two multi-hop VCs (VC2 and VC4) while the remaining VCs are single –hop. The Source End System (SES) behavior is based on [8]. However, since on NI(No Increase) field is used in CAPC, the operation based on NI in the SES is disabled. Similarly, since no NI and CI(Congestion Indication) fields are used in ERICA and the proposed scheme, the SES is modified such that the operations based on NI and CI are carried out. The values of the common parameters for the SES are shown in Table 2. The one-way propagation delay between the source or destination and attached switch is 5µs while the one –way access propagation delay between two switches is 50µs. The sources we used are staggered one (i.e., the sources become active one by one). Ten random starting times are tested for every active VCs. The mean time of becoming active for VC1, VC2, VC3, VC4, and VC5, are 0ms, 5ms, 10ms, 15ms and 20ms respectively with uniform distribution over intervals of with equal to Nrm cell times. The reason is to take into account of the different arrival times of the RM cells. The sources remain active once after startup until the end of simulation. The reason of using staggered sources is, as explained in [7], that the fairness characteristics of a scheme can be better illustrated than using non-persistent sources. Moreover, by studying the transient behavior of a scheme for persistent sources, one can also understand its performance characteristics for non-persistent bursty sources. Expected cell rate for each VC based on max-min fairness allocation VC1-25Mbps, VC2-25Mbps, VC3-75Mbps, VC4-50Mbps, VC5-50Mbps

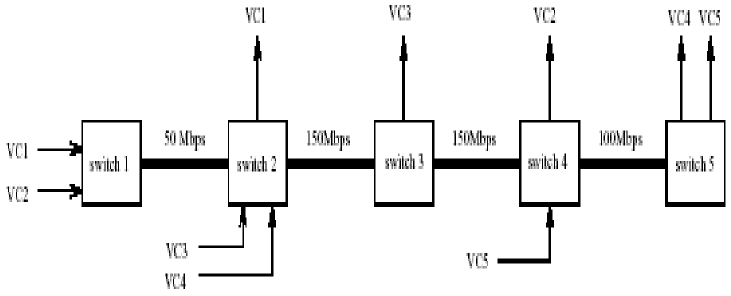

Figure 3. Simulation model for the Max-Min Scheme

Table 2. Setting of common parameters for SES

PCR	MCR	Nrm	RDF	TOF
150Mbps	PCR/1000	32	1024	2

Table 3. Setting of parameters for CAPC

IR	**Rup**	**Rdn**	**ERU**	**ERF**	**Interval**	**Qthreshold**
PCR	0.25	1.0	1.5	0.5	1ms	100 cells

Each switch attempts to fully utilize the total available bandwidth (e.g., 150Mbps for switch 2). The connection is said to be active if the switch receives a cell from the particular connection. Different Initial Cell Rates, ICRs, are used for comparison. The values of the parameters used in CAPC are based on [8] and are shown in Table 4.3. For ERICA, the counting interval N is 30 cells as suggested in [9].

V. PERFORMANCE COMPARISON

The values of ACR at different times for the different VCs are shown in Figure: 4 to 15 when the VCs become active one by one. Figures: 4 to 6 show the variation of ACRs for CAPC for three different values of ICR. The figure show that, for most cases, the ACRs of the VCs cannot converge to the steady- state values before the next VC becomes active. After all five VCs are active, it takes approximately 15 to 20ms for the VCs to achieve the max-min fairness allocation. The scheme has the longest response time when compared to the other schemes. Figure: 7 to 9 show the variation of ACR for ERICA under three different ICRs. They show that the performance of ERICA is better than that of CAPC. However, ERICA sometimes cannot converge to the max-min fairness allocation (e.g.,in Figure: 7 after VC4 becomes active in the interval between 15 and 20ms). According to the max-min fairness allocation, after VC4 becomes active, ACRs for VCs 2,3,and 4 should be 25 Mbps, 62.5mps and 62.5Mbps respectively. Figure: 10 to 12 show the variation of ACR for MIT scheme [11] under three different ICRs. They show that the performance of MIT scheme is better that that of CAPC and ERICA. For the proposed scheme, max-min allocation is always achieved and the response time of the scheme is shortest among the different schemes (Figure: 13 to 15). Moreover, the performance is approximately the same for different values of ICRs. Since the response time of CAPC is much larger than the other schemes, our comparison only focuses on ERICA, MIT scheme and Max-Min scheme. Besides, since ERICA cannot achieve max-min fairness allocation for ICR = 0.1PCR and ICR=PCR in certain time intervals, we will concentrate on the case of ICR = 0.5PCR. In Table 4, the pack queue lengths at different switches for the two schemes are shown. It shows that a significant reduction in the peak queue length is achieved by the proposed scheme. It is vital in local area networks (LANs) because the buffer size of LAN switch is usually small. Better control of queue length can reduce the number of cell loss and therefore minimizes the performance degradation due to cell loss.

Table 4. Comparison of peak queue lengths in cell with 95% confidence interval

	Switch 1	*Switch 2*	*Switch 4*	*Switch 4*
ERICA	131±4	53.8±2.8	2±0	54.2±7.6
MIT Scheme	77.9±7.4	42.4±5.1	2±0	30.5±1.6
Max-Min Scheme	66.9±4.6	22.6±3.5	2±0	21.9±1.6

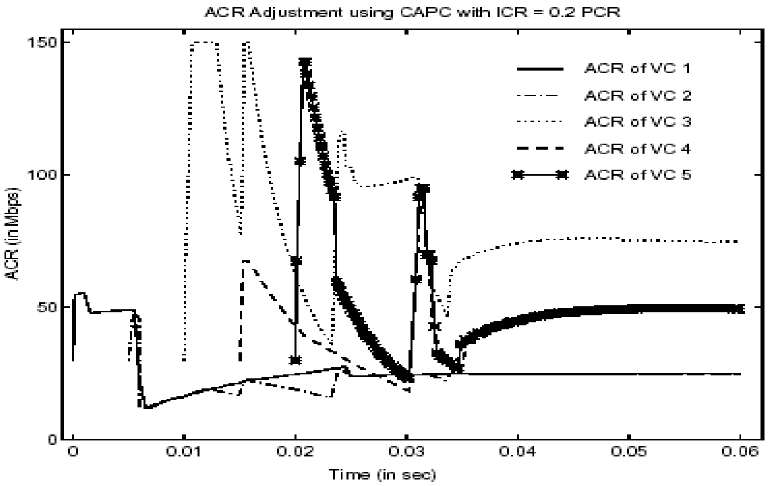

Figure 4. ACR adjustment using CAPC when ICR = 0.2PCR

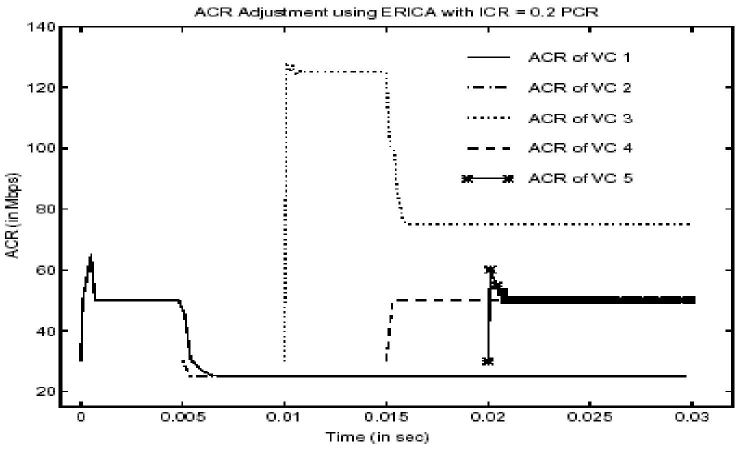

Figure 5. ACR adjustment using CAPC when ICR = 0.5 PCR

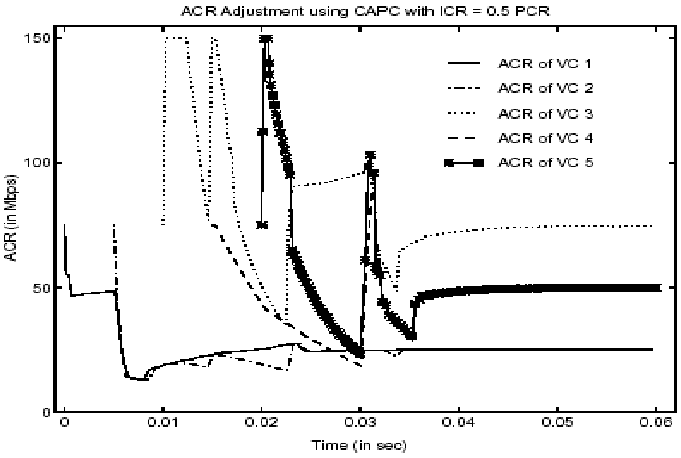

Figure 6 : ACR adjustment using CAPC when ICR = PCR

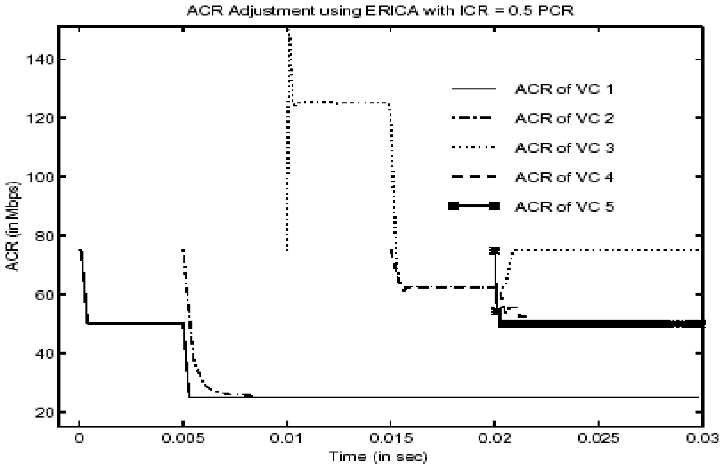

Figure 7. ACR adjustment using ERICA when ICR = 0.2 PCR

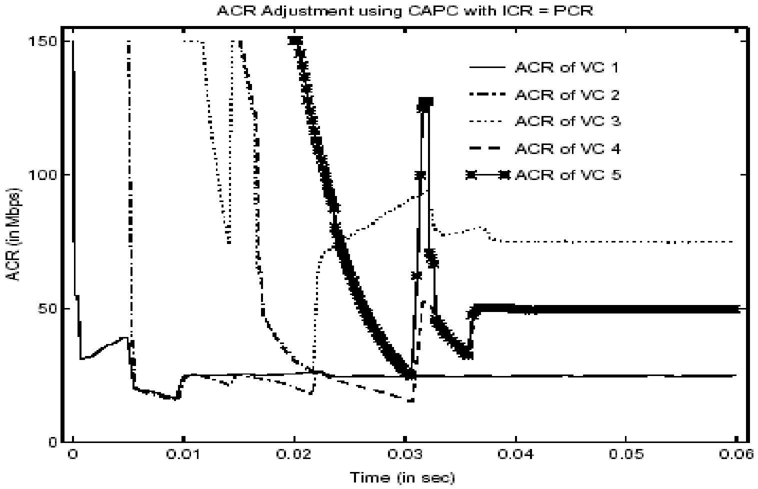

Figure 8. ACR adjustment using ERICA when ICR = 0.5 PCR

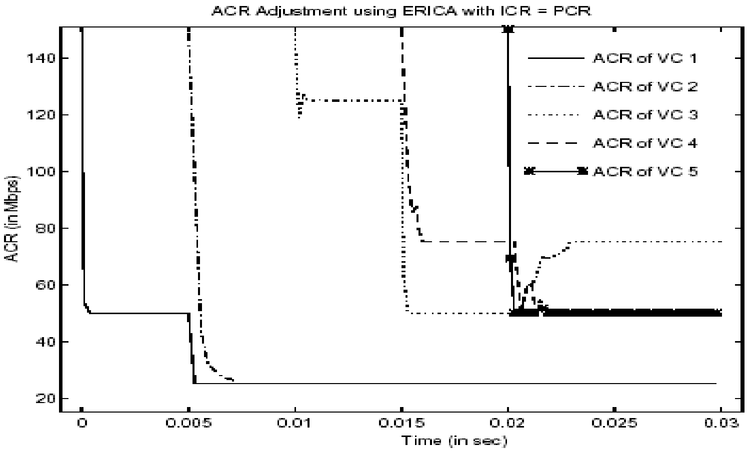

Figure 9. ACR adjustment using ERICA when ICR = PCR

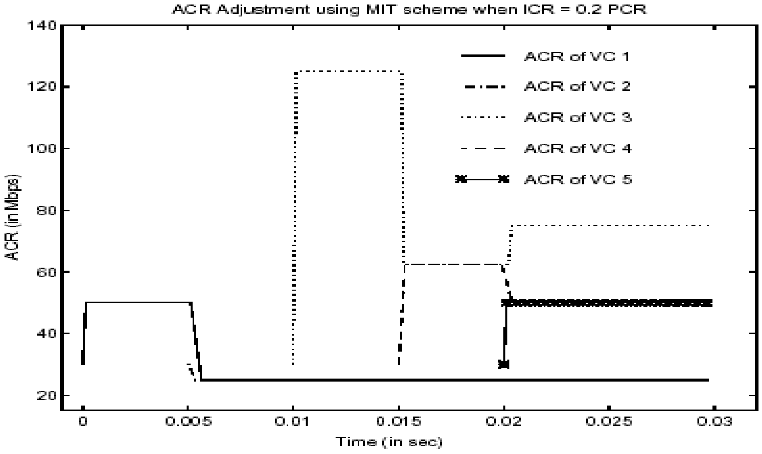

Figure 10. ACR adjustment using MIT Scheme when ICR = 0.2PCR

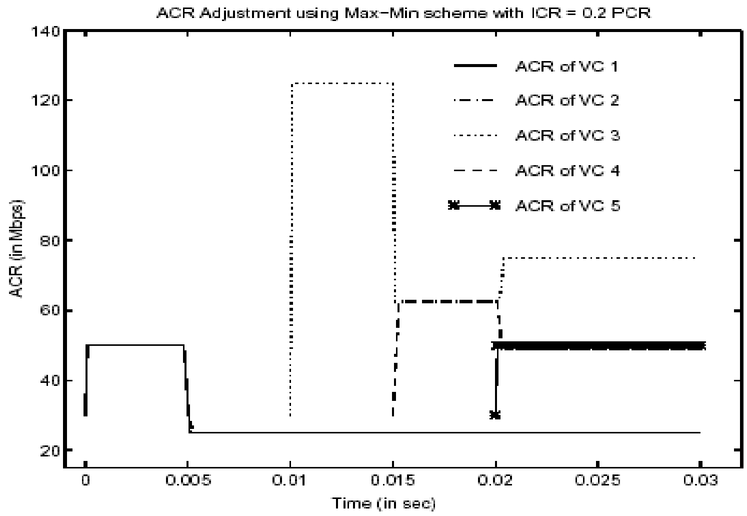

Figure 11. ACR adjustment using MIT Scheme when *ICR* = 0.5*PCR*

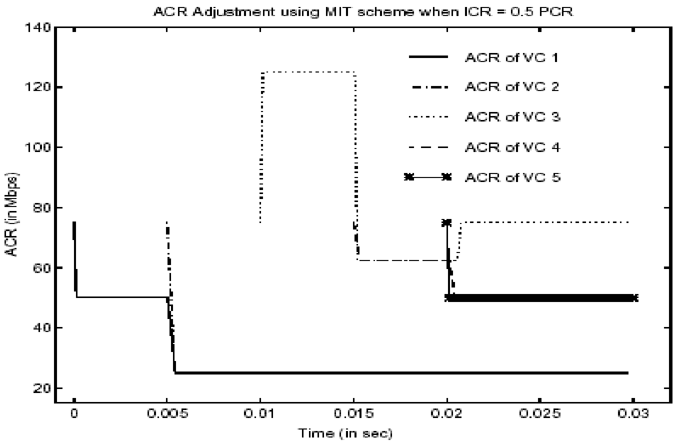

Figure 12. ACR adjustment using MIT Scheme when *ICR* = *PCR*

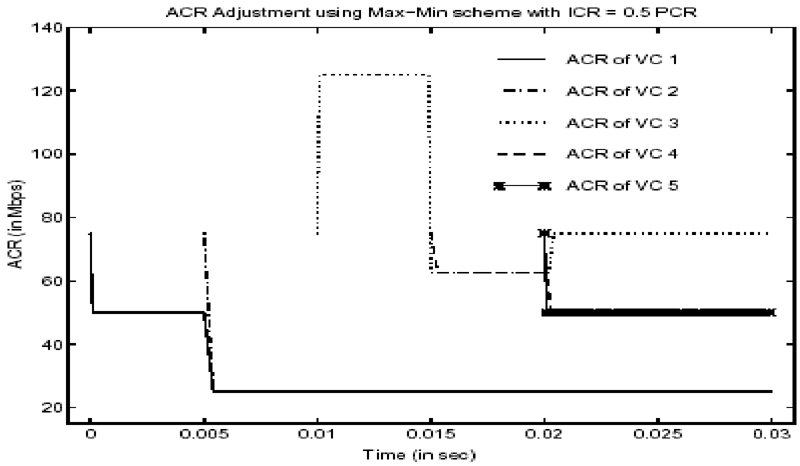

Figure 13. ACR adjustment using Max-Min Scheme when *ICR* = 0.2 *PCR*

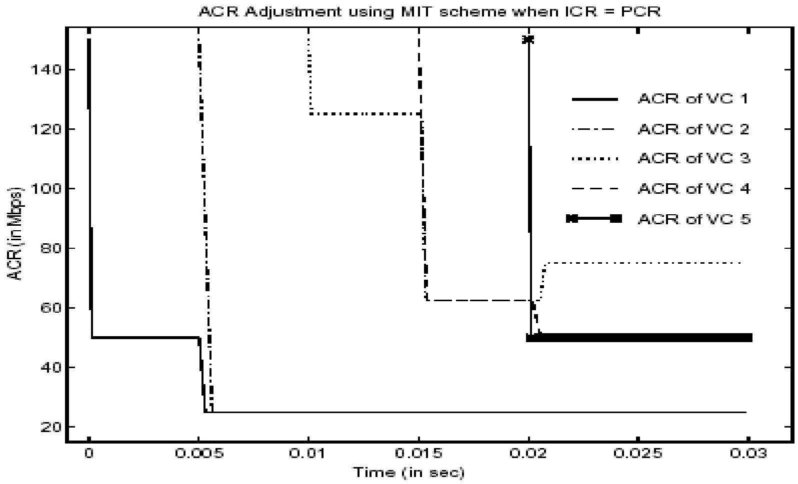

Figure 14. ACR adjustment using Max-Min Scheme when *ICR* = 0.5 *PCR*

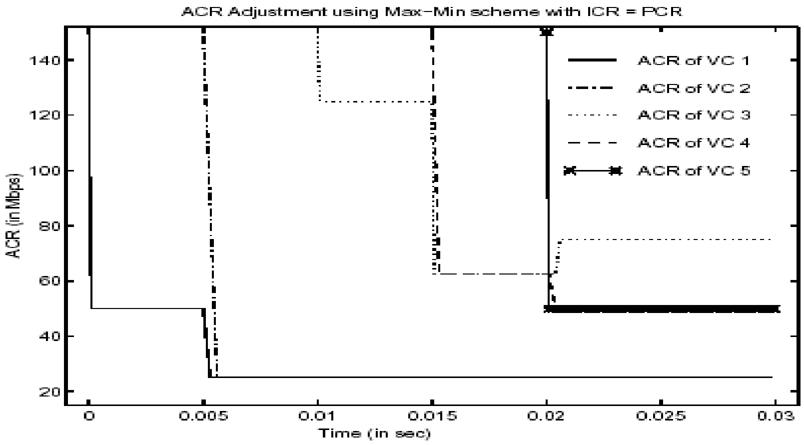

Figure 15. ACR adjustment using Max-Min Scheme when *ICR* = *PCR*

VI. CONCLUSION

This research proposes a new performance management efficient flow control algorithms for Available Bit Rate (ABR) traffic in ATM networks. ABR traffic can rely on the unreserved bandwidth. Therefore, the resources available for ABR connections may change subsequent to connection establishment. In order to effectively cope with the changing resources, certain kind of control must be provided such that network resources can be fully utilized and congestion can be controlled or even be avoided. This paper aims to find an effective mean to control the flow of the data based on the availability of the resources in the network. Therefore, a new rate based switch algorithms, called Max-Min Scheme, is proposed in this paper, which can quickly converge to the max-min fairness allocation. With this approach, the efficiency of the network can be maximized. The effectiveness of this Max-Min Scheme is verified by simulations with the use of staggered sources. It is found that the response time of the VCs to converge the max-min fairness allocation are the shortest when compared to both CAPC, ERICA and MIT scheme. Because of the fast responses, the peak queue lengths built up at the bottleneck switches are minimized. Furthermore, an analytical approximation to calculate the response times and peak queue lengths are also introduced. It is found that the estimated values are well within the confidence bound of the simulation results.

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