マルチメディア ATM 網におけるレート制御方式の性能評価

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あらまし レート制御方式は、データ通信等に利用される ABR サービスクラスに適した輻輳制御方式である。これまで、 EPRCA や EPRCA++ などのさまざまなレート制御方式が ATM フォーラムにおいて提案されてきている。レート制御方式の評価はこれまでも他数行なわれているが、それらはすべて ABR トラヒックのみを対象としており、 CBR トラヒックや VBR トラヒックの影響は全く考慮されていない。本稿では、 ATM 網のマルチメディア網への適用を考慮して、レート制御方式に基づく ABR トラヒックに加えて画像通信が混在する場合の、レート制御方式の性能をシミュレーション手法を用いて評価する。

和文キーワード レート制御方式、 EPRCA、 ERPCA++、マルチメディアトラヒック、シミュレーション手法

Performance Evaluation of Rate-Based Congestion Control Algorithms in Multimedia ATM Networks

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Abstract Rate-based congestion control promises effective traffic management for the ABR service class suitable to data communications in ATM networks. There have been proposed several rate-based congestion control schemes in the ATM Forum, including EPRCA and EPRCA++ methods. While many studies have been devoted for these schemes in the past, only ABR traffic is taken into account; the effect of VBR and CBR service classes, in which real-time traffic are applied, are not considered. In this paper, we evaluate performance of rate-based congestion control schemes in the network where not only ABR traffic but also VBR traffic are accommodated.

英文 key words Rate-Based Congestion Control, EPRCA, EPRCA++ Multimedia Traffic, Simulation Technique

1 Introduction

The rate-based scheme controls the cell emission rate of each connection between end systems. As practical realizations, several rate-based congestion control schemes have been proposed in the ATM Forum. In this paper, we focus on two schemes: EPRCA (Enhanced Proportional Rate Control Algorithm) and EPRCA++. EPRCA is a basis of standard traffic management mechanism adopted by the ATM Forum [1]. In the standard, only the behaviors of the source and destination end systems are described, and the implementation issues regarding the ATM switches are left to manufacturers. In [1], however, they suggest three types of switches, EFCI bit setting switch (EFCI), binary enhanced switch (BES), and explicit down switch (EDS), which have different processing capabilities against congestion. On the other hand, EPRCA++ is a newly proposed algorithm for improving the network performance but needs more complex functions at the switch [2]. Refer to [3] for more details of EPRCA and EPRCA++.

While a lot of studies have been devoted to evaluation of these schemes, only ABR traffic is taken into account; the effect of VBR and CBR service classes, in which real-time traffic are applied, are not considered. In this paper, we evaluate performance of rate-based congestion control schemes in the network where not only ABR traffic but also VBR traffic are accommodated. In the current paper, we assume that CBR service class is used for video traffic. Namely, when the video traffic is generated, the call setup process is performed prior to its actual cell transmissions. Since we consider the CBR service class, only the peak rate is required for the traffic descriptor in this case. Further, in the network, CBR service class cells are assumed to be given higher priority than ABR service class cells for assuring QoS of CBR service class. See, e.g., [4] for the switch architecture to provide such priority services.

The problem is, however, that video traffic essentially has a bursty nature. So the cell generation rate per frame is varied if a compression technique like MPEG is applied to the video sources. Note that we here distinguish a traffic class and a service class; CBR traffic generates cells in the constant bit rate while CBR service class is the class related to CAC. Therefore, the CBR service class may accept VBR traffic which generates cells in the variable bit rate. Then the available bandwidth (i.e., residual bandwidth) to the ABR service class is changed dependent on cell generation of the VBR traffic. It was never considered in the past studies in which the available bandwidth to the ABR service class is fixed. In the current paper, we treat such a case that the VBR traffic is applied to the CBR service class, which is most likely to be realized in the ATM network by its simplicity since VBR service class still has difficulties in implementation for CAC and UPC.

When we consider both ABR and CBR service classes in the network, the rate-based control algorithms for ABR service class must be affected by the characteristics of video traffic. In this paper, we will use sampled data taken from MPEG streams for VBR traffic. Then, we investigate the performance of ABR traffic class. For this purpose, we use EPRCA and EPRCA++, the rate-based control algorithms discussed in the ATM Forum, and demonstrate drawbacks of those algorithms through simulation experiments.

2 Simulation Model

The propagation delay between the source and destination end systems τ are set at 0.01 ms and 1.00 ms as typical values for LAN and WAN environments, respectively. The link speed at the switch is set to 156 Mbit/s.

There are the number N_{VC} of connections for the ABR traffic, and the establishment of connections is staggered by 5 ms; that is, nth connection starts its cell transmission at $(n-1) \times 5$ ms. Then all connections continue cell transmissions until the end of simulation runs. For control parameters of EPRCA and EPRCA++, we use the values suggested in [1] and [2], respectively. Each simulation is executed during 300 ms.

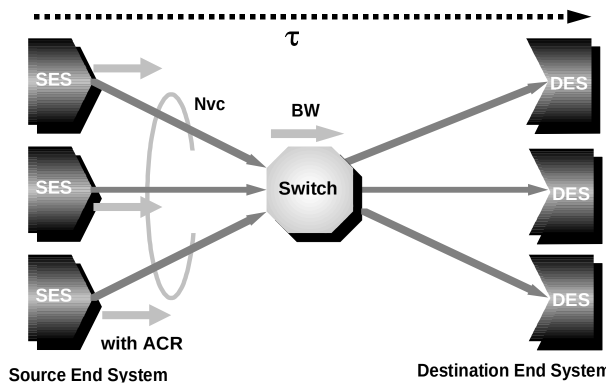

Fig. 1: Configuration of Simulation Model.

It is assumed that VBR traffic is assigned higher priority than ABR traffic; i.e., VBR traffic cells are transmitted prior to ABR cells at the switch if VBR cells exist in the buffer. Therefore, the bandwidth available to ABR traffic should be affected by the cell generation rate of VBR traffic, which is varied dependent on the time. As a typical example of VBR traffic, we adopt MPEG-1 encoded video stream of 30 frame/s, 352 $\times$ 240 pixels with average rate 4.5 Mbit/s and peak rate 14.84 Mbit/s. It means that up to ten video streams can be multiplexed since we assume that the CBR service class is used to transport video streams. In our simulation, ten identical VBR sources are multiplexed with different starting points.

EPRCA++ requires information about the bandwidth available to the ABR traffic. If we only consider the ABR traffic, it is identical to the VP capacity, being equal to the physical capacity of the link in most cases. When VBR traffic is also accommodated onto the link, however, we should introduce some method to measure the bandwidth available to the ABR traffic because it is dynamically changed due to the bursty nature of VBR traffic. Since such a method is not described in the original EPRCA++ method [2], we assume that the switch counts incoming VBR cells in a fixed time interval besides input traffic monitoring; That is, the available bandwidth for ABR traffic, BW', is estimated as

$$BW' = BW \times (T - N_{VBR})/T,$$

where T is the averaging interval, BW is the link speed, and N_{VBR} is the number of incoming VBR cells during T. In our simulation, T is set to 30 cell times. We note that in the case of EPRCA, such a mechanism is not necessary since the status on the bandwidth utilization is guessed from the queue length.

3 Effect of VBR traffic

Simulation results for $N_{VC} = 10$ and $\tau = 0.01$ (as LAN environment) are first presented in Figs. 2 through 5. Each figure contains permitted cell rate ACR at the source end system and queue length at the switch. The target utilization of EPRCA++ is set to 0.95 as suggested in [2]. ACR of selected connections and the aggregate rate for both of ABR and VBR connections are plotted in these figures. We can observe that the frequency of the rate increase and decrease is directly influenced by the aggregate generation rate of VBR traffic as can be expected. When comparing EPRCA and EPRCA++, it may conclude that the overall performance of ABR connections are not very bad even in the existence of VBR connections, and that EPRCA++ method outperforms EPRCA methods in LAN environment.

When the propagation delay becomes large, however, VBR traffic gives a different impact on each scheme. In Figs. 6 through 9, we show cell rates and the queue length for $\tau = 1.00$ ms as WAN environment. In these figures, the BES switch gives better utilization since (1) the EFCI switch uses FECN-like slower congestion notification and (2) the EDS switch frequently does major reduction. It is true that the performance of the EDS switch may be improved by an appropriate use of control parameters. However, it implies that too intelligent scheme causes unexpected results unless the careful parameter tuning is performed before applying such a scheme to real systems.

This tendency becomes more apparent when we see the results of EPRCA++. As can be observed in Fig. 9, the queue length explosion is unacceptable in the case of EPRCA++ when the target utilization is 0.95. The reason why EPRCA++ shows worst performance can be explained as follows. EPRCA++ determines the explicit rate of source end systems (ER) by observing the usable bandwidth for

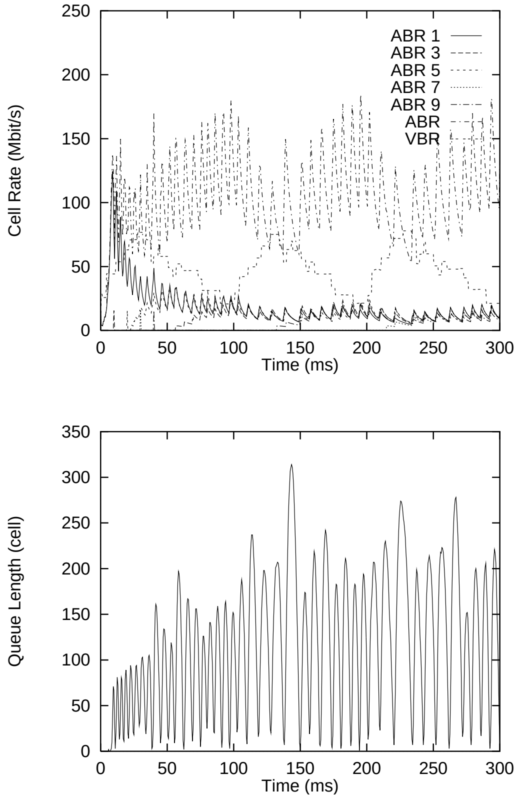

Fig. 2: EPRCA with an EFCI Switch ($N_{VC} = 10$, $\tau = 0.01$).

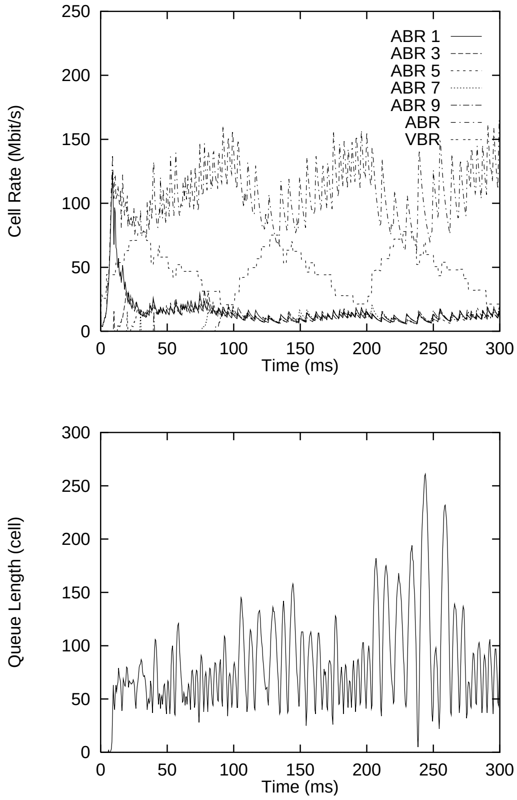

Fig. 3: EPRCA with a BES Switch ($N_{VC} = 10$, $\tau = 0.01$).

the ABR traffic so that it tries to fully utilize the link at the target utilization load. However, since it becomes too old when the RM cell containing the ER value arrives at the source end system in the case of large propagation delays. Therefore, when the cell arriving rate of VBR traffic at the switch grows (around at time 20 ms), the switch becomes overloaded more and more. Recalling that EPRCA++ uses FECN-like congestion notification, the larger τ introduces more overloaded switch. This problem can be avoided by setting target utilization properly (0.85, for example). To make the effect of the target utilization clear, we show the maximum queue length of EPRCA++ with (and without) VBR traffic for different values of the target utilization ($\tau = 1.00$, $N_{VC} = 10$) in Fig. 10. From this figure, it can be found that the queue length increases rapidly unless the target utilization is set to a proper value, and that a slightly larger value of the target utilization causes a serious effect on the network performance.

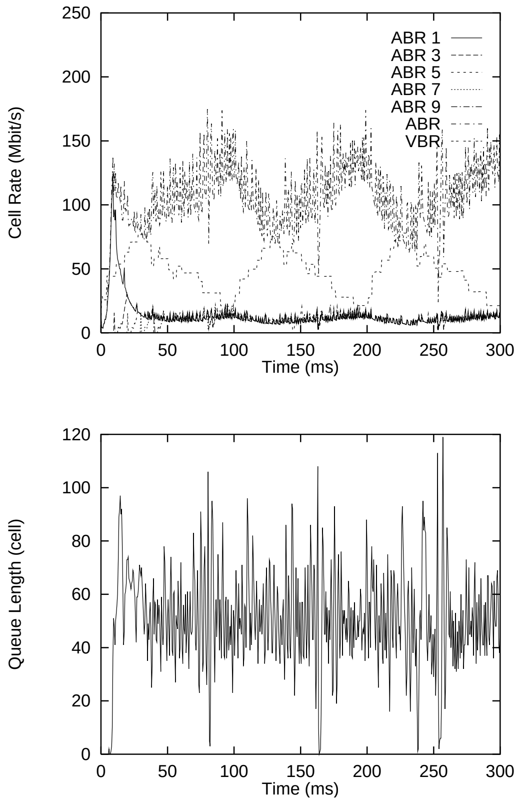

Fig. 4: EPRCA with an EDS Switch ($N_{VC} = 10, \tau = 0.01$).

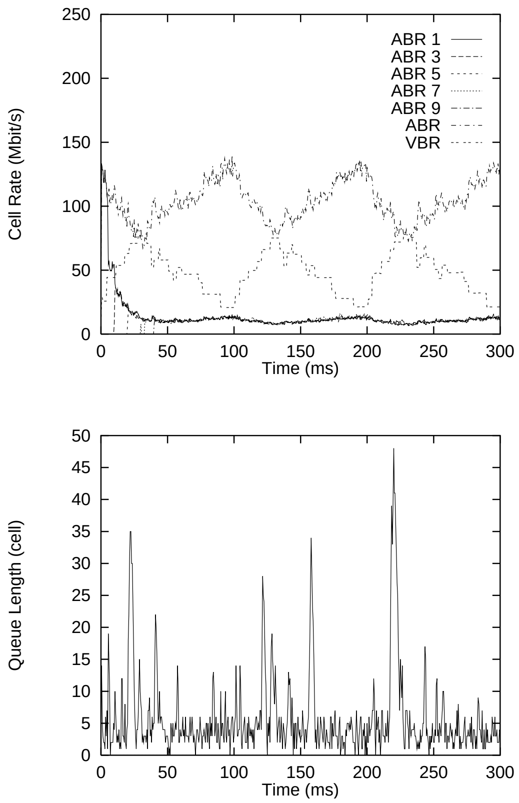

Fig. 5: EPRCA++ ($N_{VC} = 10$, $\tau = 0.01$).

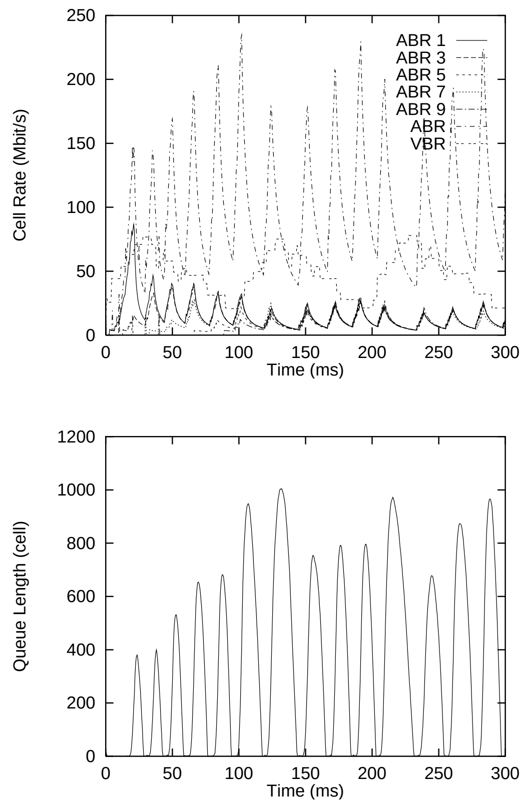

Fig. 6: Effect of VBR Traffic on EPRCA with an EFCI Switch ($N_{VC} = 10$, $\tau = 1.00$).

In summary, we show the effect of the propagation delay τ on the maximum queue length in Fig. 11 for $N_{VC} = 10$, and effects of the number of connections N_{VC} on the maximum queue length in Figs. 12 and 13 for $\tau = 0.01$ and $\tau = 1.00$, respectively.

From these figures, we may conclude that the EDS switch of EPRCA is of good performance regardless of the network

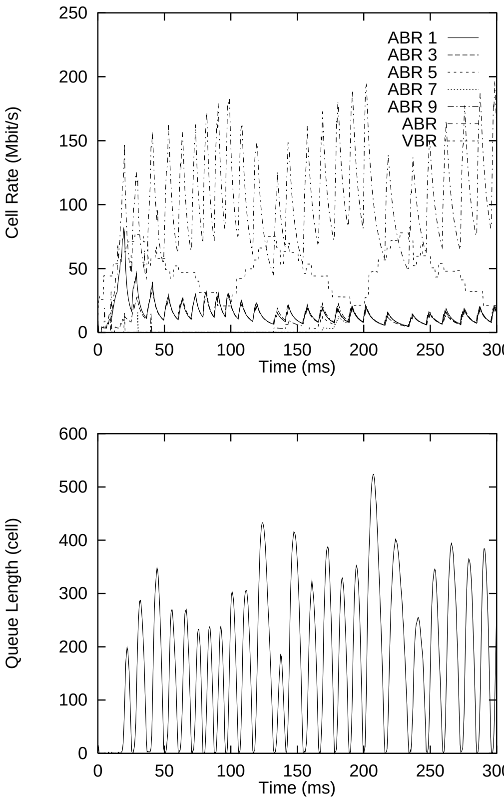

Fig. 7: Effect of VBR Traffic on EPRCA with a BES Switch ($N_{VC} = 10$, $\tau = 1.00$).

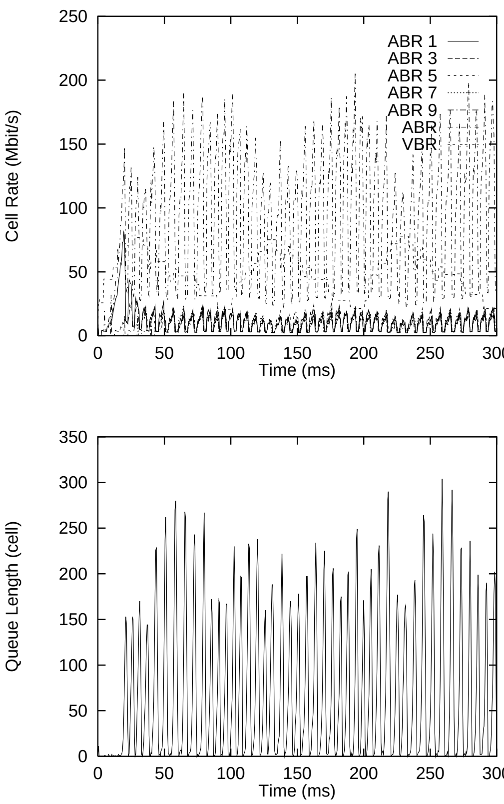

Fig. 8: Effect of VBR Traffic on EPRCA with an EDS Switch ($N_{VC} = 10$, $\tau = 1.00$).

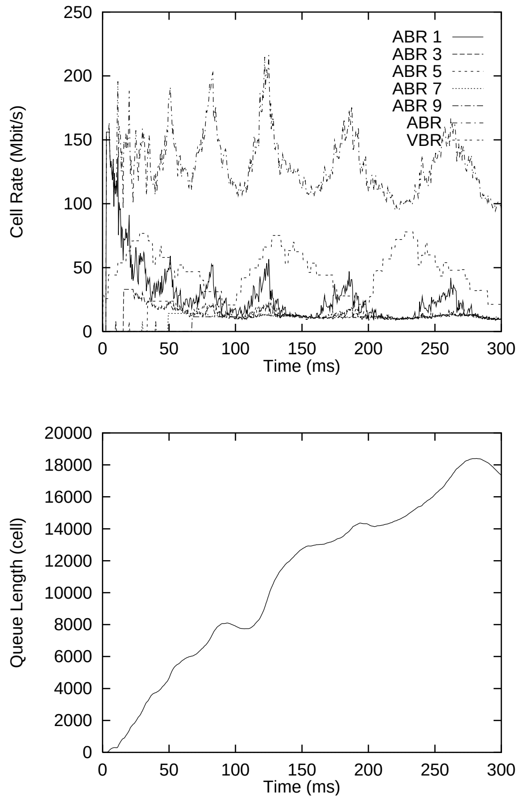

Fig. 9: Effect of VBR Traffic on EPRCA++ ($N_{VC} = 10$, $\tau = 1.00$, target utilization = 0.95).

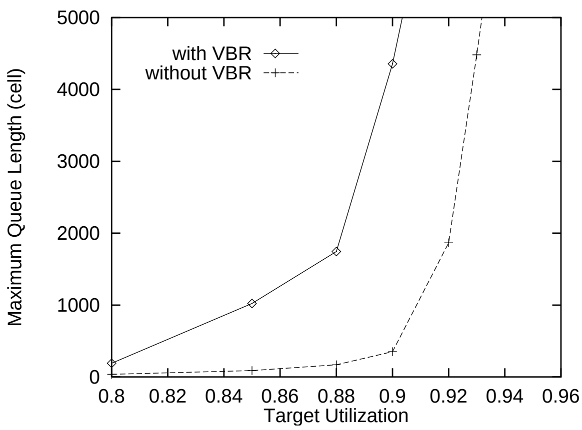

Fig. 10: Effect of the Target Utilization ($N_{VC} = 10$, $\tau = 1.00$).

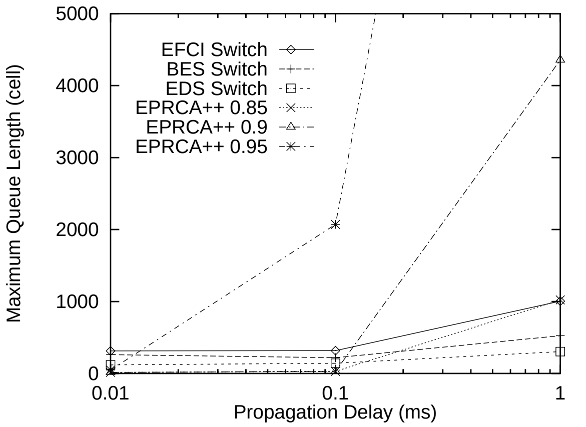

Fig. 11: Effect of τ on the Maximum Queue Length with VBR Traffic ($N_{VC} = 10$).

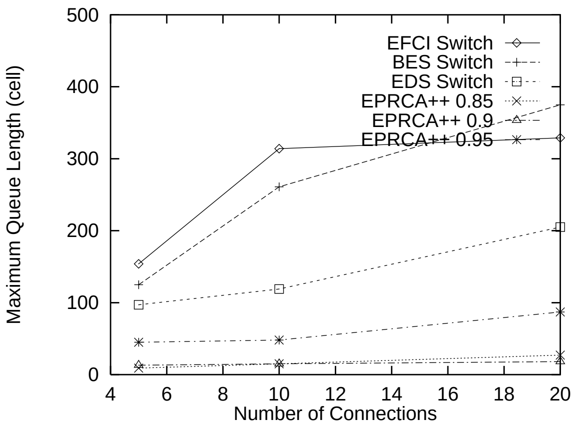

Fig. 12: Effect of N_{VC} on the Maximum Queue Length with VBR Traffic ($\tau = 0.01$).

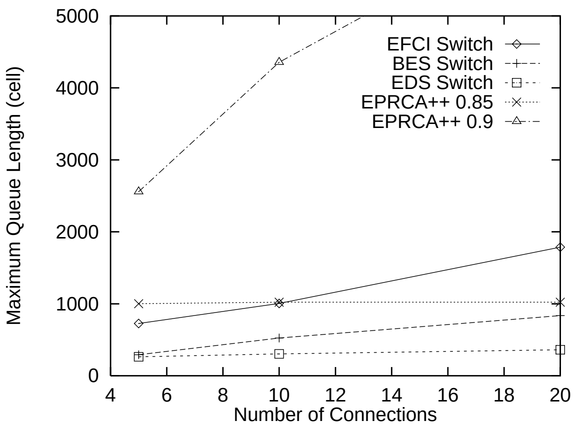

Fig. 13: Effect of N_{VC} on the Maximum Queue Length with VBR Traffic ($\tau = 1.00$).

scale, and that EPRCA++ gives almost optimal performance in the LAN environment. Furthermore, it seems to be difficult to apply EPRCA++ to the WAN environment unless control parameters are set carefully.

4 Concluding Remarks

Rate-based congestion control promises effective traffic management for the ABR service class suitable to data communications in ATM networks. In this paper, we have evaluated performance of rate-based congestion control schemes in the network where not only ABR traffic but also VBR traffic are accommodated. Through simulation experiments, we have shown drawbacks of current proposals of rate-based congestion control schemes in multimedia environment. We have illustrated that the EDS switch of EPRCA is of good performance regardless of the network scale, and that EPRCA++ gives almost optimal performance in the LAN environment. Furthermore, it has been found that it seems to be difficult to apply EPRCA++ to the WAN environment unless control parameters are set carefully.

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