Improved EPRCA Congestion Control Scheme for ATM Networks

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ABSTRACT

Traffic management and congestion control are major issues in Asynchronous Transfer Mode (ATM) networks. Congestion arises when traffic in the network is more than offered load. The primary function of congestion control is to ensure good throughput and low delay performance while maintaining a fair allocation of network resources to users. In this paper, Enhanced Proportional Rate based Congestion Avoidance (EPRCA) scheme proposed by ATM forum has been considered. But this scheme has limitation of higher cell drop problem for the bursty traffic. Improvements to EPRCA scheme have been proposed to reduce cell drop problem and results of improved EPRCA schemes were analyzed with basic EPRCA scheme.

Keywords: ATM networks, EPRCA, IEPRCA, NIST ATM Network Simulator.

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1. Introduction

Broadband Integrated Services Digital Network (B-ISDN) can offer high speed data transport, multimedia communication, high quality video conferences, video telephony, etc [17]. The Asynchronous Transfer Mode (ATM) has emerged as a standard technology for supporting gigabit BISDN services [18-20]. Using ATM, the information is usually transmitted in fixed size units called cells. The ATM technique is designed to provide fast packet switching at variable rates from 1.54 Mbps to 2 Gbps and even beyond.

Traffic Management and congestion control are major issues in ATM networks [1-6]. Congestion arises when incoming traffic to specific link is more than outgoing link capacity. When congestion problem arises, cells are discarded without being processed. The design of congestion control mechanism is essential not only for regulating traffic to prevent congestion but also for providing efficient and fair bandwidth allocation [9,15]. Among various congestion control mechanisms, rate based mechanisms are proved efficient than other mechanisms. Rate based congestion control schemes are end-to-end feedback mechanisms, and the cell transmission rate of each source end system is regulated according to congestion feedback information returned by the network [8,12,13].

In this paper, Enhanced Proportional Rate Control Algorithm (EPRCA), which is a rate based scheme for controlling congestion in ATM networks, has been considered. The improvements to EPRCA scheme is also presented in this paper. The basic and improved schemes were implemented using NIST ATM network simulator. This paper is organized as follows: The importance of Resource Management (RM) cell and its fields are presented in Section 2. The basic EPRCA mechanism, the simulation environment and results analysis of EPRCA are presented in section 3. The improvements to EPRCA schemes, with results are presented in section 4. Finally the conclusion of paper is presented in section 5.

2. Resource Management (RM) Cell

In rate based congestion control schemes, source end system periodically sends a Resource Management (RM) cell for every 31 data cells. The RM cell is used to carry control and flow information over the connection between source and destination end systems [11]. The destination end system sends an RM cell with an indicator showing the status of traffic back to the source end system. The intermediate switches may simply forward these RM cells or specify the explicit rate in RM cell based on functionality of different rate based congestion control schemes. The source end system then uses the information in the RM cell for specifying the transmission rate until a new RM cell is received.

The RM cell is used for finding status of congestion, if any, in the network. Every RM cell has the header of five bytes width. The payload type indicator (PTI) in cell header is set to a 3 bit binary, 110, as the default value, to indicate a RM cell. The protocol ID field, which is one byte long, is set to one for Available Bit Rate (ABR) application connections. The direction (DIR) bit distinguishes between forward and backward RM cells. The backward notification (BN) bit is set only in switch generated RM cells. The congestion indication (CI) bit is set by a switch to indicate presence of congestion. The no increase (NI) bit, is set by a switch to indicate moderate congestion in the network. The sequence number field value is set by source end system to indicate the current sequence number for the RM cell and the queue length field value is set by a switch in the network. The Explicit Rate (ER) field indicates the maximum rate allowed to the source and this field value is set by the switch. When the source receives the backward RM cell from the network,
it adjusts its transmission rate using the ER, CI, and NI values in the received RM Cell.

3. Basic EPRCA Scheme

The Enhanced Proportional Rate Control Algorithm (EPRCA) is a rate based scheme, in which switch explicitly specifies the rate at which transmission should be made at the source [14,16]. In this scheme, each switch in the path between source and destination end systems maintains a queue or buffer, with two congestion thresholds namely, thresholds QT (i.e. to indicate normal congestion) and DQT (i.e. to indicate severe congestion). Each switch in the network periodically computes mean allowed cell rate (MACR) that should ideally be the mean of all source end systems ACRs. The MACR value is used for computing explicit rate in RM cell.

3.1. EPRCA Algorithm
Before transmission of data by the source end system, the connection or route to be established between source and destination end systems. The route comprising of source, destination end systems, intermediate systems, and switches. The behaviour of source, destination end systems, and intermediate switch are mentioned below [10]:

Source End System behaviour
1. At the beginning of transmission, the source transmits an RM cell. The allowed cell rate (ACR) or current cell rate (CCR) is initially set to peak cell rate.
2. The source sends data cells and after every 31 data cells transmitted, one RM cell is followed.
3. The source continuously decreases its ACR until it receives an RM cell returned from the destination. Upon receipt of every RM cell, the source increases its ACR by no greater than ER.

Destination End System behaviour
1. The destination returns an RM cell upon receiving each RM cell.

Switch behaviour
1. In the network, each switch periodically computes a mean allowed cell rate (MACR) using the following formula:

\[ \text{MACR} = (1 - \text{AV}) * \text{MACR} + \text{AV} * \text{ACR}, \]

where AV is the Average Factor, which is set to a default value of 0.0625.

If the queue length is less than QT, then there is no congestion in the network. When non-congested switch receives a RM cell from a source end system and if ACR is less than MACR, then there is no need to adjust its MACR. If MACR is greater than or equal to MACR, it means that MACR is not adequately large enough, then MACR needs to be increased by using the above formula.

2. If the queue length exceeds DQT, indicating that the switch is said to be in severe congestion state, then ER needs to be replaced in RM suitably, as follows:

\[ \text{ER} = \min (\text{ER}, \text{MACR} * \text{ERF}) \]

Where ERF is Explicit Reduction Factor, set to a default value of 0.9375.

3.2 Simulation Environment
The basic EPRCA scheme described in previous section was implemented using NIST ATM Network Simulator for a sample network configuration shown in fig 1 [7].

Fig.1: A Sample Network Configuration

The network shown in fig.1, consist of four source end systems (BTE1 to BTE 4 – Broadband Terminal Equipment), four destination end systems (BTE5 to BTE8), nine communication links (link1 to link 9), two switches (switch1 and switch2), four applications (Available Bit Rate applications ABR1 to ABR4) running on source end systems and another four applications (ABR5 to ABR8) running on destination end systems. The ABR applications are attached to source and destination terminals for sending and receiving data respectively. For example, in given network configuration, four virtual channels have been considered for explanation. The first Virtual Channel (VC1) can be established is through BTE1, Switch 1, Switch 2, and BTE 5. The Second Virtual Channel (VC2) is through BTE 2, Switch 1, Switch 2, and BTE 6. The Third Virtual Channel (VC3) is through BTE 3, Switch 1, Switch 2, and BTE 7. The Fourth Virtual Channel (VC4) is through BTE 4, Switch 1, Switch 2, and BTE 8.

In our simulation, the source end systems transmit cells at its given Allowed Cell Rate which is initially set to PCR with default value of 149 Mbps. The bandwidths of all links (i.e. link 1 to link 9) were set to 155 Mbps. The default values for various control parameters of switches and source end systems are also set, as mentioned in Table 1 and Table 2 respectively.
Table 1: Control parameters for Switch1 & Switch 2 for EPRCA scheme

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queue length (in cells)</td>
<td>1000</td>
</tr>
<tr>
<td>Low threshold (in cells)</td>
<td>600</td>
</tr>
<tr>
<td>Very Congested Queue Threshold (in cells)</td>
<td>900</td>
</tr>
<tr>
<td>Explicit Reduction Factor (ERF)</td>
<td>0.9375</td>
</tr>
<tr>
<td>Major Reduction Factor (MRF)</td>
<td>0.95</td>
</tr>
<tr>
<td>Average Factor (AV)</td>
<td>0.0625</td>
</tr>
</tbody>
</table>

Table 2: Control parameters of source end systems for EPRCA scheme

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Cell Rate (ICR)</td>
<td>7.49 Mbps</td>
</tr>
<tr>
<td>Minimum Cell Rate (MCR)</td>
<td>1.49 Mbps</td>
</tr>
<tr>
<td>Peak Cell Rate (PCR)</td>
<td>149.76 Mbps</td>
</tr>
</tbody>
</table>

3.3 Results Analysis
The performance of EPRCA Scheme is measured based on cell drop percentage during transmission period of data cells. The graph showing cell drop percentage over transmission time is shown in figure 2.

Fig 2 Percentage of Cell drop Vs Time at Switch 1 for basic EPRCA Scheme

From the above graph, higher percentage of cell drop is noticed at the beginning of transmission, because ACR was set to PCR. The cell drop at switch 1 is approximately 33% and need a mechanism to reduce.

4. Improved EPRCA Schemes
Improvements to EPRCA scheme have been proposed to reduce the cell drop problem by considering the following modifications to basic EPRCA scheme.

4.1 Improved EPRCA (IEPRCA) Scheme 1
In this, the behavior of source end systems are modified by changing value of PCR to get reduced cell drops as well as optimal link utilization. In basic EPRCA scheme, a default value of 149.7 Mbps is set to PCR. This PCR value is assigned to Initial Cell Rate (ICR) and all source end systems start transmitting cells at higher rates (i.e. with PCR) initially, resulting high cell drops at switch1. The experimental tests have been conducted by varying values for PCR and able to notice that the maximum network efficiency can be reached by selecting PCR value at an optimal value equal to 100 Mbps. The improved EPRCA with optimal PCR value (i.e. modified source end system behavior) was implemented and graph for percentage of cell drop at switch1 over transmission time is Fig. 3.

Fig.3: Percentage of Cell drop Vs Time at Switch 1 for IEPRCA scheme

From the graph, it has been noticed that, the IEPRCA scheme1 gives 21% cell drop, whereas in the case of basic EPRCA scheme it is approximately 33%. So the IEPRCA scheme1 effectively reduces cell drop problem by selecting PCR value at optimum and hence better than basic EPRCA scheme.

4.2 Improved EPRCA (IEPRCA) Scheme 2
The modification of switch behavior is also considered to improve the performance of EPRCA scheme. The modified switch behavior is given below.

1. When non-congested switch receives forward RM cell from source end system, it computes mean ACR (MACR) using the following formula:

\[ MACR = (1 - AV) \times MACR + AV \times CCR \]
4.3 Improved EPRCA (IEPRCA) Scheme3

To reduce the cell drop still further, the effects of method 1 and method 2 have been combined to achieve yet another improved scheme, called, IEPRCA scheme3. In this scheme3, the optimal value of 100 Mbps is set to PCR for source end system and also switch behavior is modified as in IEPRCA scheme2. The IEPRCA scheme3 was implemented and results are shown in form of graph for % cell drop vs time at intermediate switch1 in shown in Fig 5.

4.4 Performance Comparison of EPRCA and improved EPRCA schemes

The performance of IEPRCA schemes and basic EPRCA can be compared by considering the amount of % cell drop at intermediate switch1 and it was tabulated in table 3.

Table 3: Percentage of cell drop for EPRCA and IEPRCA schemes

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Scheme</th>
<th>% cell drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EPRCA</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>IEPRCA Scheme1</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>IEPRCA Scheme2</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>IEPRCA Scheme3</td>
<td>17</td>
</tr>
</tbody>
</table>

From the above the table, it has been noticed that, IEPRCA scheme3 results with 17% cell drop which is considerably less than that of basic EPRCA scheme as well as IEPRCA scheme1 and scheme2. Hence it can be
concluded that IEPRCA scheme3 is far better than the basic IEPRCA scheme.

5. Conclusion

In this paper, 3 methods have been proposed to enhance the performance of basic EPRCA scheme, (i) by setting PCR to optimal value (IEPRCA scheme1), (ii) by modifying the switch behavior (IEPRCA scheme2), and (iii) by setting optimal PCR value and modified switch behavior (IEPRCA scheme3). The IEPRCA scheme3 found to achieve the best results when compared to basic EPRCA scheme as well as other improved schemes IEPRCA scheme1 and IEPRCA scheme2.

References


Author’s Biography

M. Sreenivasulu received B.Tech degree in Computer Science and Engineering, from K.L. College of Engineering (K.L. University), Vaddeswaram, A.P. India, in 1990. He completed M.E. in Computer Science & Engineering, from Jadavpur University, Calcutta, India, in 1999. He received Ph.D. in Computer Science and Engineering, from J.N.T.University, Anantapur, A.P, India, in the year 2013. He is having 21 years of teaching experience. He is currently working as Professor & Head of Computer Science and Engineering Department, K.S.R.M.College of Engineering, Kadapa. He is member of IEEE, life member of IE(I), and ISTE. He published 15 papers in international journals and in the proceedings of National and International Conferences.