TCP-Friendliness of Modified Explicit Rate Adjustment

Azamuddin Ab. Rahman & Osman Ghazali
College of Art and Science
Universiti Utara Malaysia, 06010 UUM Sintok, Malaysia
{s86401 | osman }@uum.edu.my

Abstract - Explicit Rate Adjustment (ERA) protocol is among the Layered Multicast Protocols (LMPs) that was designed for supporting multimedia data transmission. It uses combination of equation-based and packet pair estimation techniques to estimate the rate for data transmission. Although ERA protocol has several advantages over previous LMPs, there are a few flaws in its design and implementation. The flaws are concerning with Round Trip Time (RTT) and Packet Loss Rate (PLR), which are the main parameters of TCP-Equation Model. Thus, some modifications on ERA protocol have been made to improve its performances. The modified protocol is called modified ERA. This paper reports the evaluation performance ERA and modified ERA in term of TCP-Friendliness. The evaluation is performed using simulation and the result show modified ERA achieves superior performance.

I. INTRODUCTION

In a rapidly developing field in video streaming over the best-effort Internet, Layered Multicast Protocols (LMPs) have attracted the attention of research community. Many researchers have been actively involved in designing their LMPs e.g. PLM, WEBRC, FLID-DL etc. All these LMPs attempted to achieve the desirable LMP properties such as smoothness, responsiveness, less packet loss, efficiency of network utilization, fairness, scalability and TCP-friendliness. Despite the attention and considerable research effort toward LMPs, the desirable LMP properties in particular congestion control mechanisms are still being discussed [1, 2].

Explicit Rate Adjustment (ERA) [3], the receiver-driven layered multicast protocol was proposed in 2003. It includes the improvement over the previous of MR-MCC such as RLC, PLM and FLID-DL. This protocol estimates an explicit target rate using the combination of Packet Pair estimation technique [4] and TCP-Equation Model technique [5].

Some drawbacks have been found in ERA that make ERA protocol is not really suitable to implement in the network. The drawbacks in ERA are Round Trip Time estimation and Packet Loss Rate estimation. So, this work attempts to solve the problems by implementing Scalable Round Trip Time (SRTT) estimation technique by Ghazali and Hassan [6] and loss event rate (LER) with Min-max operation estimation technique by Nahm and Jay Kou [7]. Then, we perform comparative evaluation of ERA and modified ERA using TCP-friendliness as the performance metric.

The rest of this paper is organized as follows. The next section provides an overview of TCP-Friendliness, Section III provides an overview of TCP-equation model, Section IV describes the modification on RTT estimation, Section V describes the modification on loss rate estimation, Section VI explains the experimental design, Section VII presents and discusses the results and finally section VIII concludes this paper.

II. TCP-FRIENDLINESS

Using TCP for multimedia data is not practical because multimedia applications require a smooth transmission rate and cannot tolerate long delay [8]. Therefore, some multimedia applications use UDP for data transmission. However, UDP does not have congestion control mechanism, which may cause problem to TCP when UDP competes with TCP. Since most Layered Multicast Protocols are using UDP, they should have rate control mechanisms that prevent TCP flows from being overwhelmed by competing UDP flows. Thus, TCP-friendliness concept has been proposed as the mechanism to control non-TCP protocol.

Several researchers define TCP-friendliness in their works. TCP-Friendly is defined as a competing flow uses no more bandwidth than conformant TCP connection in the same network condition [9]. According to Ghazali & Hassan in [10], TCP-Friendliness is defined as the throughput of non-TCP that competes with data flows should not exceed the throughput of competing data flows. Puangprompitag in [11], define TCP-Friendly as that a TCP flow and a non-TCP flow should receive similar steady-state bandwidth share as long as they have similar transmission behavior.
III. TCP EQUATION MODEL

TCP equation that model TCP behavior has been proposed as a rate estimator, which is used by non-TCP protocols to control congestion and to be friendly towards TCP data flows. The most popular model is the TCP Reno equation model proposed in [5] by Padhye et al., please refer to (1) for the outline of the model. The protocol used in this work employs the TCP-equation model to estimate TCP-compatible rates, and adjust the sending or reception rate correspond to the estimated target rate.

\[ R_{TCP} = \frac{s}{RTT \sqrt{\frac{2l}{3} + 3RTO}} \frac{3l}{l(1+32l^2)} \]  

(1)

where \( R_{TCP} \) is the throughput of TCP connection, \( s \) is the segment size (in bytes), \( RTT \) represents the round trip time, \( RTO \) is the retransmission timeout, and \( l \) denotes the loss rate (between 0.0 and 1.0).

IV. MODIFICATION ON RTT ESTIMATION

For the modification of round trip time purpose, the double one-way technique is replaced with Scaleable Round Trip Time (SRTT) estimation that was proposed by Ghazali and Hassan [6]. The SRTT technique solves the feedback implosion problem at the sender even in heterogeneous environment. In addition, the receivers behind the same bottleneck share the same path in RTT estimation and as a result they obtain the same target rate.

The operation of scaleable of RTT is shown in Figure 1, the sender sent RTT estimation announcement packet (green arrow) to all receivers only once, and then the routers will replicate the packet to all receivers. When the receivers receive the packet, they join the RTT layer by sending the IGMP join request (blue arrow) to Router 2. The join request from Receiver A is the first request received by Router 2. Upon receiving the join request from Receiver A, Router 2 immediately sends join request to Router 1. When Router 2 receives join request from Receiver B and Receiver C, it will not send another join request to Router 1 as the request already sent. This prevents the join requests implozing the upper routers and the sender. Upon receiving join request from Router 2, Router 1 will forward the RTT layer packet (black arrow) to Router 2. Upon receiving RTT layer data packets from Router 1, Router 2 replicates the packets and forwards the packet the all subscribing nodes.

![Figure 1. A Multicast Tree with Scaleable RTT Estimation](image)

V. MODIFICATION ON LOSS RATE ESTIMATION

In ERA, the loss rate is estimated by packet loss rate technique. Although the technique is simple and easy to implement in layered multicast, it has several drawbacks where PLR does not accurately model TCP behavior and it takes so long observation period. The solution for these problems is solved with the implementation of LER and Min-max smoothing techniques [7]. The LER recommended as a better representation of TCP behavior [12].

LER uses a dynamic history window and the exponential weighted moving average. An average loss interval is computed as the weighted average of the last \( k \) loss intervals as follows:

\[ l_{avg}(n) = \frac{\sum_{i=0}^{k-1} w_i l_{n-i}}{\sum_{i=0}^{k-1} w_i} \]  

(1)

and for weights \( w_i \):
\[ w_i = \begin{cases} 1 & \text{for } 1 < i < \frac{n}{2}, \\ 1 - \frac{i - \frac{n}{2}}{\frac{n}{2} + 1} & \text{for } \frac{n}{2} < i < n. \end{cases} \] (2)

The recommended windows size is \( k=8 \), which gives weights of 1, 1, 1, 0.8, 0.6, 0.4, and 0.2 for \( w_1 \) through \( w_8 \) respectively.

However, even with LER network protocols still exhibit volatile behaviour. Therefore, Min-max smoothing technique is used to smooth LER sample. Detail of Min-max algorithm was described in [7].

VI. EXPERIMENTAL DESIGN

For the simulation setting, eight parameters that influence the behavior of the ERA and modified ERA are set to default values as in Table 1. The parameters include layering scheme, layer granularity, number of layers, length of PP bunch, min PP required, rate adaptation interval, bandwidth delay product (BDP) and rate multiplicative factor.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>SIMULATION SETTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layering Scheme</td>
<td>Non-cumulative Layering</td>
</tr>
<tr>
<td>Layer granularity</td>
<td>20 Kbps</td>
</tr>
<tr>
<td>Number of layers</td>
<td>100</td>
</tr>
<tr>
<td>Length of PP bunch</td>
<td>2</td>
</tr>
<tr>
<td>Min PP required</td>
<td>4</td>
</tr>
<tr>
<td>Bandwidth Delay Product (BDP)</td>
<td>2 BDP</td>
</tr>
</tbody>
</table>

In this experiment, a simple scenario as in Figure 2 is used to evaluate the performance of LMPs. Although it is simple, it is the appropriate and suitable model for evaluating the protocols in this study.

We use DVMRP routing protocol at all routers, and RED queuing policy with buffer size of double bandwidth delay product for all routers. Constant bit rate (CBR) is used as LMP data source, and we set the packet size of all flows to 1000 bytes. The TCP type used in this experiment is TCP Reno which is the most used TCP [13]. The maximum size of TCP congestion window is set to 1000 packets to remove the effect of the maximum window size.

We start the multicast source at time zero and its sinks at 3 seconds later. In order to avoid synchronisations, all TCP sessions start at between 3 and 4 seconds using RNG seeds. All simulation experiments were running 20 times produce average results and quoted with the error bars 95% confidence level. Beside that, it was run for 200 seconds which is long enough for observing steady-state behaviour.

The analysis is based on the trace file produced by the simulations and the data between the ranges of 100 to 200 seconds is used in the analysis. This is to allow the protocol to achieve its steady state. The results are averaged for all of the simulation runs.

VII. RESULT AND DISCUSSION

TCP-Friendliness is used to measure how fair a non-TCP flow competes with TCP flow. To test TCP-Friendliness, the experiments compare the behavior of each LMP with the behavior of competing TCP flows (1, 2, and 4 flows). Figure 3 shows the trends of Modified ERA and ERA protocols when LMP flow competes with 1, 2 and 4.
TCP flows. Table 3, 4 and 5 shows TCP-Friendliness ratio of the both protocols where each table represent the result from the different simulation.

**TABLE 3**

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Friendliness Ratio</th>
<th>Average Throughput (LMP)</th>
<th>Average Throughput (TCP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERA</td>
<td>0.4650 (Unsatisfactory)</td>
<td>0.386824</td>
<td>0.570952</td>
</tr>
<tr>
<td>Modified ERA</td>
<td>0.9991 (Satisfactory)</td>
<td>0.480122</td>
<td>0.482792</td>
</tr>
</tbody>
</table>

For the first set of experiment in Table 3 where 1 LMP flow compete with 1 TCP flows, the estimated average throughput of modified ERA and TCP flow is roughly 0.48012 Mbps and 0.48279 Mbps respectively. The TCP-friendliness is 0.9991, which is very satisfactory. The estimated average throughput of ERA and TCP is 0.38682 Mbps and 0.5709 Mbps respectively. The TCP-friendliness is 0.4650, which is poor.

**TABLE 4**

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Friendliness Ratio</th>
<th>Average Throughput (LMP)</th>
<th>Average Throughput (TCP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERA</td>
<td>0.4966 (Unsatisfactory)</td>
<td>0.19528</td>
<td>0.41992</td>
</tr>
<tr>
<td>Modified ERA</td>
<td>0.90087 (Satisfactory)</td>
<td>0.311344</td>
<td>0.3456</td>
</tr>
</tbody>
</table>

For the second set of experiment in Table 4 where 1 LMP flow compete with 2 TCP flows, the estimated average throughput of modified ERA and TCP flow is roughly 0.3113 Mbps and 0.3456 Mbps respectively. The TCP-friendliness is 0.9009, which is very satisfactory. The estimated average throughput of ERA and TCP is 0.1953 Mbps and 0.4199 Mbps respectively. The TCP-friendliness is 0.4966, which is poor.

**TABLE 5**

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Friendliness Ratio</th>
<th>Average Throughput (LMP)</th>
<th>Average Throughput (TCP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERA</td>
<td>0.38697 (Poor)</td>
<td>0.08792</td>
<td>0.2272</td>
</tr>
<tr>
<td>Modified ERA</td>
<td>0.99557 (Excellent)</td>
<td>0.19441</td>
<td>0.19528</td>
</tr>
</tbody>
</table>

For the third set of experiment in Table 5 where 1 LMP flow compete with 4 TCP flows, the estimated average throughput of modified ERA and TCP flow is roughly 0.1944 Mbps and 0.1953 Mbps respectively. The TCP-friendliness is 0.9956, which is very satisfactory. The estimated average throughput of ERA and TCP is 0.08797 Mbps and 0.2272 Mbps respectively. The TCP-friendliness is 0.3868, which is poor.

As evidenced by the simulations conducted, modified ERA protocol competes fairly with TCP for all different network conditions, in the other hand ERA achieve poor TCP-friendliness.

**VIII. CONCLUSION**

We present in this paper some modification on ERA protocol which provides solution for RTT estimation and LER estimation. It achieves more satisfactory TCP-Friendliness. Scaleable Round Trip Time (SRTT) estimation and LER with Min-max smoothing technique have significantly improved the performances of modified ERA protocol.

**ACKNOWLEDGEMENT**

The authors would like to express the grateful thanks to staffs at the College of Art and Science, Universiti Utara Malaysia for their moral support.

**REFERENCES**


