APPENDIX 1

CLMA RUN-TIME TRACE

To ensure that our ns-2 implementation of CLMA performs as per our design, we have checked Run-time Trace with two node receivers. Apart from benchmark topology we took this simple topology for every simulation. We use the following scenario for our Run-time Trace.

![Simulation Topology for CLMA Validation](image)

**Figure A1.1 Simulation Topology for CLMA Validation**

The input and output bandwidth are 10 Mbps each and the bottleneck bandwidth is 400 Kbps. The CLMA source and sink start at 1 second.
Table A1.1 Simulation Parameters for Validation of CLMA

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>Start time (in sec) for CLMA source and sink</th>
<th>Stop time (in sec) for CLMA source and sink</th>
<th>Start time (in sec) for TCP source and sink</th>
<th>Stop time (in sec) for TCP source and sink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior link</td>
<td>Bottleneck link</td>
<td>CLMA source and sink</td>
<td>TCP source and sink</td>
<td>CLMA source and sink</td>
</tr>
<tr>
<td>1 Mb</td>
<td>400 Kb</td>
<td>1</td>
<td>20</td>
<td>50</td>
</tr>
</tbody>
</table>

line 1: GLVAR inbp = 1e6
line 2: GLVAR btnbp = 400e3
line 3: GLVAR scenario = 4
line 4: GLVAR packetSize = 500
line 5: GLVAR runtime = 200
line 6: GLVAR run_nam = 0
line 7: GLVAR nukDebug = 1
line 8: GLVAR MrtMode = PIM-DM
line 9: GLVAR PP_burst_length = 2
line 10: GLVAR PP_estimation_length = 3
line 11: GLVAR Queue_sched_ = DropTail
line 12: Bottleneck Link : 20ms 400e3
line 13: InLink node 2 : 5ms 1e6
line 14: InLink node 3 : 5ms 1e6
line 15: OutLink node 4 : 5ms 1e6
line 16: OutLink node 5 : 5ms 1e6
line 17: CLMA sender on node 2 placed at 0
line 18: CLMA receiver on node 4 placed at 1
line 19: CLMA Trace 1 for node 4
line 20: flow ID of TCP Reno 1 = 2
line 21: Attach TCP Reno 1 to node 3
line 22: Attach TCP sink 1 to node 5
line 23: Connect TCP Reno 1 and TCP Sink 1
line 24: Attach FTP 1 on TCP Reno 1
line 25: FTP 1 start at 20

**Line Comments**

1-11 Simulation configurations/parameters
7 Turn run-time trace on
12-16 Exterior links and bottleneck link configuration
17-25 Place sources and sinks, CLMA at 1 seconds and FTP at 20 seconds

line 26: every RRAT, rate adaptation process:
Time Estimate=2.9029036896856022 Now=2.9545508103419005

line 27: Rpp is min of R'pp:

line 28: List of R'pp = 399999.99999999895 399999.99999999895 399999.99999999895 399999.99999999895 399999.99999999895 399999.99999999895 399999.99999999895 399999.99999999895 399999.99999999895 399999.99999999895 399999.99999999895

line 29: Rpp = 399999.99999999895
line 30: hh_npkts=10, hh_nloss=1, npkts=34, nloss=0
line 31: Calculate Rtcp
PLR=0.0, Rtcp: n/a

line 32: choose_layer(): Rtarget: 400000

line 33: choose_layer(): The Target Layer is 19, R19 = 400000.0

line 34: CLMA/ns: 2.95455 node 4 layer 7 ADD-LAYER
line 35: CLMA/ns: 2.95455 node 4 layer 8 ADD-LAYER
line 36: CLMA/ns: 2.95455 node 4 layer 9 ADD-LAYER
line 37: CLMA/ns: 2.95455 node 4 layer 10 ADD-LAYER
Line Comments
26 At every RRAT, rate adaptation algorithms start.
27-29 Calculate $R_{pp}$ from Min of $R'_{pp}$
30-31 Calculate $R_{tcp}$. Yet PLR = 0. So, $R_{tcp}$ is not applicant for target rate.
32-33 Choose the number of layers to be subscribed
34-45 Subscribe to the optimal number of layers
46: every RRAT, rate adaptation process:
Time Estimate=22.141840432665823 Now=22.153485531323518
47: $R_{pp}$ is min of $R'_{pp}$:
48: List of $R'_{pp}$ = 400000.0000000163 400000.0000000163 400000.0000000163 400000.0000000163 400000.0000000163 400000.0000000163 400000.0000000163 200000.00000000815
49: $R_{pp}$ = 200000.00000000815
50: hh_npkts=863, hh_nloss=2, npkts=828, nloss=4
51: Calculate $R_{tcp}$
$PLR=0.004807692307692308$
$R_{tcp} = 1386939.5073044538$
52: choose_layer(): $R_{target}$: 200000
choose_layer(): The Target Layer is 9 \( R9 = 200000.0 \)

CLMA/ns: 22.93768 node 4 layer 18 DRP-LAYER 18

CLMA/ns: 22.93768 node 4 layer 17 DRP-LAYER 17

CLMA/ns: 22.93768 node 4 layer 16 DRP-LAYER 16

CLMA/ns: 22.93768 node 4 layer 15 DRP-LAYER 15

CLMA/ns: 22.93768 node 4 layer 14 DRP-LAYER 14

CLMA/ns: 22.93768 node 4 layer 13 DRP-LAYER 13

CLMA/ns: 22.93768 node 4 layer 12 DRP-LAYER 12

CLMA/ns: 22.93768 node 4 layer 11 DRP-LAYER 11

CLMA/ns: 22.93768 node 4 layer 10 DRP-LAYER 10

**Line Comments**

46 At every RRAT, rate adaptation algorithms start.

47-49 Calculate \( Rpp \) from Min of \( R'pp \)

50-51 Calculate \( Rtcp \)

52-53 Calculate \( Rtarget \), and choose the number of layers to be subscribed

54-62 Subscribe to the optimal number of layers
APPENDIX 2

VALIDATION OF PACKET-PAIR APPROACH

In order to validate our Packet-bunch Probe implementation, the topology depicted in Figure A2.1, is used. The source sends data in pairs to sink via four routers (R0-R3). The bottleneck link is link \textit{R1-R2} with capacity of 32 Kbps. The routers are drop-tail FIFO, with the buffer size of twice delay-bandwidth product.

![Figure A2.1 Simulation topology of Packet-pair validation](image)

The Packet-bunch Probe in our CLMA modules can consistently yield

\[ R_{pp} = 32 \text{ Kbps}. \]

We then shift the bottleneck from the mid-point to link (R0-R1), and link (R2-R3). Our packet-bunch probe implementation still yields within an accuracy of 2\% in all tests.
APPENDIX 3

TCP FRIENDLINESS WITH TWO NODE RECEIVERS

CLMA has good inter-protocol fairness as well as intra-protocol fairness (in particular with respect to TCP).

The objective of the scenario shown in Figure A3.1 is to test TCP-friendliness in simple topology. Here CLMA session shares with a TCP session. The first session starts at the beginning of the simulation with CLMA source and after 20 seconds another session starts with TCP source. When CLMA source is allowed to transmit first, the results are shown in Figure A3.2. This shows a good fairness towards TCP. Regardless of which connection is started first the same fairness is observed.

Figure A3.1 Simulation topology of TCP Friendliness
In this scenario the congestion window size is 2000 packets. Any protocol in the internet must be friendly with TCP. Our TCP friendliness is relying on the Reno flavor, which is the most commonly used flavor of TCP. The packet size is 500 bytes. From Figure A3.2 it can be seen how fairly the bandwidth is shared between TCP and CLMA sources. Also this brings out how responsive the new source is towards changes in network conditions. In chapter 3 we have tested the TCP friendliness with benchmark topology. The results show the friendliness doesn’t change when the topology changes or the number of nodes increases. This shows that a good scalability is possible.

Figure A3.2 TCP Friendliness (CLMA first)