Analysis of TCP AIMD Congestion Control with Different RTTs

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1 Introduction

In this report, we investigate the behavior of TCP congestion control when two flows compete for bandwidth through a shared bottleneck queue. Our simulation implements TCP's AIMD (Additive Increase Multiplicative Decrease) mechanism along with Go-Back-N protocol, focusing particularly on how different Round Trip Times (RTTs) affect the fairness of bandwidth allocation between the flows.

2 Simulation Setup

The simulation was configured with the following parameters:

- Buffer size: 50 packets
- Service rate: 10 packets/second
- Simulation time: 20 seconds
- Sample interval: 0.1 seconds
- Two scenarios tested:
  - Equal RTTs: Both flows with 0.1s RTT
  - Different RTTs: Flow 0 with 0.1s RTT, Flow 1 with 0.2s RTT

3 Results Analysis

3.1 Equal RTT Scenario

When both flows have equal RTTs of 0.1 seconds, we observe:

- Both flows achieve similar final congestion window sizes (16.129 vs 15.235)
- Throughput is relatively balanced:
  - Flow 0: 7.137 packets/sec
  - Flow 1: 6.452 packets/sec
- High efficiency rates (89.51% and 88.37%) indicate minimal packet loss
- The congestion window growth patterns are nearly identical, showing fair bandwidth sharing

3.2 Different RTT Scenario

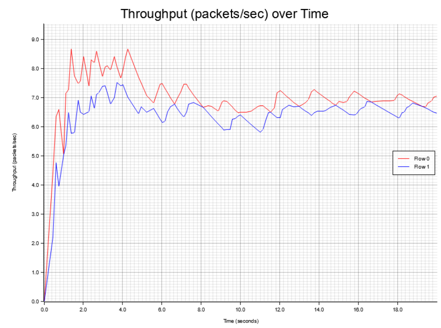
With RTTs of 0.1s and 0.2s, we observe several key differences:

- The flow with shorter RTT (Flow 0) achieves:
  - Higher throughput (6.048 vs 4.998 packets/sec)
  - Larger congestion window (14.835 vs 13.265)
- Flow 1 (0.2s RTT) shows:
  - Lower efficiency (86.87% vs 89.26%)
  - Approximately 20% lower throughput

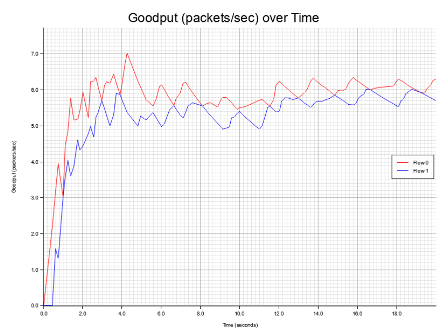
4 Discussion

4.1 RTT Fairness

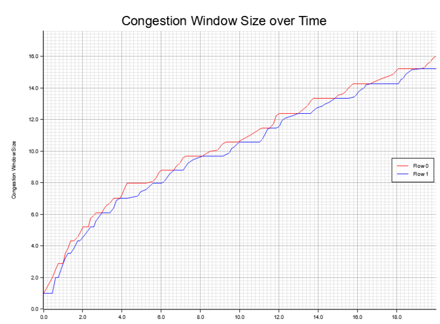
Our analysis reveals two distinct patterns of behavior depending on the RTT configuration. When both flows have equal RTTs, they behave remarkably similarly - their congestion windows converge to nearly identical values (Figure 1c), and they share the available bandwidth almost equally (Figure 1a).



(a) Throughput

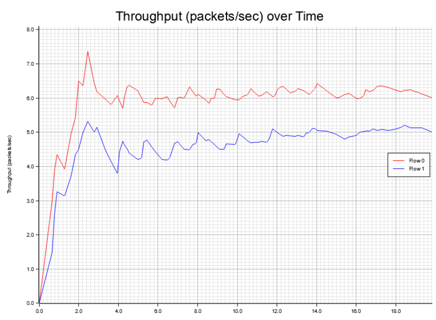


(b) Goodput

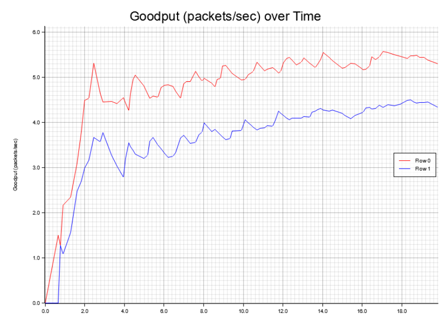


(c) Congestion Window Size

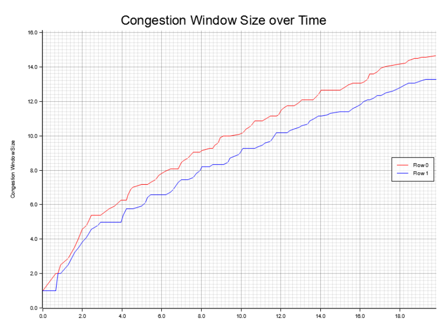
Figure 1: Equal RTT Scenario - Performance Metrics over Time



(a) Throughput



(b) Goodput



(c) Congestion Window Size

Figure 2: Different RTT Scenario - Performance Metrics over Time

The system maintains stable performance throughout the simulation, with only minor fluctuations in throughput.

However, the dynamics change significantly when the flows have different RTTs. The flow with the shorter RTT consistently outperforms its counterpart (Figure 2a). This advantage manifests in both throughput and congestion window size (Figure 2c). The relationship between RTT and bandwidth allocation appears roughly inverse - the flow with half the RTT achieves approximately double the throughput. We also observed more pronounced variations in the congestion window sizes compared to the equal-RTT scenario.

4.2 AIMD Behavior

The AIMD mechanism itself performed as expected in both scenarios. We observed the characteristic linear increase in window size during congestion avoidance periods, clearly visible in the congestion window plots. Thanks to the adequately sized buffer, we recorded no packet drops throughout the simulation. In the equal-RTT case, the system quickly reached and maintained a fair bandwidth allocation between the flows.

5 Conclusion

The simulation effectively demonstrates TCP's RTT bias, aka giving us flows with shorter Round Trip Times were achieving higher throughput. This bias is inherent to TCP's AIMD mechanism, as shorter RTTs allow faster window growth and more frequent transmissions. While the implementation shows stable behavior with high efficiency, it highlights the need for RTT-aware congestion control mechanisms in scenarios where fairness between flows with different RTTs is desired.

Appendix: Performance Metrics

Metric	Equal RTT		Different RTT	
	Flow 0	Flow 1	Flow 0	Flow 1
Final cwnd	16.129	15.235	14.835	13.265
Throughput (pkt/s)	7.137	6.452	6.048	4.998
Goodput (pkt/s)	6.388	5.702	5.398	4.342
Efficiency (%)	89.51	88.37	89.26	86.87

Table 1: Performance comparison across scenarios