CSC 573 - PROJECT 2
Comparative Analysis of TCP Congestion Control Protocols

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TABLE I
TEAM MEMBER CONTRIBUTION

Team Member	Unity ID	Percentage Contribution
Akul Gopal Devali	adevali	33.34%
Tanay Taralbhai Shah	tshah6	33.33%
Umang Sureshbhai Diyora	udiyora	33.33%

TABLE II
TASK DISTRIBUTION

Sub-Tasks	Akul	Tanay	Umang
Research and understanding of ns-3 packages for TCP protocols	30%	35%	35%
Topology setup and configuration	35%	35%	30%
Cubic TCP implementation	40%	30%	30%
DCTCP implementation	30%	35%	35%
Experimental setup for client-server interactions	35%	35%	30%
Performance measurements and plotting	30%	30%	40%
Report preparation	33%	33%	34%
Average contribution	33.34%	33.33%	33.33%

I. TCP ANALYSIS

This project investigates the behavior and performance of two TCP congestion control algorithms: TCP Cubic and DCTCP (Data Center TCP). We implemented a dumbbell topology in ns-3 to evaluate how these protocols behave individually and when coexisting in the same network environment.

A. Experimental Setup

We configured a standard dumbbell topology with two sender servers (S1, S2) and two destination servers (D1, D2), connected through two routers (R1, R2). All links were established with 1 Gbps bandwidth. For each experiment, we transferred 50 MB of data using ns-3's bulk sender application and measured throughput and flow completion time across five different scenarios:

1) Exp-1: S1 sends traffic to D1 using TCP Cubic
2) Exp-2: Both S1 and S2 send traffic using TCP Cubic simultaneously
3) Exp-3: S1 sends traffic to D1 using DCTCP
4) Exp-4: Both S1 and S2 send traffic using DCTCP simultaneously
5) Exp-5: S1 uses TCP Cubic while S2 uses DCTCP simultaneously

Each experiment was repeated three times, and we calculated average values and standard deviations.

B. Plot of Average Throughput

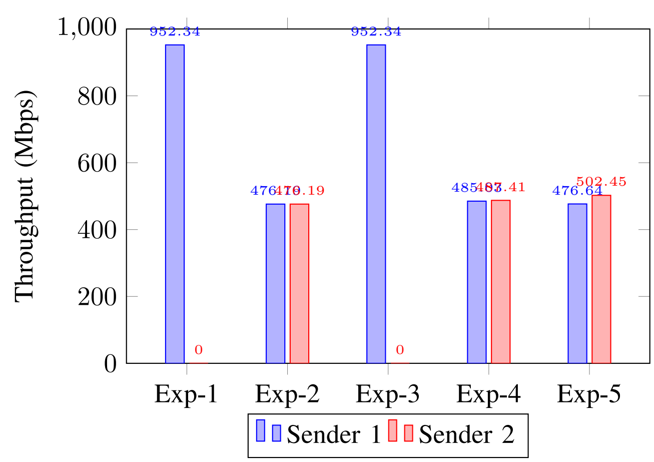

Fig. 1. Average throughput comparison across different experiments

C. Plot of Average Flow Completion Time

II. ANALYSIS AND OBSERVATIONS

A. Single Flow Performance (Exp-1 vs Exp-3)

Both TCP Cubic and DCTCP demonstrated identical throughput (952.34 Mbps) and flow completion time (0.435 seconds) in single-flow scenarios. This indicates that when operating alone without competition, both protocols are able to utilize the available bandwidth effectively.

The consistency in these results can be attributed to the absence of congestion, as both protocols have nearly optimal

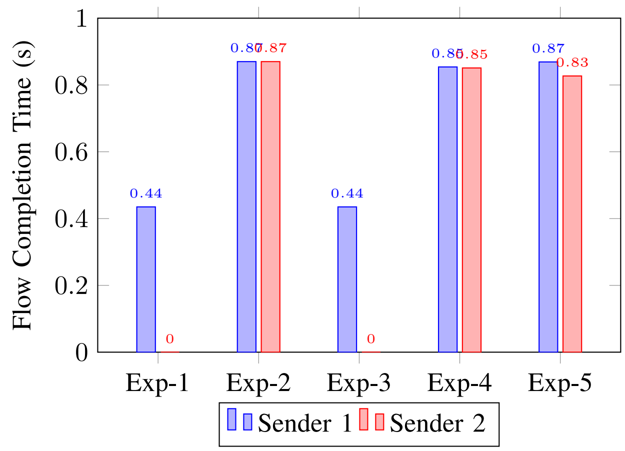

Fig. 2. Average flow completion time comparison across different experiments

conditions to operate within the 1 Gbps network capacity. The standard deviation for throughput in TCP Cubic (6.1×10^{-5}) shows remarkable stability across test runs.

B. Multiple Flow Performance (Exp-2 vs Exp-4)

When two flows compete using the same protocol:

- **TCP Cubic (Exp-2):** Both senders achieve almost identical throughput (476.19 Mbps) and flow completion time (0.870 seconds), demonstrating TCP Cubic's fair bandwidth sharing mechanism. The standard deviation of 0 suggests perfect consistency across our test runs.
- **DCTCP (Exp-4):** Senders achieved 485.03 Mbps and 487.41 Mbps respectively with higher standard deviations (6.54 and 15.87), indicating more variability in performance. Flow completion times were slightly lower but less consistent than TCP Cubic, averaging around 0.85 seconds.

Both protocols successfully divided the available bandwidth when handling multiple flows, but TCP Cubic demonstrated more consistent fairness with less variation between runs.

C. Mixed Protocol Scenario (Exp-5)

When TCP Cubic and DCTCP compete:

- TCP Cubic sender achieved 476.64 Mbps throughput with low variability (SD: 0.64)
- DCTCP sender achieved 502.45 Mbps with higher variability (SD: 27.43)
- Flow completion time was 0.869 seconds for TCP Cubic versus 0.827 seconds for DCTCP

Our results indicate that DCTCP gained a slight advantage in the mixed environment, achieving approximately 5

D. Protocol Coexistence

Our experiments demonstrate that both TCP protocols can coexist reasonably well, with neither protocol severely impacting the performance of the other. In the mixed scenario, the bandwidth allocation remained close to the fair share point of 500 Mbps per connection, with DCTCP taking a small advantage.

This generally fair coexistence can be attributed to:

- Both protocols responding appropriately to congestion signals
- Similar congestion window adjustment mechanisms despite different mathematical models
- Effective queue management in the router interface

III. Conclusion

Our comparative analysis of TCP Cubic and DCTCP reveals that:

1) In single-flow scenarios, both protocols achieve similar performance, utilizing nearly all available bandwidth.
2) In multiple-flow scenarios with identical protocols, TCP Cubic demonstrates more consistent fair sharing than DCTCP.
3) When competing together, DCTCP shows slightly higher throughput but with greater variability.

These findings suggest that TCP Cubic may be preferred in scenarios where consistent fair sharing is critical, while DCTCP might offer slight performance advantages in mixed environments but with less predictability.

For future work, it would be valuable to investigate these protocols under varying network conditions, including different RTTs, buffer sizes, and competing traffic patterns. Additionally, examining performance with more than two competing flows would provide further insights into scalability aspects of these congestion control algorithms.