Assignment 4, Part 2: Congestion Control Analysis

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1. Experimental Analysis

Experiment 1: Fixed Bandwidth

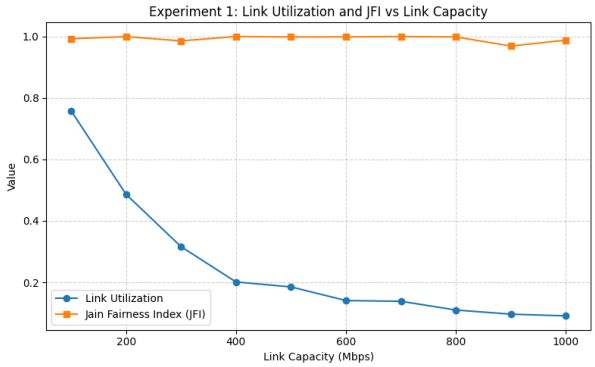

Figure 1: Experiment 1: Link Utilization and JFI vs Link Capacity

Observations:

- **Jain Fairness Index (JFI):** The JFI remained near-perfect (approximately 1.0) across all bandwidths, indicating that the two flows shared the bandwidth very fairly.
- **Link Utilization:** Utilization was highest at 100 Mbps (around 75%) and decreased as link capacity increased, dropping to below 10% at 1 Gbps. This is likely because the fixed-size file transfer finishes before the congestion window has sufficient time to grow and saturate the high-capacity link.

Experiment 2: Varying Loss

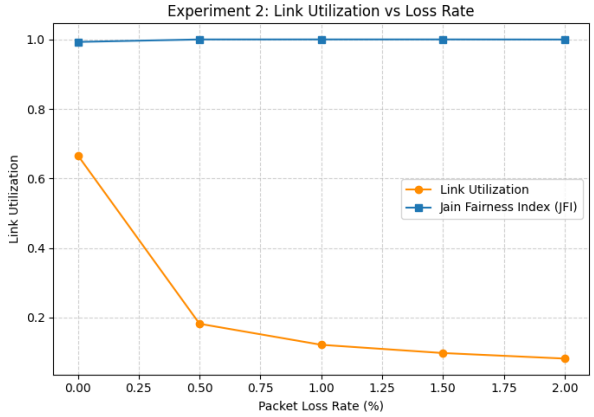

Figure 2: Experiment 2: Link Utilization vs Loss Rate

Observations:

- Link utilization is highly sensitive to packet loss.
- Utilization dropped sharply from ∼68% at 0% loss to ∼18% with just 0.5% loss.
- This is expected, as CUBIC is a loss-based algorithm. Each loss event is interpreted as congestion, triggering a window reduction and severely throttling throughput.
- JFI remains constant and fair.

Experiment 3: Asymmetric Flows

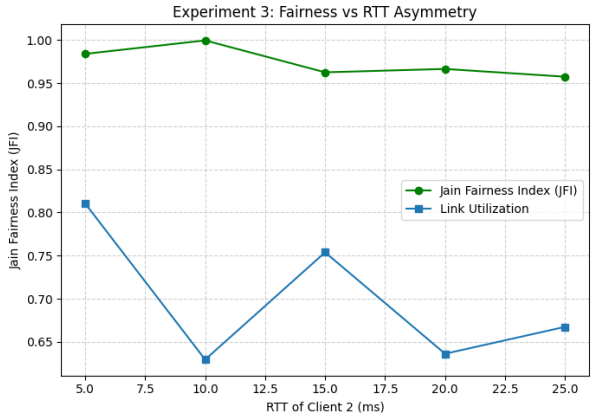

Figure 3: Experiment 3: Fairness vs RTT Asymmetry

Observations:

- Fairness remained high (JFI > 0.95) across all scenarios.
- There is a slight downward trend in fairness as the RTT disparity increases (e.g., JFI is 0.958 at 25ms).
- CUBIC's growth is time-based, not RTT-based, which makes it less susceptible to RTT unfairness than TCP Reno. However, the flow with the shorter RTT can still complete ACK cycles faster, giving it a slight advantage in discovering new bandwidth.

Experiment 4: Background UDP Traffic

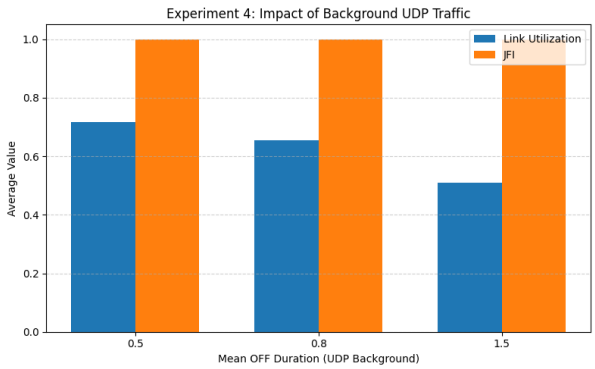

Figure 4: Experiment 4: Impact of Background UDP Traffic

Observations:

- **Link Utilization:** As the UDP "OFF" time decreased (i.e., UDP traffic became heavier and more frequent), the link utilization increases.
- **Jain Fairness Index (JFI):** JFI remained at or near 1.0 in all cases.