Evaluating the Impact of L4S on TCP Performance

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1 INTRODUCTION

The Latency Challenge

- Applications like XR, cloud gaming, and tele-operation feel unresponsive if queueing delay exceeds 10 ms.

Limitations of Classic TCP

- **Cubic** fills buffers under bursty load, causing persistent delay [1, 2].
- **BBR** mispredicts capacity when RTT or bandwidth shifts suddenly [3].

What L4S Promises

- **Sub-millisecond delay** even under jitter or bandwidth changes
- **High throughput** without bufferbloat
- **Fair coexistence** between scalable and legacy traffic [4, 5]

2 BACKGROUND

L4S = Dual-Queue AQM + ECN + Scalable CCAs (e.g., TCP Prague, ECN-BBRv3)

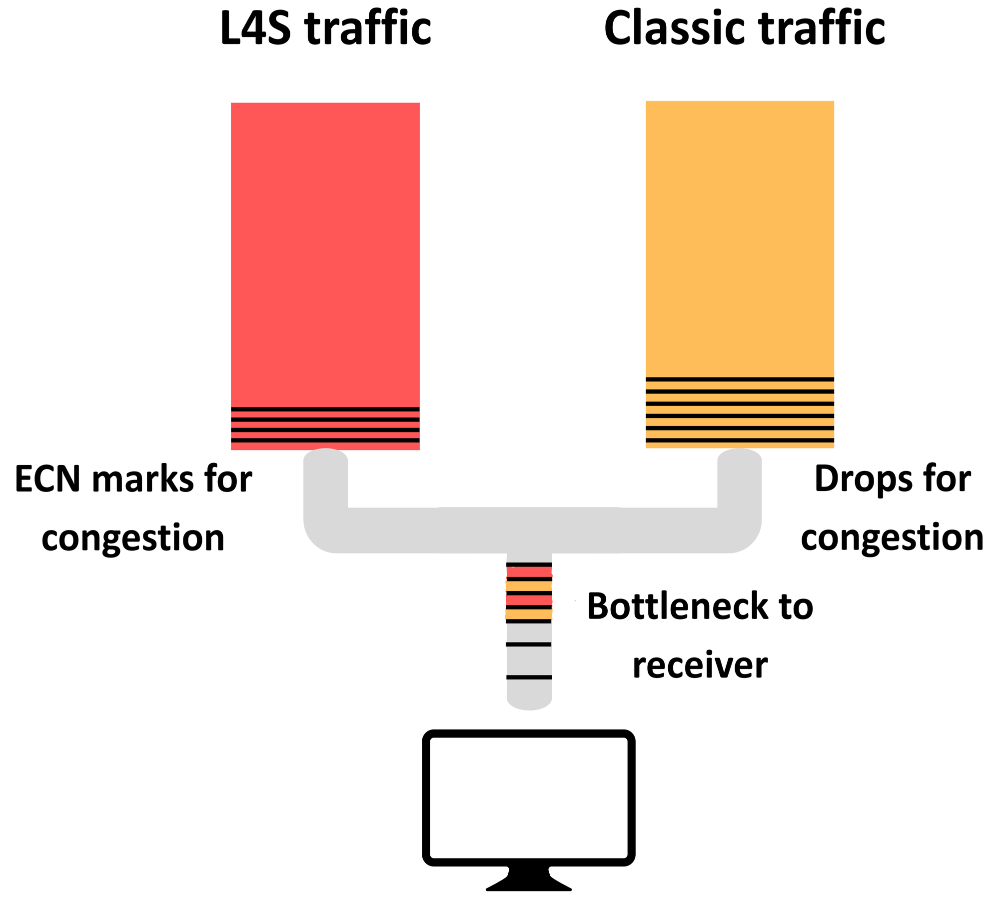

Figure 1: L4S Dual-Queue Architecture

3 RESEARCH OBJECTIVE

This aim of this project was to evaluate **whether L4S can deliver on its promises**, using a **simulation-based testbed in ns-3**.

We addressed these **research questions**:

1. How does **TCP Prague** perform under **RTT jitter** compared to **TCP Cubic**?
2. How does L4S react to **rapid bandwidth changes** in wired and Wi-Fi networks?
3. Is L4S **fair when sharing a bottleneck** with legacy TCP?
4. How do scalable CCAs like **TCP Prague** and **ECN-BBRv3** interact in **coexistence**?
5. Is L4S robust to **wireless packet loss?**

4 METHODOLOGY

ns-3

- We simulated **L4S** in **ns-3** using **DualPI2**, **TCP Prague**, and **ECN-BBRv3**.
- We evaluated **throughput**, **mean and 95th-percentile queueing delay**, and **fairness (JFI)** using long-lived TCP flows.
- Experiments are run over **two topologies**:

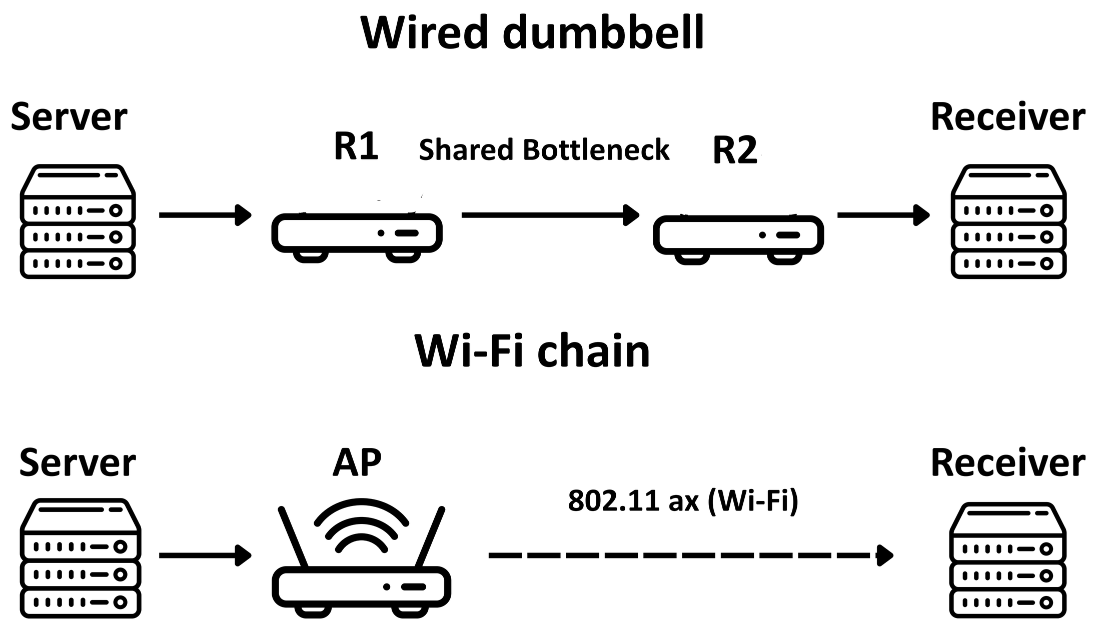

Figure 2: topologies used in the ns-3 simulations.

5 RESULTS

RQ1–RQ2. Delay & Adaptation

Prague keeps <1 ms delay under jitter and bandwidth shifts. Cubic shows **higher delay** and adapts **slower**.

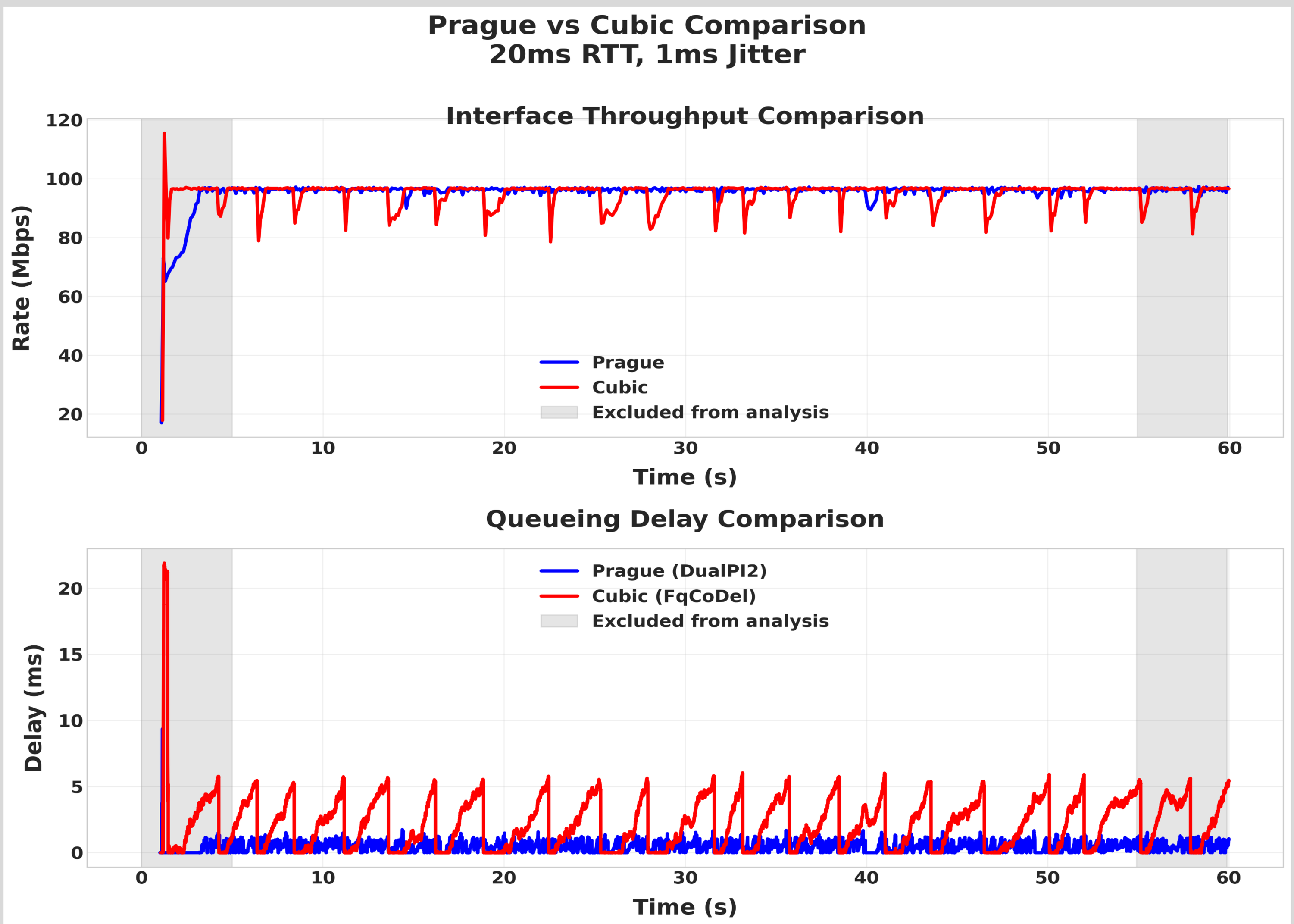

Figure 3: Prague vs Cubic with ±1 ms RTT jitter, 20 ms RTT.

RQ3–RQ4. Fairness

Prague gets 4× more throughput than **Cubic** in shared queues, but shares fairly **with ECN-BBRv3.**

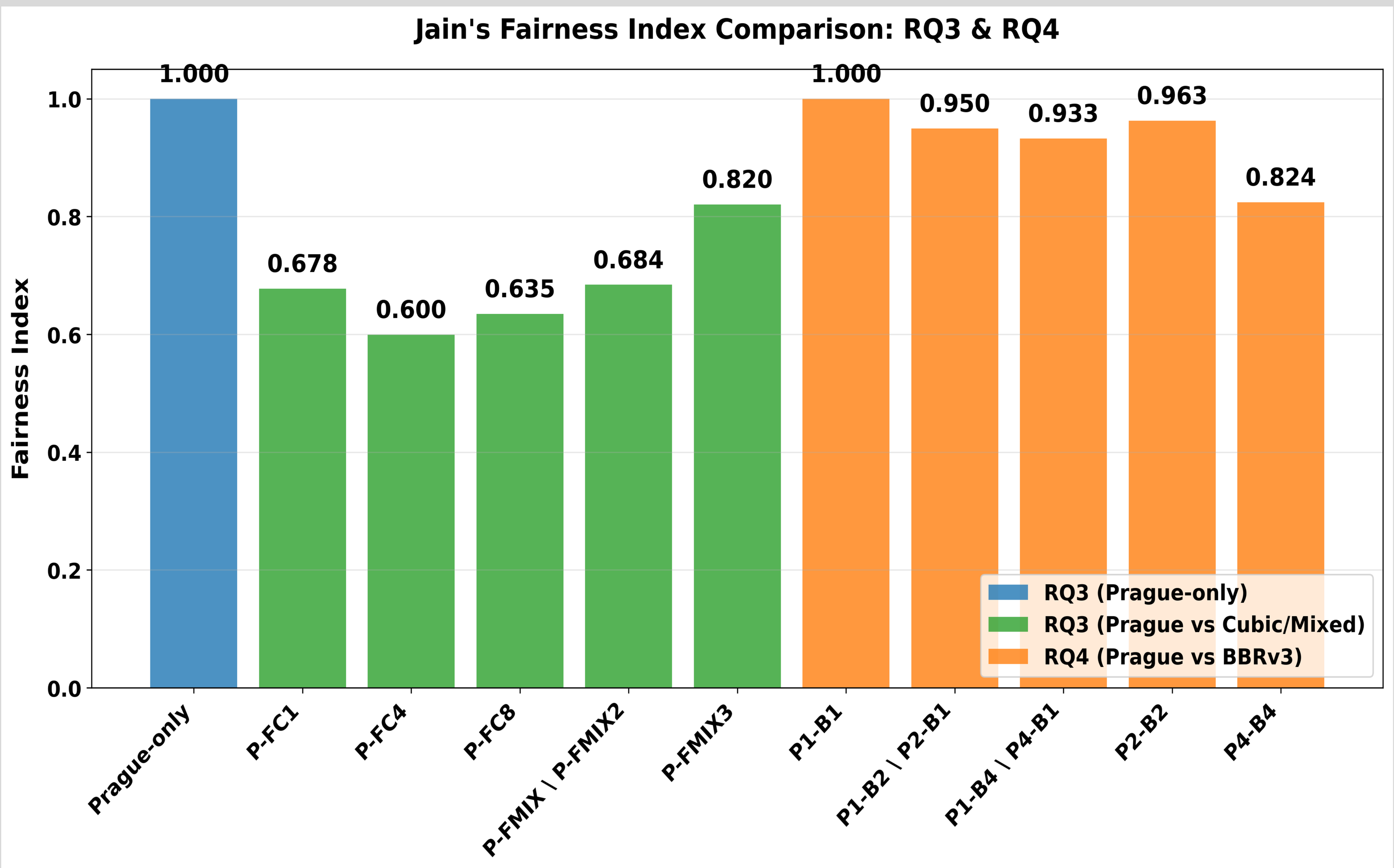

Figure 4: Jain's Index across traffic mixes with Cubic and ECN-BBRv3.

RQ5. Loss Sensitivity

Prague sees only a 5–8% drop vs. **Cubic** under **random Wi-Fi loss.**

Loss Rate	Prague Mean Throughput	Cubic Mean Throughput
1%	34.0 Mb/s	36.1 Mb/s
5%	32.1 Mb/s	34.6 Mb/s
10%	29.8 Mb/s	32.4 Mb/s

Table 1: Mean throughput under Wi-Fi loss for Prague vs Cubic.

6 CONCLUSIONS

- L4S meets its goals of **low delay and stable throughput** across varied conditions.
- Prague **outperforms** Cubic in both **delay** and **adaptability**, but dominates unfairly in shared queues.
- Scalable flows like ECN-BBRv3 **share bandwidth fairly**.

7 LIMITATIONS

- Real testbeds are needed to validate these simulations.
- Our ECN-BBRv3 model is a patched approximation.
- Future work should tune AQM parameters and test diverse traffic patterns.

REFERENCES

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