Testing the impact of in-transmission bandwidth and delay variation on selected TCP variants

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1. Background

The Transmission Control Protocol (TCP) is a protocol that is fundamental to transmitting data on the internet.

Due to its importance in computer networks, **we need to know its boundaries and limits to maximize efficiency and prevent potentially catastrophic errors.**

Research on behavior of TCP and its variants when in-transmission delay and bandwidth changes occur mostly consists of work from decades ago, **which does not include CCAs that are common nowadays.** Two of these were tested in this paper:

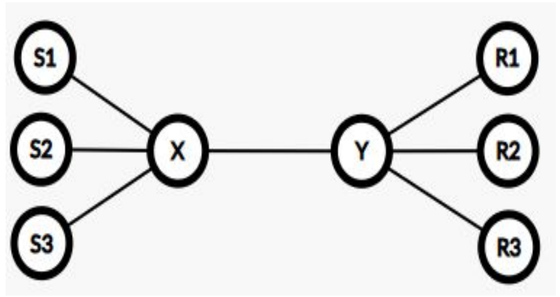
- **TCP CUBIC**
- **BBRv1**

2. Research Question

"How do TCP CUBIC and BBRv1 perform when bandwidth or delay varies significantly during transmission?"

3. Methodology

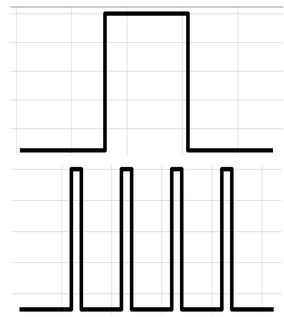
- **Wireless dumbbell topology used**
- Access link bandwidth constantly higher than bottleneck bandwidth
- Access link delay = 0
- Constant transmission
- Maximum queue size of 2 x BDP
- Implemented in the **ns-3 framework**
  - Great when no physical setup
  - A variety of built-in tools for proper connection simulations
  - Full implementation on GitHub



4. Experiments

6 scenarios ran:

- Large bandwidth step
- Small bandwidth step
- Multi-flow bandwidth step
- Small delay spikes
- Big delay spike
- Bandwidth and delay step



Metrics checked:

- Packets lost
- Congestion window size over time
- Throughput over time
- Fairness (JFI) for multi-flow tests

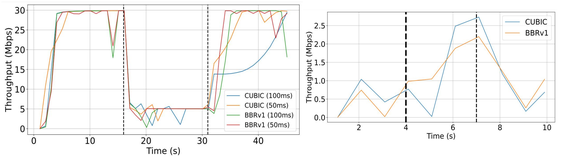
5. Results

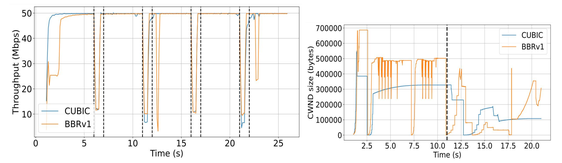
Similarities:

- Connection instability on bandwidth fluctuation (especially in case of frequent/high steps)
- Relatively similar recovery from bandwidth drops
- Lack of domination (high JFI) on short bandwidth-varying connections
- Near-zero bandwidth drop on delay spikes
- Little to no packet loss on delay spikes

Differences:

- BBRv1 adapted to sudden bandwidth increases way faster
- CUBIC recovered slightly slower in case of frequent delay spikes
- BBRv1 struggled to adapt to a bandwidth + delay change - causing issues with cwnd size and packet loss





6. Conclusions

- **BBRv1 proved to be better for in-transmission bandwidth or in-transmission delay**
- **However, in case of both, CUBIC prevailed**
- Both CCAs experienced similar issues to ones found in studies from the past

More research on this topic would be highly beneficial:

- More scenarios
- Testing other common CCAs (BBRv3)
- Utilizing physical setups