Data Transport for the Orbiting Internet

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Introduction

- *Internet from space* is becoming a viable reality
- SpaceX, Amazon, Telesat are/will be deploying low earth orbit (LEO) satellite constellations
  - … competing with/complementing terrestrial networks
- 1000s of satellites in multiple orbital shells and planes per shell
- Inter-satellite and ground station to satellite links

LEO Satellite Network Characteristics

- Aggregate bandwidth in the order of hundreds of Tbps
  - comparable to today's aggregate fibre capacity
- Sub-10ms round-trip time between Earth and first-hop satellite
- Low end-to-end latency - can be smaller than best theoretical fibre path can support

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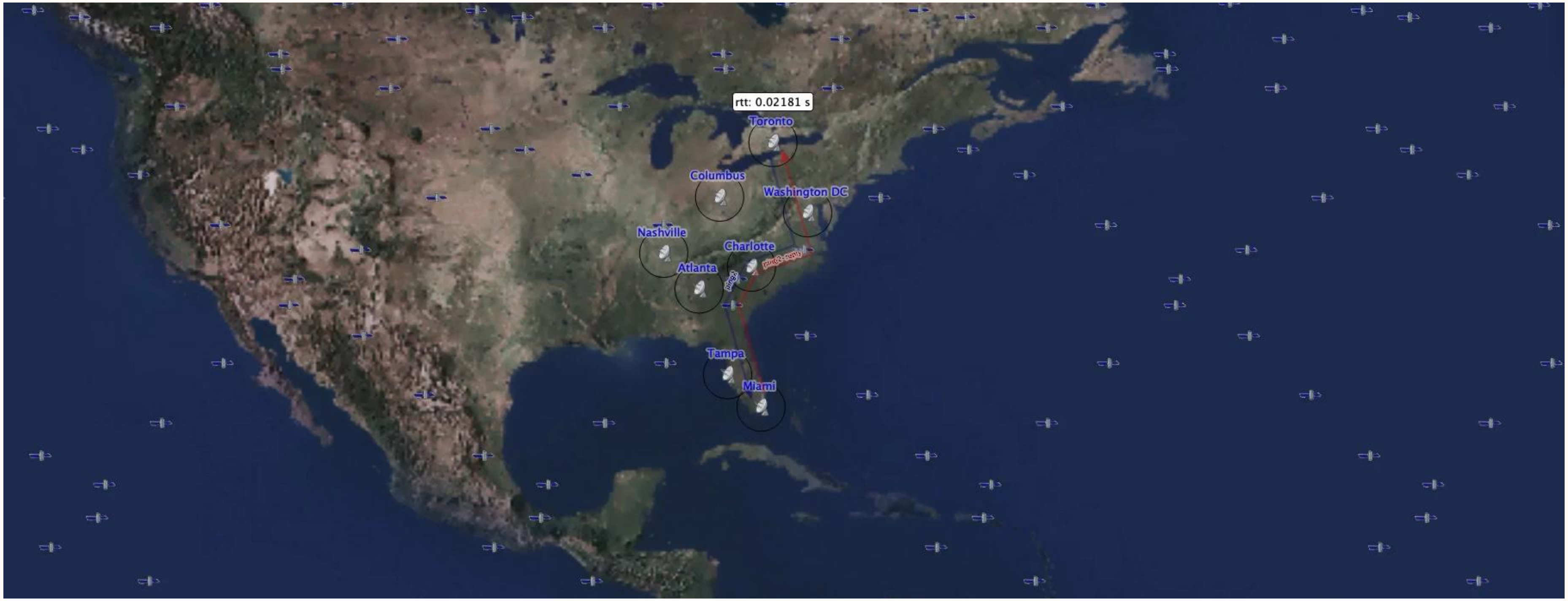
Network Dynamics



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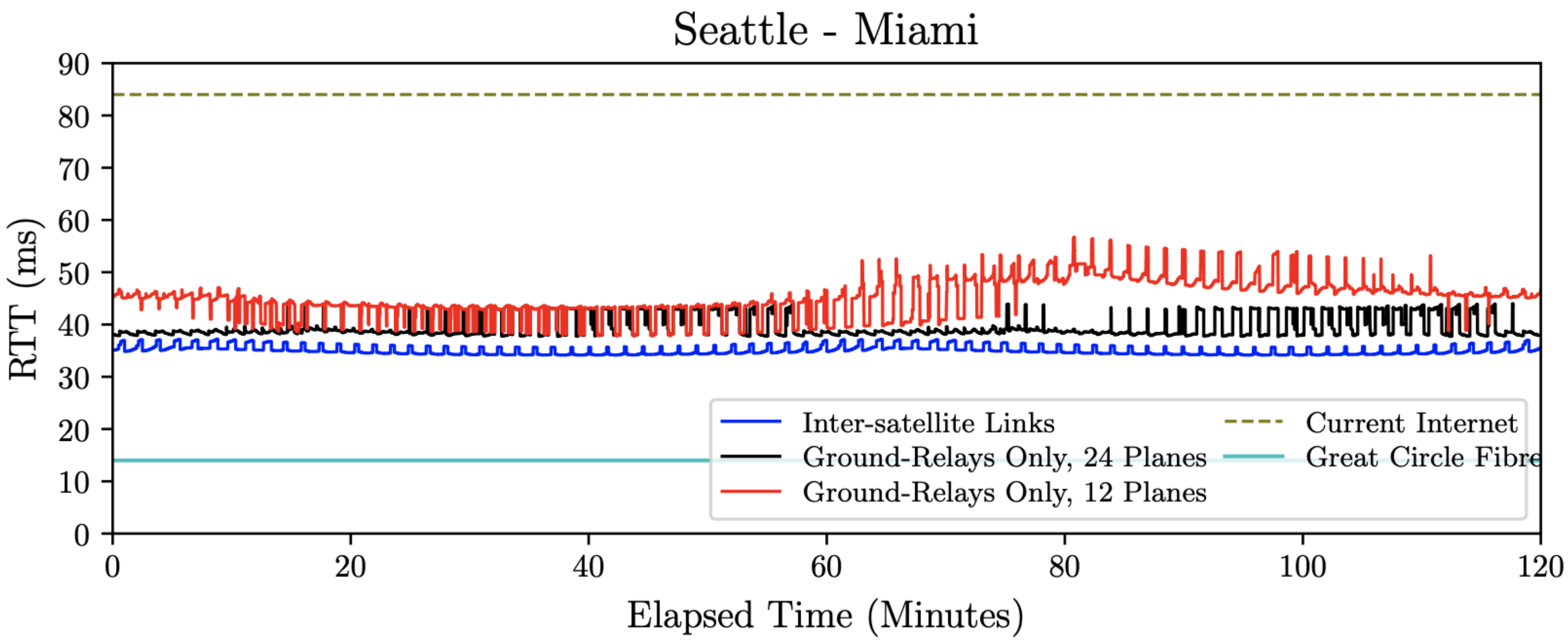
Non-Congestive Latency Variation



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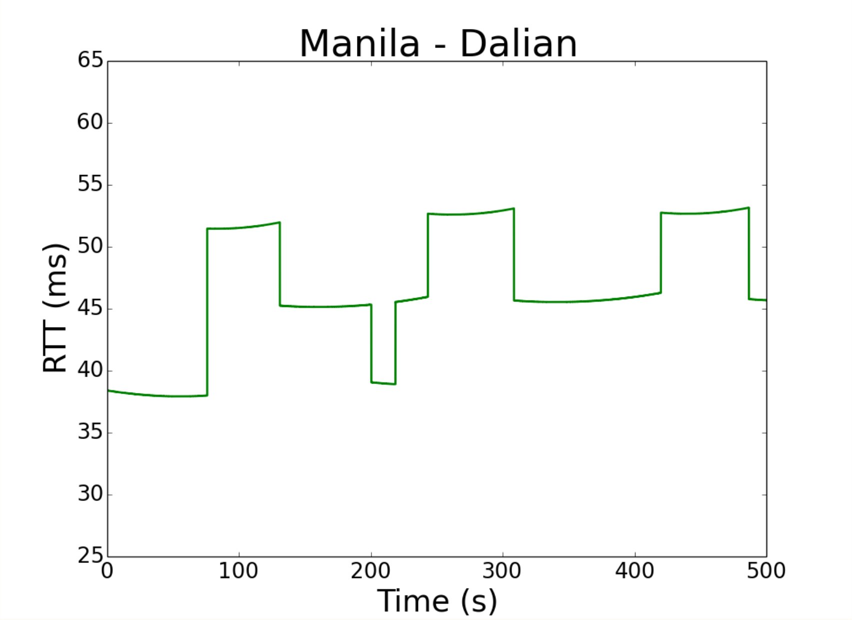
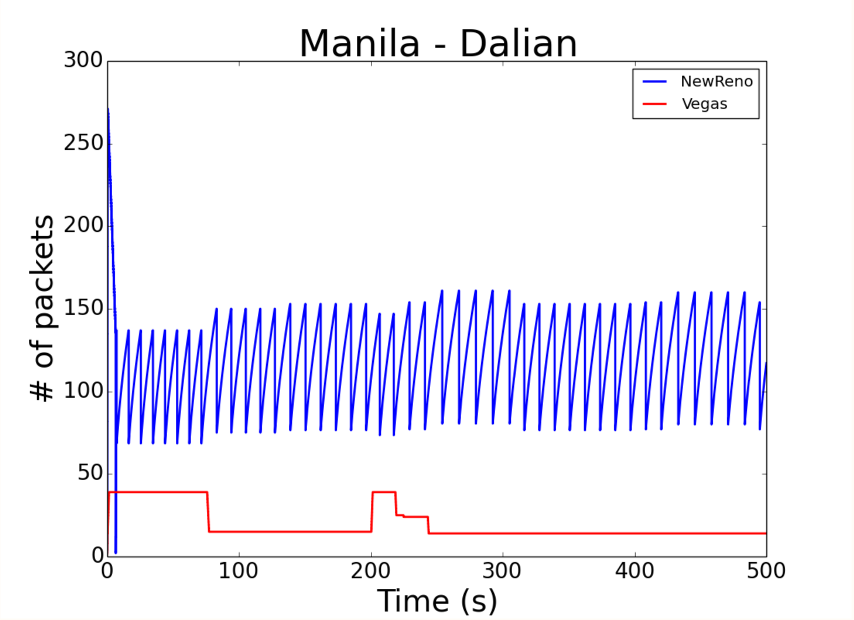
Loss- and Delay-based Data Transport

round trip time



congestion window size



Kuiper constellation - shell K1, 1156 satellites, 630km altitude, 34 orbital planes, 34 satellites per plane, 51.90 inclination, 10Mbps link speed, 100 packet buffers

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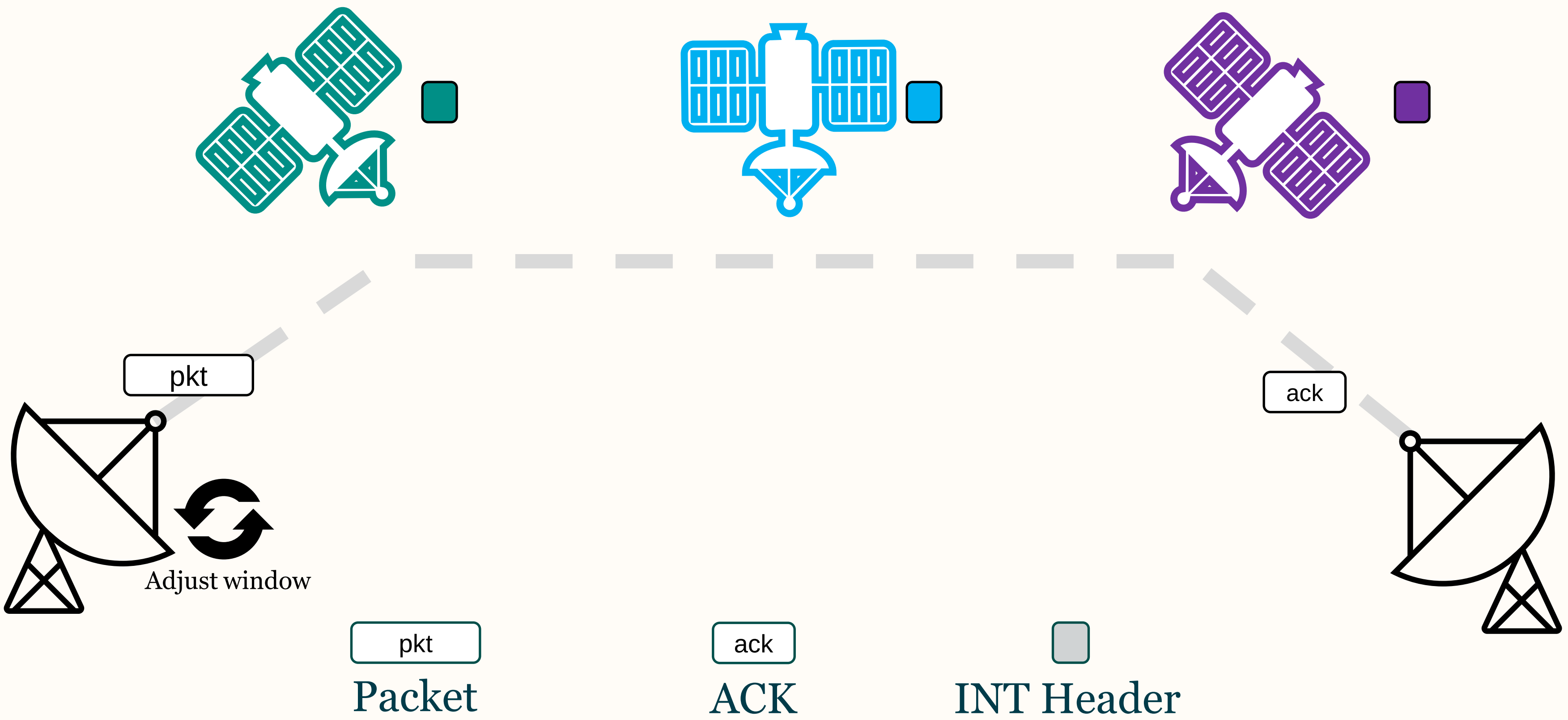
OrbTCP

- Novel Data Transport built on top of TCP
- Leverages In-Network Telemetry (INT) to gather per-hop congestion information
    - Minimize buffer occupancy and latencies for end hosts
    - Maximize application throughput and network utilization
    - Swiftly respond to network hotspots

INT Overeiew



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Congestion Control

- The sender determines the amount of congestion at each hop by calculating the number of in-flight bytes for each outgoing link
  - Additive Increase – Proportional to the number of flows sharing the bottleneck, with the base value being 5% of the BDP
  - Multiplicative Decrease – maintains a target utilization (0.95%) to ensure low buffer occupancy and full link utilization.

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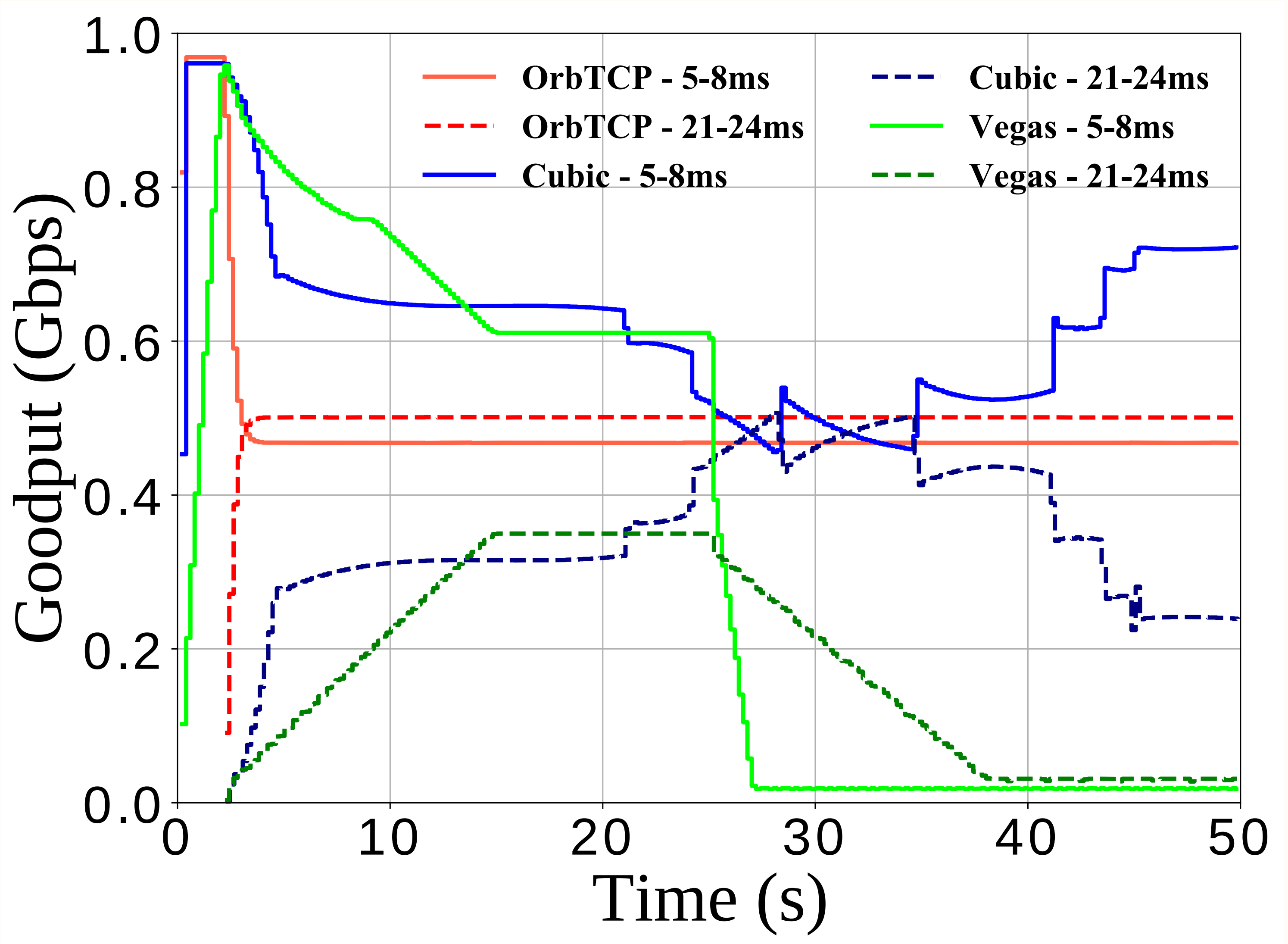
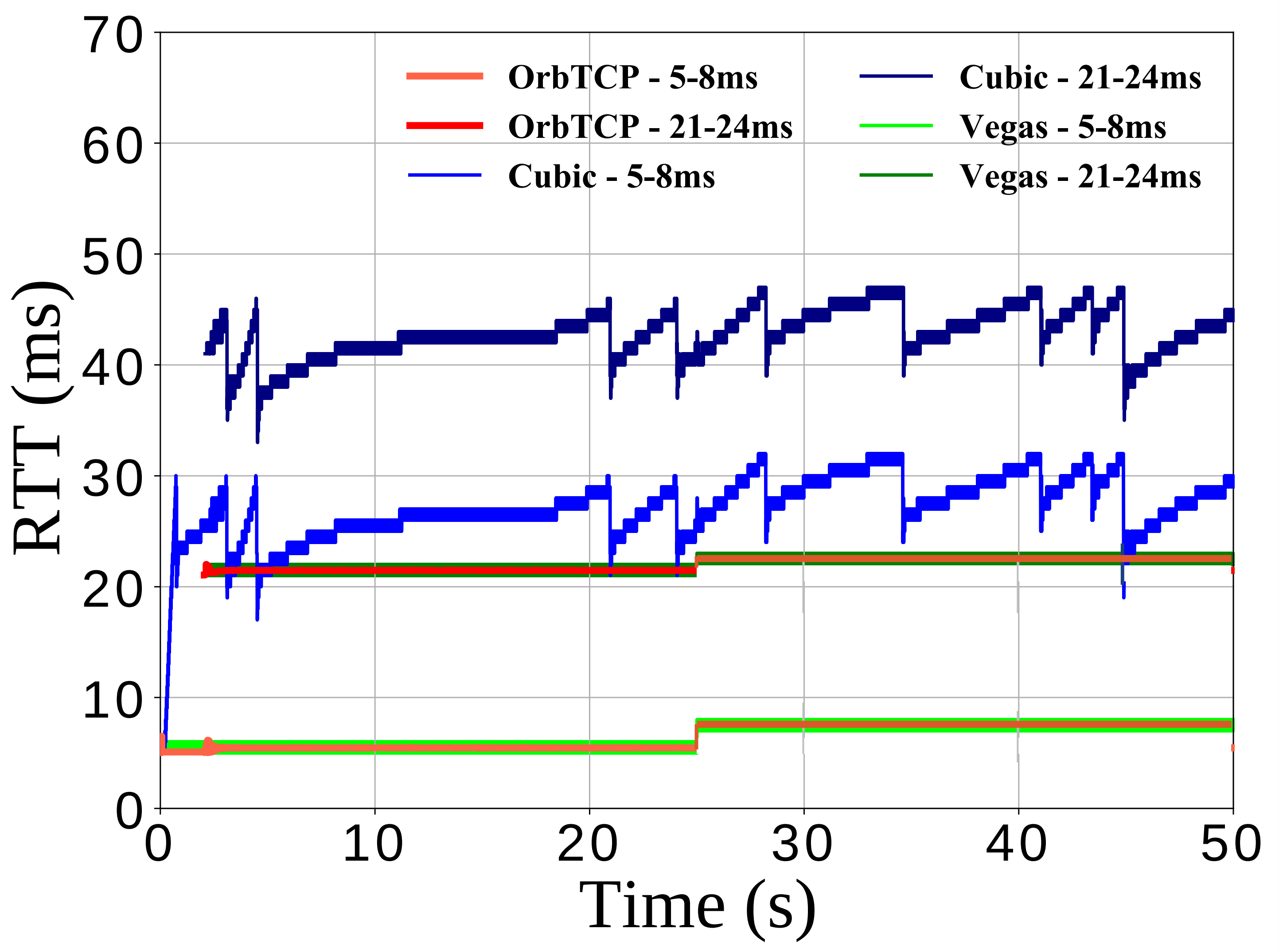
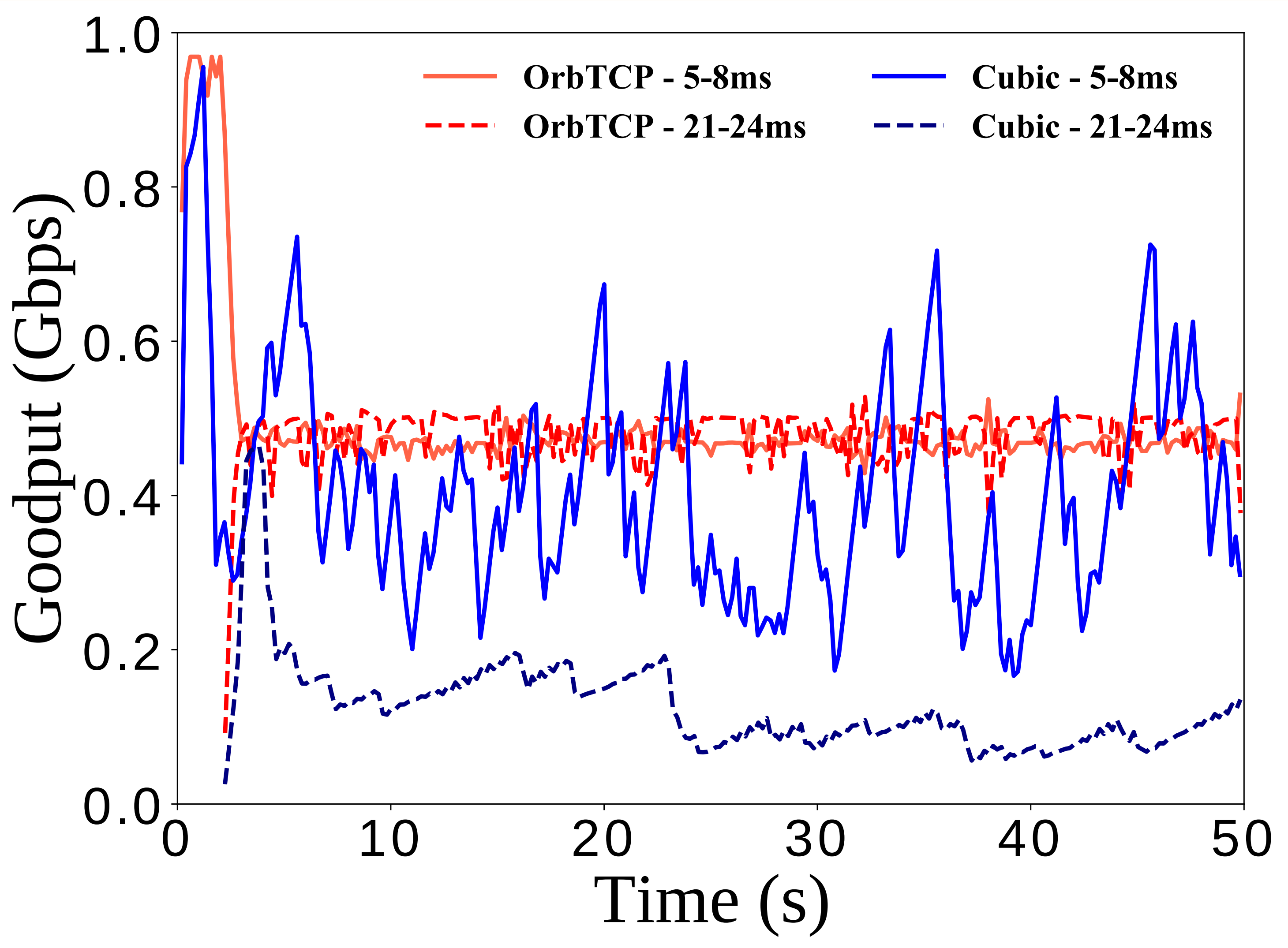
Latency Change Experiment



Latency Change Experiment



Non-Congestive Loss



Current Work

- Large-scale experimentation using the developed LEO satellite network model in OMNeT++

- Explore a multipath for OrbTCP

LEO Satellite Model – OMNeT++

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