Benchmarking Methodology for Reliable Transport Protocols in Integrated Space and Terrestrial Networks

draft-lai-bmwg-istn-transport-00

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Outline

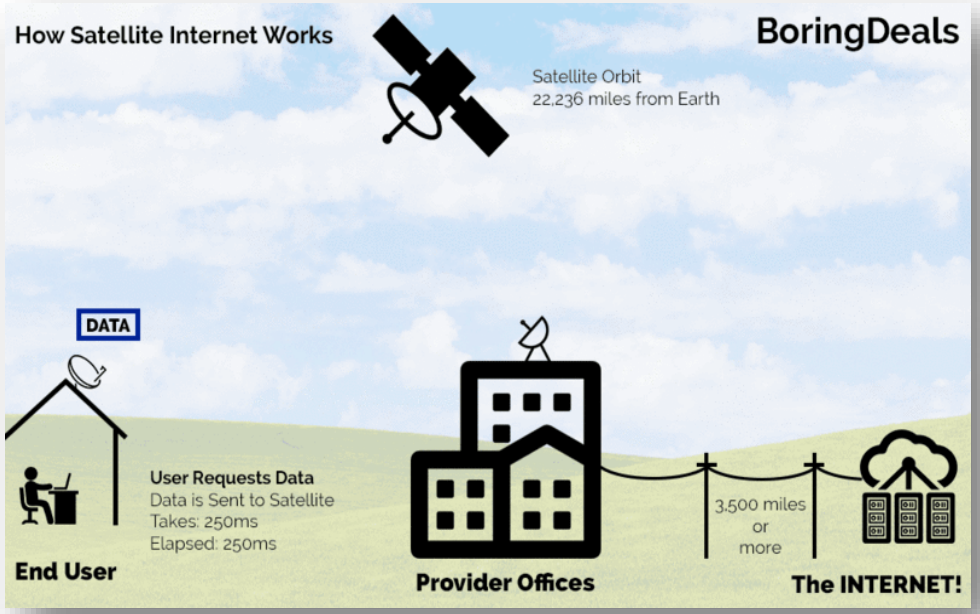
- **Background and Motivation**
- Test Setup
- Benchmarking Tests
- Preliminary Results
- Conclusion and Future Work

Satellite Internet Services

- **Satellites have long been used to provide Internet services**
  - Especially for regions where fiber optic cables may not be feasible
- **The unique satellite links involve challenges on transport protocols**
  - Geostationary satellites (~36000km) involve high propagation delay and packet losses
  - The IETF has a range of RFCs discussing the **benchmarking methodology** [RFC6349] and **enhancement recommendations** [RFC357,2488] for transport protocols

Viasat
AUTHORIZED RETAILER

HughesNet
AUTHORIZED RETAILER



Network Working Group
Request for Comments: 2488
BCP: 28
Category: Best Current Practice

M. Allman
NASA Lewis/Sterling Software
D. Glover
NASA Lewis
L. Sanchez
BBN
January 1999

Enhancing TCP Over Satellite Channels
using Standard Mechanisms

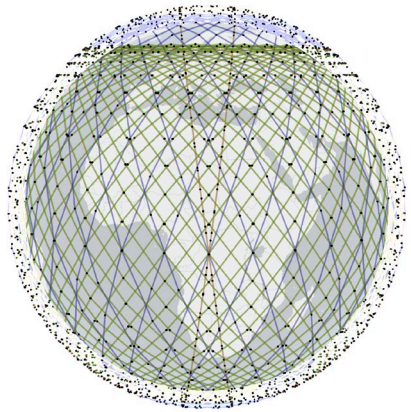
Framework for TCP Throughput Testing

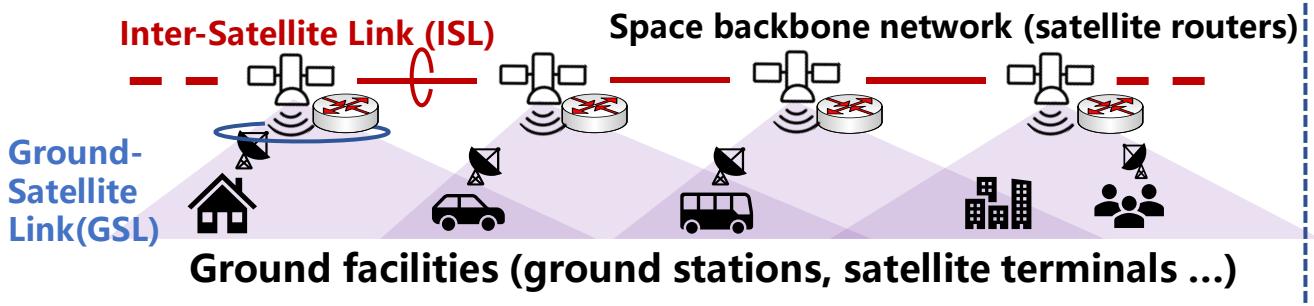
Abstract

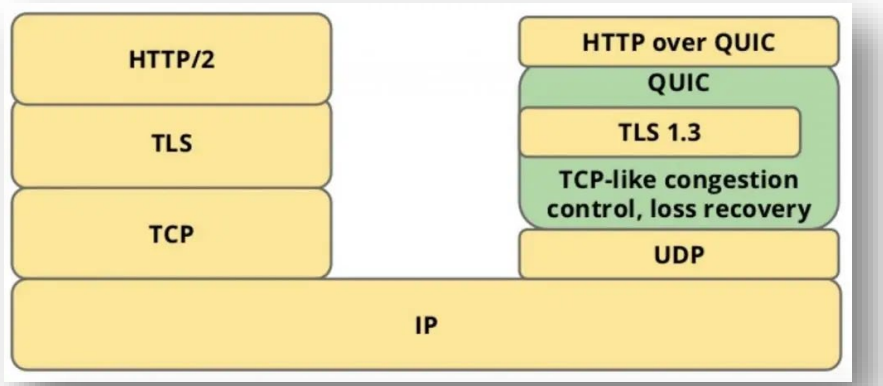
This framework describes a practical methodology for measuring end-to-end TCP Throughput in a managed IP network. The goal is to provide a better indication in regard to user experience. In this framework, TCP and IP parameters are specified to optimize TCP Throughput.

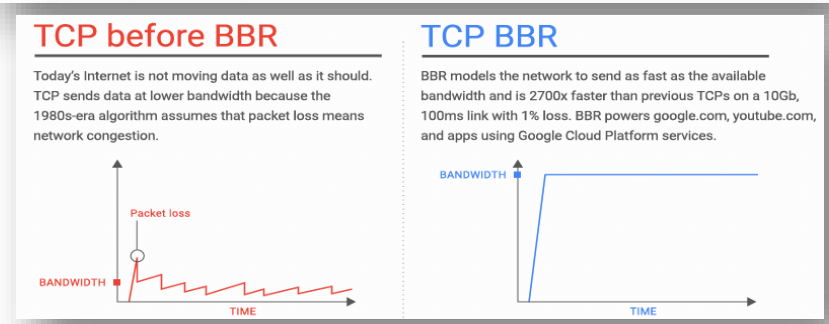
Satellite Internet Services

- **Both of them have evolved significantly in recent years**
  - **Satellites:** from GEO satellites to Low-Earth Orbit (LEO) satellite constellations
    - much lower latency as compared to its predecessors; high LEO dynamics
  - **Transport:** new protocols (e.g. QUIC …), new algorithms (e.g. BBR …)
    - from loss-based and delay-based to model-based





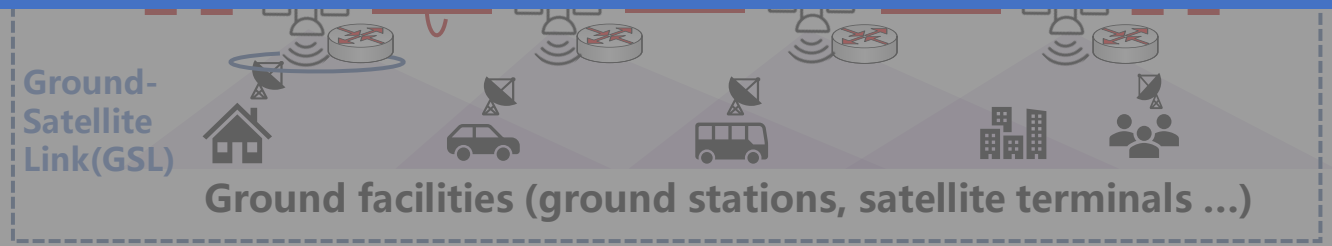


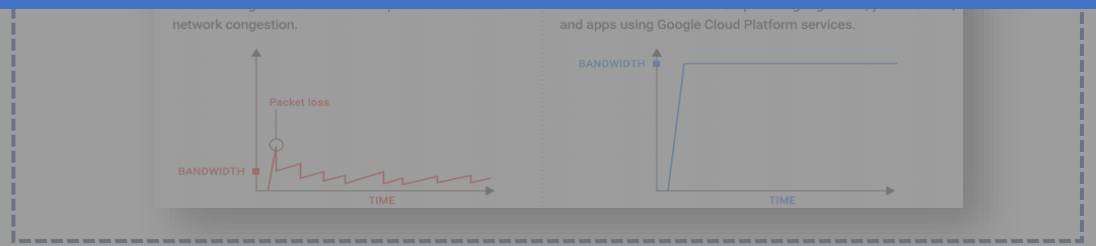


Satellite Internet Services

- Both of them have evolved significantly in recent years

Towards emerging LEO satellite networks which will carry a large amount of Internet traffic, well-defined and reproducible benchmarking methodology and performance indicators for transport layer protocols should be needed.





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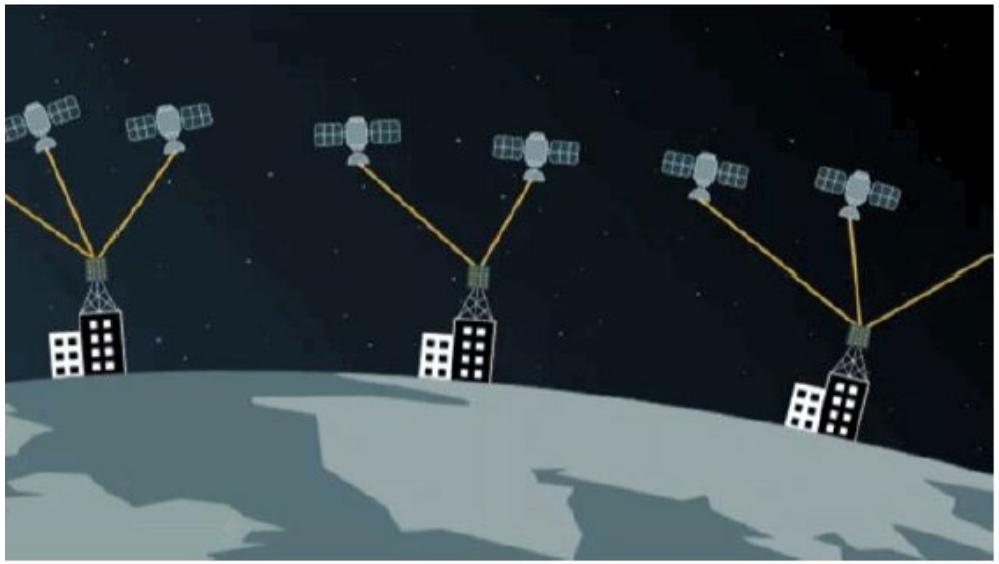
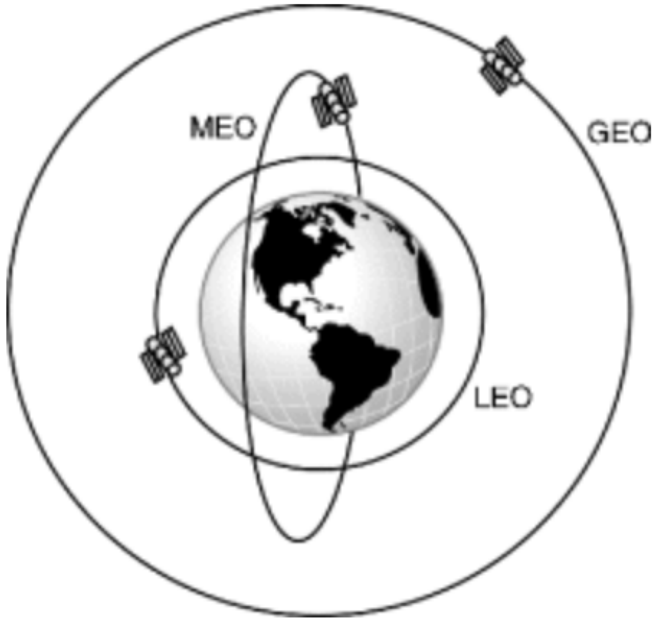
Goal of The Testbed

- **Goal**: The testbed setup is expected to:
  - create an **isolated** benchmarking environment that **appropriately simulates the unique characteristics of integrated space and terrestrial network (ISTN)**
- **ISTN characteristics**
  - **Large-scale constellation**
  - **Frequent and sudden packet losses, which are caused by many factors like:**
    - Failure-prone space environment
    - Endless handover
  - **Dynamic end-to-end Latency**
    - Due to the topology dynamics and routing fluctuations



Testbed Setup

- **A data-driven approach is RECOMMENDED** to build a testbed for ISTNs
  - ①**Collect realistic and public satellite trajectory** (e.g. TLE data from Celestrak)



Communications Satellites	
Active Geosynchronous	
GEO Protected Zone	GEO Protected Zone Plus
Intelsat	SES
Iridium	Iridium NEXT
Starlink	OneWeb
Orbcomm	Globalstar
Swarm	Amateur Radio
Experimental Comm	Other Comm

https://celestrak.org/NORAD/elements/

Testbed Setup

- **A data-driven approach is RECOMMENDED** to build a testbed for ISTNs
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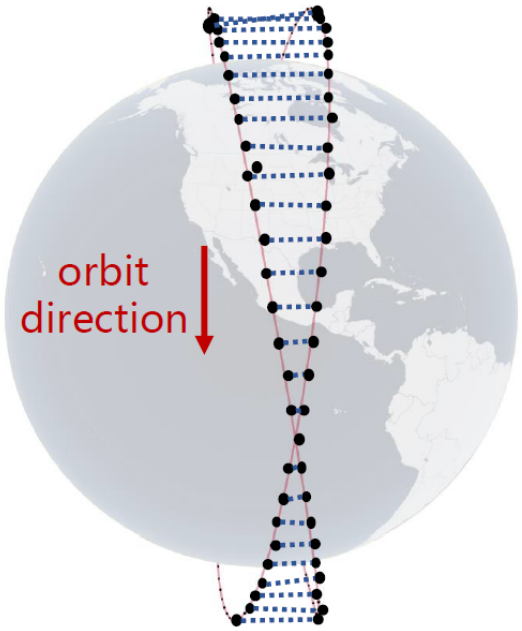
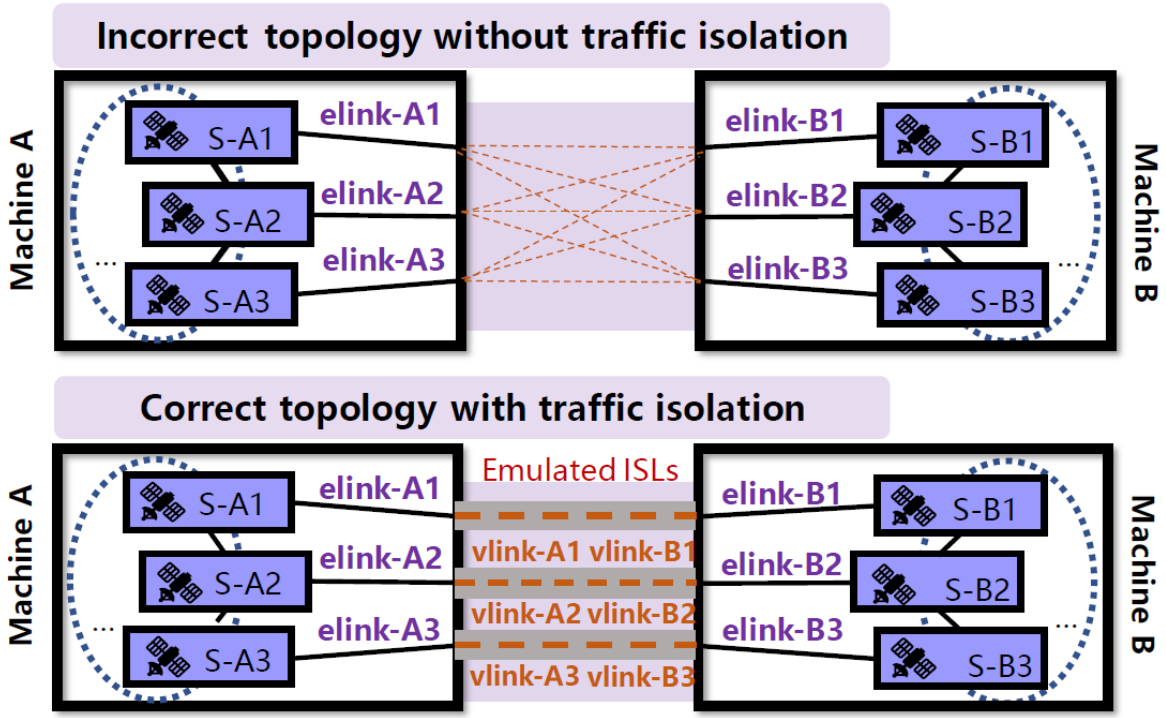
  - **②Exploit virtualization techniques to build a virtual ISTN in the lab environment**



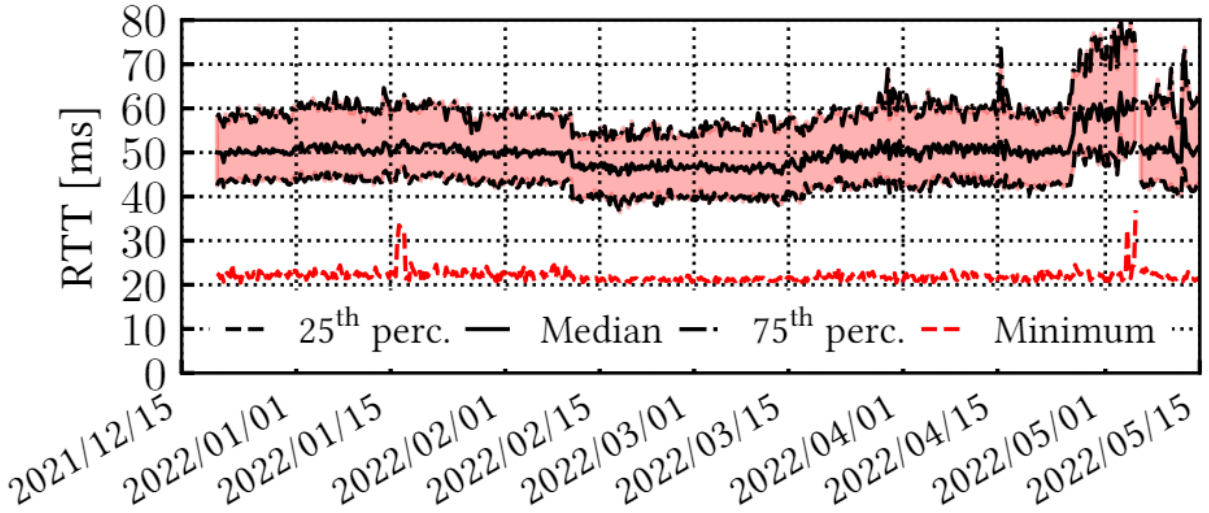


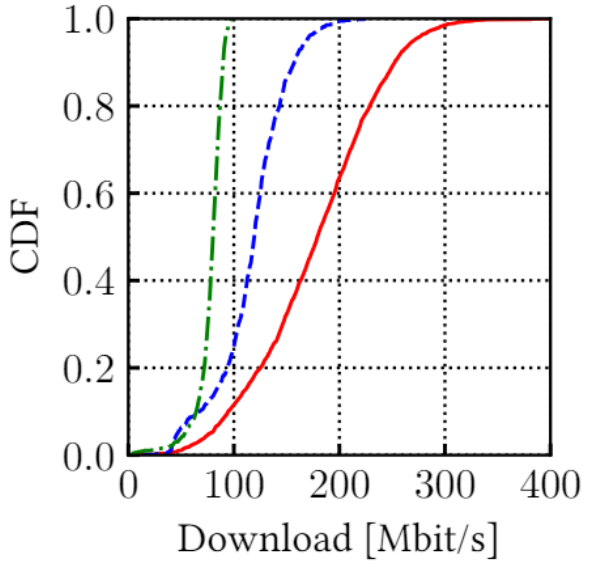
Each virtual machine or container mimics a satellite or a ground station

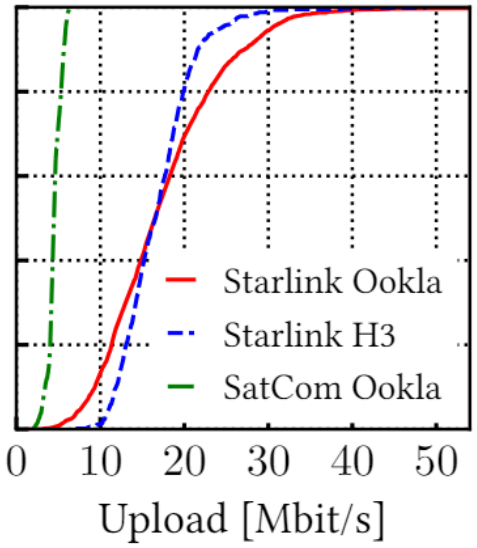
Lai, Zeqi, Hewu Li, Yangtao Deng, Qian Wu, Jun Liu, Yuanjie Li, Jihao Li, Lixin Liu, Weisen Liu, and Jianping Wu. "StarryNet: Empowering Researchers to Evaluate Futuristic Integrated Space and Terrestrial Networks." In 20th USENIX Symposium on Networked Systems Design and Implementation (NSDI 23), pp. 1309-1324. 2023.

Testbed Setup

- **A data-driven approach is RECOMMENDED** to build a testbed for ISTNs
  - **①Collect realistic and public satellite trajectory** (e.g. TLE data from Celestrak)
  - **②Exploit virtualization techniques to build a virtual ISTN in the lab environment**
  - **③Configure each satellite link (e.g. loss and latency) based on real measurements**



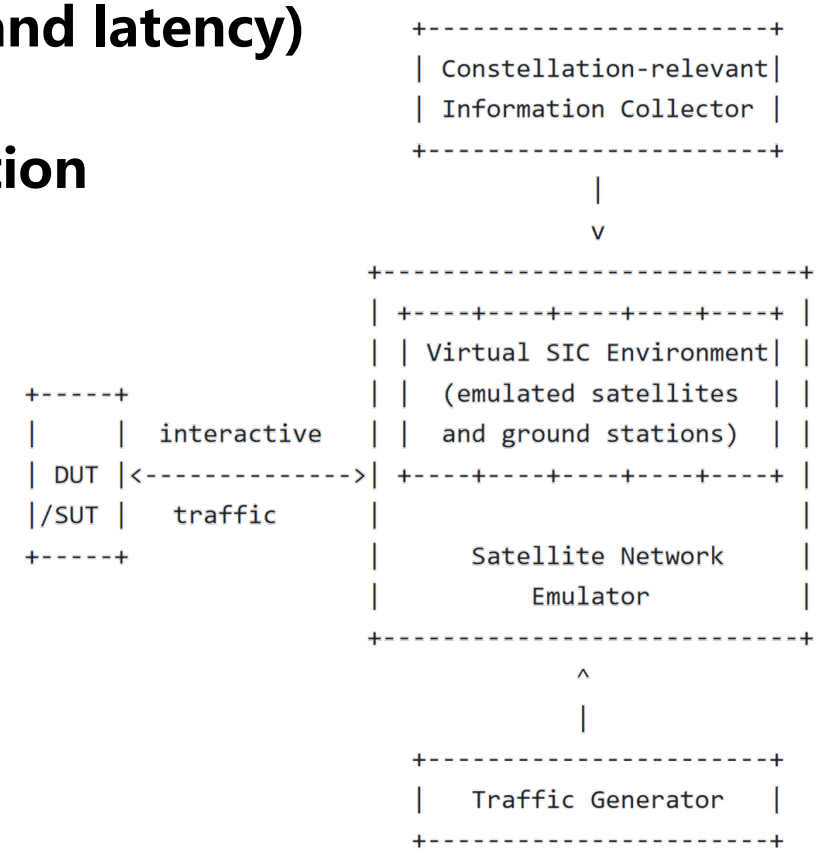




Michel, François, Martino Trevisan, Danilo Giordano, and Olivier Bonaventure. "A first look at starlink performance." In Proceedings of the 22nd ACM Internet Measurement Conference, pp. 130-136. 2022.

Testbed Setup

- **A data-driven approach is RECOMMENDED** to build a testbed for ISTNs
  - **①Collect realistic and public satellite trajectory** (e.g. TLE data from Celestrak)
  - **②Exploit virtualization techniques to build a virtual ISTN in the lab environment**
  - **③Configure each satellite link (e.g. loss and latency)**
  - **④Deploy the DUT/SUT (the transport layer protocol) for evaluation**
    - **TCP、QUIC**
    - **Congestion Control: BBR, Cubic …**



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Benchmarking Tests (1/3)

- **A range of performance indicators should be considered**

- **Throughput**
  - Several common **tools for throughput measurement** are readily available in the network community, e.g. **"iperf" for TCP** and **"qperf" for QUIC**
  - For the ISTN environment, we recommend that the throughput test SHOULD be run over a **relatively longer duration** (i.e., greater than 3 mins or 180 seconds) **to improve the repeatability and characterize the variations**

Benchmarking Tests (2/3)

- **Round-Trip Time (RTT)**
  - The RTT of each TCP segment / QUIC Packet SHOULD be recorded for the calculation of the after-mentioned buffer delay metric
  - **The average and each quartile value** of the RTT records SHOULD be reported.
  - The 90-th, 95-th, and 99-th RTT valued are also RECOMMENDED to be reported, **as tail performance is also a KPI for ISTN**

- **Transfer Efficiency**
  - Transfer efficiency represents the percentage of Bytes that were not retransmitted
  - The TCP Efficiency defined in [RFC6349] **applies to transfer efficiency for both TCP and QUIC here**

Benchmarking Tests (3/3)

- **Buffer Delay Percentage**
  - Buffer Delay Percentage represents the increase in RTT during a TCP Throughput test versus the inherent or baseline RTT [RFC6349]
  - **As the baseline RTT [RFC6349] always changes in ISTN**, we suggest calculating **Buffer Delay Percentage at each second** and the **average value** throughout each test **SHOULD be reported**
  - Specifically, for each second (t), the Buffer Delay Percentage is calculated as follows:

$$\text{Buffer Delay \% (t)} = \frac{\text{Average RTT during t - Baseline RTT (t)}}{\text{Baseline RTT(t)}} \times 100$$

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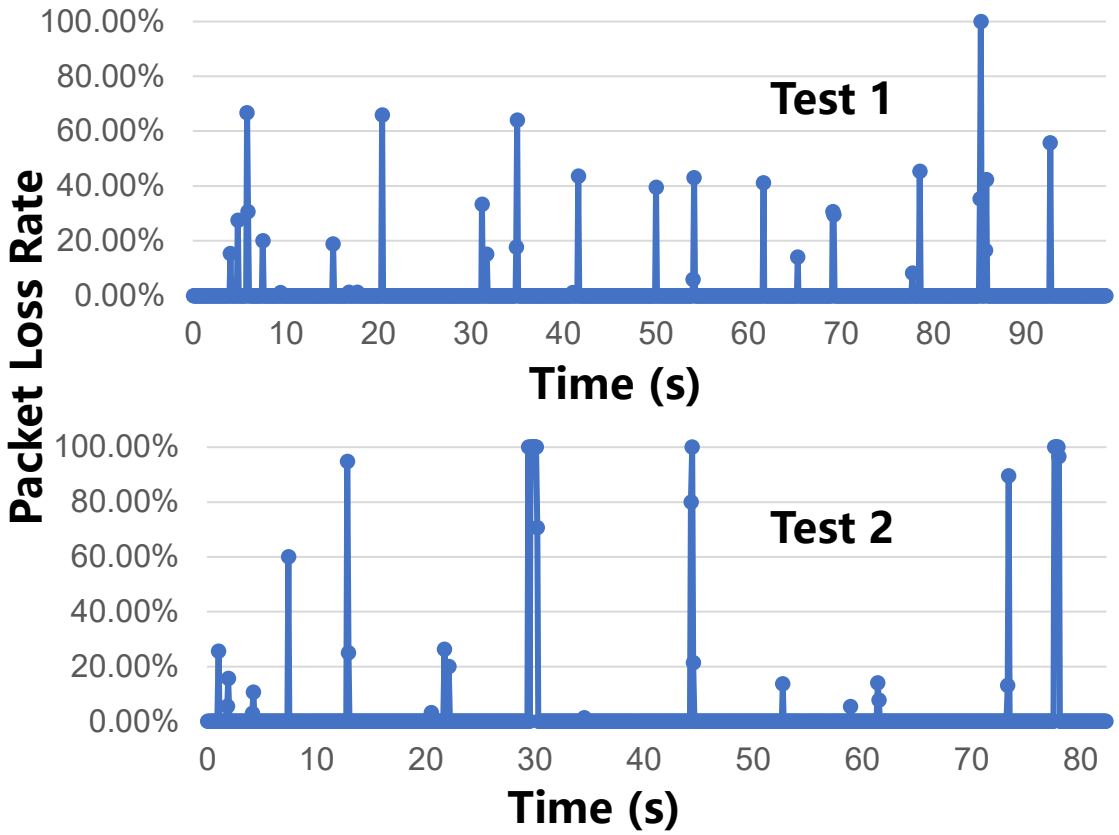
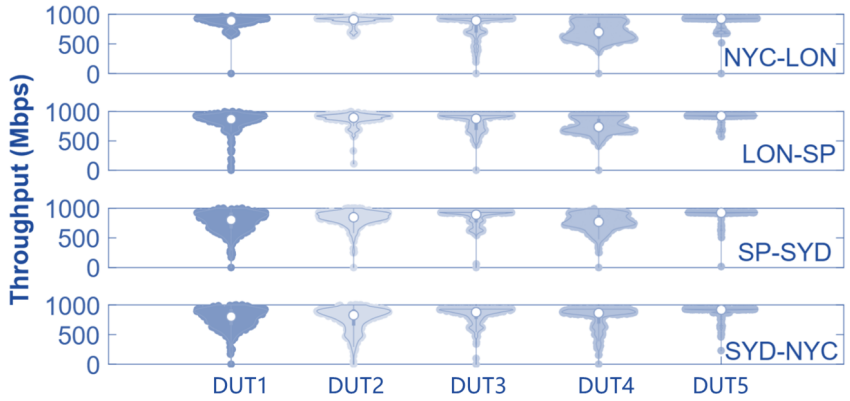
Preliminary Results

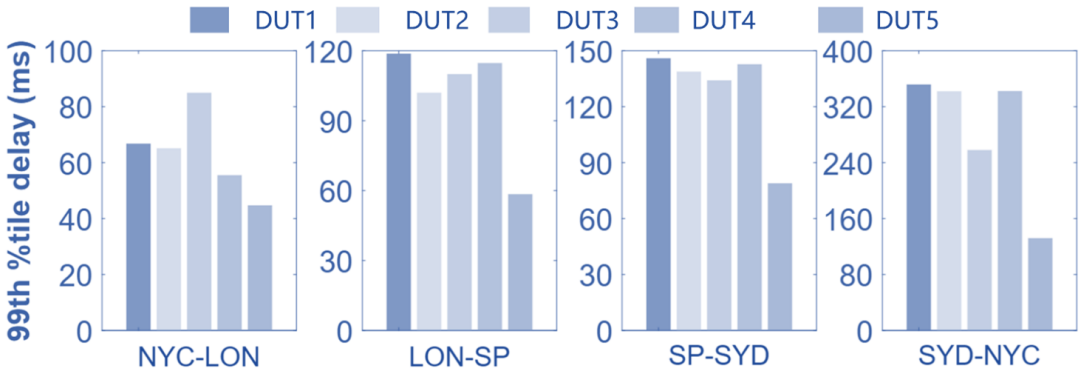
- **Real Satellite-Trace-Driven Test**
  - To feed the testbed setup
  - Two Tests: Packet Loss Rate per 0.1s



- **Preliminary Benchmarking Results**
  - Throughput of transport strategies



  - 99-th Delay of transport protocols



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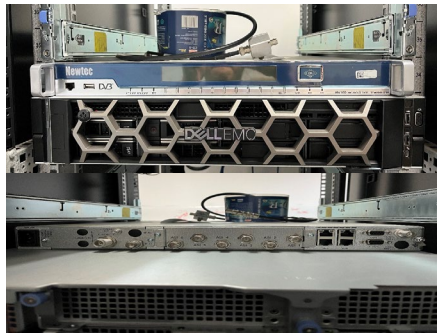
Conclusion and Future Work

- **A reproducible benchmarking methodology for reliable transport protocols in ISTN is needed**
- **A preliminary methodology encompassing the testbed setup and benchmarking tests was proposed in our draft**
- **Next Step: Collaboration with our industrial partner**
- **Deploying & Updating the benchmarking methodology** through collaboration with other *satellite operators / network experimentation platforms*
  - **China Telecom: Tiantong Mobile Satellite Communications System**
  - **China Satellite Network Group Co., Ltd**
  - Benchmarking in their non-operating network environment



THANKS

Comments & Questions

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