Considerations for Benchmarking Network Performance in Integrated Space and Terrestrial Networks

draft-lai-bmwg-sic-benchmarking-(01)

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Reminder (1/2): Why We Need New Methodology

- (IETF-112) Problems and Requirements of Benchmarking Methodology for Integrated Space and Terrestrial Networks (ISTN)
  - **Trend**: We are on the high-way towards ISTN, networking the globe through low-earth-orbit (LEO) mega-constellations and terrestrial networks.
  - **New Network**: ISTN are featured by global-level high dynamicity and unexplored uncertainty, requiring NEW network designs, which should be comprehensively and systematically benchmarked **in lab** before launch.
  - **Requirements**: (a) Constellation and Network Realism, (b) Flexibility at Mega-constellation Scale, (c) Realistic Data and Test Cases, (d) Low-cost and Easy-to-use.
  - Existing benchmarking methodologies are insufficient.

Reminder (2/2): Considerations for New Methodology

- (IETF-115) Considerations for Benchmarking Network Performance in Integrated Space and Terrestrial Networks (ISTN)
  - What is the expected **qualified** and **in-lab** benchmarking methodology for ISTN?
- A Data-Driven, Emulation-based Benchmarking Approach:

① community-driven data collection

- Public ISTN information, such as constellation topology, user measurements …

② real-data-driven ITE setup

- Build an ITE via VM- or container-based emulation, with mimicked LEO behaviors (dynamics)

③ specify DUT/SUT and run test cases

- Deploy DUT/SUT in ITE
- Run specific test cases
- Collect and report results

Update towards Concrete Benchmarking Methodology

- Parameter Setup of the Benchmarking Environment for ISTN
  - Concretizing Stage-①: community-driven data collection.
  - Driven by (a) Regulatory Data, (b) Live Data and (c) Crowd-sourcing Data.
  - Showcases: Network Performance under Different Environment Setups.
- Future Work
  - Concretizing all the following stages, by cooperating with academia, industrial and IETF community.

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Parameter Setup of the Benchmarking Environment

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Terminology In Last Draft

Setup To Present Today

5.2.1 Constellation Orbital Parameters (1/3)

- Regulatory-Data-Driven Orbital Parameters: SHOULD be tested
  - Orbital parameters of the constellations are reviewed and made public by regulatory agencies (eg. FCC, ITU, etc.).
  - Should be followed by the operators in principle, thus representing the ideal situation of the constellations.
- Live-Data-Driven Orbital Parameters: is RECOMMENDED
  - Based on live constellation GP data (*general perturbations* orbital data, also known for TLE) from celestrak.org.
  - Produced by fitting observations (radar and optical) from US Space Surveillance Network (SSN) and provided continuously, representing the live situation of the constellations.

5.2.1 Constellation Orbital Parameters (2/3)

- Regulatory-Data-Driven Orbital Parameters: SHOULD be tested
  - Both Polar-orbit and Inclined-orbit constellations SHOULD be tested, unless the DUT/SUT is designed with orbital preferences, and MUST be stated in the report.
  - A table of the SoA constellations' parameters is provided:

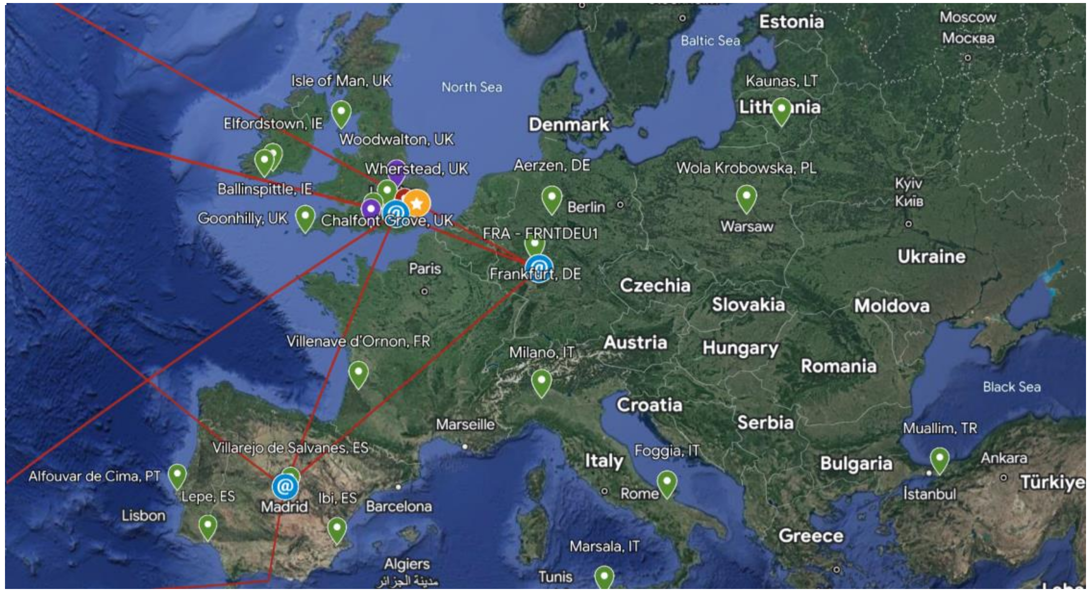
Name and Shell	Altitude (km)	Inclination (degree)	# of orbits	# of satellites per orbit	Polar / Inclined
Starlink	550	53	72	22	Inclined
Starlink-2	540	53.2	72	22	Inclined
Starlink-3	570	70	36	20	Inclined
Starlink-4	560	97.6	6	58	Polar
Starlink-5	560	97.6	4	43	Polar
Kuiper	630	51.9	34	34	Inclined
Kuiper-2	610	42	36	36	Inclined
Kuiper-3	590	33	28	28	Inclined
Telesat	1015	98.98	27	13	Polar
Telesat-2	1325	50.88	40	33	Inclined
OneWeb	1200	87.9	12	49	Polar
OneWeb-2	1200	55	8	16	Inclined

5.2.1 Constellation Orbital Parameters (3/3)

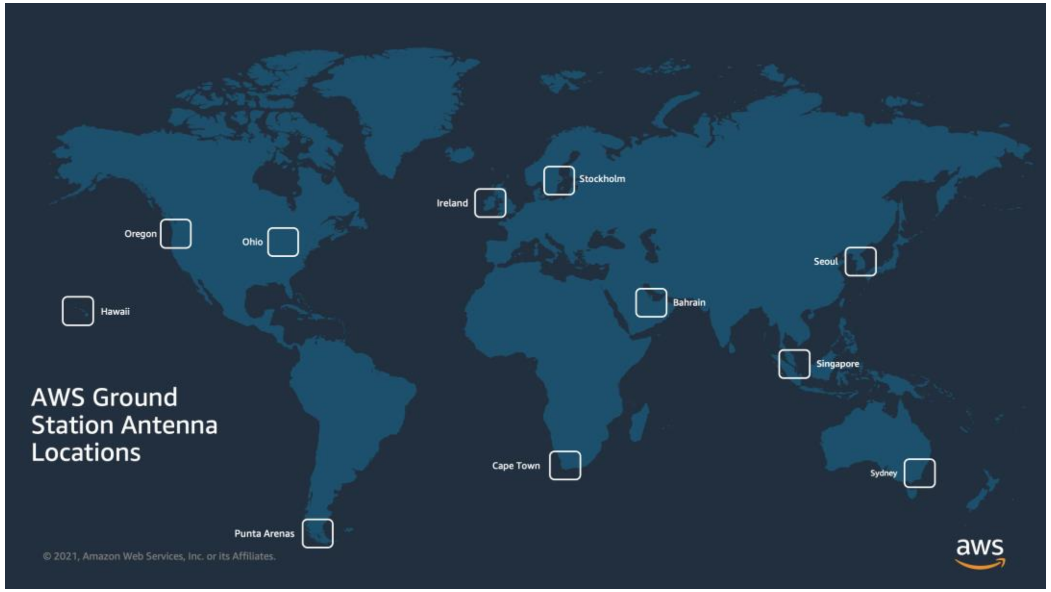
- Live-Data-Driven Orbital Parameters: is RECOMMENDED
  - Among GP and SupGP, SupGP data is RECOMMENDED.
    - SupGP (Supplemental GP) is derived directly from owner/operator-supplied orbital data, providing reduced latency and improved accuracy.
  - The Max Age of GP or SupGP SHALL be less than 1 day and MUST be less than 5 days.
  - Extra Orbital Determination Process
    - Comparing to Regulatory-Data, Live-Data is more accurate (in terms of per-satellite position), and also easy-to-get. However, Live-Data requires extra orbital determination process (implying inter-satellite relationship) to support network experiments.
    - Once the orbital determination process is standardized, Live-Data-Driven Orbital Parameters shall SHOULD be used to benchmark.

5.2.2 Ground Station (GS) Distribution

- Crowd-Sourcing-Data-Driven GS distribution is RECOMMENDED.
    - Which is often refined by fans community based on Regulatory-Data.
- Other OPTIONAL Open Data:
    - *Amazon AWS*, *Azure Orbital*, and other open Ground Station Distribution.



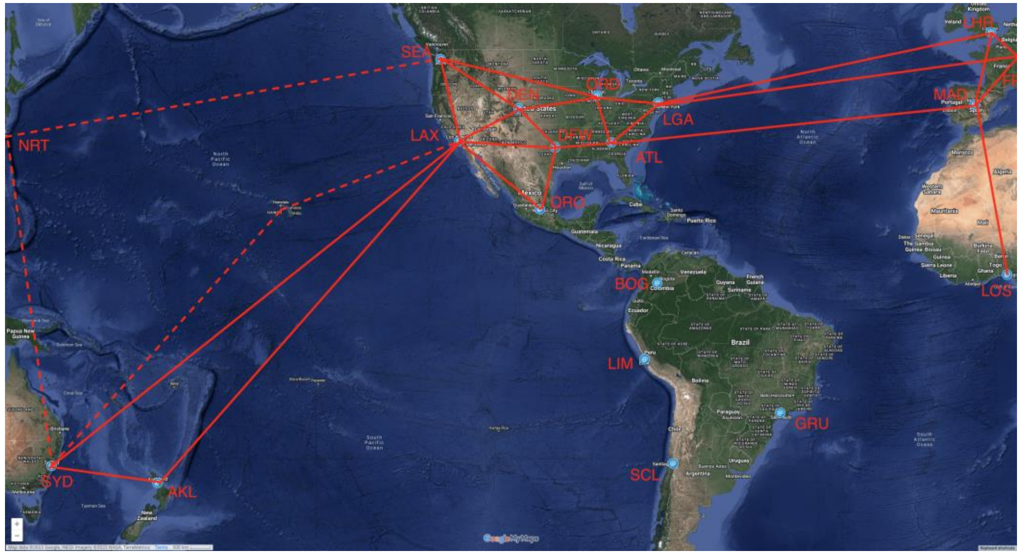
Starlink GS in EU, featuring details from community



Amazon AWS Ground Station as a Service

5.2.3 Connectivity Pattern

- Crowd-Sourcing-Data-Driven:
  - e.g. Inter-Ground Station Connectivity of Starlink Ground Stations (figure) is explored with `traceroute` from the fans community.



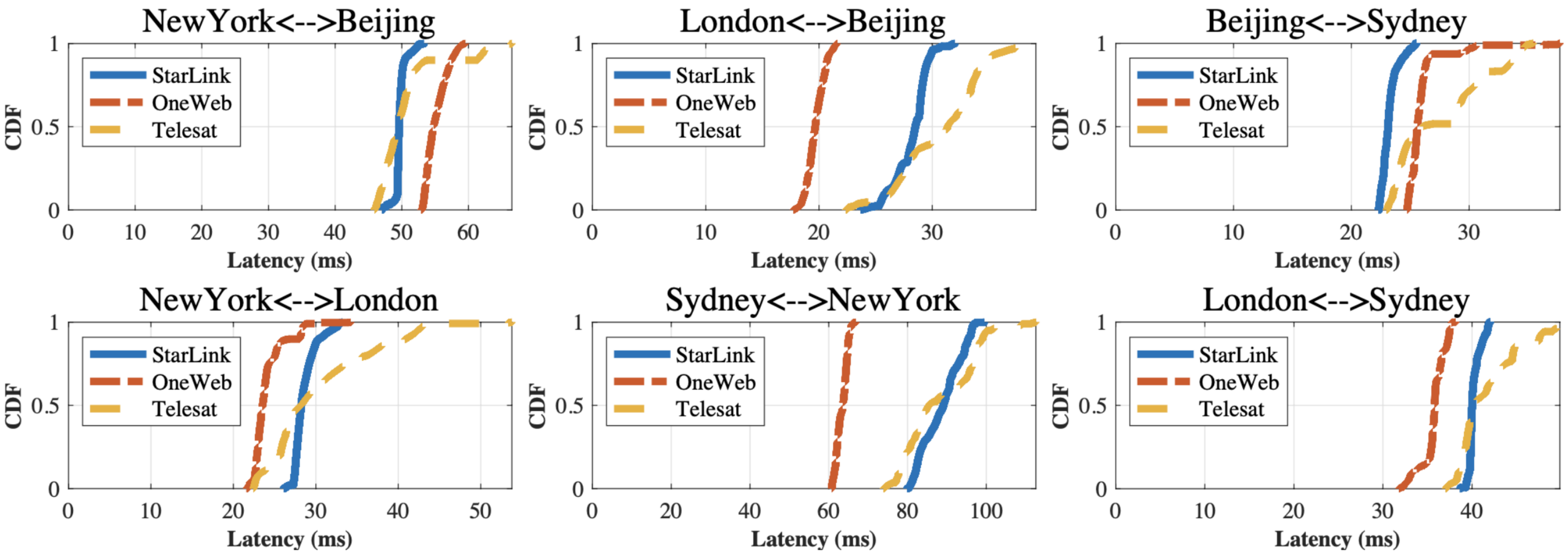
- Strategy-based Parameter Setup:
  - Inter-Satellite Connectivity
    - [+Grid] is RECOMMENDED, where the satellites are connected with 4 neighbors and form a massive grid across the constellation.
    - [Inner-orbit Only], [motif] are other OPTIONAL strategies.
  - Ground-Satellite Connectivity
    - [Nearest Ground Station with Antenna Quota] is RECOMMENDED.
      - Where each ground station is with 8 antenna quota is RECOMMENDED.

5.2.4 Network Link

- Strategy-based Network Link Setup is RECOMMENDED
  - The propagation latency of ground-satellite link (RF) and inter-satellite link (free-space optical) could be derived from distance and light-speed.
  - The capacity of ground-satellite link could be set as 1 ~ 5 Gbps. Specific value MAY be derived from frequency band info from regulatory data.
  - The capacity of inter-satellite link could be set as 5~20 Gbps.
- Related Crowd-Sourcing Data
  - Measurement data (figure) on path latency and bandwidth from real satellite users are relative, but we didn’t find a good way to use.
  - They may help on determining the coefficient when calculating latency from distance.

Show Cases

- Latencies under different constellations with Regulatory-Data
  - Statistics of latency (OSPF) between ground stations around the world



Future Work


- With Self-owned Devices:
  - Collecting more data with big devices (satellite dishes and high-end servers).
- With Academia:
  - *StarryNet*, our latest work on ISTN emulator, will be presented on NSDI'23.
- With Industrial:
  - Working closely with our cooperation partner (satellite communication operator) on ISTN design and benchmarking.
- With IETF Community, see you in-person at IETF-117 and more:
  - Request for comments on what we present here today, and in future.
  - Toward benchmarking methodology for routing / transport / security in ISTN
    - Definition and measurement methodology of specific metrics
    - Distribution of end-users, Duration of benchmarking
    - Dedicated Setup of DUT/SUT in ISTN ……

THANKS

Comments & Questions

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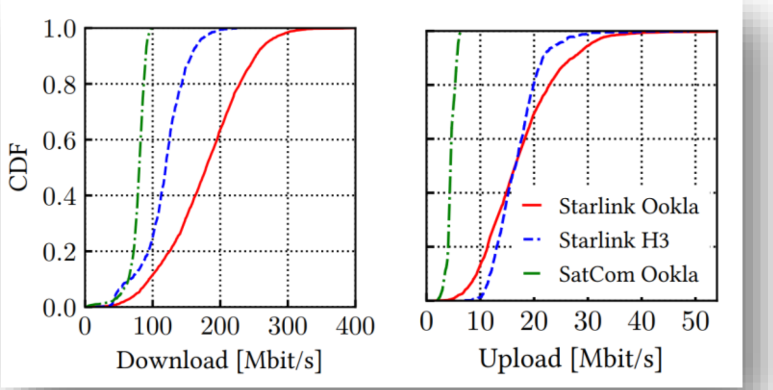
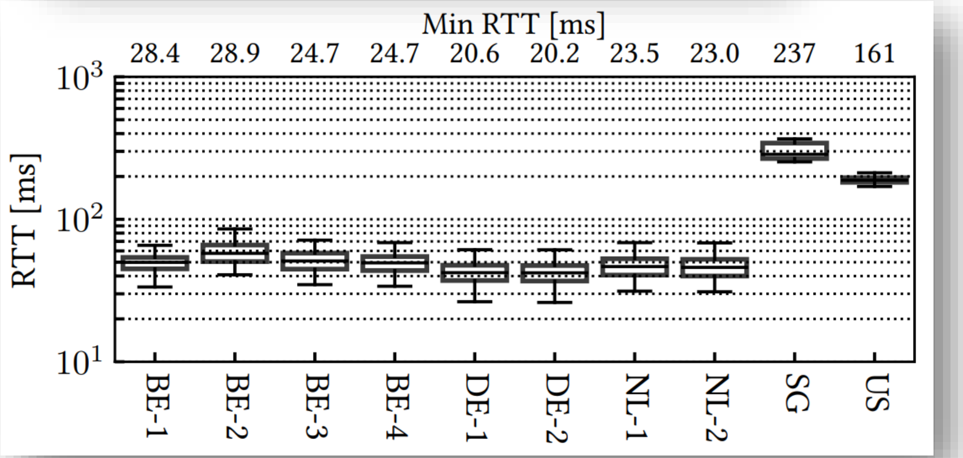
Backup

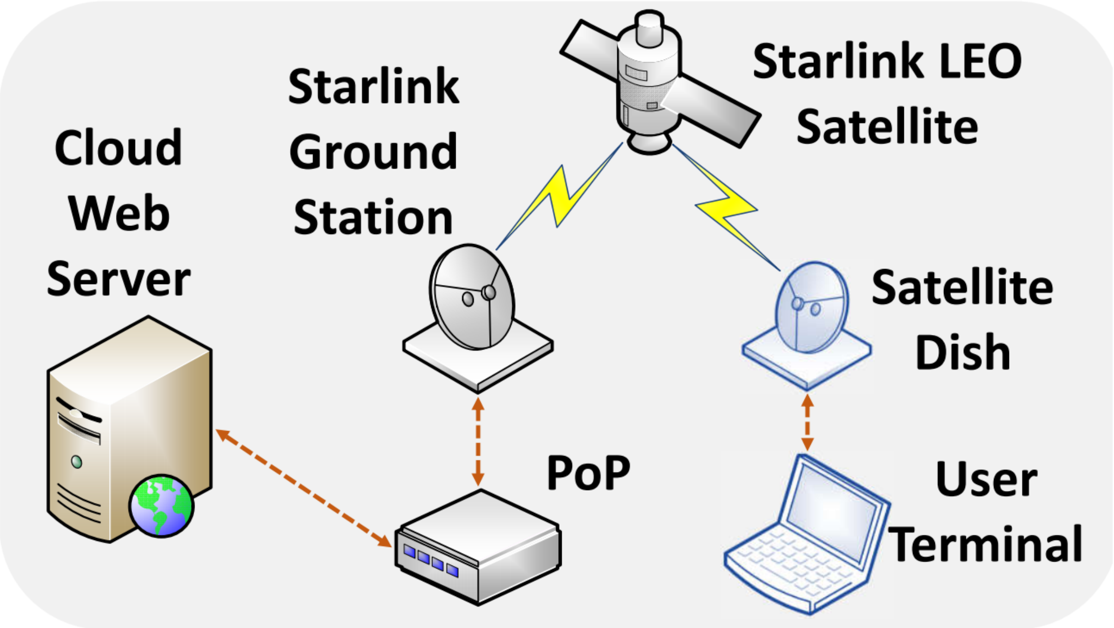
- **How to evaluate the network fidelity of the isolated test environment?**
  - Real-data-driven based configuration





Public LEO satellite performance

Configure link delay and capacity

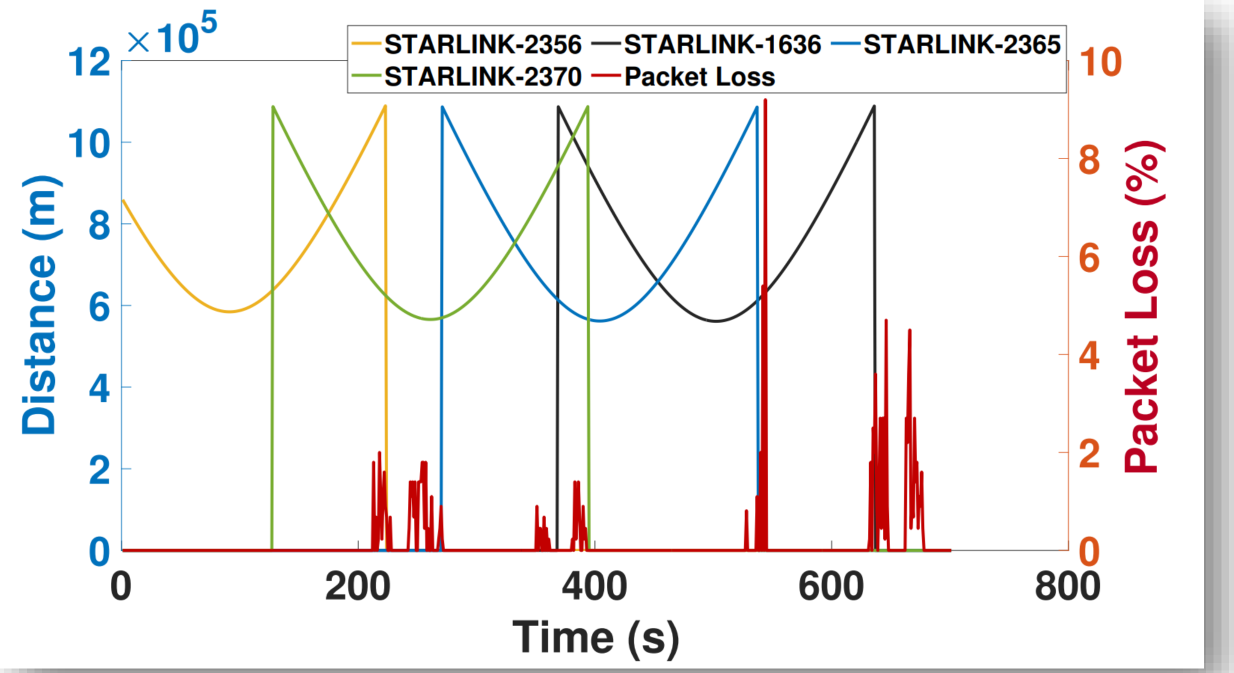


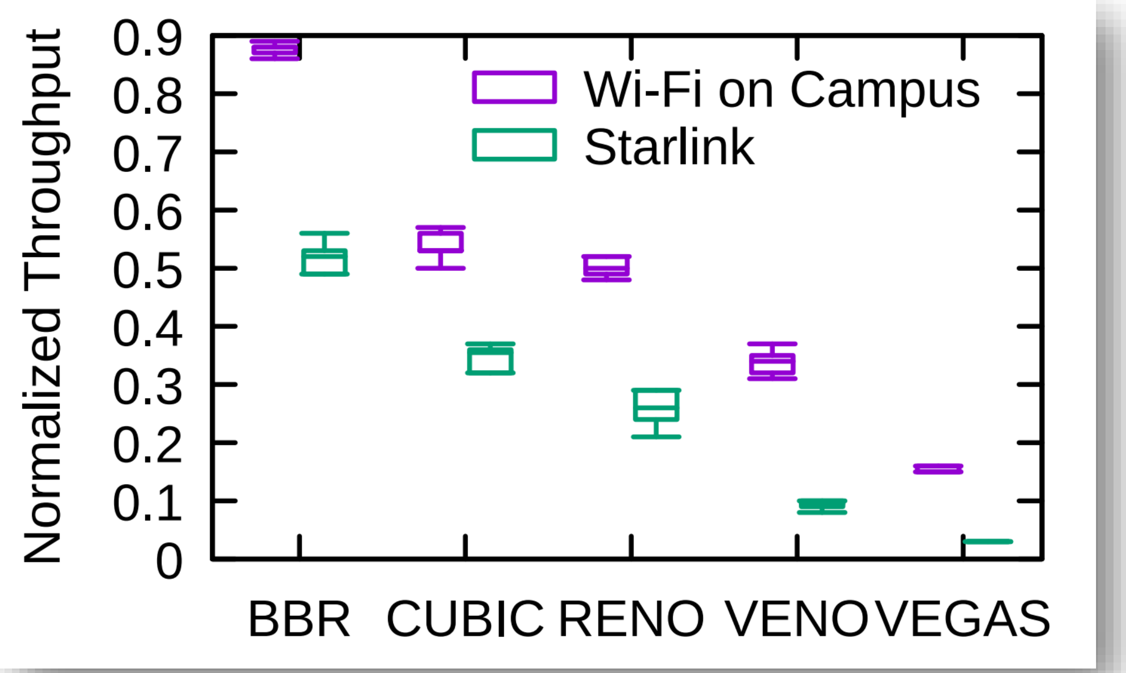
Test Environment: emulated LEO network (e.g. VM/container-based emulation, and use tc to configure link delay and capacity)

Michel, François, et al. "A first look at starlink performance." Proceedings of the 22nd ACM Internet Measurement Conference. 2022.

Backup

- **What is unique in LEO network performance?**
  - Packet loss observed in ISTN due to LEO dynamics
  - Result in different TCP congestion control performance





Kassem, Mohamed M., et al. "A browser-side view of starlink connectivity." *Proceedings of the 22nd ACM Internet Measurement Conference*. 2022.