Considerations for Benchmarking Network Performance in Integrated Space and Terrestrial Networks

draft-lai-bmwg-sic-benchmarking-02

Zeqi Lai, Hewu Li, Qi Zhang, Qian Wu, Yangtao Deng

Tsinghua University
Zhongguancun Laboratory

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

- (IETF-112) Problems and Requirements of Benchmarking Methodology for Integrated Space and Terrestrial Networks (ISTNs)
  - **Trend**: We are on the high-way towards ISTN, networking the globe through low-earth-orbit (LEO) mega-constellations and terrestrial networks.
  - **New Network**: ISTNs 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 the New Methodology

- (IETF-115) Considerations for Benchmarking Network Performance in Integrated Space and Terrestrial Networks (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

- (IETF-116, Stage-①) Data Collection & Parameter Setup
  - Driven by (a) Regulatory Data, (b) Live Data and (c) Crowd-sourcing Data.

Today: Update towards **Concrete** Benchmarking Methodology

- **Stage-① update**: Updated Setup Strategy with **new data collected**.
- **Stage-② specification**: How to build a **container-based laboratory testbed**.
- Showcase: **Current capability of the testbed** we built.

- Future Work
  - Concretizing all the following stages, by cooperating with **industrial partners**, **IETF community** and **academia**.

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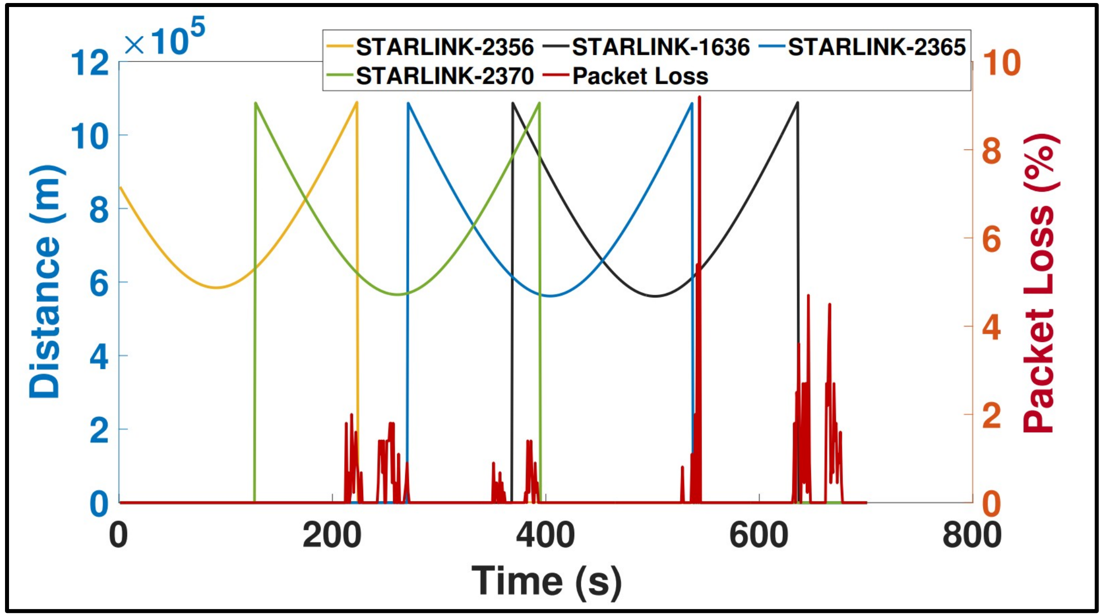
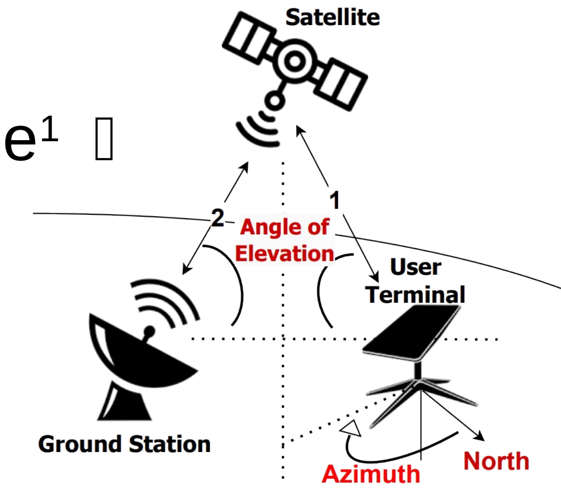
Updated Environment Setup with New Data Collected (1/2)

- Packet loss ratio of ground-satellite links
  - According to data from recent studies[1] (which is aligned with our real-world measurement), the packet loss ratio of ground-satellite links is RECOMMENDED to be set **dynamically between 0 and 5% (during each test)**, where higher loss ratios occur when one ground-satellite **link handover** event.



1. Kassem M M, Raman A, Perino D, et al. A browser-side view of starlink connectivity[C]//Proceedings of the 22nd ACM Internet Measurement Conference. 2022: 151-158.

Updated Environment Setup with New Data Collected (2/2)



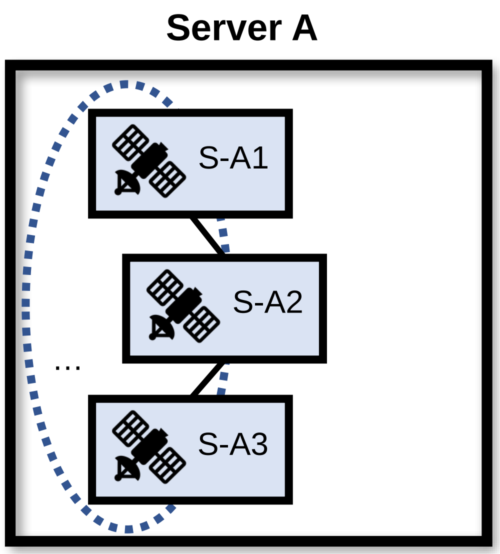
- Ground-satellite connectivity
  - Other factors affecting strategies in real-world systems include[1]

    (1) angle of elevation, (2) azimuth,
    (3) satellite launch dates, (4) whether one satellite is sunlit.
  - Specifically, for a specific ground station or user terminal, a satellite with the following characteristics is preferred:
    - (1) a higher angle of elevation,
    - (2) an azimuth that could avoid interference with geostationary orbit satellites,
    - (3) newer launch dates,
    - (4) a solar panel being sunlit.
  - These factors constitute a more complete strategy and are OPTIONAL if the data of these factors are available.

1. Tanveer H B, Puchol M, Singh R, et al. Making Sense of Constellations: Methodologies for Understanding Starlink's Scheduling Algorithms[J]. arXiv preprint arXiv:2307.00402, 2023.

Container-based Laboratory Testbed

- **Exploiting Linux containers to build a large-scale ISTN testbed**
  - Each container simulates a satellite, a ground station or a user terminal



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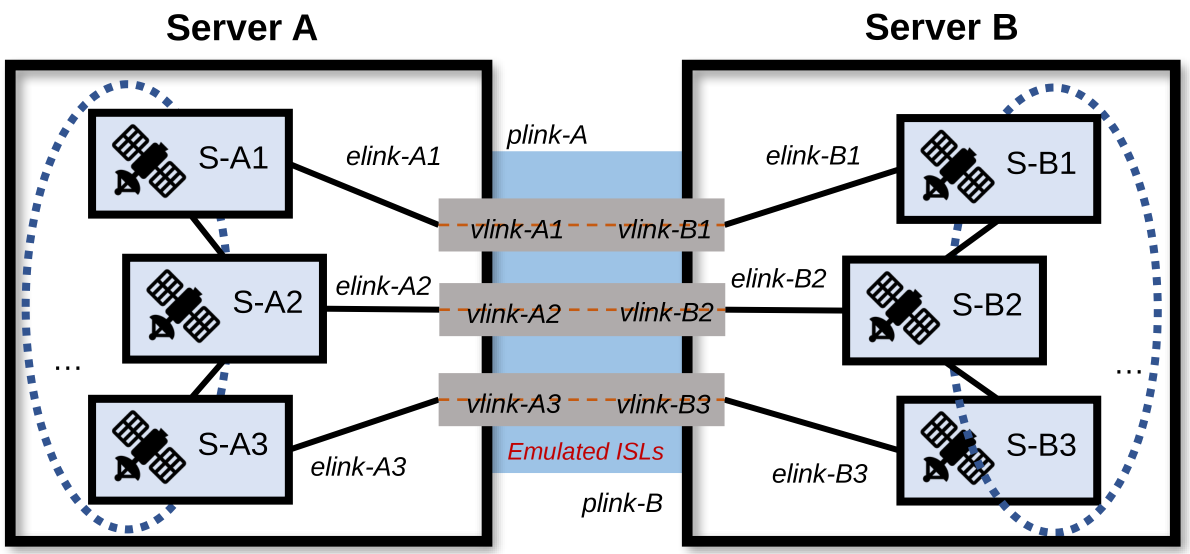
  - Exploiting high-performance cluster to build a scalable testbed (e.g 1584 satellites, or according to the benchmarking requirement)



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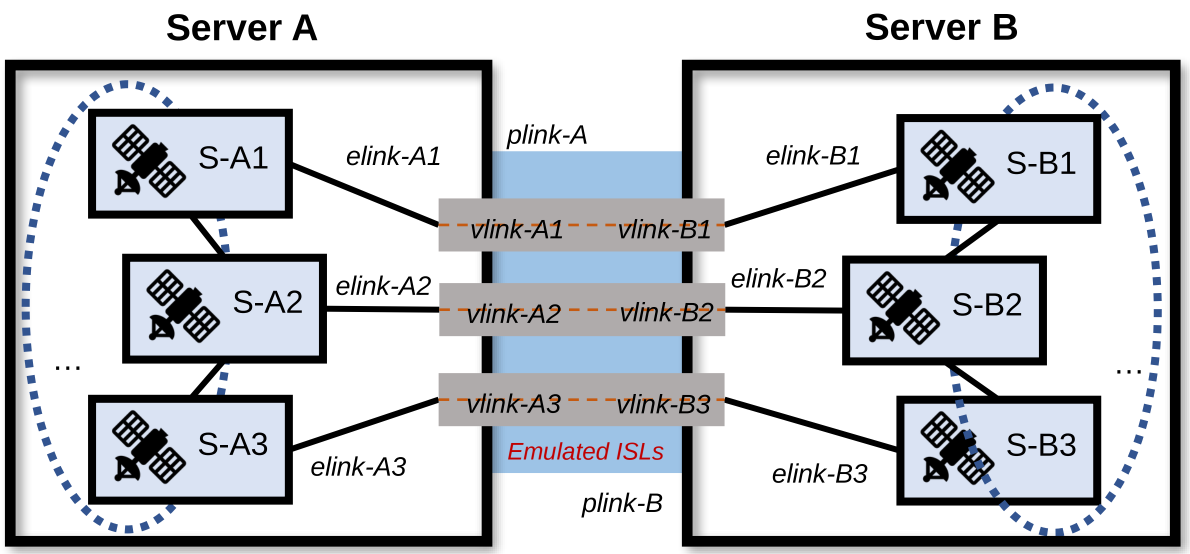
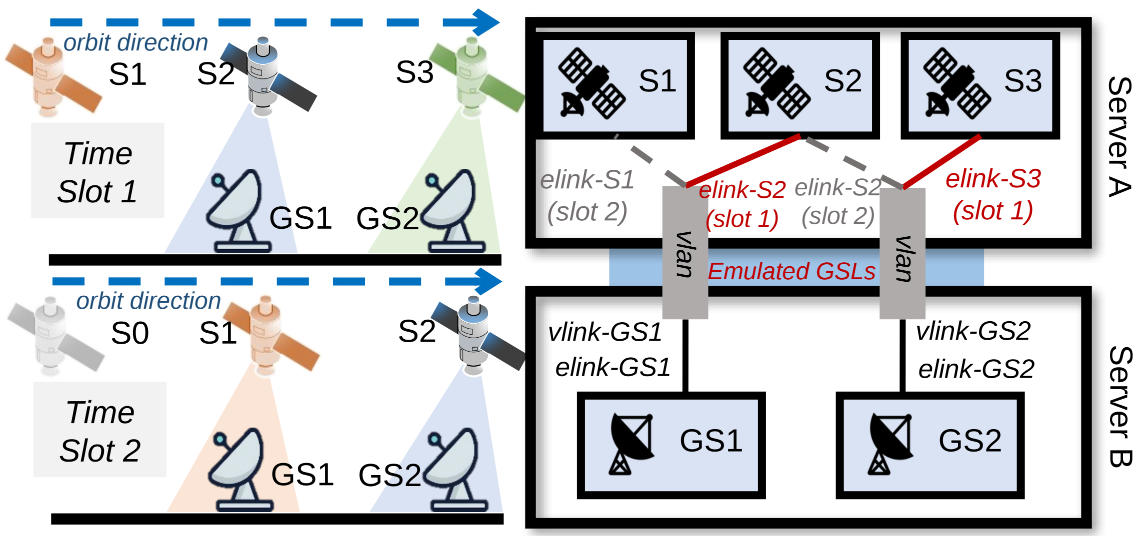
  - Dynamically adjusting inter-container connectivity to simulate LEO dynamics





Container-based Laboratory Testbed

- **Current testbed capability**

Constellation \ Metrics	Height (km)	Constellation Size (number of satellites)	Creation Time (min) Nodes/Links/Total			Avg. CPU (%) Interval = 1/2/3 (s)			Avg. Memory (%) Interval = 1/2/3 (s)			Minimum # of Required Workers
Starlink S1 (72*22, 53°)	550	1584	5.9	4.6	10.5	7.2%	7.0%	6.3%	3.9%	3.5%	3.4%	2
Starlink S2 (72*22, 53.2°)	540	1584	5.9	4.6	10.5	7.2%	7.0%	6.3%	3.9%	3.5%	3.4%	2
Starlink S3 (36*20, 70°)	570	720	3.0	2.1	4.9	1.2%	1.1%	1.0%	2.7%	2.6%	2.6%	1
Starlink S4 (6*58, 97.6°)	560	348	1.9	1.3	3.2	1.0%	1.0%	1.0%	2.7%	2.6%	2.4%	1
Starlink S5 (4*43, 97.6°)	560	172	1.6	1.2	3.2	1.0%	1.0%	1.0%	2.3%	2.3%	2.3%	1
Starlink Full (4408 satellites)	hybrid	4408	13.3	7.9	21.2	39.6%	37.0%	34.3%	10.4%	9.1%	8.9%	7
Kuiper K1 (34*34, 51.9°)	630	1156	4.4	3.8	8.2	2.6%	2.4%	2.3%	3.8%	3.5%	3.2%	2
Kuiper K2 (36*36, 42°)	610	1296	4.7	4.2	8.9	3.9%	3.6%	3.2%	4.0%	3.6%	3.5%	2
Kuiper K3 (28*28, 33°)	590	784	3.2	2.4	5.6	1.3%	1.2%	1.2%	2.7%	2.6%	2.6%	2
Kuiper Full (3236 satellites)	hybrid	3236	5.7	4.8	10.5	24.6%	23.9%	23.2%	6.3%	6.2%	6.2%	6
Telesat T1 (27*13, 98.98°)	1015	351	1.9	1.3	3.2	1.0%	1.0%	1.0%	2.6%	2.5%	2.4%	1
Telesat T2 (40*33, 50.88°)	1325	1320	4.8	4.2	9.0	3.9%	3.7%	3.3%	4.0%	3.6%	3.5%	2
Telesat Full (1671 satellites)	hybrid	1671	3.1	2.4	5.5	7.2%	7.0%	6.4%	4.2%	3.7%	3.6%	3

Next Step: Collaboration with our Industrial Partner

- Integrating our container-based satellite network simulator with other network experimentation platform
  - **Tsinghua:** Future Internet Technology Infrastructure **(FITI),** a high-performance Internet backbone for network education and experiments
  - **China Telecom: Tiantong Mobile Satellite Communications System**, Test network environment (non-operating network environment)

THANKS

Comments & Questions

zhangqi@zgclab.edu.cn

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