Considerations for Benchmarking Network Performance in Integrated Space and Terrestrial Networks
draft-lai-bmwg-sic-benchmarking-00

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Background: A New Era of Satellite Internet

- **Broadband Satellite Constellations** in low earth orbit (LEO) are gaining tremendous popularity
  - **Operational:** SpaceX’s Starlink (as of Nov 2022, launched over 3000 LEO satellites; provide Internet access to over 500,000 subscribers; aim for global mobile phone service after 2023).
  - **Proposed:** OneWeb (648 satellites), Amazon Kuiper (3276 satellites), Boeing (147 satellites) in plan.

- Promising future direction: **Integrated Space and Terrestrial Network (ISTN)**
  - Emerging satellites can be equipped with high-speed ground-satellite (Ku/Ka-band) and inter-satellite links (laser).
  - Integrating broadband LEO satellites with terrestrial networks for pervasive and performant Internet services.
Why Benchmarking in ISTN is Important?

- **Motivation**
  - Like in other kinds of conventional networks, network techniques (e.g. new network topology, protocol, functionality) are expected to be carefully evaluated in an *Isolated Test Environment (ITE)*, before they are deployed in a live production environment.
  - Unlike in traditional situations, for ISTN core infrastructures (i.e. satellite router/switch), post-launch upgrades (especially onboard hardware) are difficult and thus require a more systematic and comprehensive *assessment* prior to launch.

- **Recap: Problems and Requirements of Evaluation Methodology for ISTN**
  - Unique characteristics (e.g. *LEO dynamics, mega-scale*), limitation of existing benchmarking methodologies.

- **Remaining Questions**
  - What aspect of ISTN-related problem could be pursued for benchmarking network DUT/SUT?
  - Clarify the work scope that fits the BMWG charter.
Major goal: a series of recommendations concerning the **key performance characteristics of internetworking technologies**, or benchmarks for network devices, systems, and services.

**Controlled lab environment**

1. **What play an important role in ISTN performance?**
   - Constellation topology; network protocol; hardware capability …

2. **Key performance characteristics pertinent to ISTN**
   - Service quality; service availability; network reliability, scalability …

3. **Important metrics describing the above characteristics**
   - User-perceived latency/throughput/loss; routing convergence …

4. **How to specify methodologies to collect these metrics?**
   - What is the expected **in-lab benchmarking methodology** for ISTN?
   - Concrete approach and test cases (details in our draft and next pages)

5. **Requirements for reporting ISTN benchmarking results**
   - Using common and unambiguous report format
A Data-Driven, Emulation-based Benchmark 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
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Constellation information from public FCC filings (e.g. # of orbits, # of satellites per orbit, inclination, height ...), user measurements ...

These ISTN-relevant data can guide us to reasonably build and configure an isolated test environment (ITE)
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Exploiting data-driven emulation to build the ITE
- e.g. using VMs or containers to mimic satellites and their time-varying distance/visibility

Topography of A Live ISTN

A Virtual Representation in A Lab Environment
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Example:
① In a lab environment, evaluating the power consumption of a new routing protocol implemented on a satellite hardware prototype;

② Evaluating TCP/QUIC throughput in an emulated ISTN experimental environment.

(II) Emulation on Test Servers

A number of virtual, emulated nodes + 1 real prototype

Hardware-in-the-loop emulation

Interactive ISTN Traffic

(I) CubeSat (DUT/SUT)

Satellite Processor

Power Monitor

Power measurement
Next Steps

● **Further Discussion & Clarification on:**
  - The class of network functions, systems, or services that are important in emerging LEO satellite Internet constellation and ISTN.
  - Key performance characteristics pertinent to ISTN.
  - A set of important benchmarking metrics.
  - Concrete benchmarking methodology.
  - Proper test cases tailored for ISTN environment.

● **Tools and platforms for building lab-level ISTN test environment**
  - StarryNet [NSDI2023 (to appear)] (a container-based large-scale ISTN emulator).
  - Facilitating the ITE creation for ISTN benchmarking in a flexible and convenient way.
THANKS

Comments & Questions

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draft-lai-bmwg-istn-methodology-02

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How to evaluate the network fidelity of the isolated test environment?

- Real-data-driven based configuration

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

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