Considerations for Benchmarking Network Performance in Integrated Space and Terrestrial Networks

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

• ([IETF-112](https://www.ietf.org)) 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:

<table>
<thead>
<tr>
<th>① community-driven data collection</th>
<th>② real-data-driven ITE setup</th>
<th>③ specify DUT/SUT and run test cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>◆ Public ISTN information, such as constellation topology, user measurements …</td>
<td>◆ Build an ITE via VM- or container-based emulation, with mimicked LEO behaviors (dynamics)</td>
<td>◆ Deploy DUT/SUT in ITE ◆ Run specific test cases ◆ Collect and report results</td>
</tr>
</tbody>
</table>
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.

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
Parameter Setup of the Benchmarking Environment

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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:

<table>
<thead>
<tr>
<th>Name and Shell</th>
<th>Altitude (km)</th>
<th>Inclination (degree)</th>
<th># of orbits</th>
<th># of satellites per orbit</th>
<th>Polar / Inclined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starlink</td>
<td>550</td>
<td>53</td>
<td>72</td>
<td>22</td>
<td>Inclined</td>
</tr>
<tr>
<td>Starlink-2</td>
<td>540</td>
<td>53.2</td>
<td>72</td>
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<td>Starlink-3</td>
<td>570</td>
<td>70</td>
<td>36</td>
<td>20</td>
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<td>Starlink-4</td>
<td>560</td>
<td>97.6</td>
<td>6</td>
<td>58</td>
<td>Polar</td>
</tr>
<tr>
<td>Starlink-5</td>
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<tr>
<td>Kuiper</td>
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<tr>
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<tr>
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<tr>
<td>OneWeb</td>
<td>1200</td>
<td>87.9</td>
<td>12</td>
<td>49</td>
<td>Polar</td>
</tr>
<tr>
<td>OneWeb-2</td>
<td>1200</td>
<td>55</td>
<td>8</td>
<td>16</td>
<td>Inclined</td>
</tr>
</tbody>
</table>
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.
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

Considerations for Benchmarking Network Performance in Integrated Space and Terrestrial Networks

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draft-lai-bmwg-istn-methodology-02

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Backup

• 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)

Backup

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