Towards a Global Telemetry System for Evaluating LEO ISP Performance

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1. Background and Motivation

- Emergence of Low-Earth Orbit (LEO) ISPs offers global coverage, especially in remote regions
- LEO uses “bent-pipe” architecture as shown in Figure 1
- Lack of empirical studies comparing LEO and terrestrial ISP performance using real-world data

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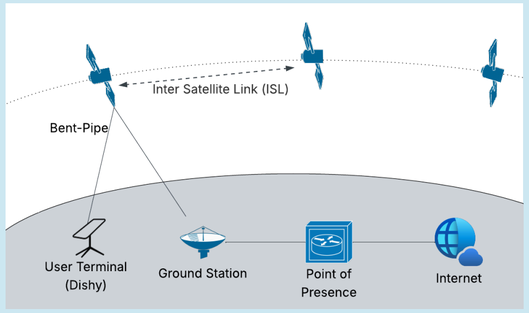


Fig. 1: LEO “bent-pipe” architecture

- Need for a unified global telemetry system to support consistent, fair, and transparent ISP performance analysis
- Two primary passive telemetry sources: **MLab - NDT 7** and **Cloudflare Radar - AIM**
- Datasets available via BigQuery (MLab-Cloudflare partnership)

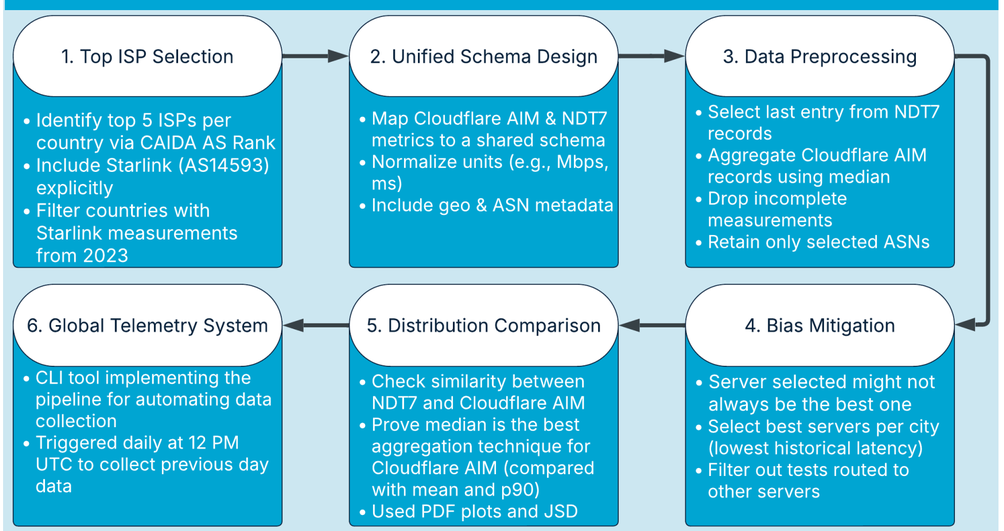
MLAB / CLOUDFLARE

2. Research Questions

How can heterogeneous internet performance datasets from platforms like MLab and Cloudflare be harmonized to support accurate and fair comparison between LEO and terrestrial ISP performance?

- To what extent are MLab (NDT7) and Cloudflare Speedtest datasets methodologically compatible?
- What normalization, resolution alignment, and debiasing techniques are necessary to integrate data from multiple measurement platforms for reliable comparison between LEO and terrestrial ISPs?

3. Methodology



4. Results and Analysis

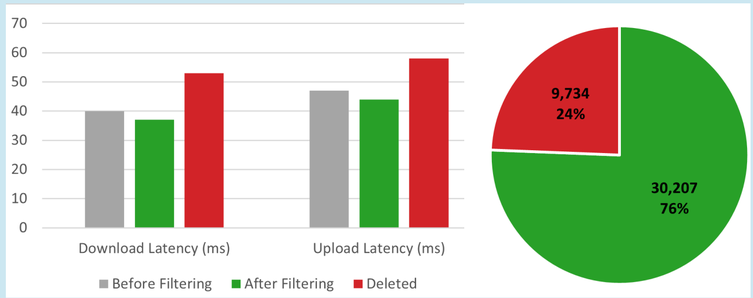


Fig. 2: Server filtering effects on Cloudflare AIM data (5-11May 2025)

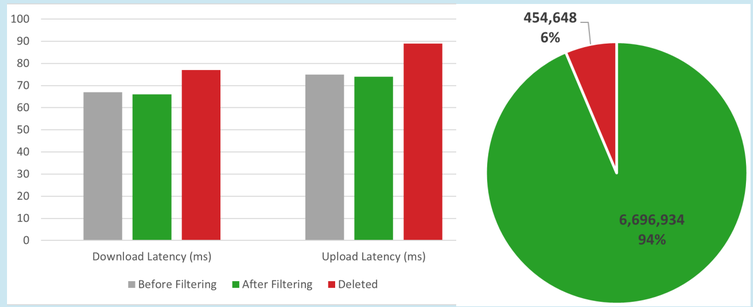


Fig. 3: Server filtering effects on NDT7 data (5-11May 2025)

- Figures 2 and 3 show the server-based filtering technique removes high latencies from the data, which is the expected result
- The data captures the network performance of a typical user experience, being free of the distance factor introduced by unusual server assignments
- All methodology implemented in the **Global Telemetry System** (CLI tool), which is triggered daily from the LEO-Viewer Backend at 12:00 PM UTC

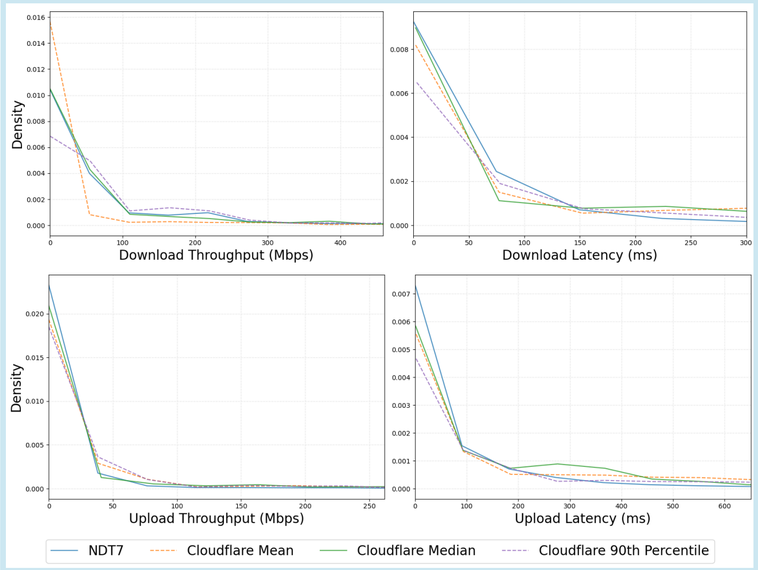


Fig. 4: Throughput and Latency PDFs in Australia for NDT7 and Cloudflare AIM, aggregated using mean, median and p90, after applying server-based filtering (5-11 May 2025)

Table 1: JSD between NDT7 and Cloudflare AIM (using different aggregation methods) in Australia (5-11 May 2025)

Metric	Mean	Median	P90
Download Latency	0.0322	0.0259	0.0584
Download Throughput	0.0660	0.0086	0.0274
Upload Latency	0.0349	0.0239	0.0646
Upload Throughput	0.0251	0.0116	0.0318

- Figure 4 illustrates the PDFs of upload and download throughput and latency in Australia, calculated for NDT7 and Cloudflare, aggregated with mean, median and p90
- Median sticks closest to the NDT7 data, also confirmed by the JSD (illustrated in the Table 1), where all values are below 0.1 (very good), but median has the lowest value

5. Conclusions and Future Work

- We harmonized MLab (NDT7) and Cloudflare AIM datasets by unifying schemas, applying median aggregation, and using server-based geo-filtering, enabling fair and reproducible comparisons between LEO and terrestrial ISPs across latency, throughput, jitter, and packet loss.
- Our analysis shows that after normalization and bias mitigation, the two datasets are compatible (JSD < 0.1), supporting reliable integration; this approach is implemented in a CLI pipeline with future extensions toward real-time monitoring and broader dataset inclusion.

Limitations

- include lack of real-time data and reduced measurement density in underrepresented regions.

Future work

- includes integrating additional datasets (e.g., RIPE Atlas, Ookla) and extending the system for real-time monitoring and anomaly detection.