Understanding DNS Dynamics over the Starlink Network

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Find the paper here

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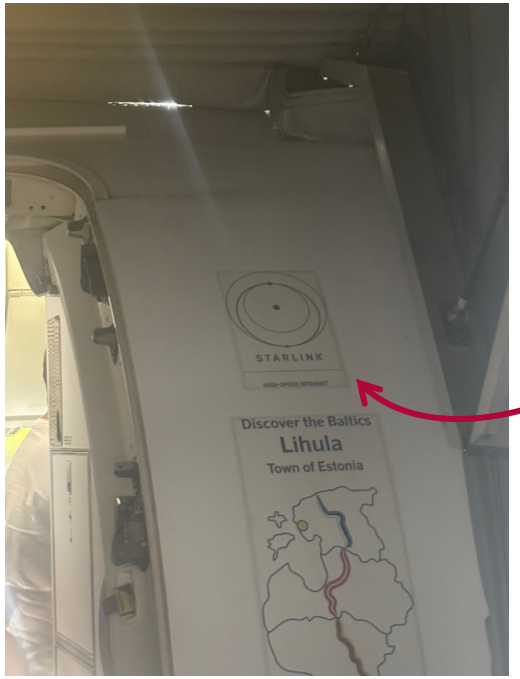
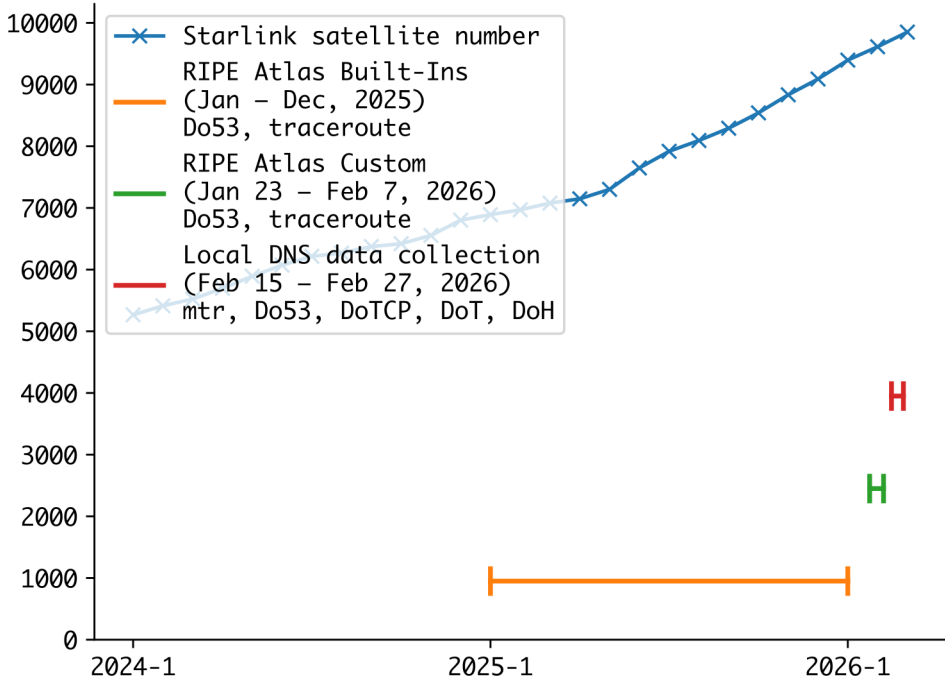
Why study Starlink?

- Starlink enters a stage of "maturation"
- Still, Starlink grows rapidly in both ground infrastructure and the number of satellites



Starlink roll-out in planes (free of charge)

- Applications (e.g., video streaming) have been observed to degrade performance [1,2]



Growth of Starlink satellite number over time and our study data timeframe

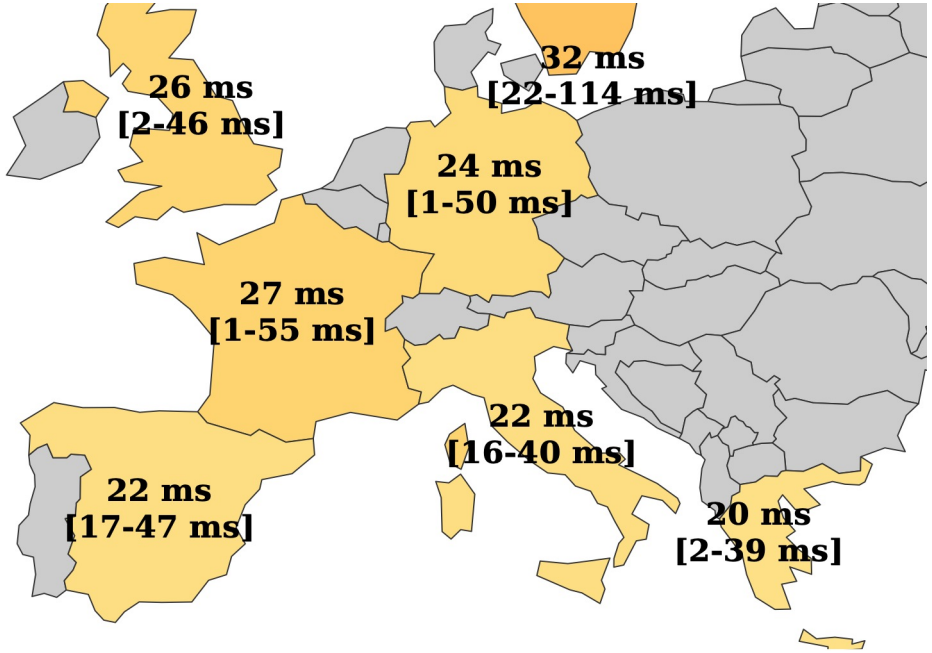
[1] Michel et al. "A First Look at Starlink Performance" (2022)

[2] Mohan et al. "A Multifaceted Look at Starlink Performance (2024)

Why do we study DNS in Starlink?

- DNS is one of the most important protocols we have during Internet usage
- Nearly every single application relies on DNS

- **But:** Missing knowledge of DNS resolution behavior in Starlink



DNS resolution times in European countries. Top number is the median latency, while the lower number of the range to the 95th percentile.
Queries for google.com using DNS4EU (Unfiltered) performed using RIPE Atlas

Objectives of our Study

How does default DNS resolver choice in Starlink work? ?

↓

What DNS resolution time do we observe in Starlink? ?

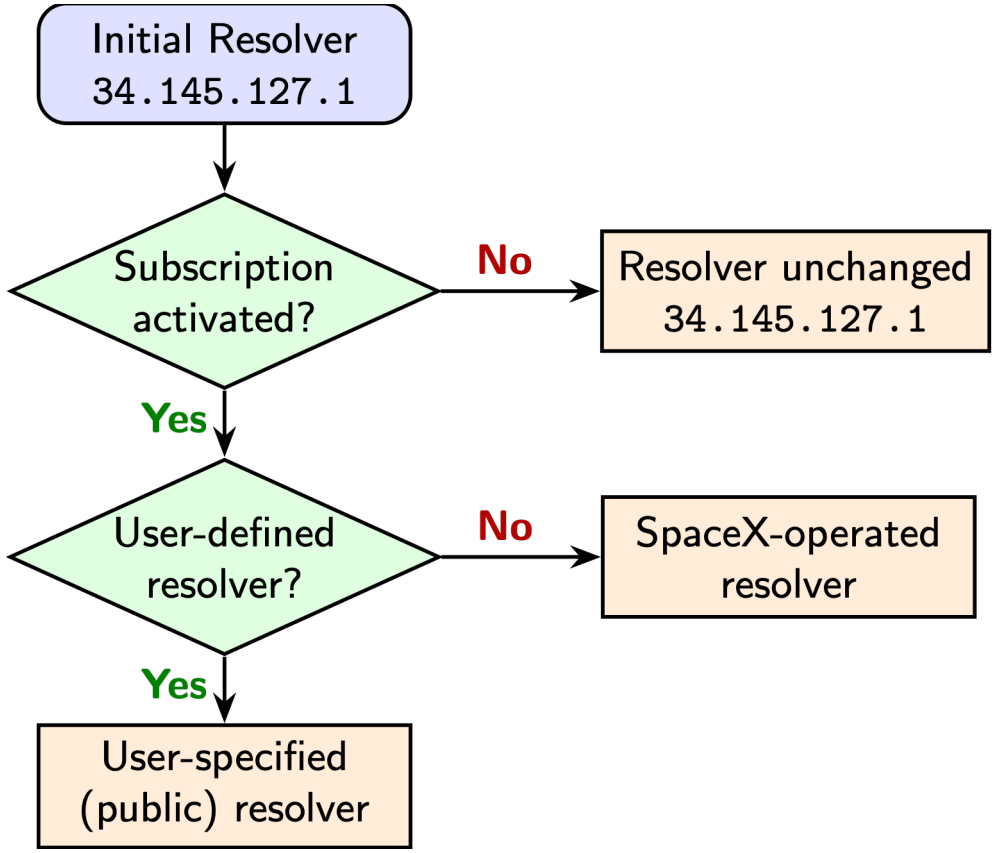
↓

What causes DNS latency? ?

↓

How could we improve DNS resolution time? ?

Understanding the Resolution Process



Assumed DNS resolver setting for Starlink users

[3] Starlink. “What IP addresses does Starlink provide?”, Online: https://starlink.com/de/support/article/1192f3ef-2a17-31d9-261a-a59d215629f4 (Accessed: April 2026)

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DNS Resolution Time: Study Methodology

Data Source	RIPE Atlas	Own Starlink Antenna @ Uni
Global Vantage Points	✅	✅
Arbitrary DNS Protocols	❌	❌
Arbitrary DNS Resolvers	⚠️	✅
Historical Measurements	✅	❌

- Foundational Do53 (i.e., DNS over UDP) measurements to root servers:
  ⇒ *RIPE Atlas Built-In for whole of 2025 and global vantage points*

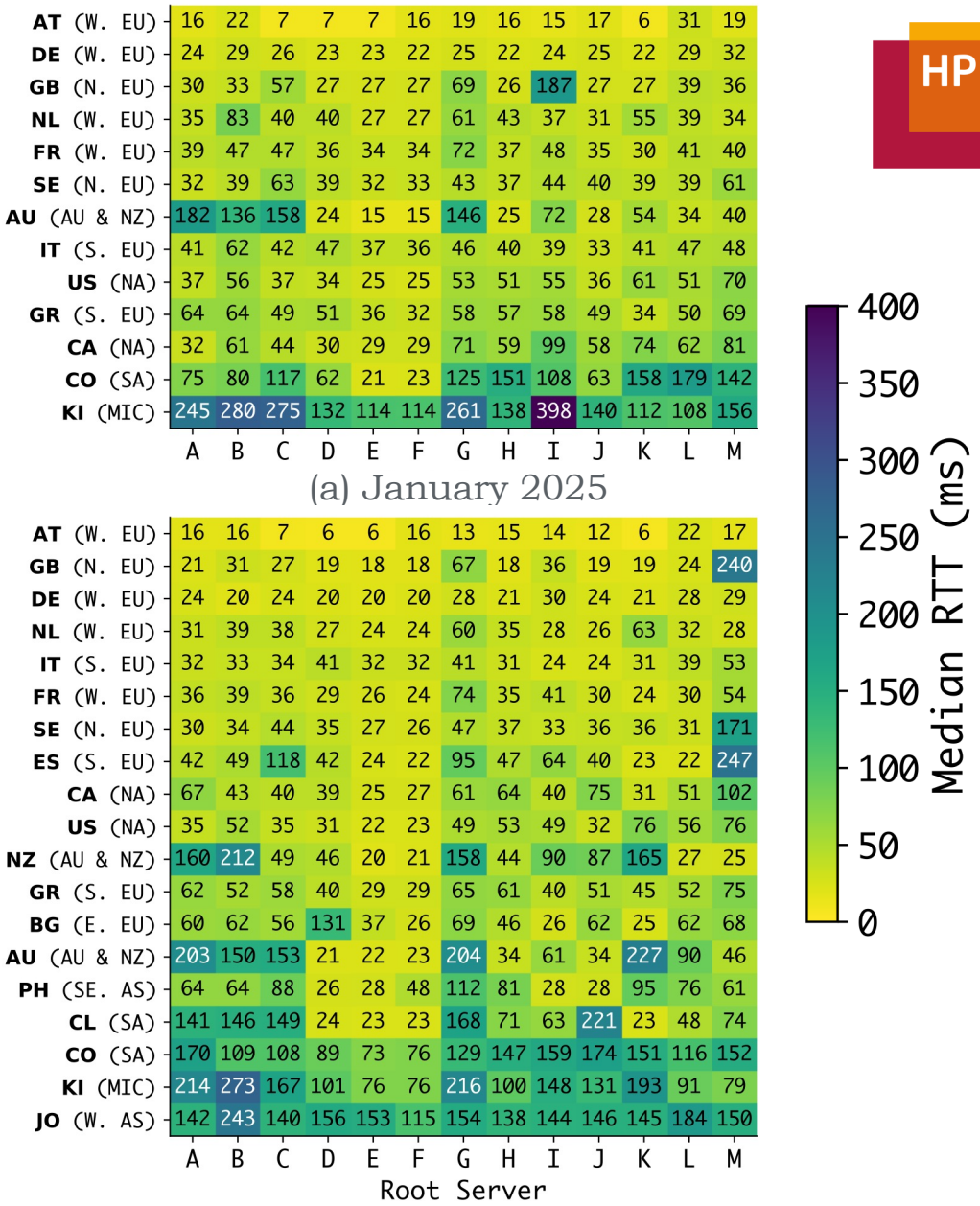
- With our Starlink antenna, we can use arbitrary software and targets
  ⇒ *Measurements for specific targets and protocols*

Active RIPE Atlas Starlink Probes on a World Map as of May 2026
Total: 123 IPv4 Probes in AS14593

DNS Resolution Time: Development in 2025

- DNS latencies similar to earlier performance observations in non-DNS Starlink studies [5]:
  - European countries show low Do53 latencies
  - Likely correlated with GS deployment
- Latency highly dependent on following factors:
  - Number of vantage points per root server
  - Number of ground stations in close probe proximity

Takeaways:
- Oceania worst, while Europe is best
- Latencies highly region dependent, likely by state of ground infrastructure



(a) January 2025

(b) December 2025

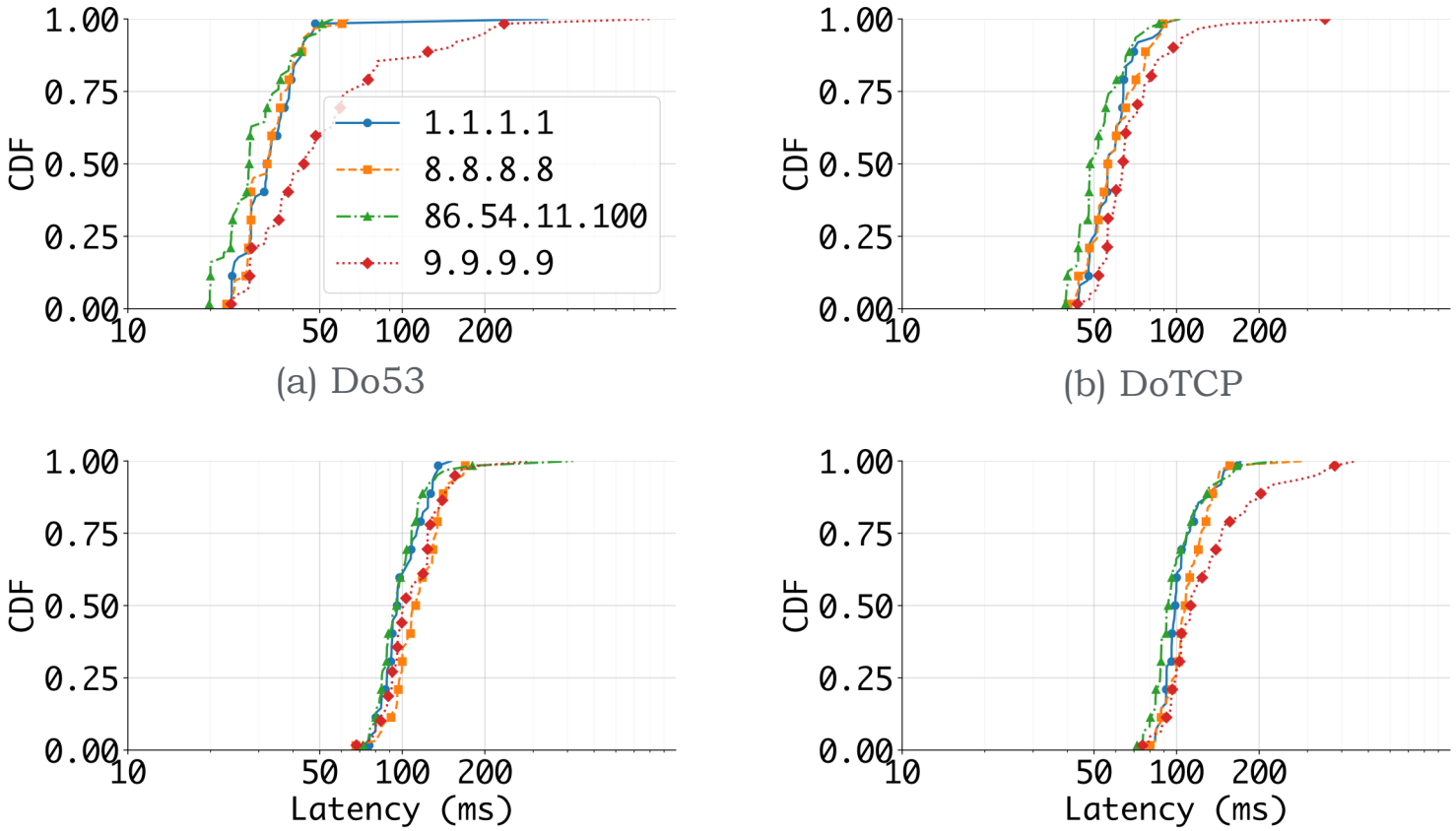
Heatmap of Do53 latencies using RIPE Atlas built-in measurements

[4] Richter et al. "Breaking Through the Clouds: Performance Insights into Starlink's Latency and Packet Loss" (2025)

DNS Resolution Time: Impact of DoE and Resolvers

- Do53 latency on median $\approx 30\,ms$ (only outlier is Quad9)
- DoTCP roughly twice the Do53 latency (50th percentile $\approx 60\,ms$)
- DoE (i.e., DoT & DoH) median $\approx 110\,ms$

- Resolvers very similar
  - Quad9 is slightly worse compared Google, Cloudflare, and DNS4EU



(a) Do53 (b) DoTCP (c) DoT3 (d) DoH2

Fig. 5: Comparison of DoE protocols and resolver with queries for uncached domains

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Causes of DNS Latencies: Methodology

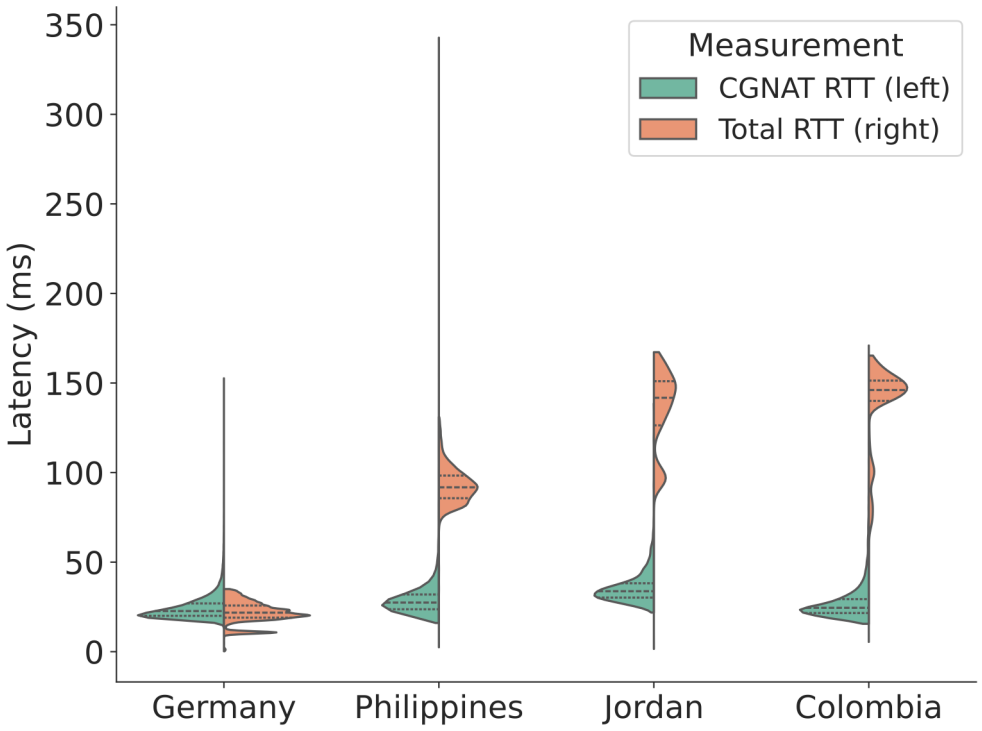
- Each DNS measurement also came with traceroute measurements
- Issue: Satellites and GSes are sub-IP layer and cannot be observed in the traceroute

- But:
  - Starlink documentation gives information about the trace (accidentally?) [5]
  - Hop with address `100.64.0.1` is the address assigned to CGNAT (complying with RFC 6598)
  - In the following, we assume that this is the first hop of the "terrestrial Internet"

[4] Starlink. "What IP addresses does Starlink provide?", Online: https://starlink.com/de/support/article/1192f3ef-2a17-31d9-261a-a59d215629f4 (Accessed: April 2026)

Causes of DNS Latencies: The Traversal through the Satellite Constellation

⇒ How much of the latency results from the traversal through the constellation?



Latency to CGNAT hop and to last hop

Country	Ratio
Kiribati	76.75 %
France	73.86 %
Canada	79.94 %
Austria	111.99 %
Philippines	13.05 %
United States	71.47 %
Germany	102.02 %

Ratio of CGNAT-hop to total latency

CGNAT-hop causes most of the latency
⇒ Satellite constellation traversal causes most latency, especially if DNS latency is generally low!

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How can we improve?

- If a public DNS provider already provides relatively low latency, they have **little chance of improving** even further for Starlink users

- Possible improvements:
  1. **DNS Caching on the Starlink antenna** with regular updates
  2. **DNS Resolvers in Space (e.g., on the satellite)**
     - **Puts caching closer to the Starlink user**

Key Findings

- Starlink Do53 performance $\approx 30\,ms$ across resolvers
- DoE perform along their required round-trips with slight encryption overhead
- A major cause of latency is the traversal over the satellite network
  - Possible improvements: Improved routing or edge resolution in satellites for cached domains

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