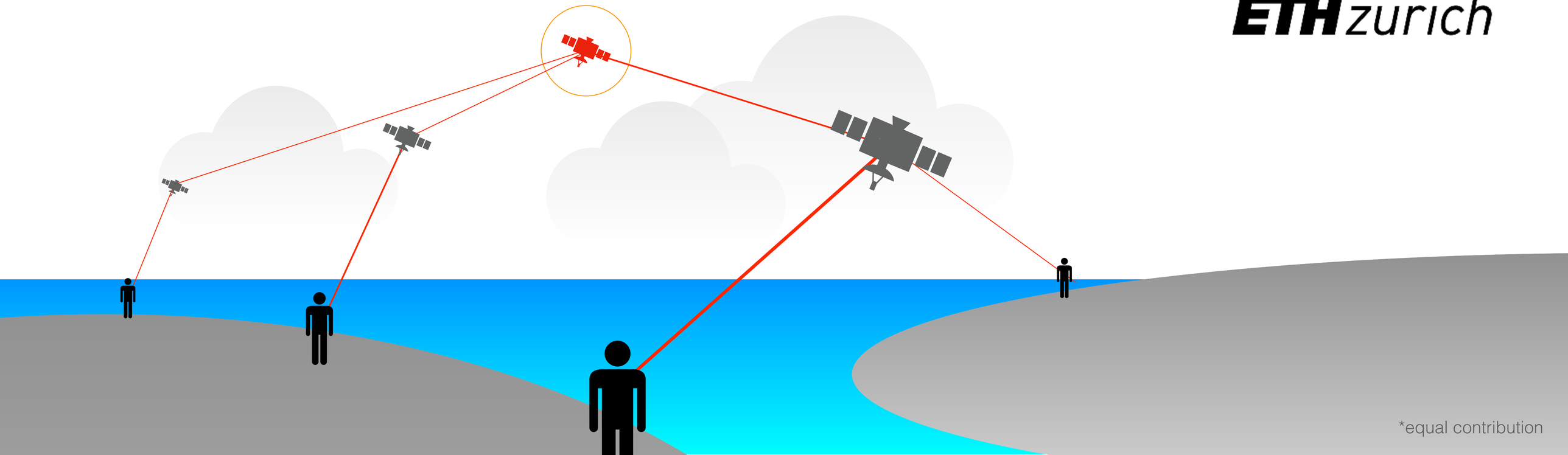
In-orbit computing

An outlandish thought experiment?

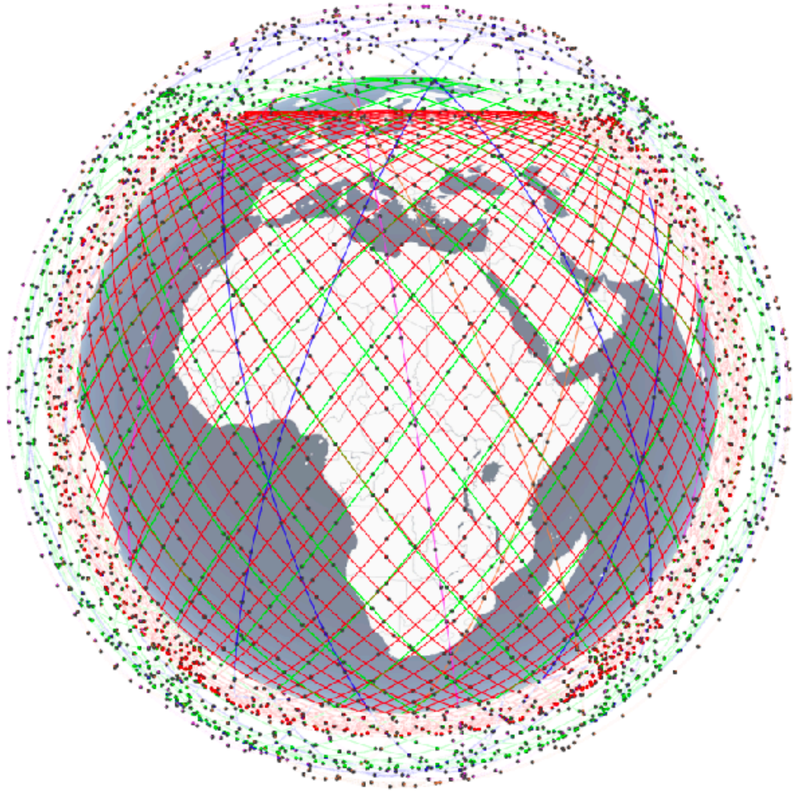
Debopam Bhattacherjee*, Simon Kassing*, **Melissa Licciardello**, Ankit Singla

ETH zürich

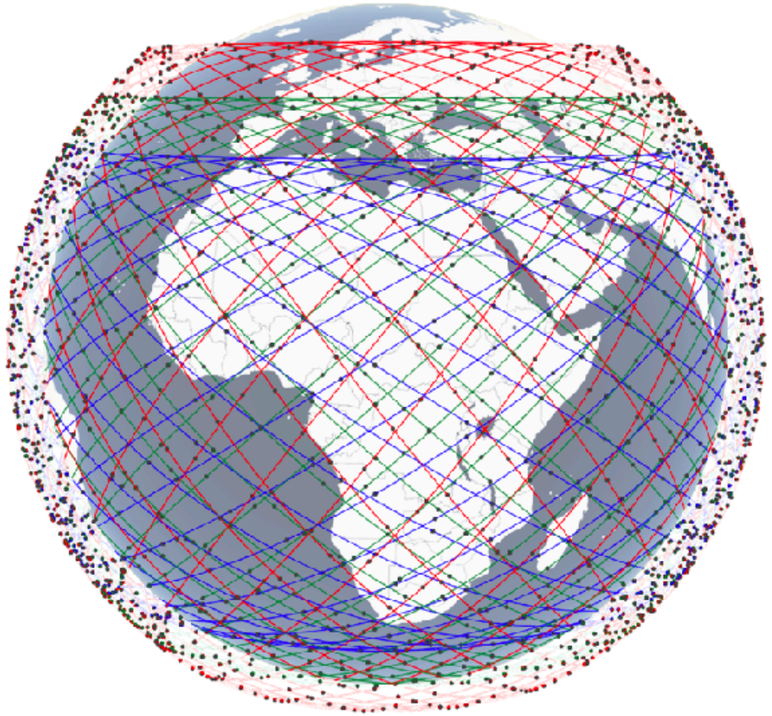


*equal contribution

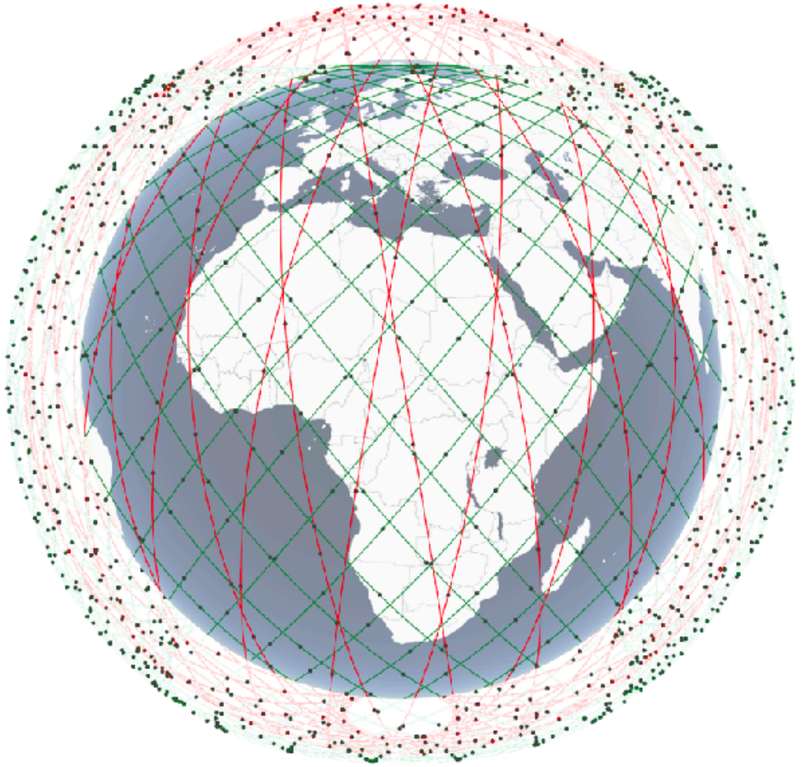
Tens of thousands of satellites



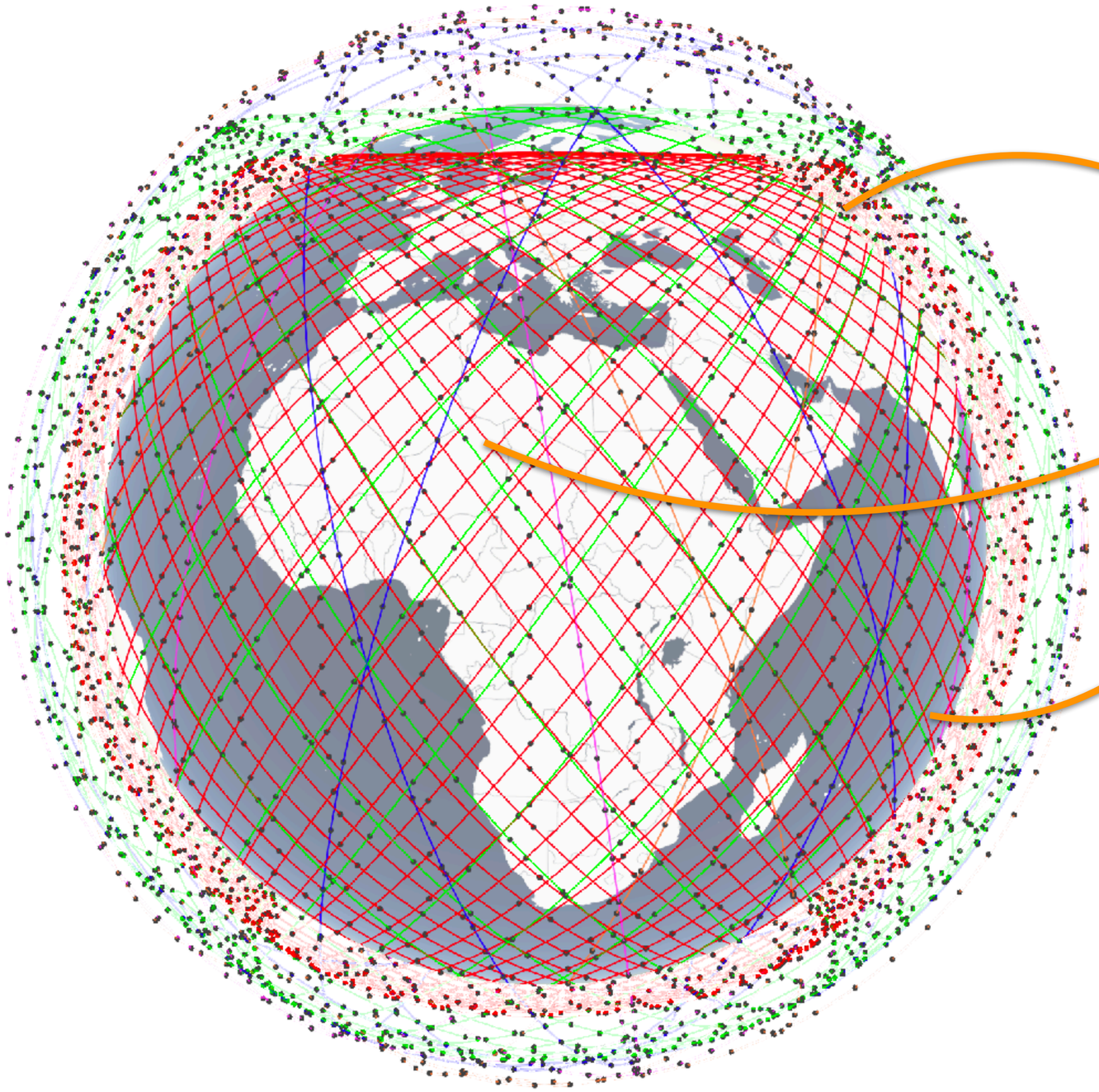
Starlink Phase1



Kuiper



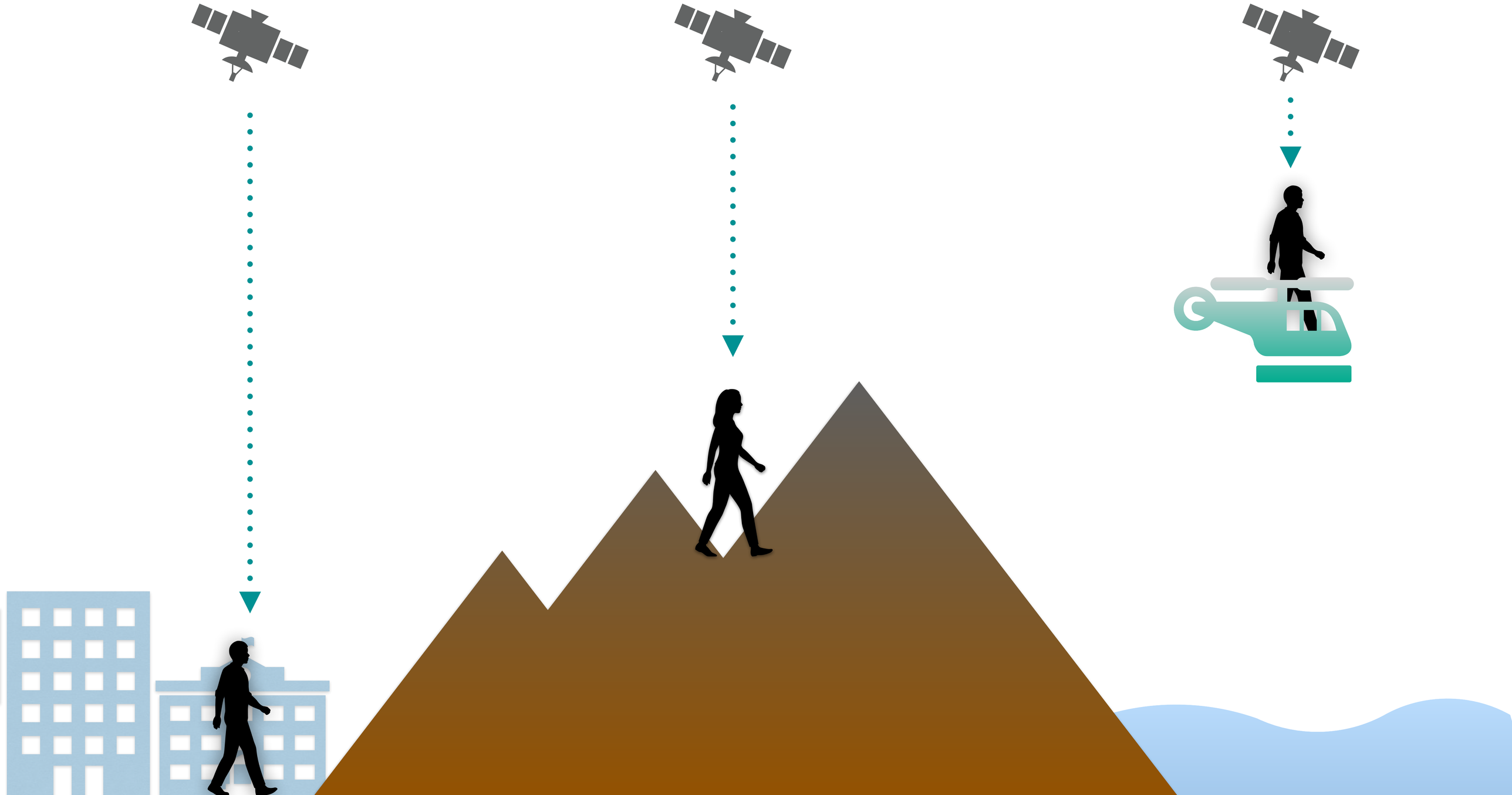
Telesat



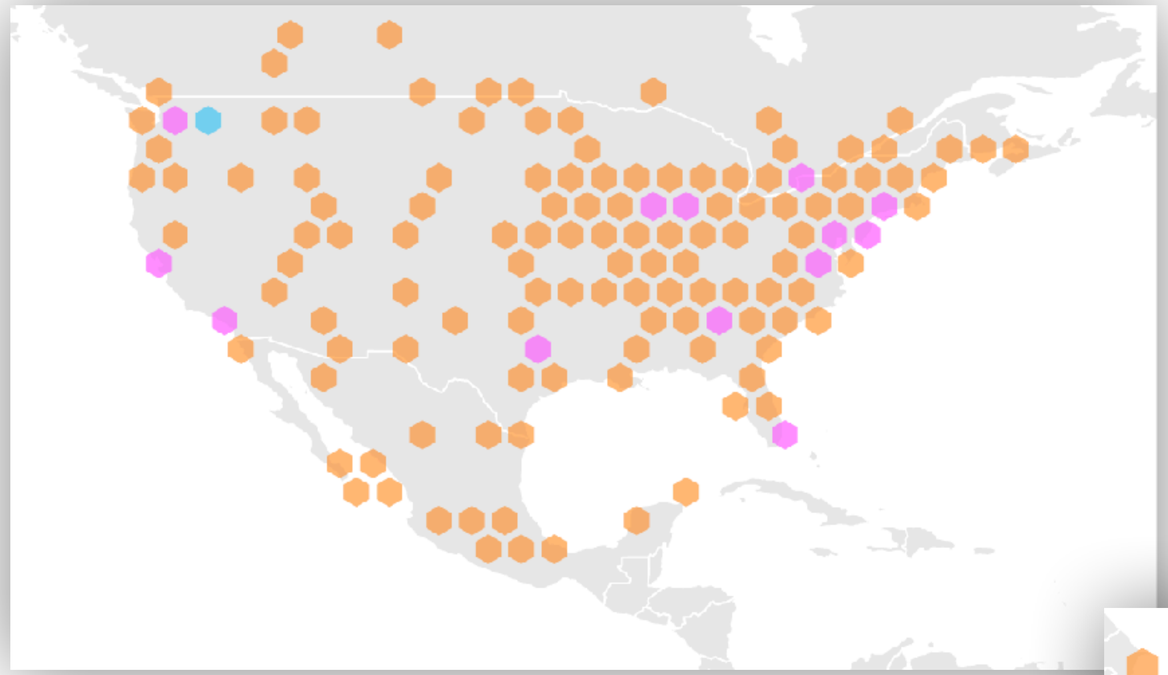
Compute?

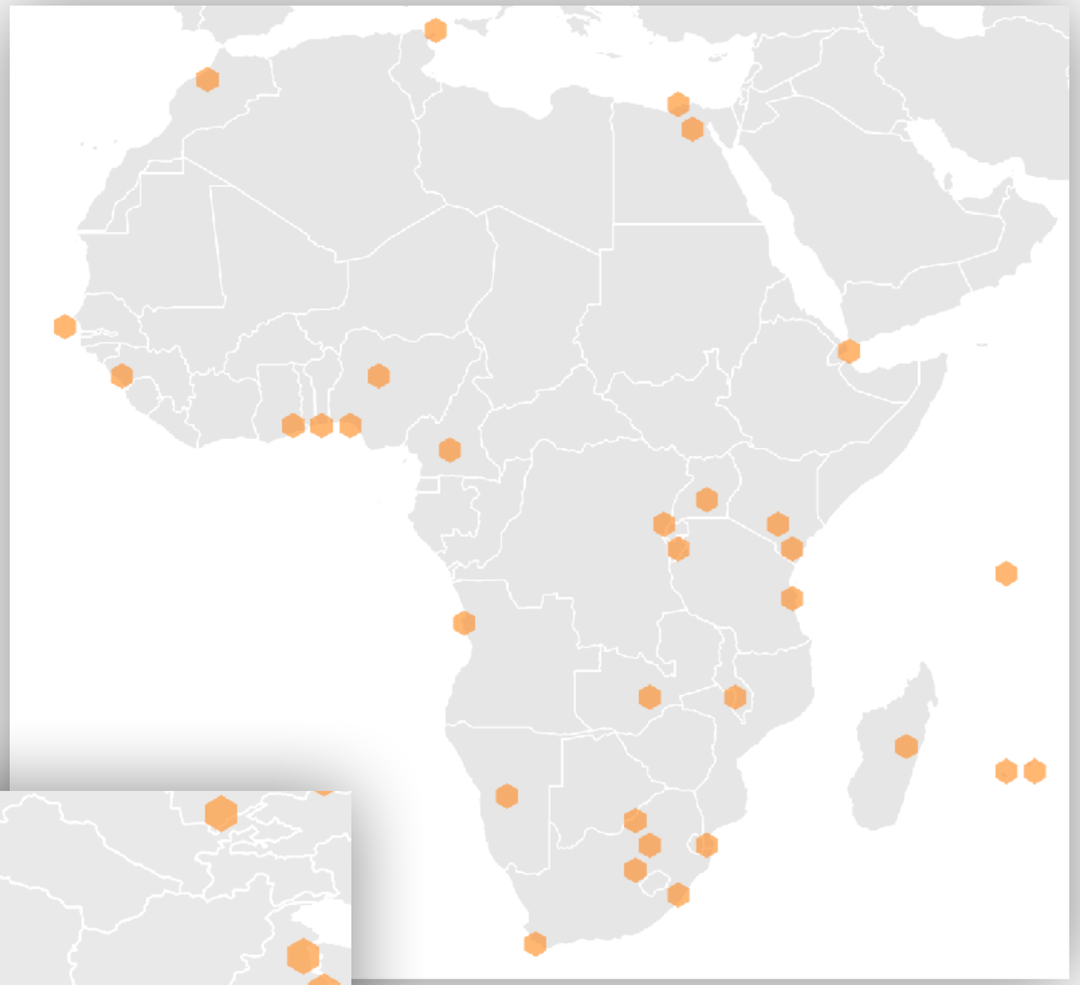
1. What can we gain?

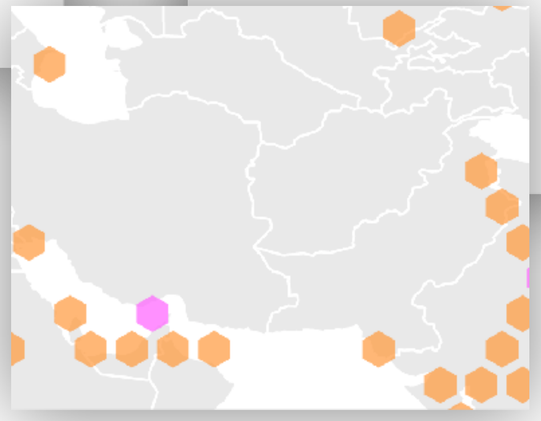
2. Is it *worth* it?



CDN and Edge



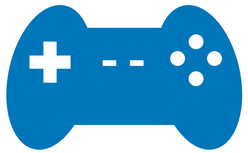




> 100 ms

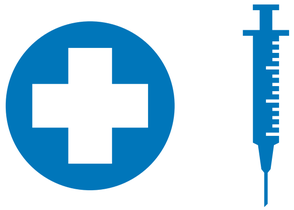
https://www.akamai.com/fr/fr/resources/visualizing-akamai/media-delivery-map.jsp

How *low* is low latency?



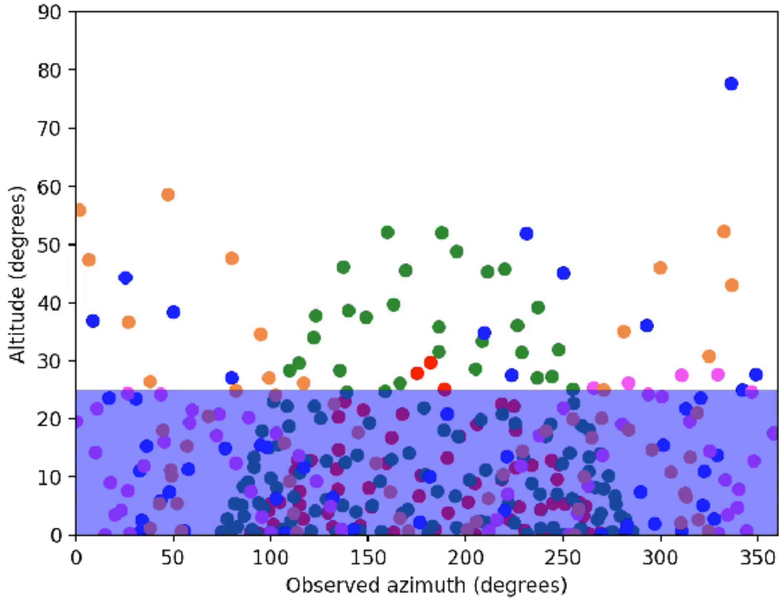
Web browsing & Gaming

Augmented Reality

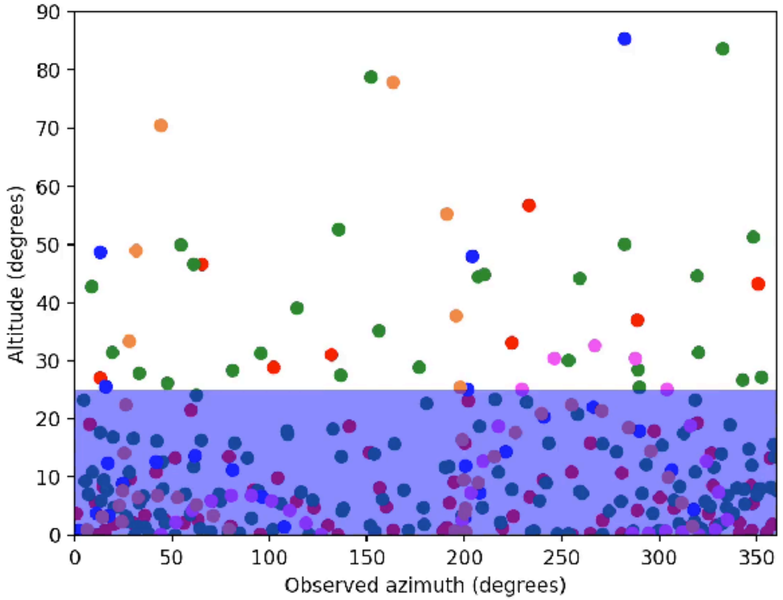


Tactile Internet

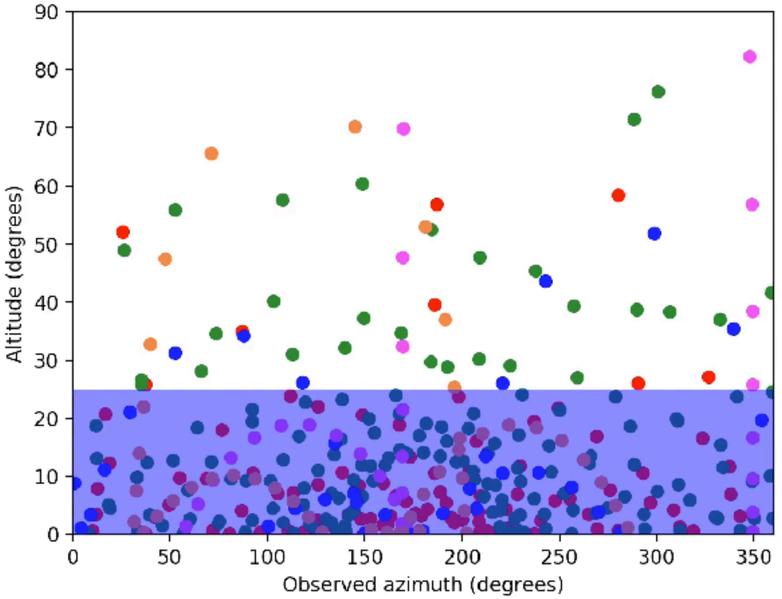
Satellites availability



Oslo, Norway

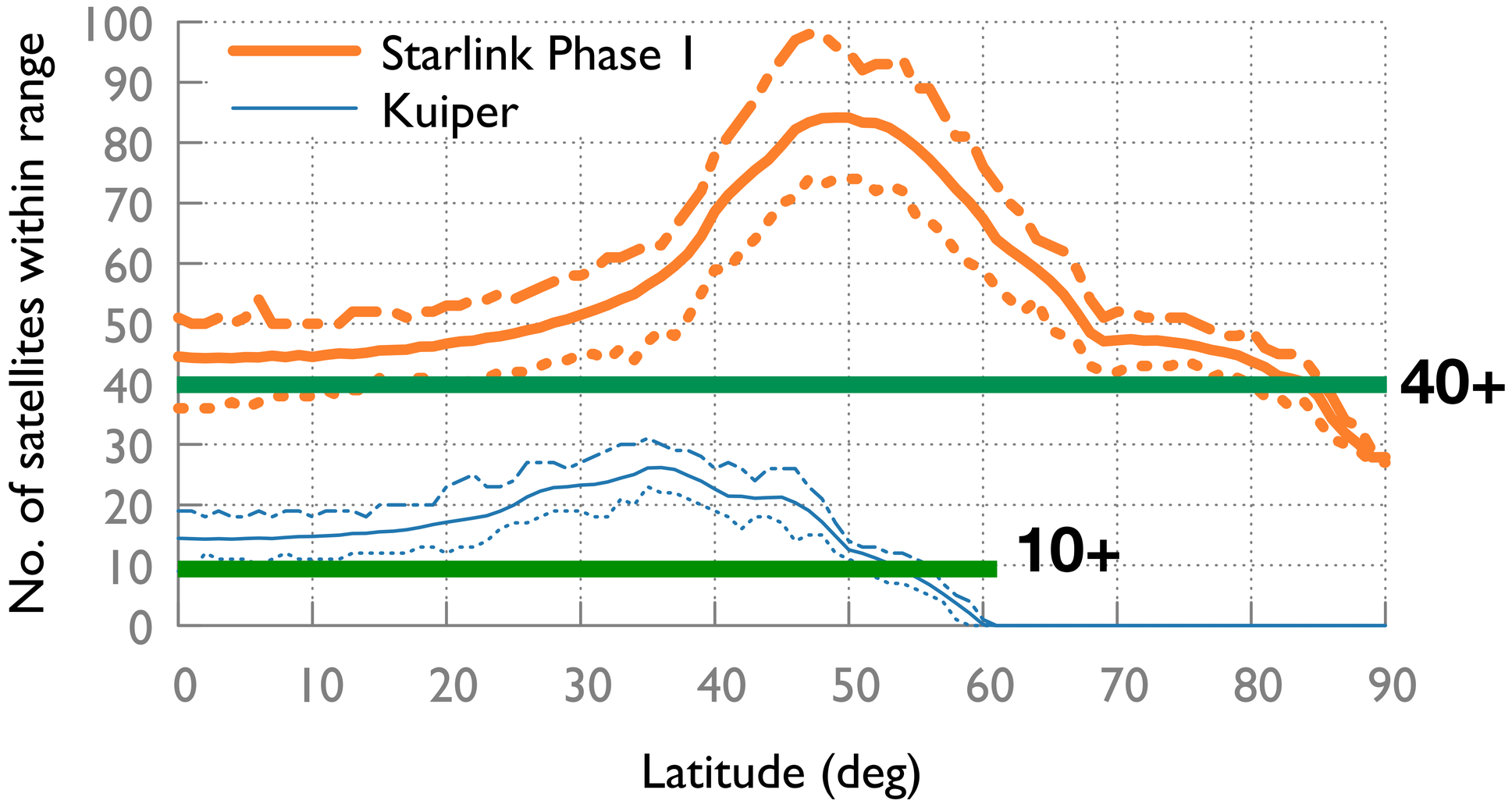


Delhi, India

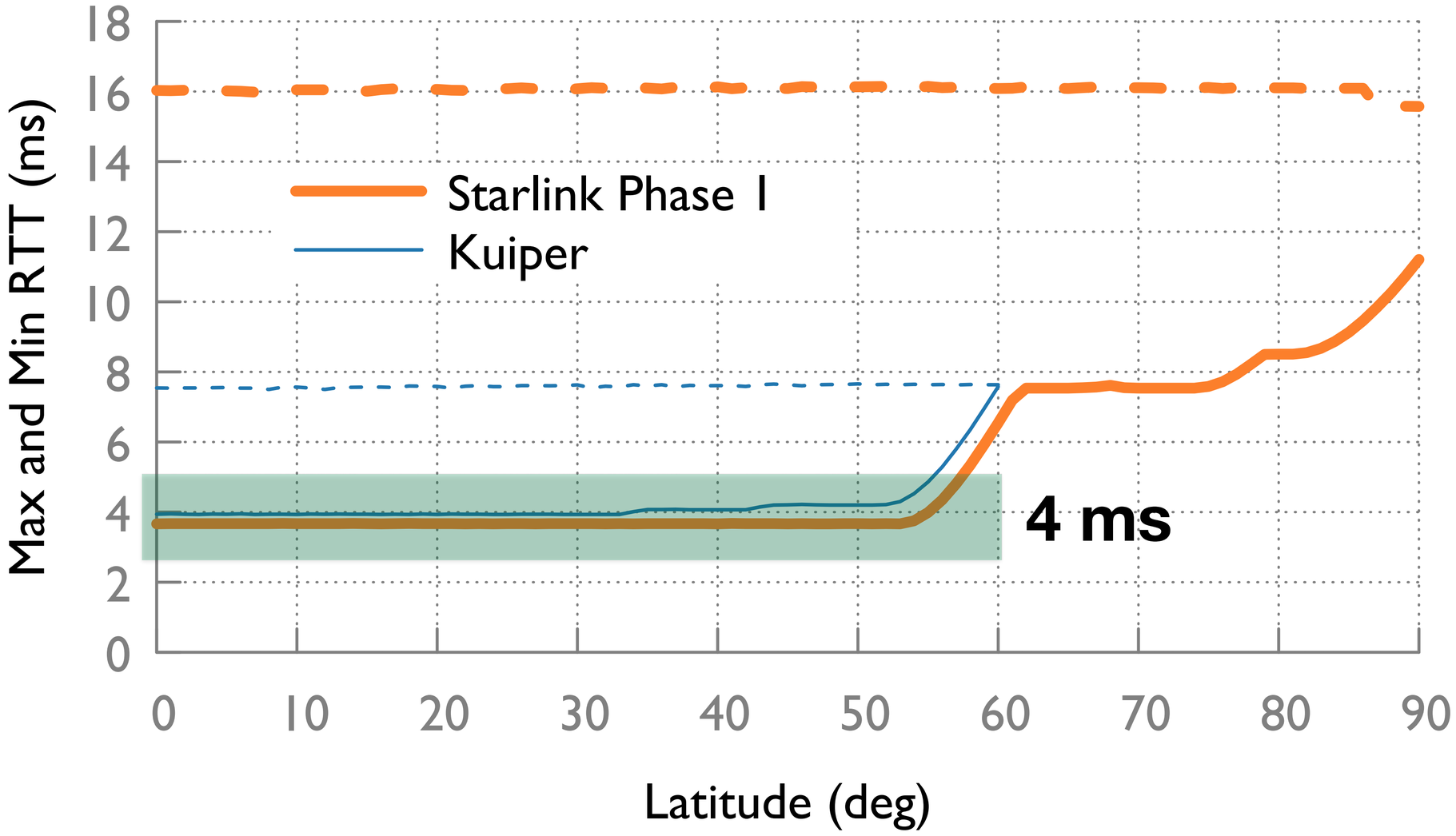


Santiago, Chile

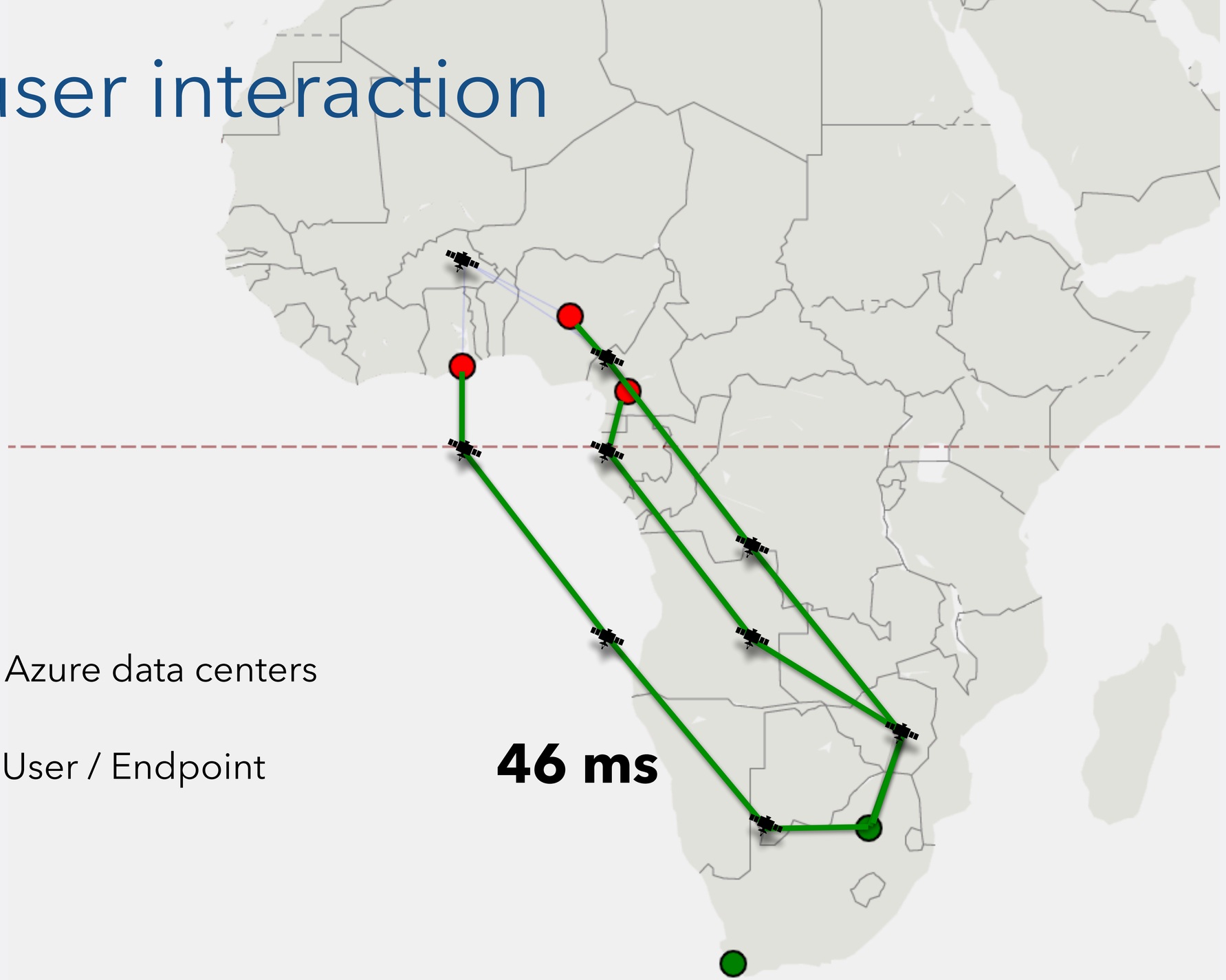
How many?


Starlink Phase 1
Kuiper
40+
10+
No. of satellites within range
Latitude (deg)
0
10
20
30
40
50
60
70
80
90
100

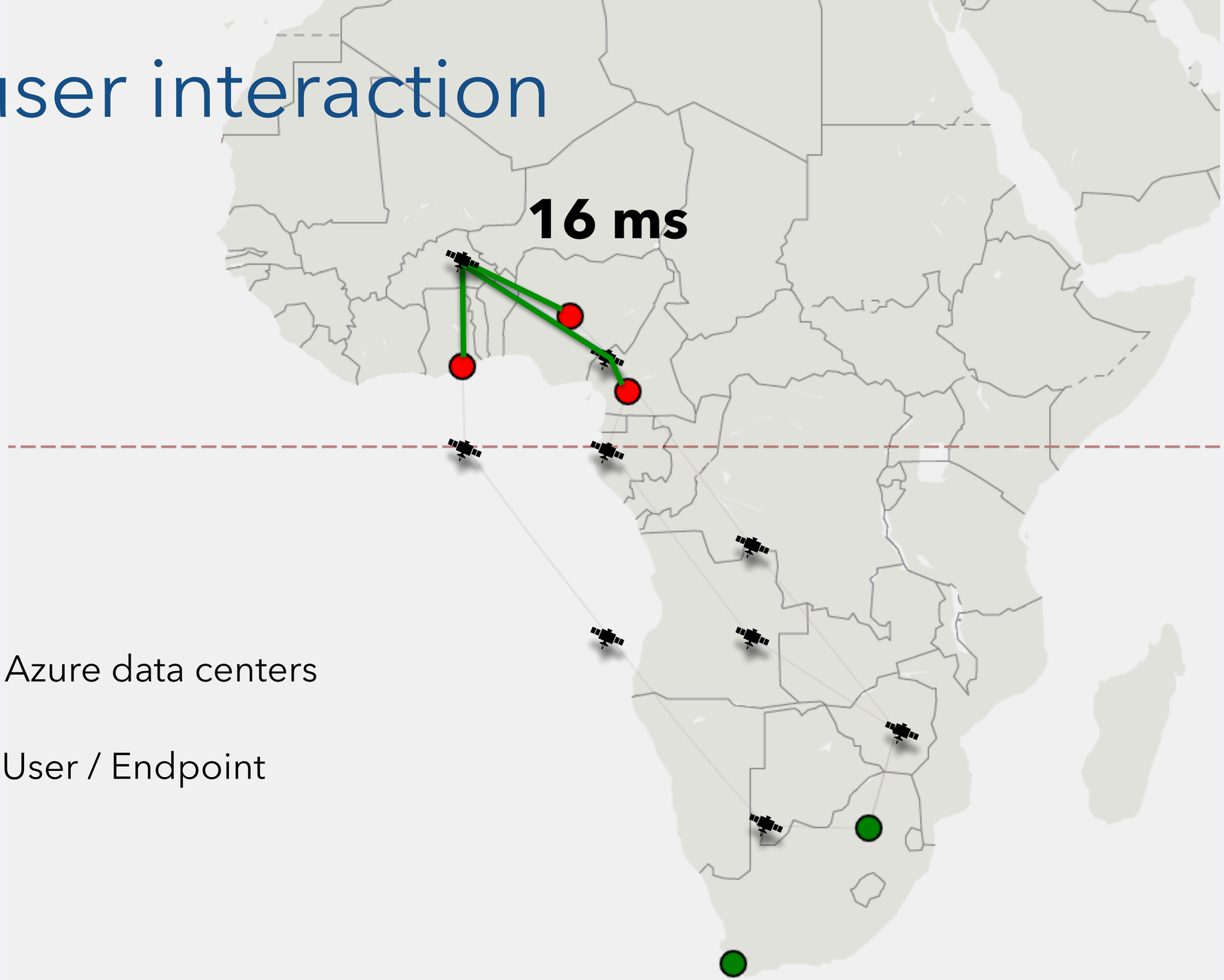
How far?


Max and Min RTT (ms)
18
16
14
12
10
8
6
4
2
0
Starlink Phase I
Kuiper
4 ms
0
10
20
30
40
50
60
70
80
90
Latitude (deg)

Multi-user interaction



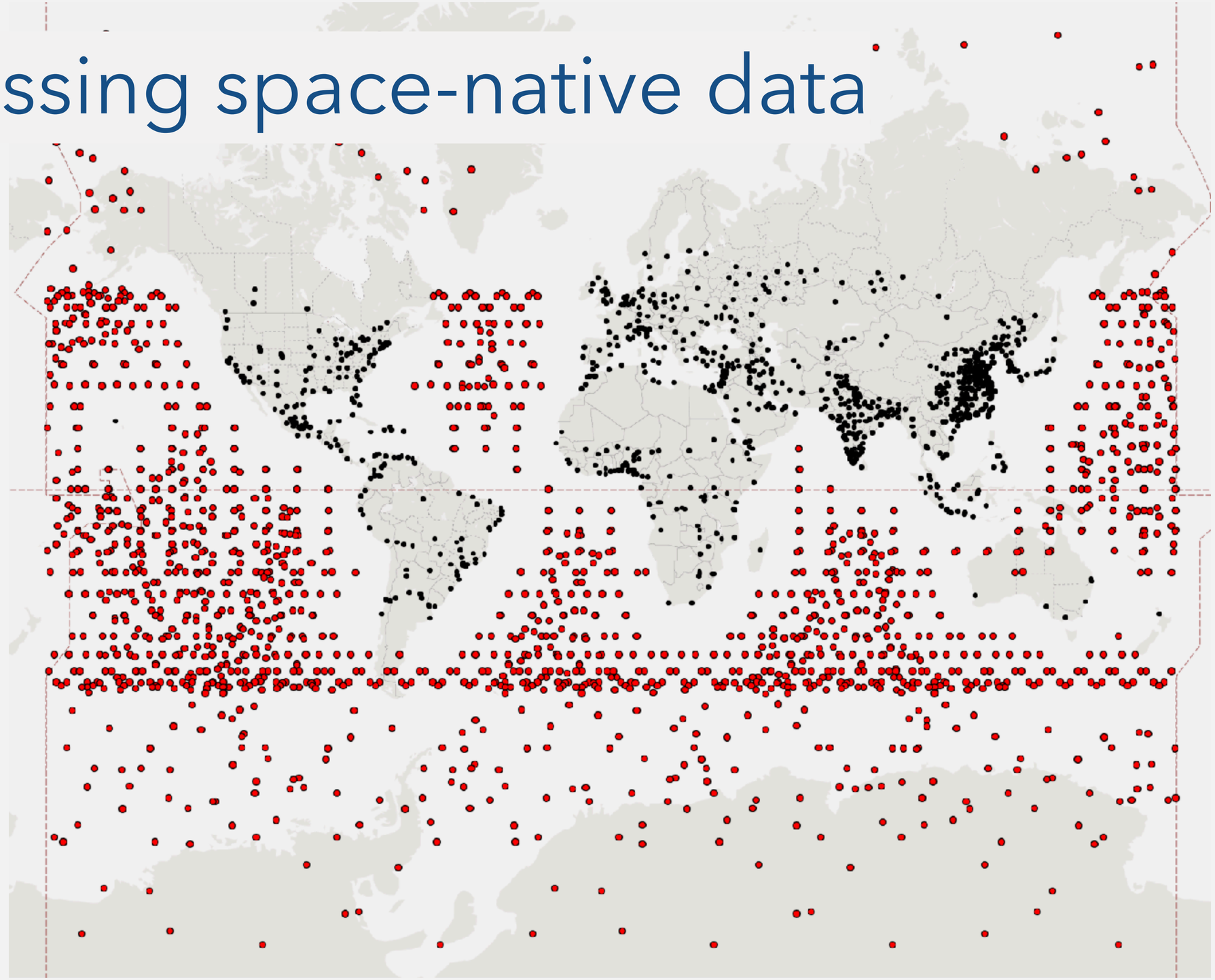
Multi-user interaction



Azure data centers

User / Endpoint

Processing space-native data



Is it even feasible?

Weight and volume overhead

- High-end server (S): 64 cores, 2.4-3.35 GHz, up to 2TB memory
- Weight: 6%, Volume: 1%
- Increased mass/satellite, fewer satellites/launch

Radiation hardening

- Commodity hardware below inner Van Allen radiation belt (643+ km) ?

Is it even feasible?

Power consumption

- High-end server S would consume 15-23%
- Additional payload

Heat generation

- Harder to dissipate without atmosphere
- Additional radiators, thermoelectric harvesters

Is it even feasible?

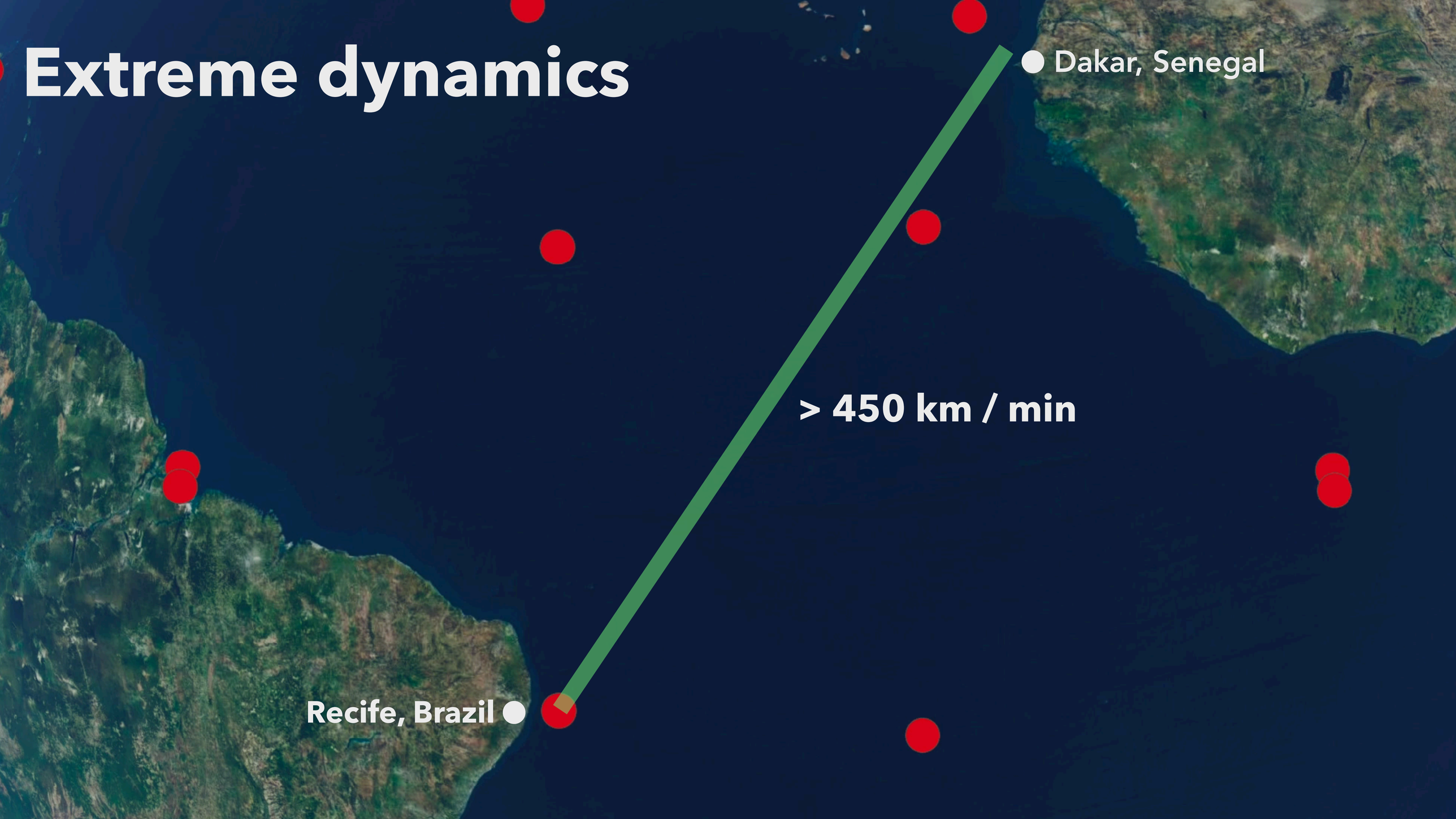
Life-cycle

- Lifespan of ~5 years (DC: ~3 years)
- Continuous replenishment
- Backup satellites

Cost

- At least **3x higher**

Extreme dynamics

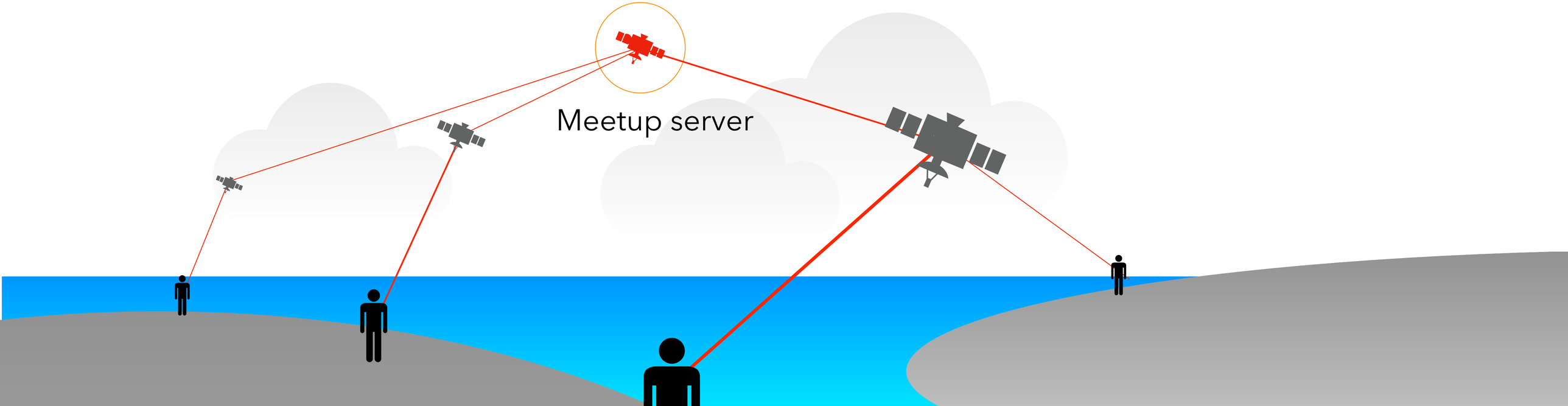


Virtual stationarity

LEO **meetup-server** needs hand-off

Highly dynamic yet **predictable** trajectories

Virtually stationary satellites



Minmax vs. Sticky

Naive Minmax

Picks the **latency-optimal** satellite at each instant.

Frequent handoffs

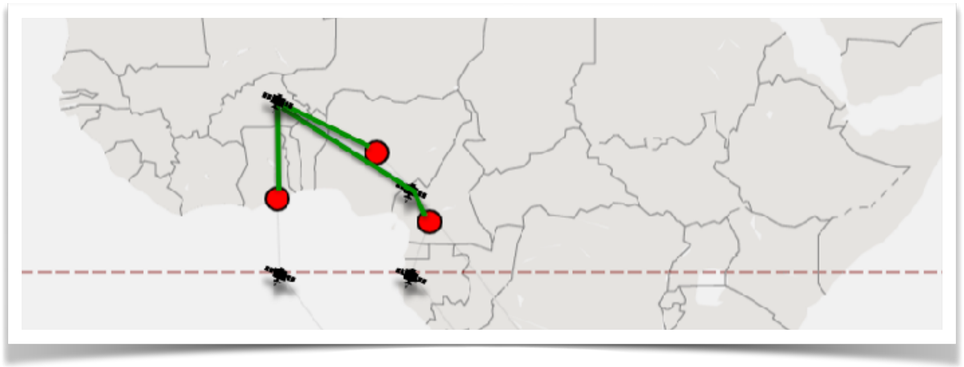
Sticky

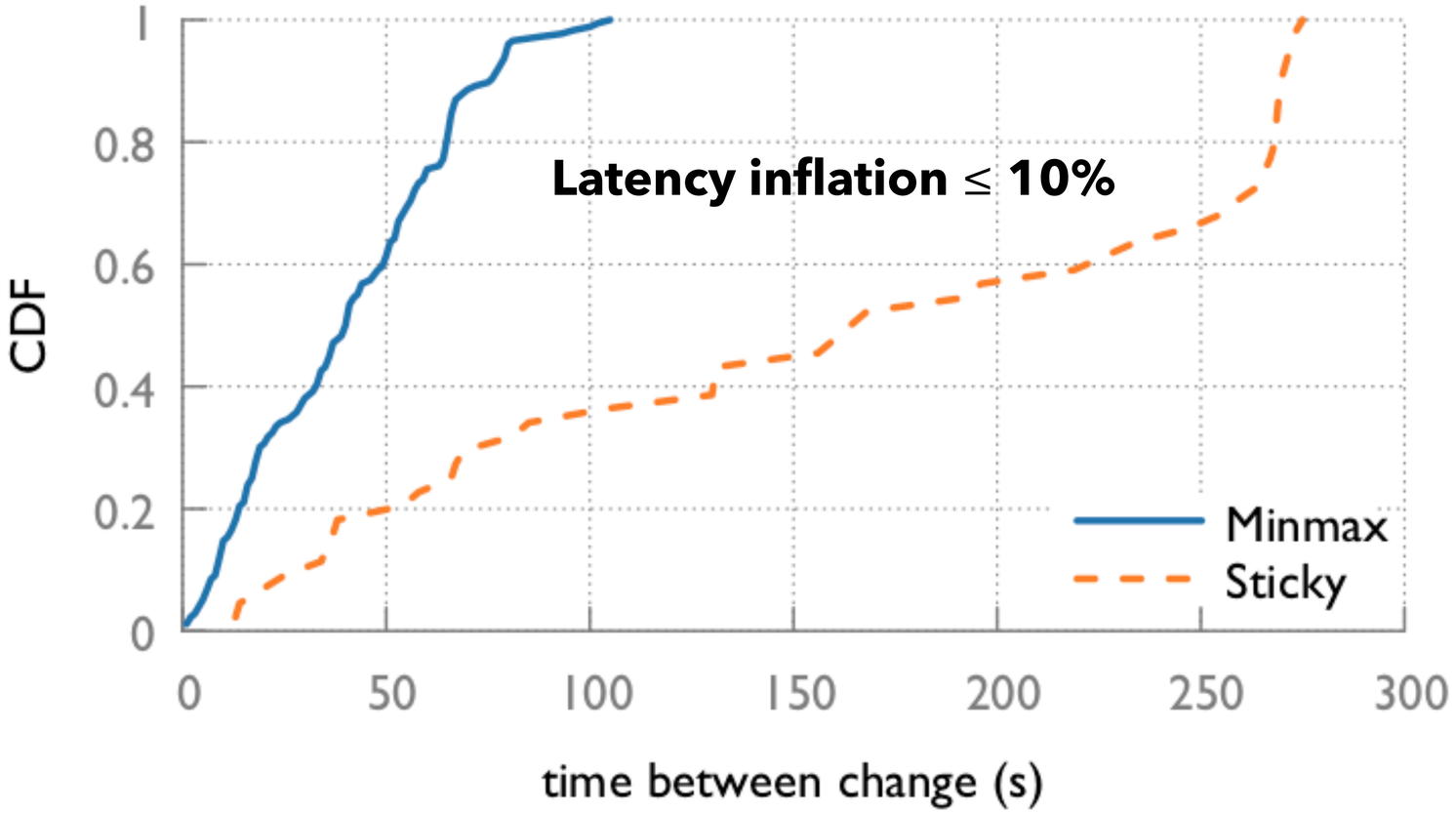
Plans ahead by leveraging **predictable** satellite motions

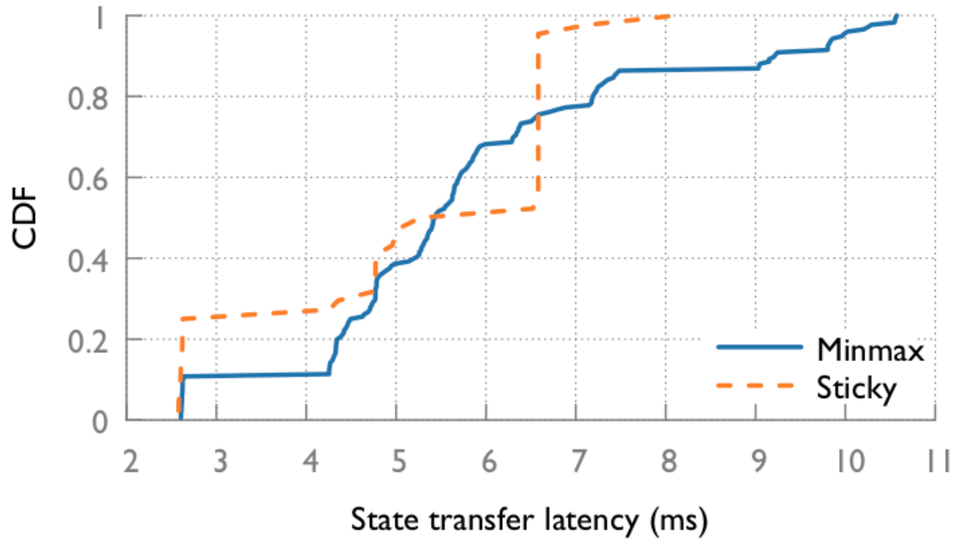
Picks candidates having longest time until next handoff

Selects the one offering least latency for hand-off

Minmax vs. Sticky







Compute anywhere, all the time, at low latency

Most potential issues aren't too prohibitive

Outlandish idea?

"OrbitsEdge Astraeus takes Edge computing to space. We deliver high-performance computing datacenters in orbit, above the clouds, which can process and analyze the vast amounts of data being created in space."

http://orbitsedge.com

"SpaceBelt Data Security as a Service:
A network of 10 Low Earth Orbit (LEO) satellites for the purpose of offering space-based secure cloud data storage and global connectivity services"

http://spacebelt.com

Check our paper @ HotNets 2020

In-orbit Computing: An Outlandish thought Experiment?

Debopam Bhattacherjee*, Simon Kassing*, Melissa Licciardello, Ankit Singla
ETH Zürich