CSC 525:
Computer Networks

Satellite Communication Networks

- The primary reason is coverage
  - Rural areas
  - Oceans, mountains, polar areas
  - Enough market?
- Recent Low Earth Orbit (LEO) constellations make it possible to compete with terrestrial networks on low-latency communication and general Internet services.
  - How to design this kind of networks?

Satellites

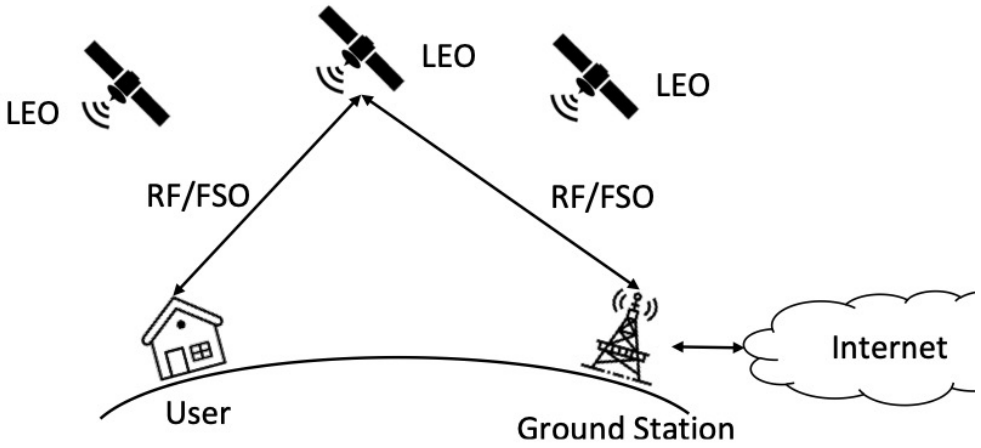
- Altitude: distance from sea level
  - Geostationary (at 35,786 km)
  - Medium Earth Orbit (> 2000 km)
  - Low Earth Orbit (< 2000 km)
- Tradeoff
  - Coverage, number of satellites required
  - Latency

- https://upload.wikimedia.org/wikipedia/commons/b/b4/Comparison_satellite_navigation_orbits.svg

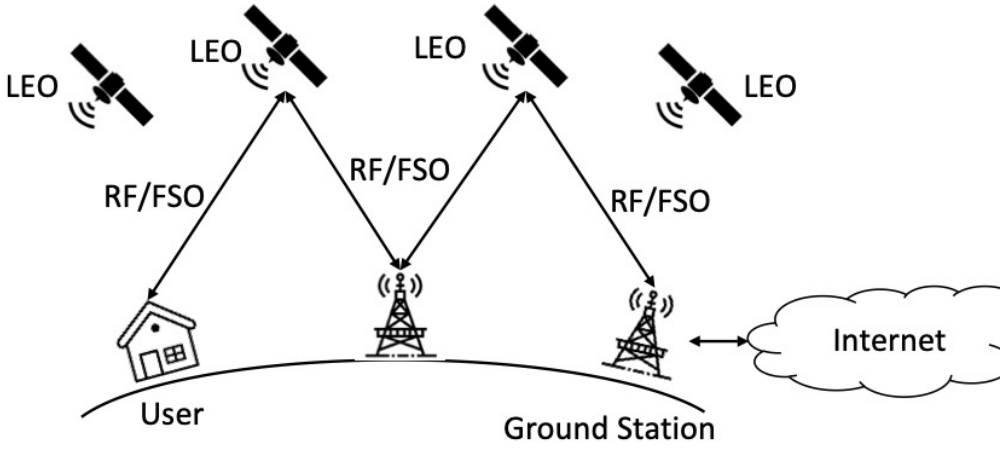
Low Earth Orbit (LEO) Sat Networks

- Use satellites in LEO to provide Internet access.
- Challenges:
  - Provide good coverage and good network services
  - With low cost
- A number of failed projects in the 90's
  - Teledesic, Iridium, GlobalStar
- Revived and gaining momentum in recent years
  - Starlink (US, 12k sats), Kuiper (US, 3k sats), OneWeb (Europe, 7k sats), Telesat (Canada, 1.7k sats)
  - Satellite miniaturization, lower launching cost, better antenna and communication technology.

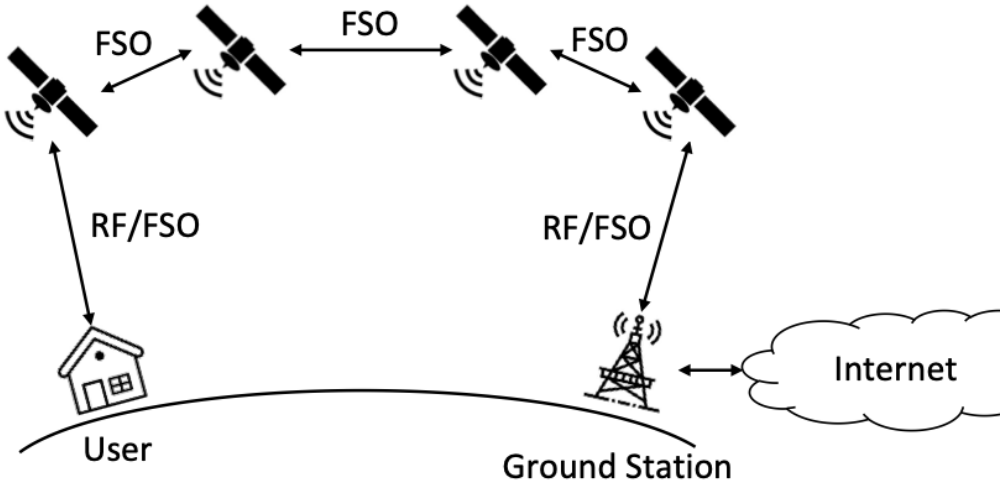
General Architecture



(a) one relay LEO/ground station

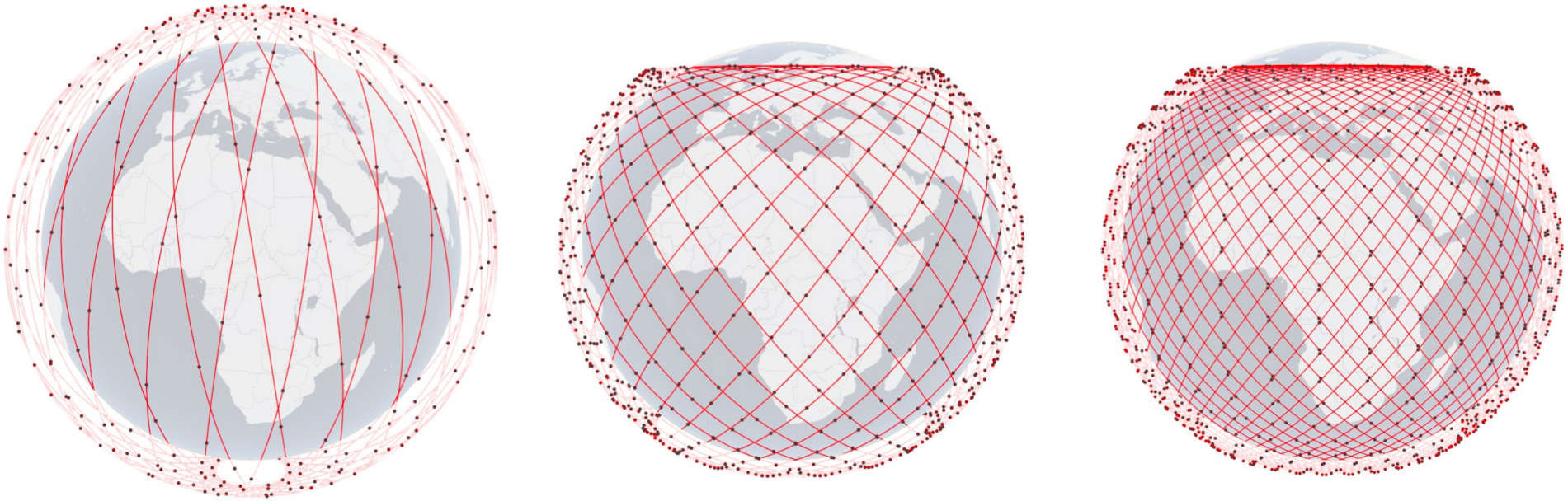


(b) multiple relay LEOs/ground stations



(c) multiple interconnected relay LEOs

LEO Constellations



(a) Telesat T1 (b) Kuiper K1 (c) Starlink S1

Fig. 11: *Constellation trajectories.* *(a) Telesat T1* — 27×13, 1,015 *km*, 98.98° *(b) Kuiper K1* — 34×34, 630 *km*, 51.9° *(c) Starlink S1* — 72×22, 550 *km*, 53°. *Satellites are black dots, while orbits are marked in red.*

System	Altitude (km)	Inclination (°)	Planes	Satellites per plane	Number of satellites
Telesat	1,015	98.98	6	13	298
	1,325	50.88	20	11	
OneWeb	1,200	87.9	12	49	716
	1,200	55	8	16	
SpaceX	550	53	72	22	1,584
Amazon	630	51.9	17	34	578

TABLE I: Summary of the initial-phase orbit characteristics of each constellation. All four designs have already been approved by FCC.

System	Altitude (km)	Inclination (°)	Planes	Satellites per plane	State	Number of satellites
Telesat	1,015	98.98	27	13	P	1,671
	1,325	50.88	40	33	P	
OneWeb	1,200	87.9	36	49	P	6,372
	1,200	55	32	72	P	
	1,200	40	32	72	P	
SpaceX	540	53.2	72	22	P	4,408
	550	53	72	22	A	
	560	97.6	6	58	P	
	560	97.6	4	43	P	
	570	70	36	20	P	
Amazon	590	33	28	28	A	3,236
	610	42	36	36	A	
	630	51.9	34	34	A	

TABLE II: Summary of the orbit characteristics of the complete constellations. *A* represents shells approved by the FCC, while *P* represents pending changes.

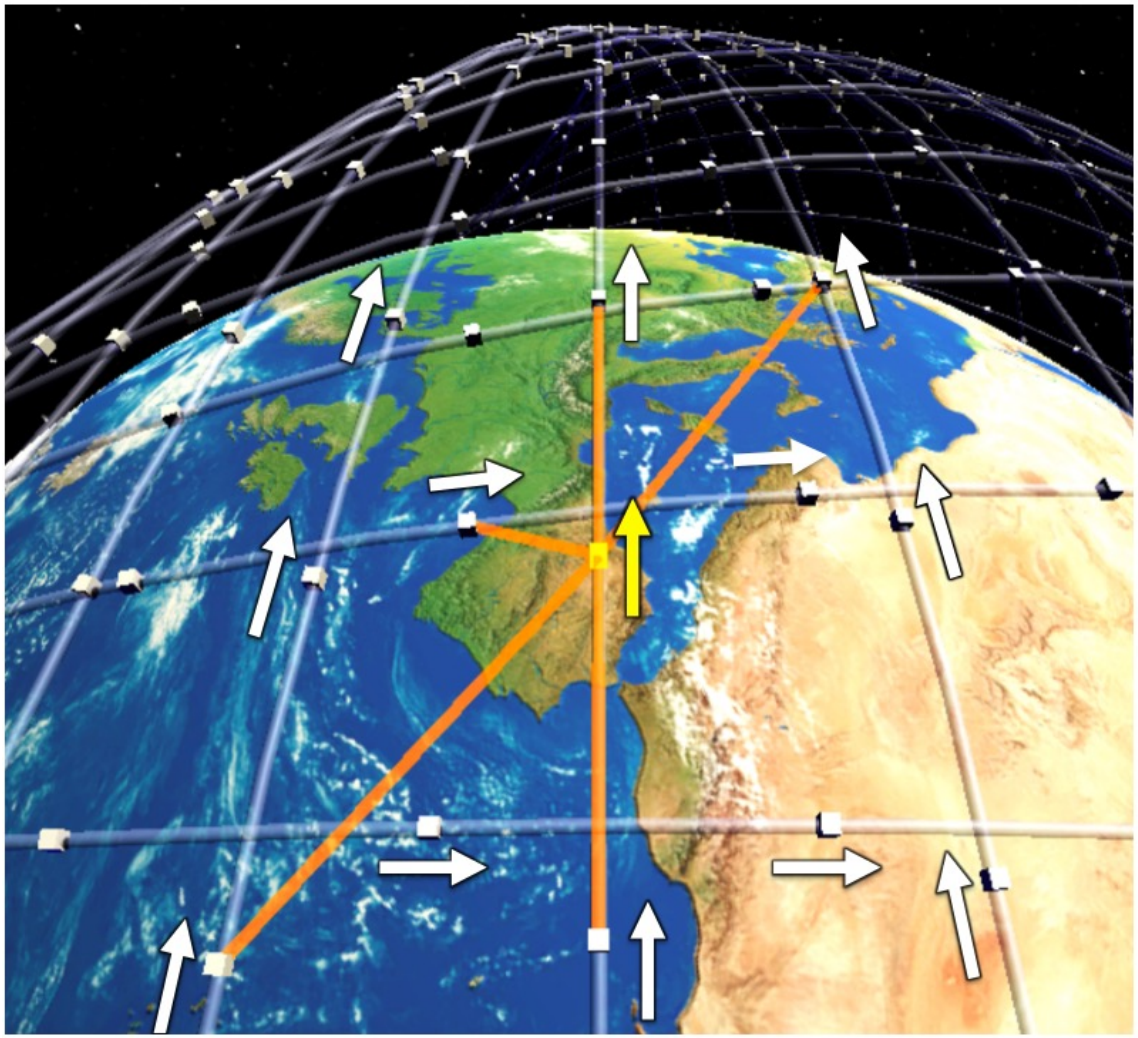
Starlink constellation (phase 1)

- https://starlink-g1.gcgbarbosa.com/

- This paper tries to reverse engineering the Starlink network design.

How to connect ISLs

ISL: inter satellite links



How to do routing

- Source routing:
  - Every ground station knows all the satellites and their orbits, can compute shortest paths, and instruct the satellites where to forward the packets.
  - Computationally doable

Latency (NYC – LON)

Only use overhead sats.

Good but not great.

Need to use more visible atellites.

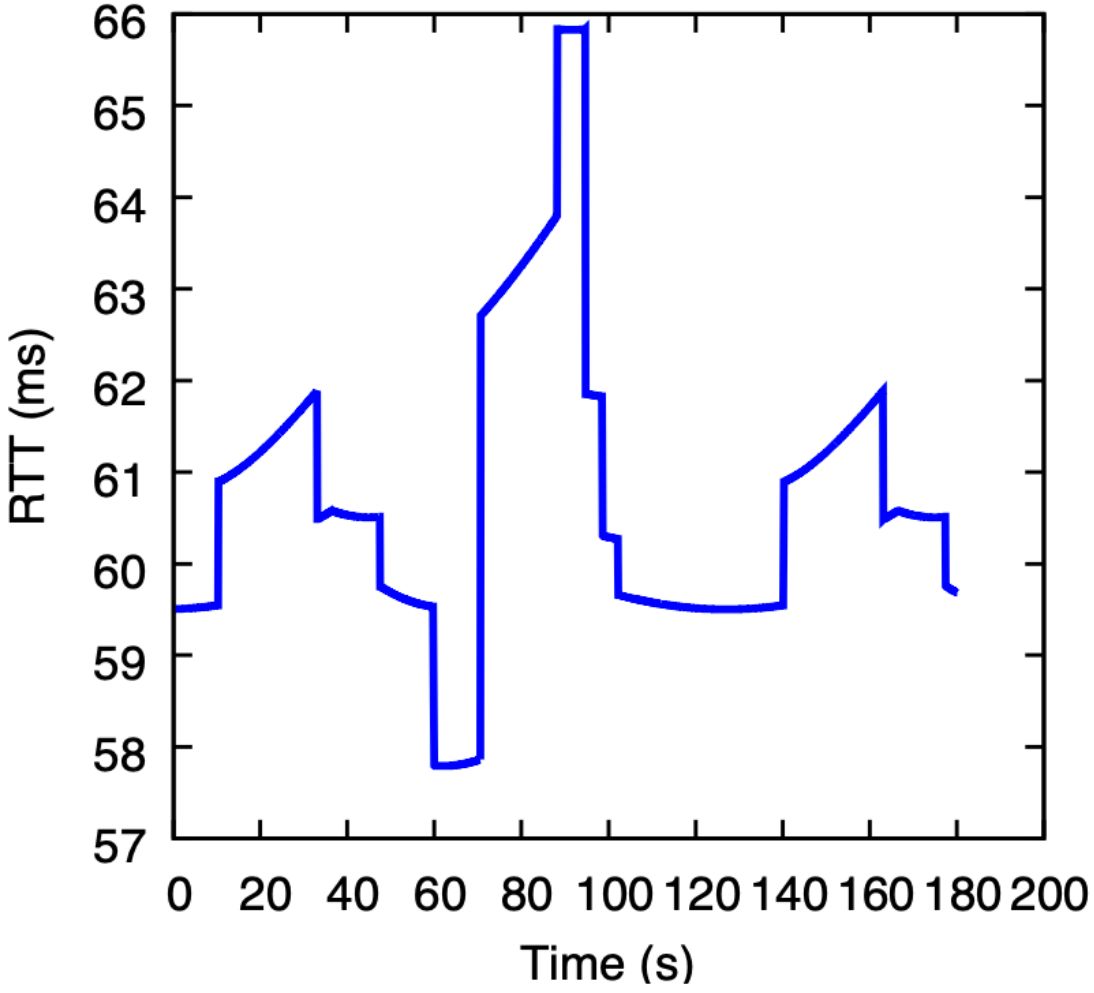
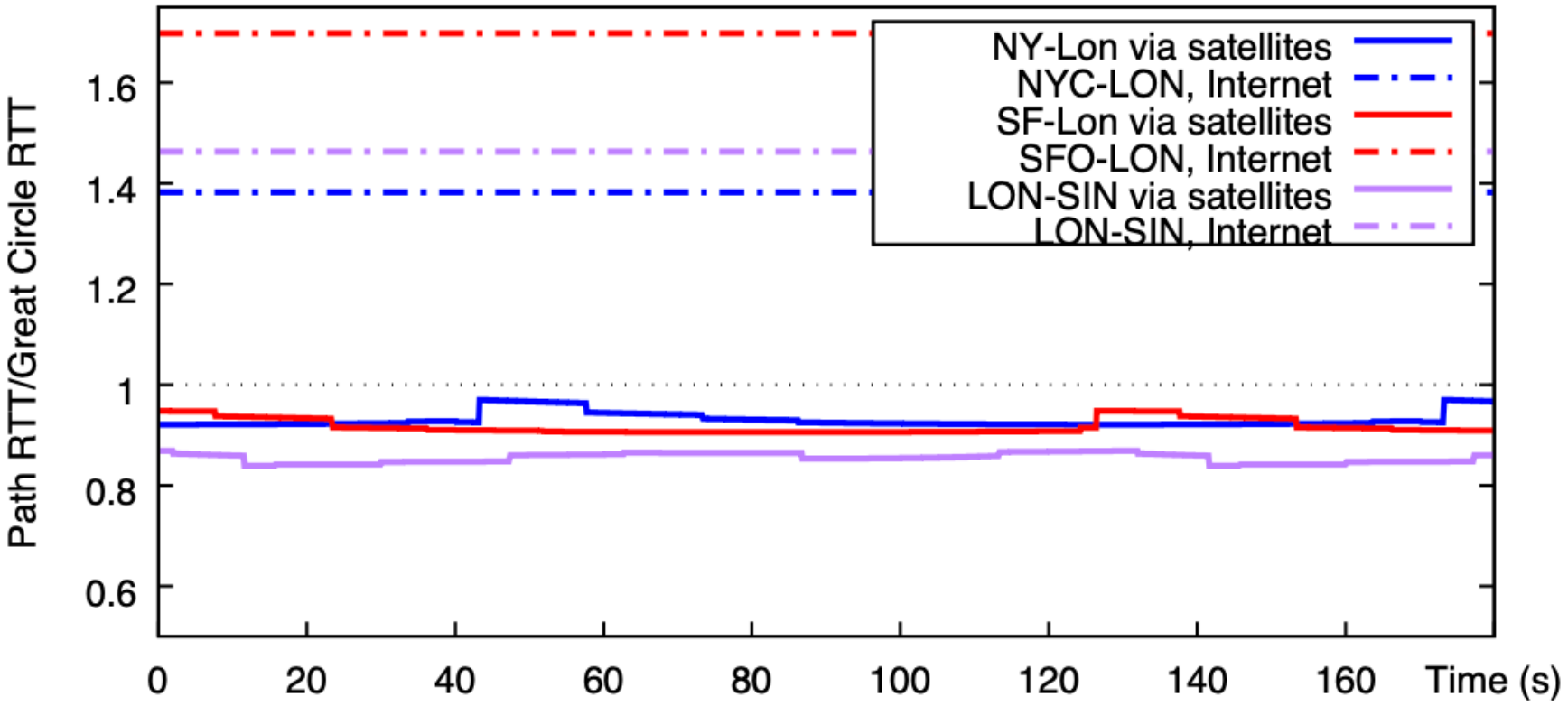


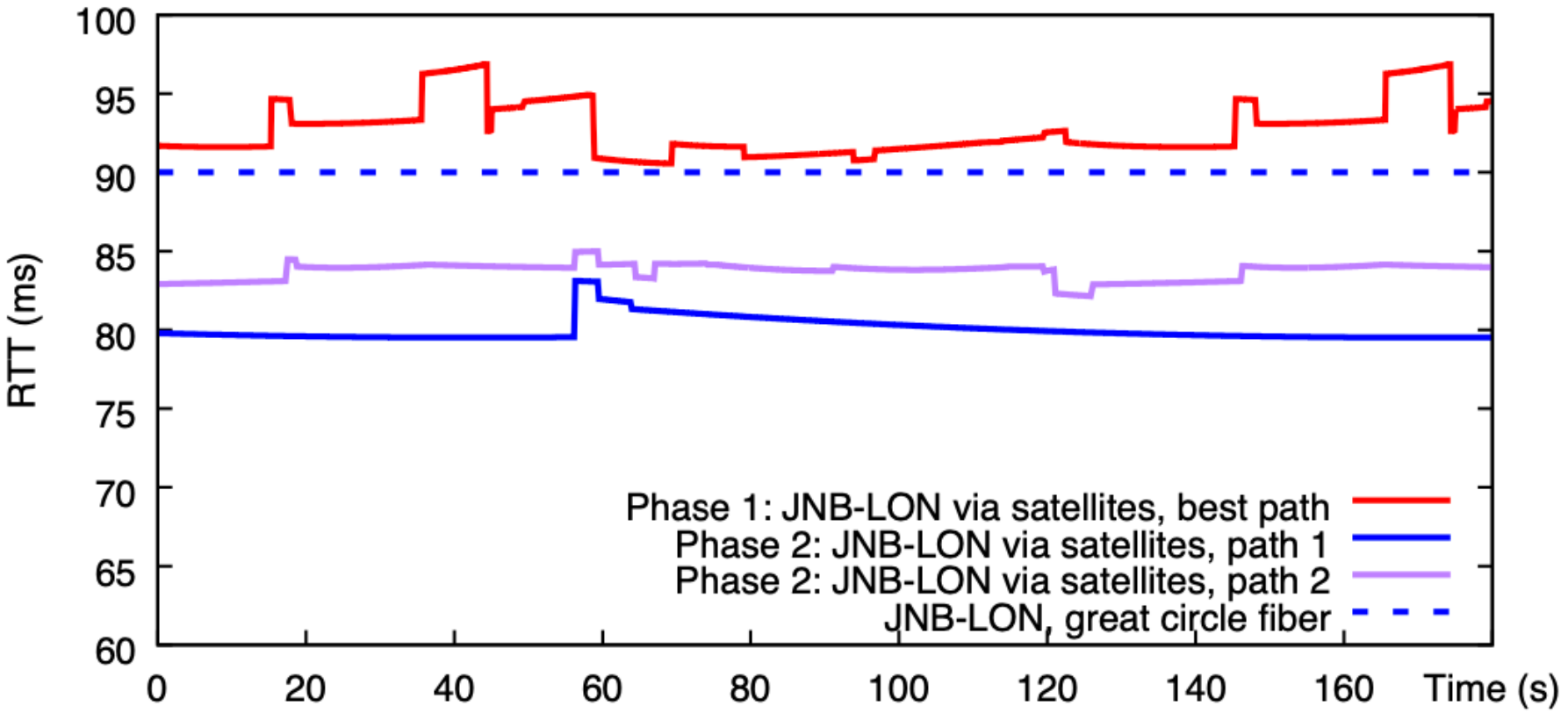
Figure 7: NYC to London RTTs via overhead satellites.

Use more satellites



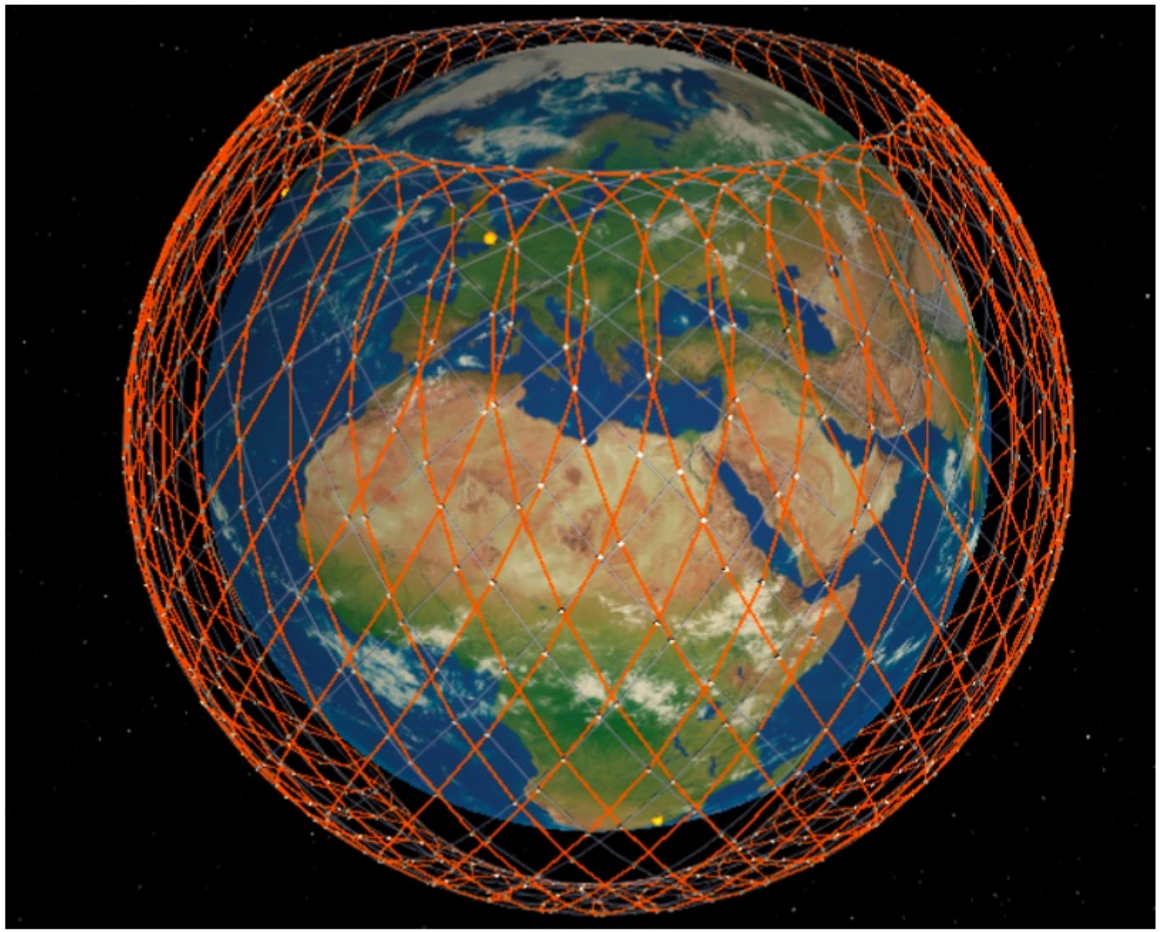
Better than great circle RTT

JND-LON



Better than Internet RTT, but not great circle RTT.
Need the help of the 2nd layer of satellites.

Sides links of Phase 2 sats



Summary

- Recorded video by the author

  https://youtu.be/AdKNCBrkZQ4