

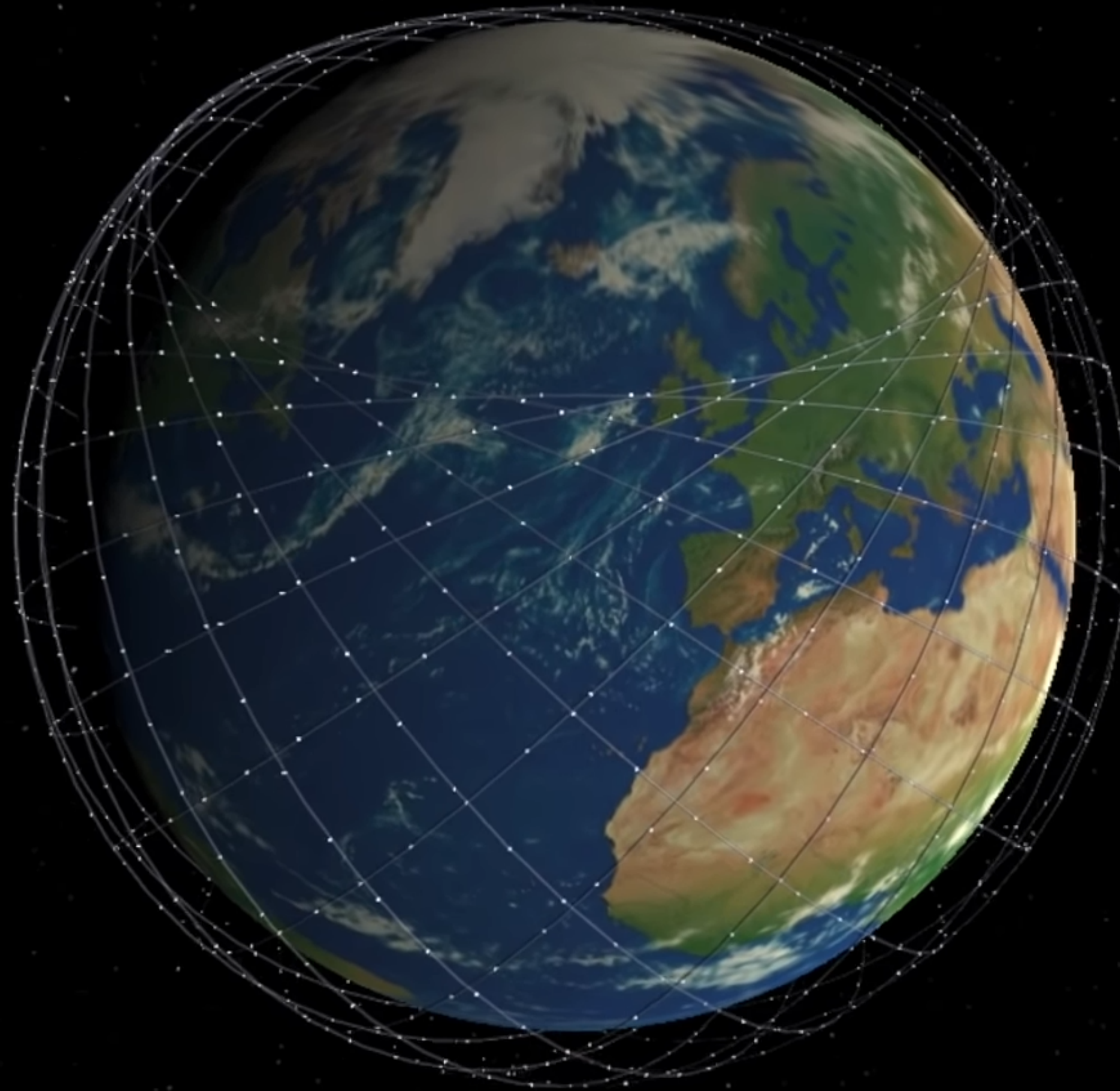
# Lecture 17: Satellite Networks

CS 234 / NetSys 210: Advanced Computer Networks

Sangeetha Abdu Jyothi

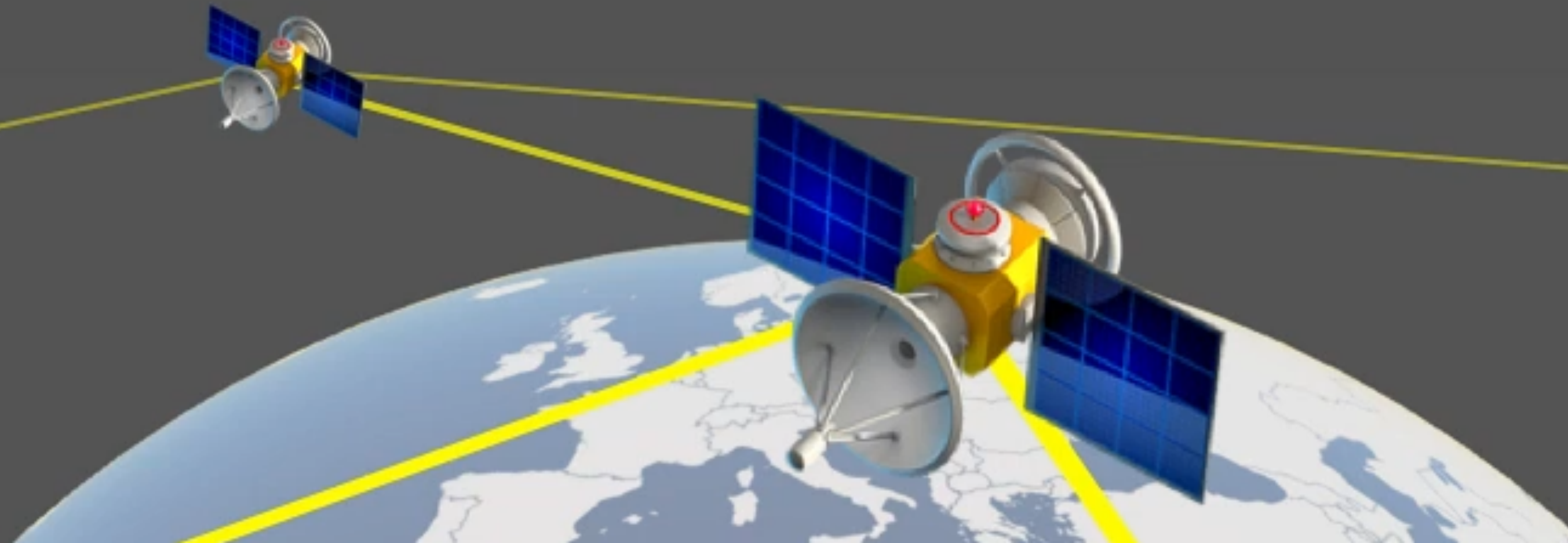
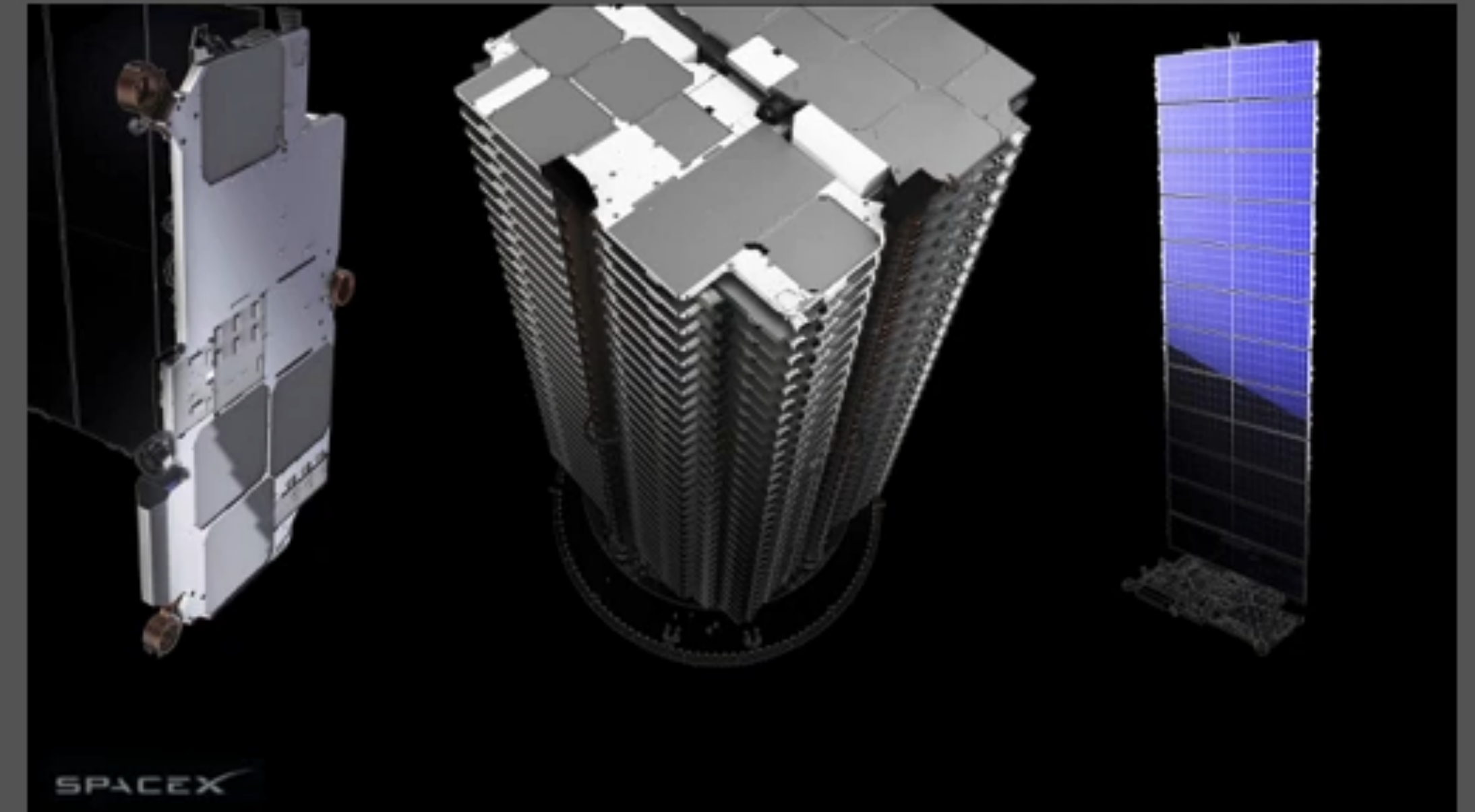
# Starlink Network

24 orbital planes  
53 degrees inclination  
66 satellites per plane  
550km altitude





# Recent Advances





# Amazon Kuiper

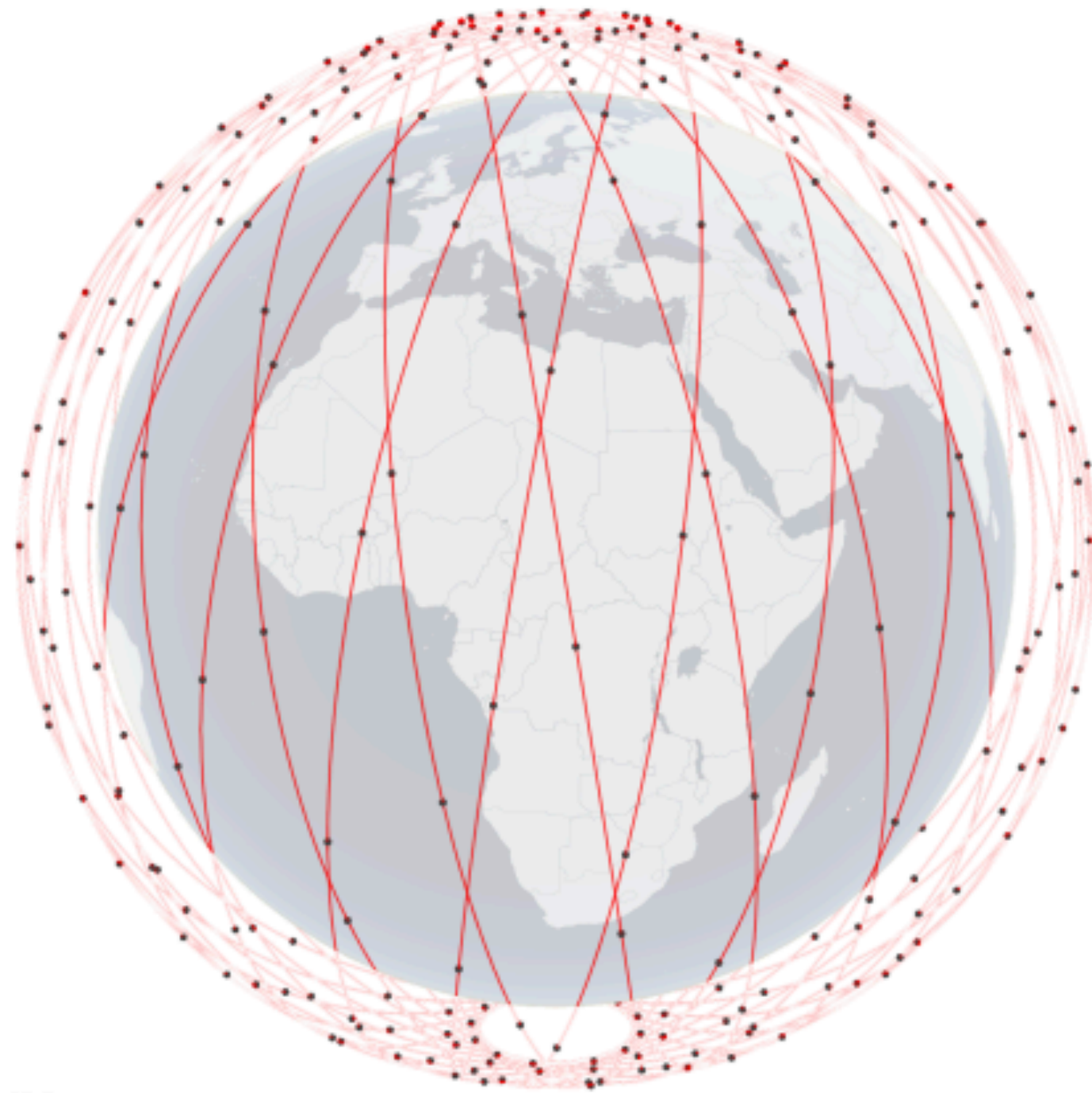
## Amazon Kuiper

3,200 planned  
in 3 phases

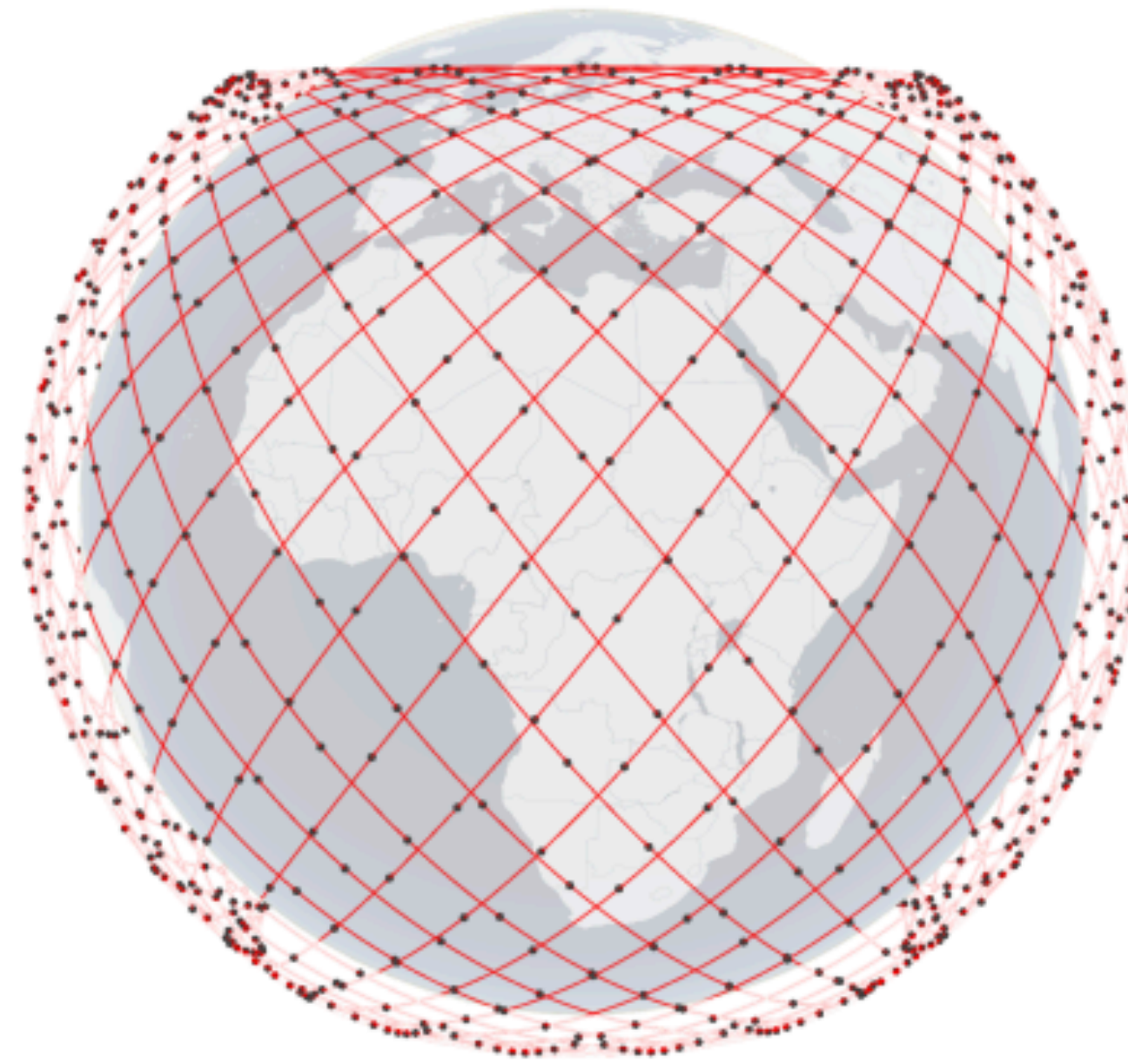




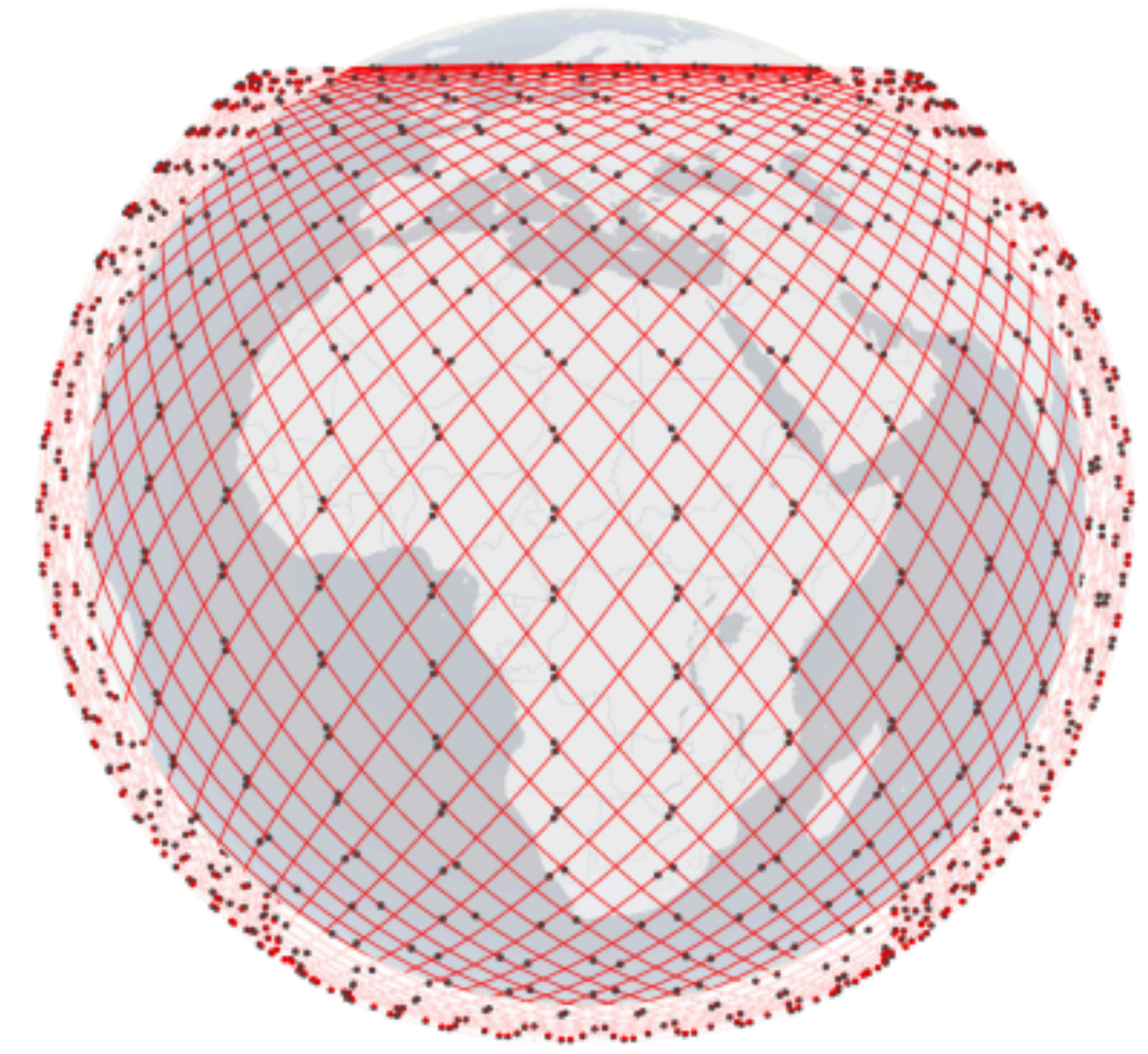
# Satellite Networks



(a) Telesat T1



(b) Kuiper K1

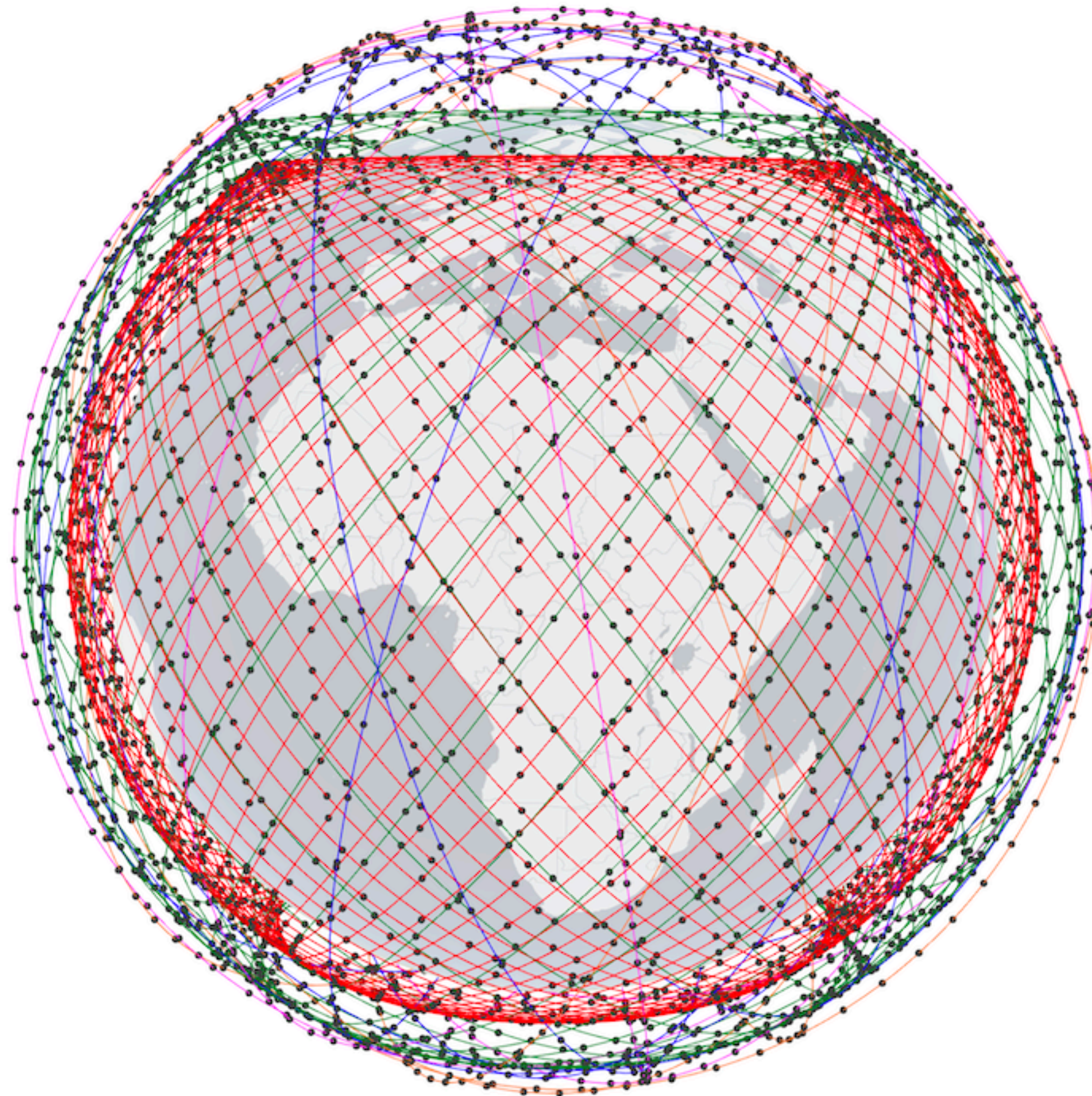


(c) Starlink S1

Other networks: OneWeb, LinkSure, Astrome, Hongyan, ...

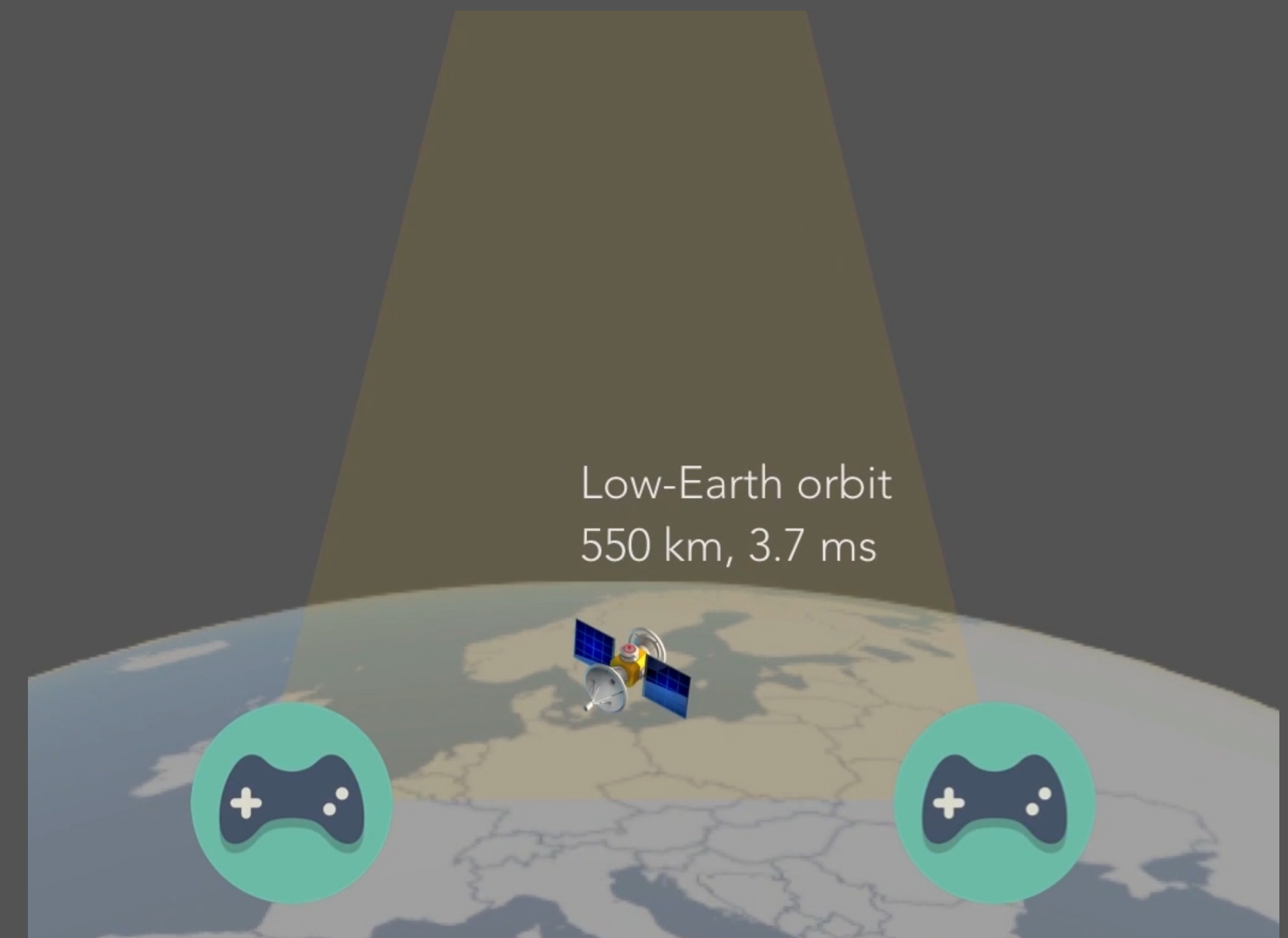


# Multiple Shells (Starlink)





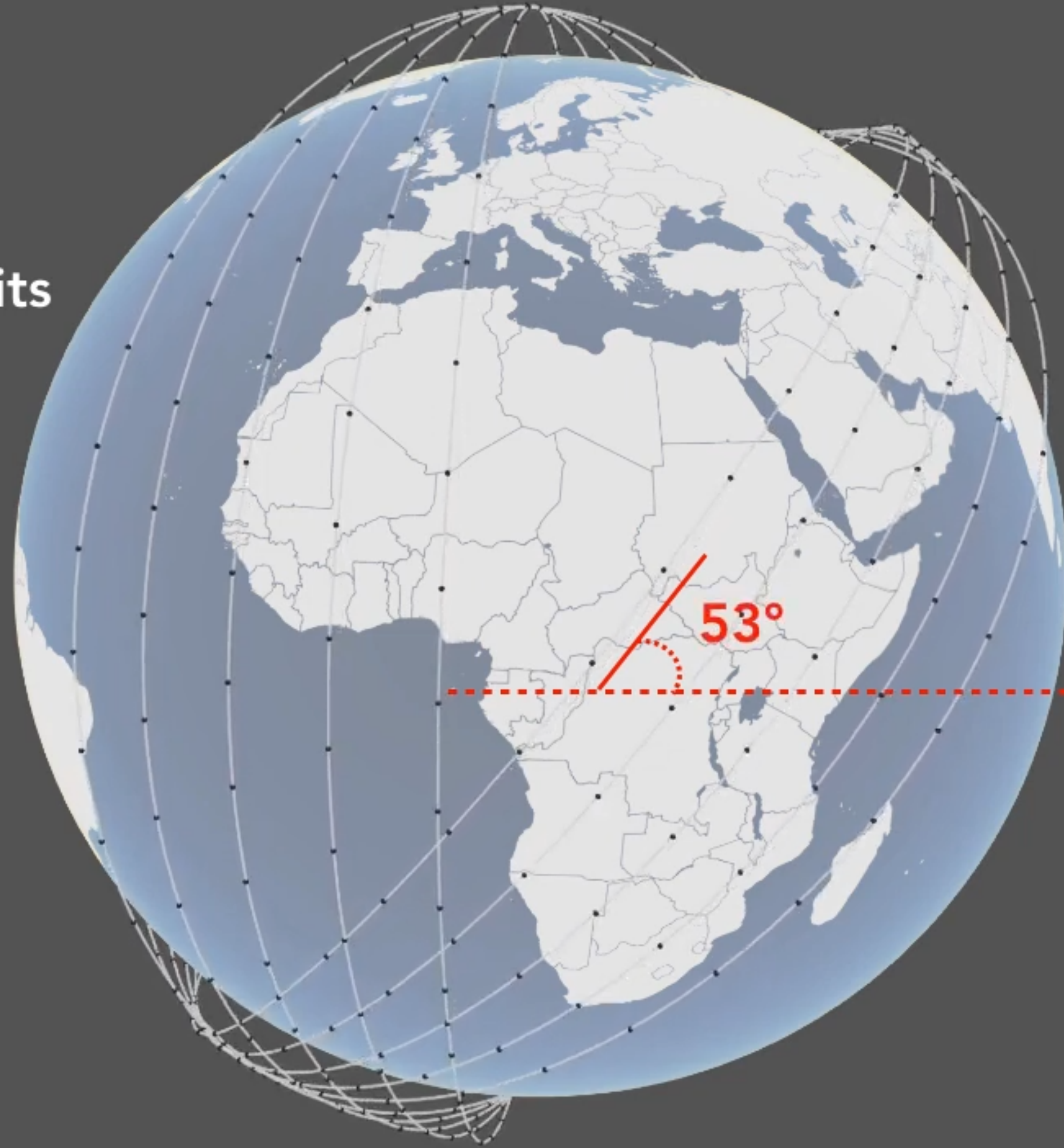
# Altitude



# Inclination

Polar orbits

Inclined orbits



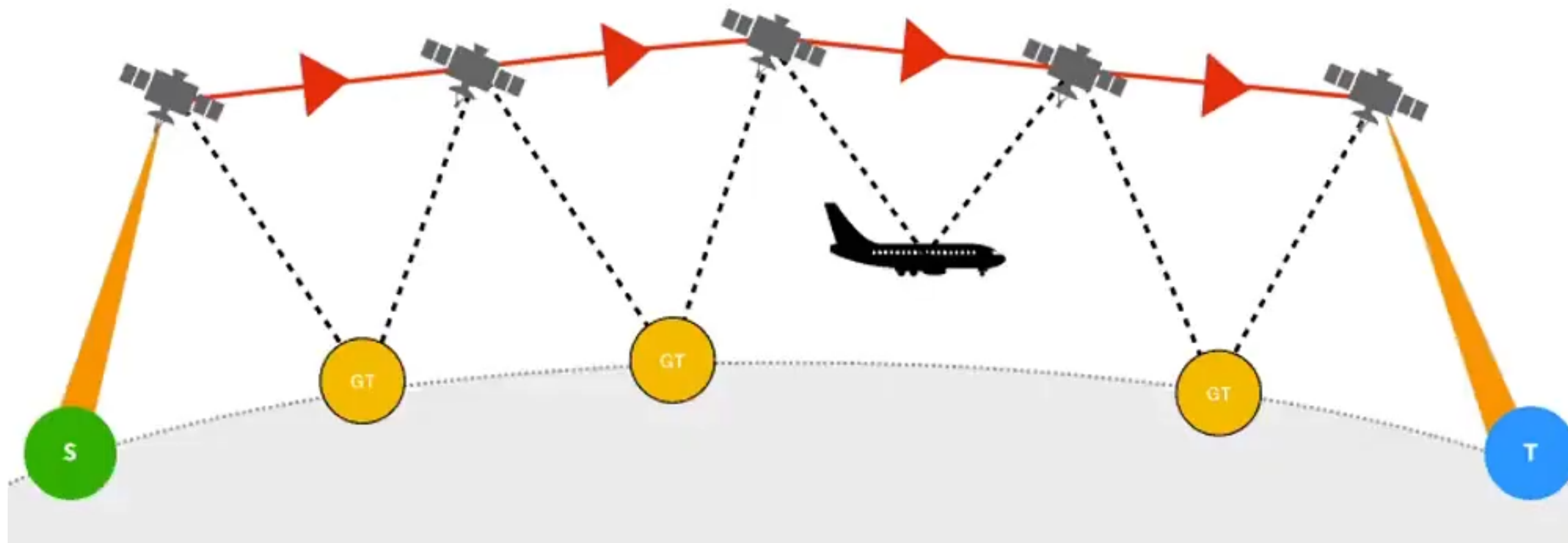


# Connectivity

+Grid

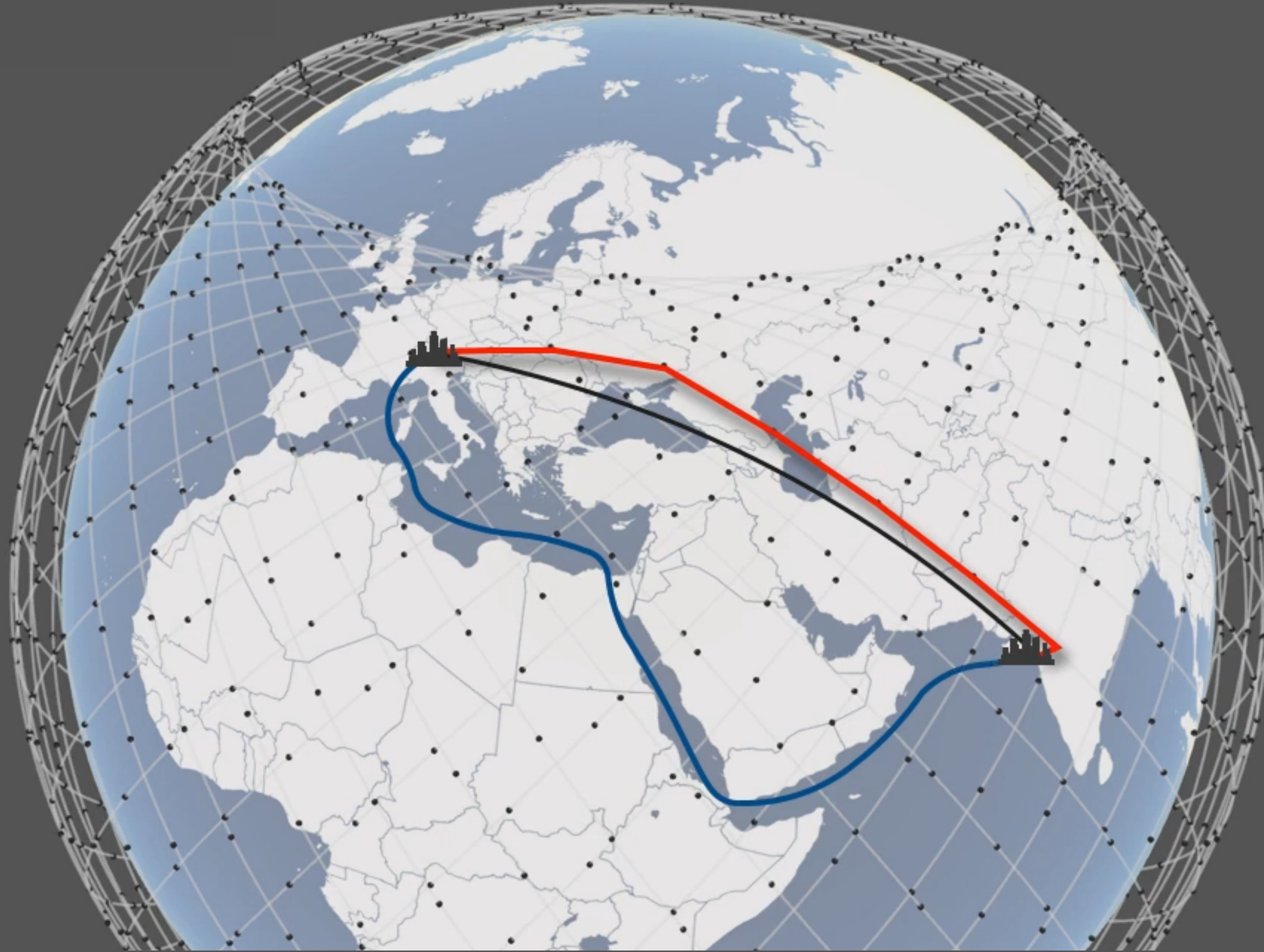


# ISL vs. Bent Pipe

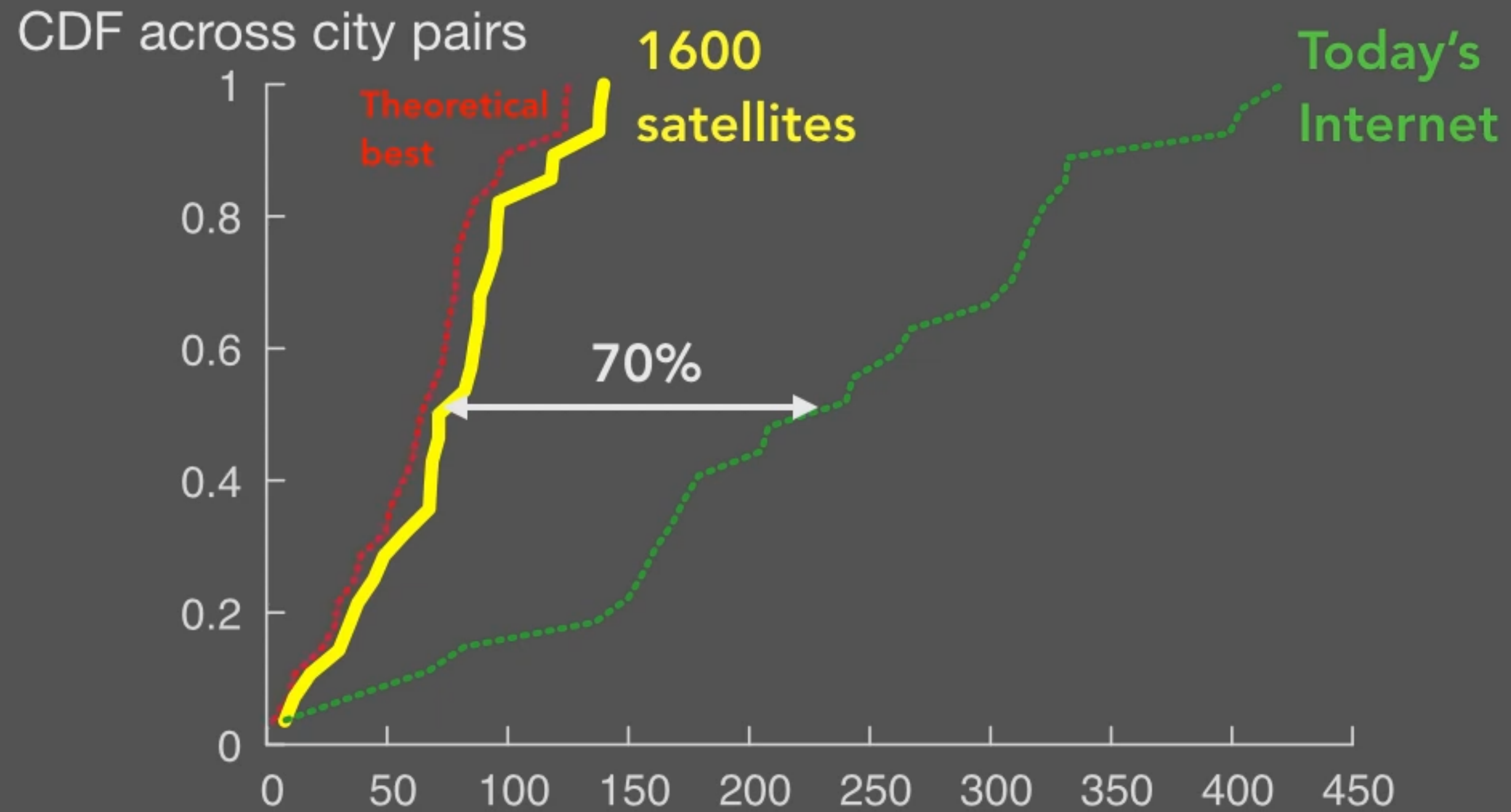




# Latency



# Latency Performance





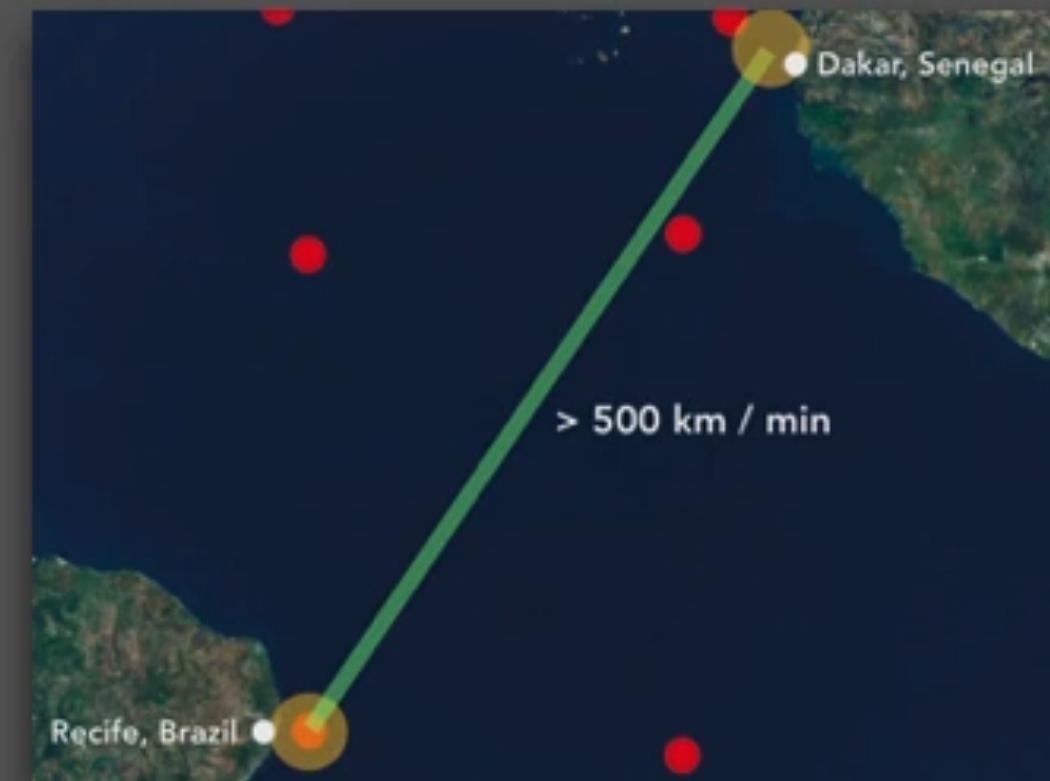
# System Dynamics





# Challenge

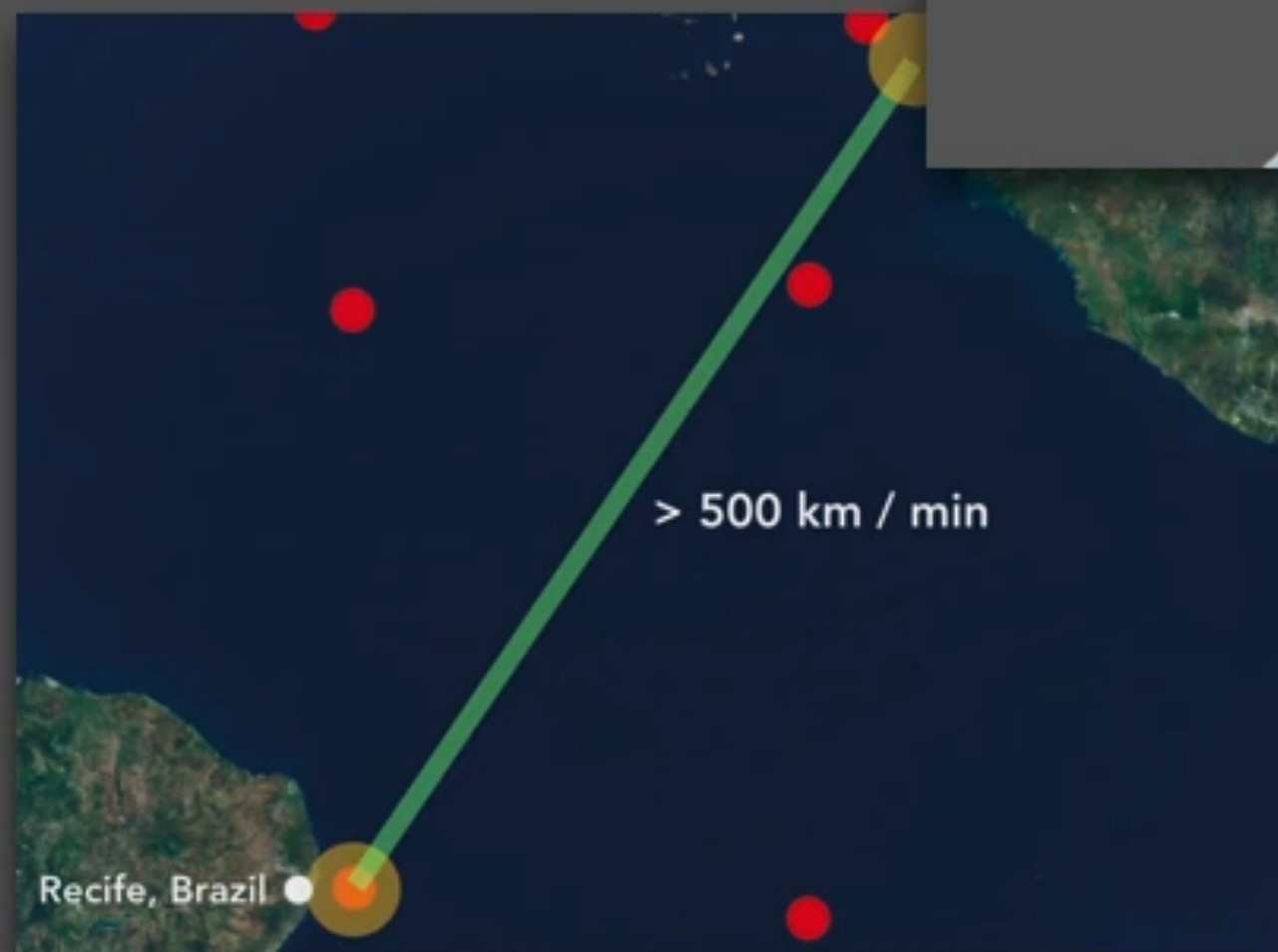
## How do we connect satellites?



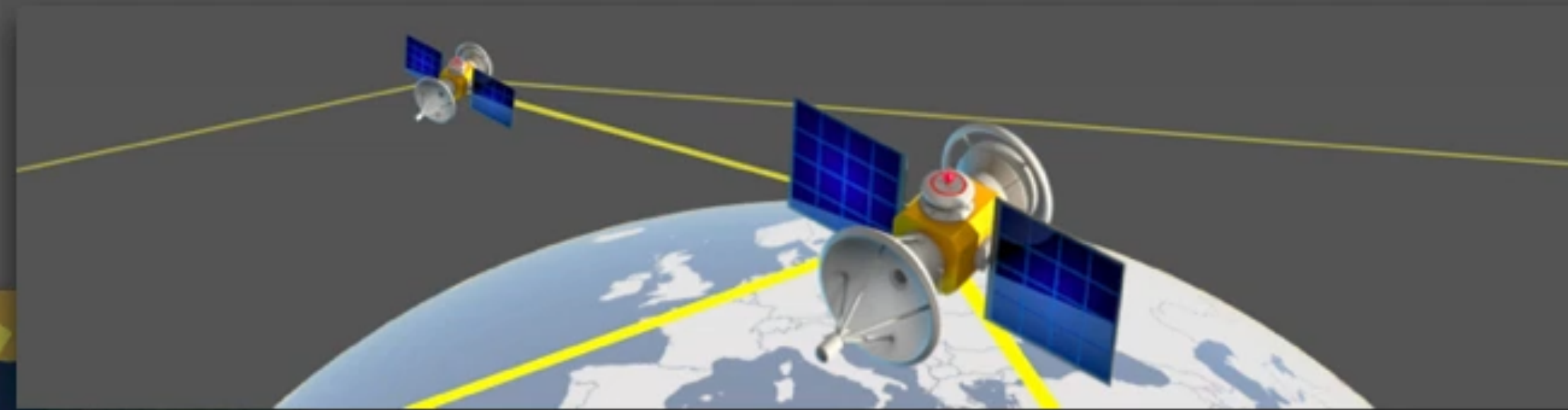


# Key Constraints

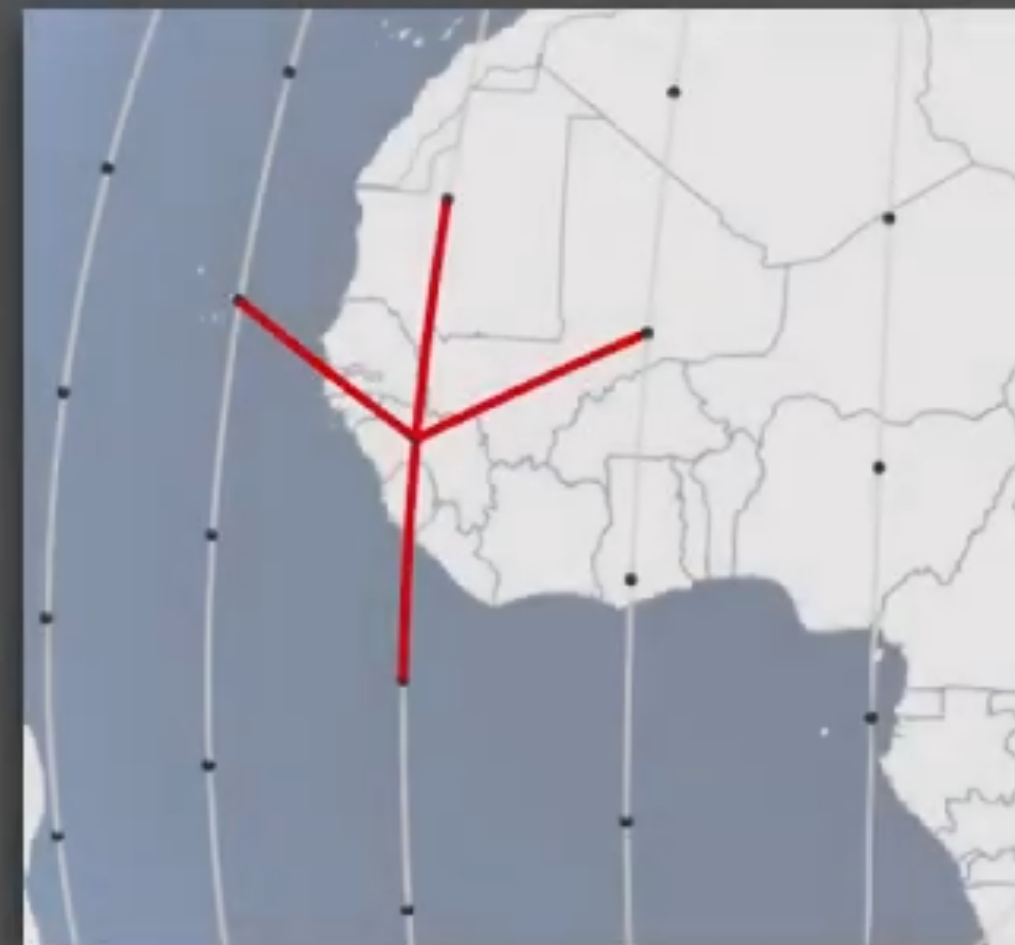
System dynamics



Link setup times



Max. no of links  
per satellite

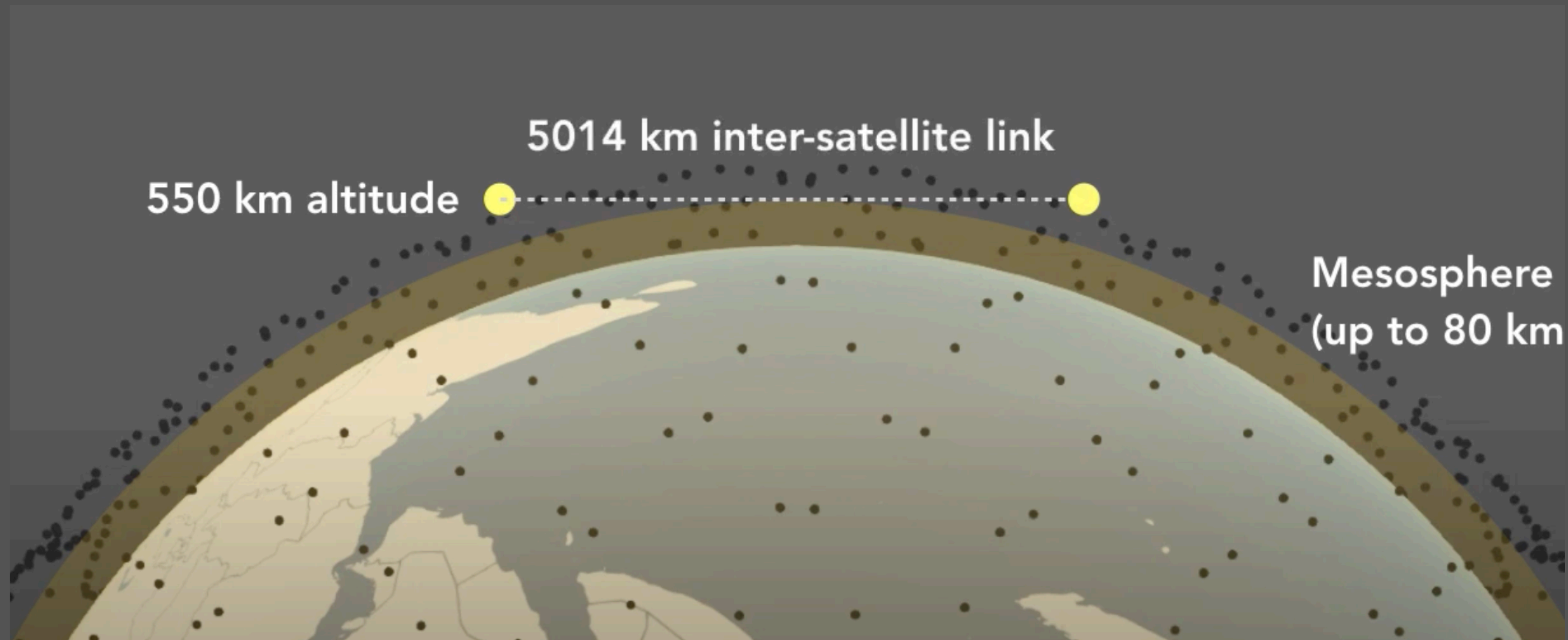


# Assumptions

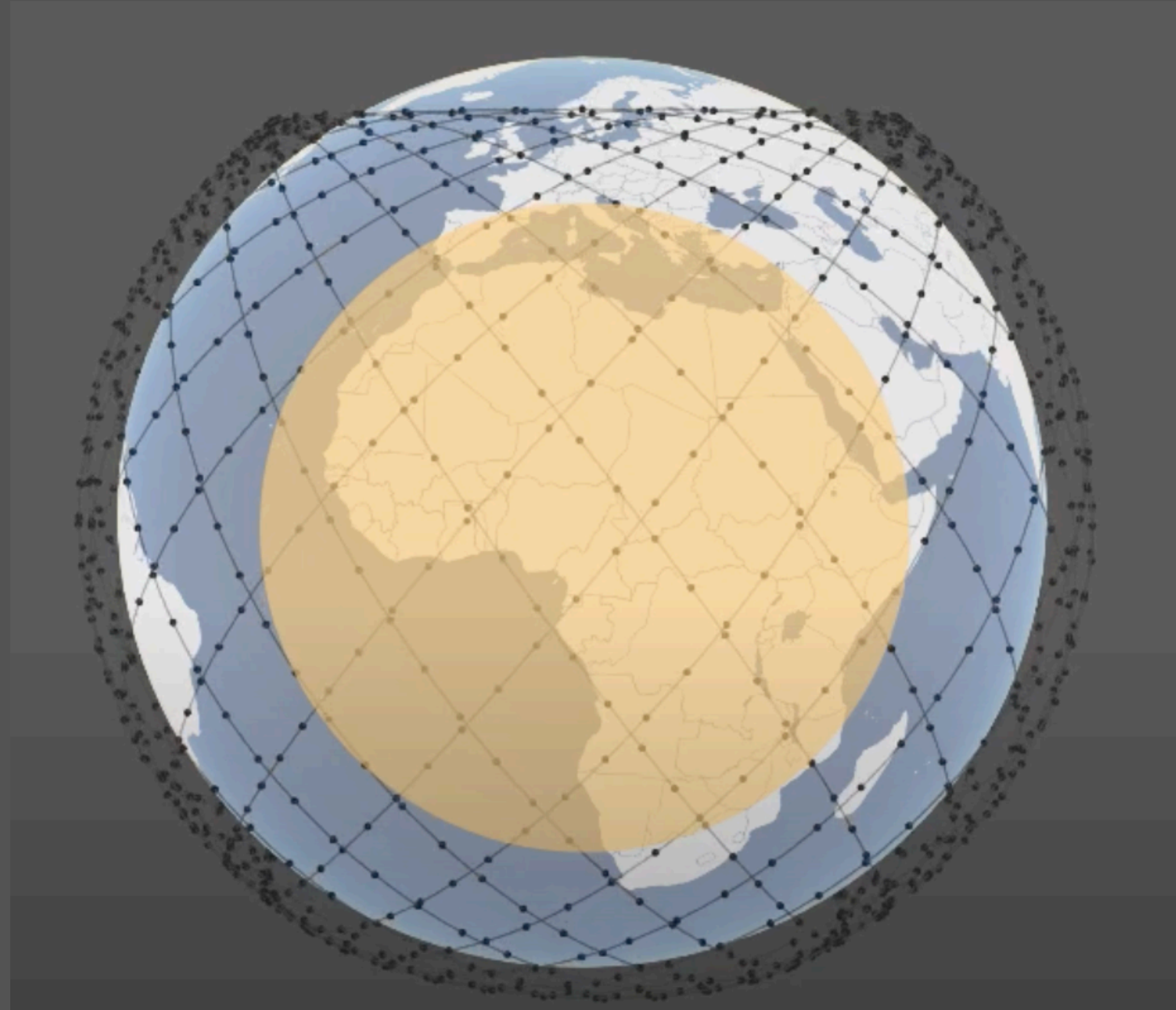
- Satellite Trajectories are given
- Traffic matrices drawn from intuition
- Ground-satellite connectivity is range bounded
- +Grid is the baseline



# Can use much longer links



Much larger design space





# Traffic Matrix



# Metrics



$$\text{Stretch} = \frac{L_{Sat}}{L_{Geodesic}}$$

Hop count 

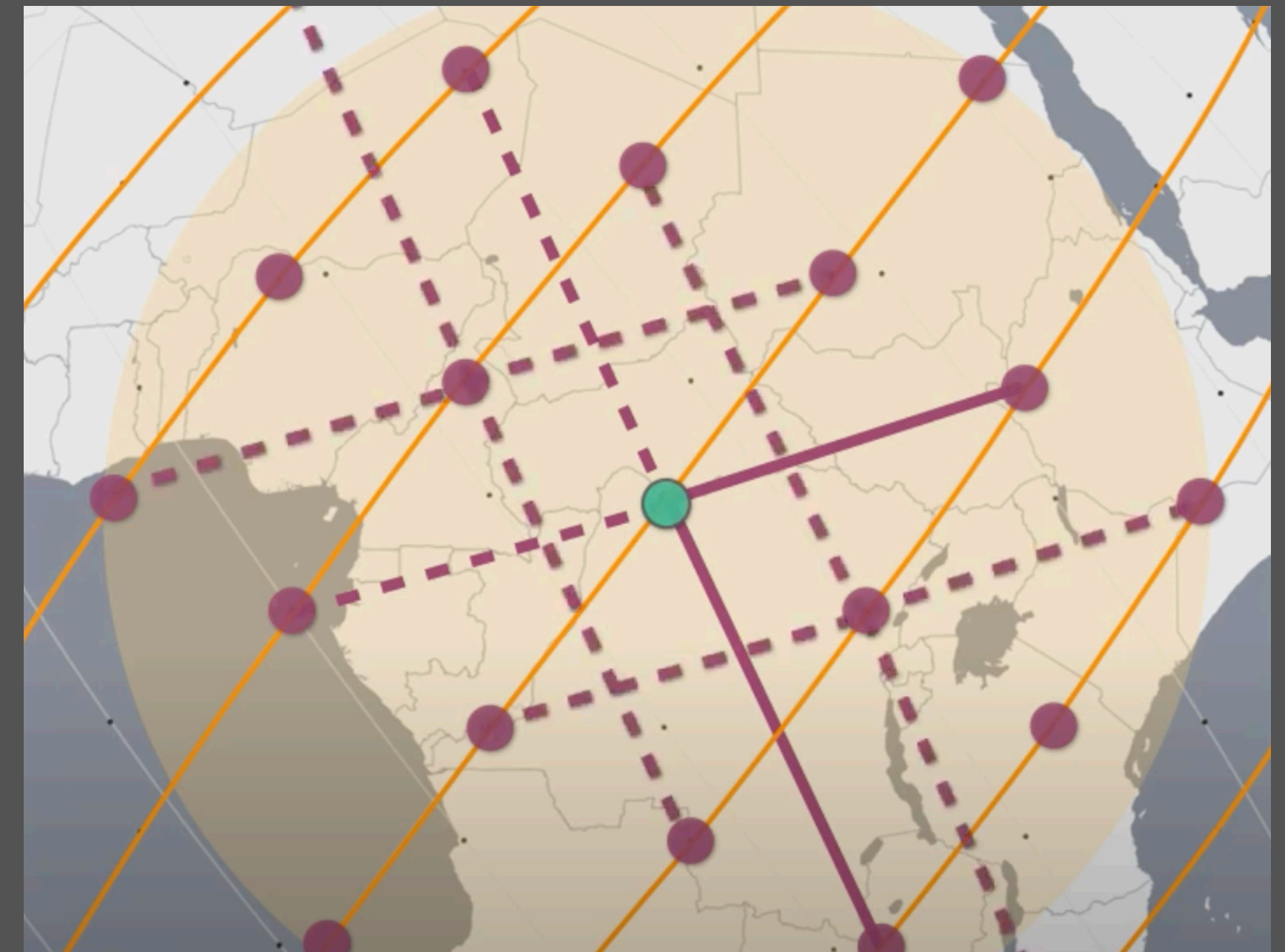
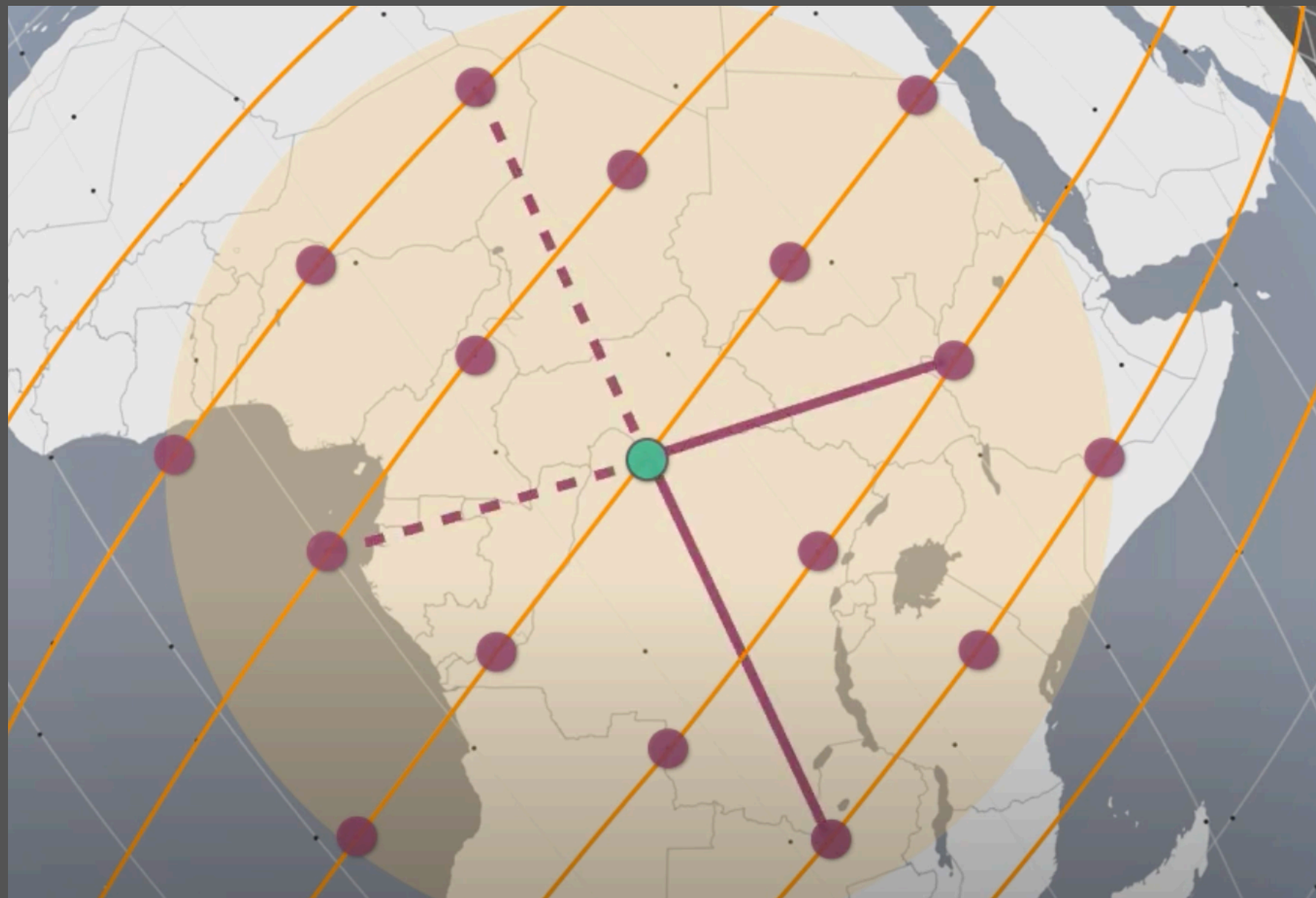


# Why not use ILP?

For 1000 cities, would take  $\sim 10^{29}$  days

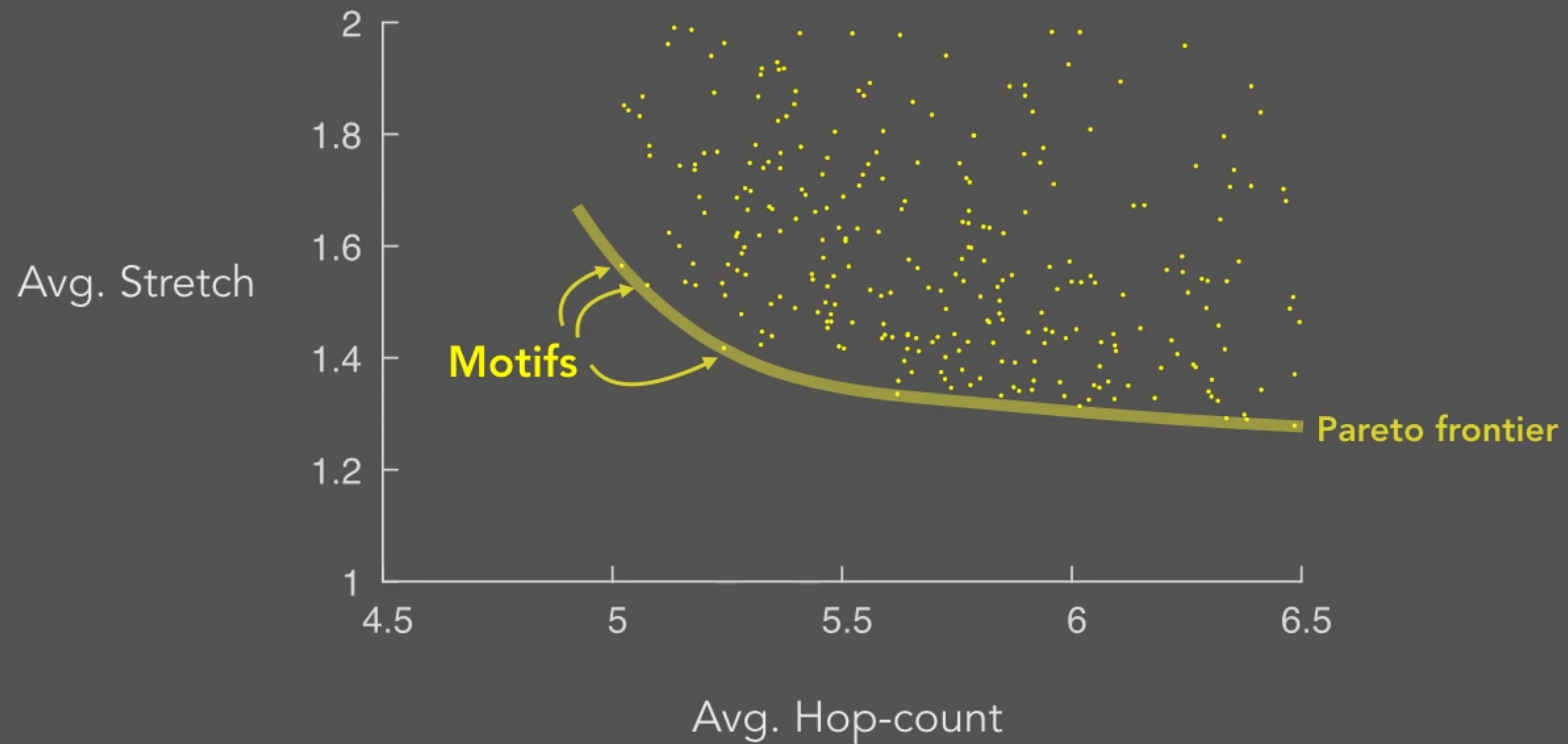
One minute apart  $\sim 91\%$  links are different

# Motifs



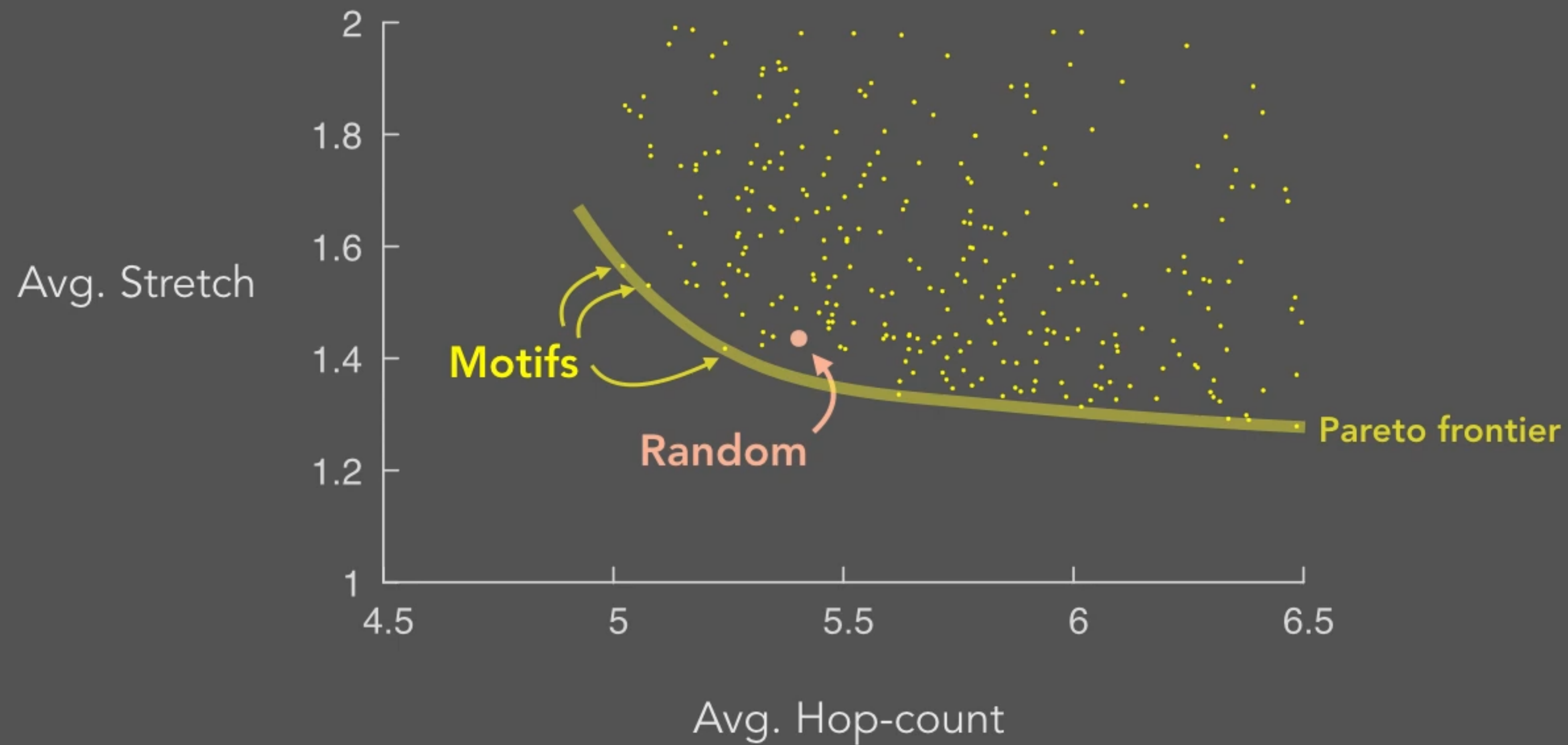


## A large number of design points



# Performance - Random

A large number of design points



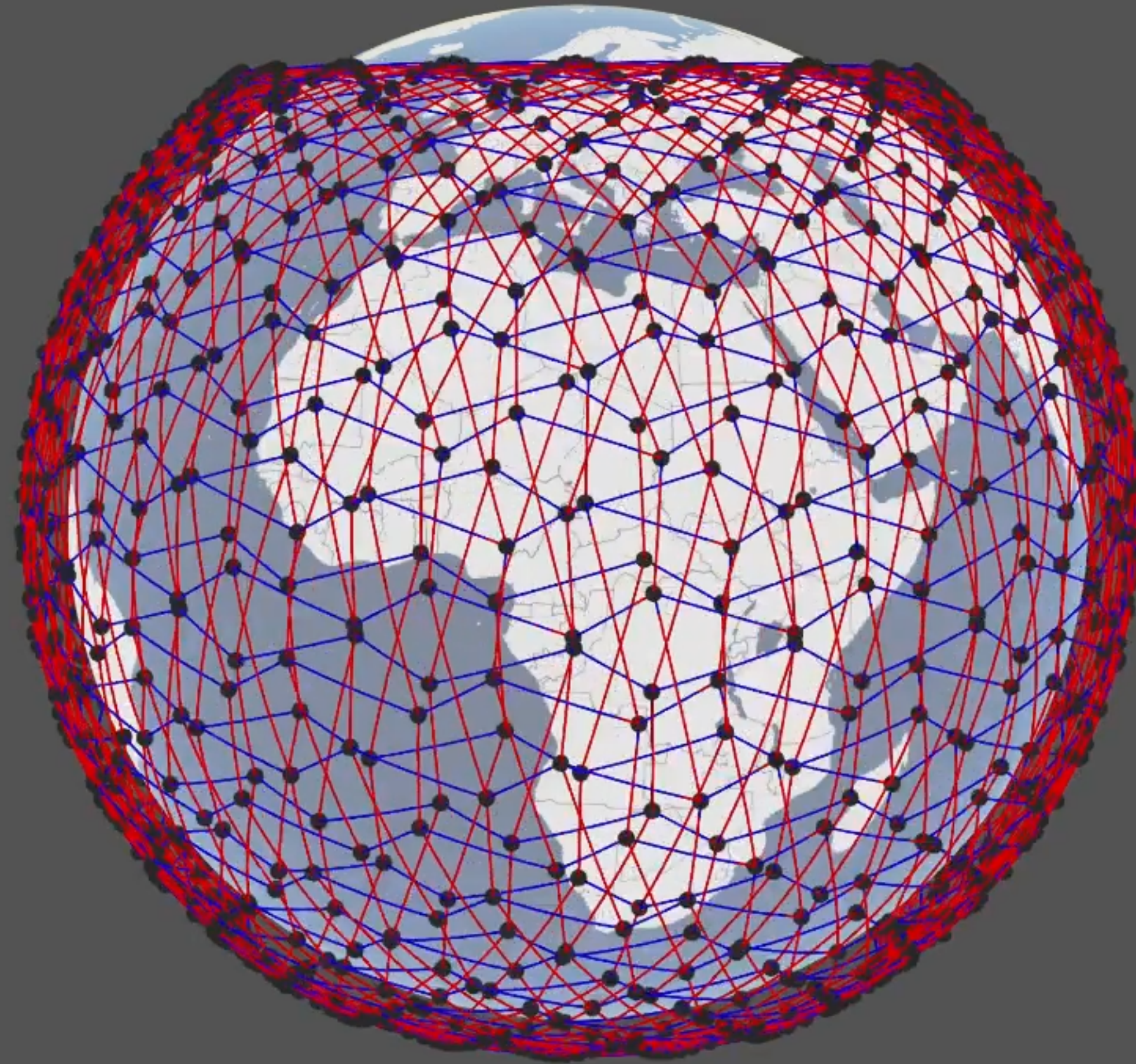


# Performance - Grid



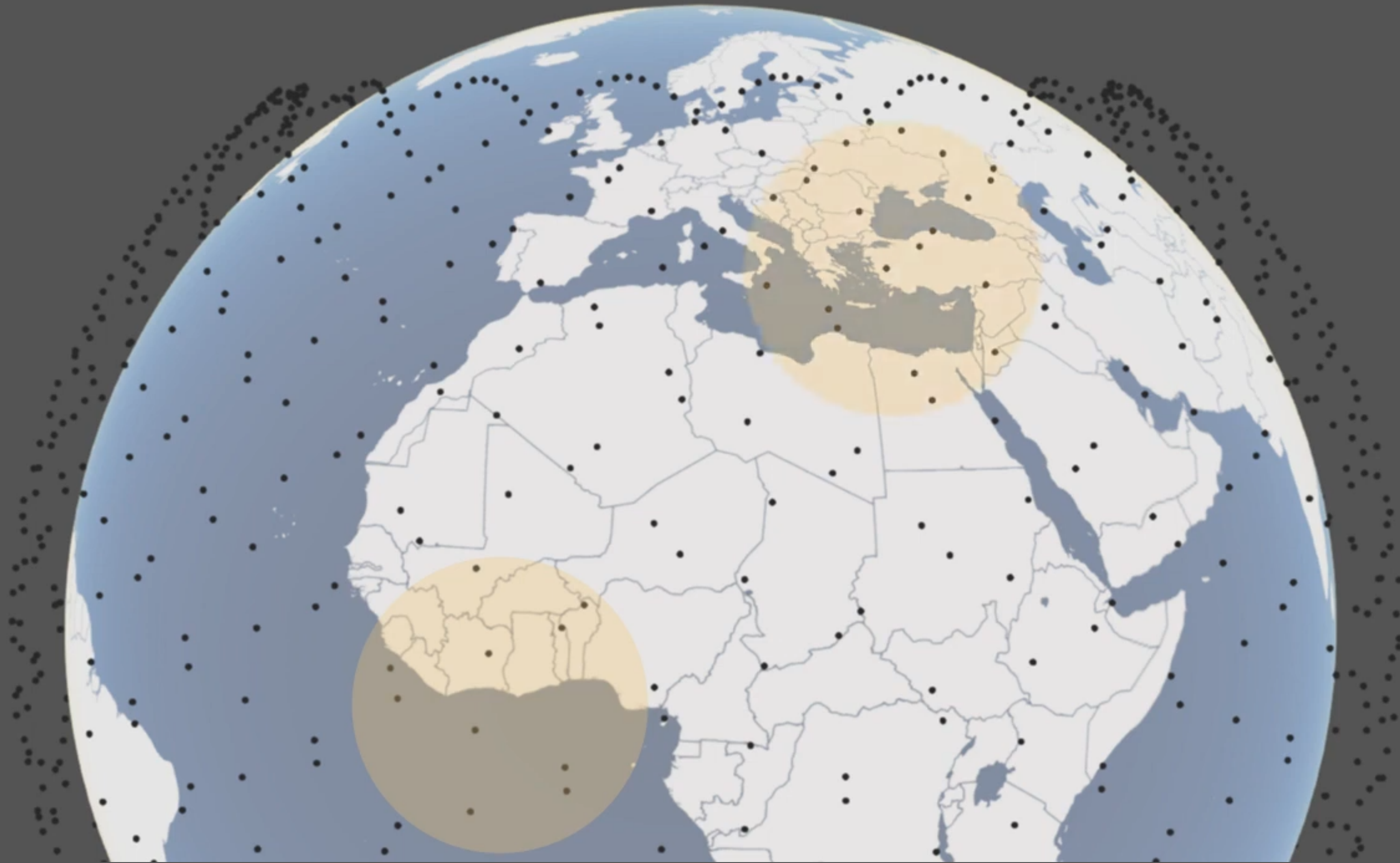


# High-Performing Motif



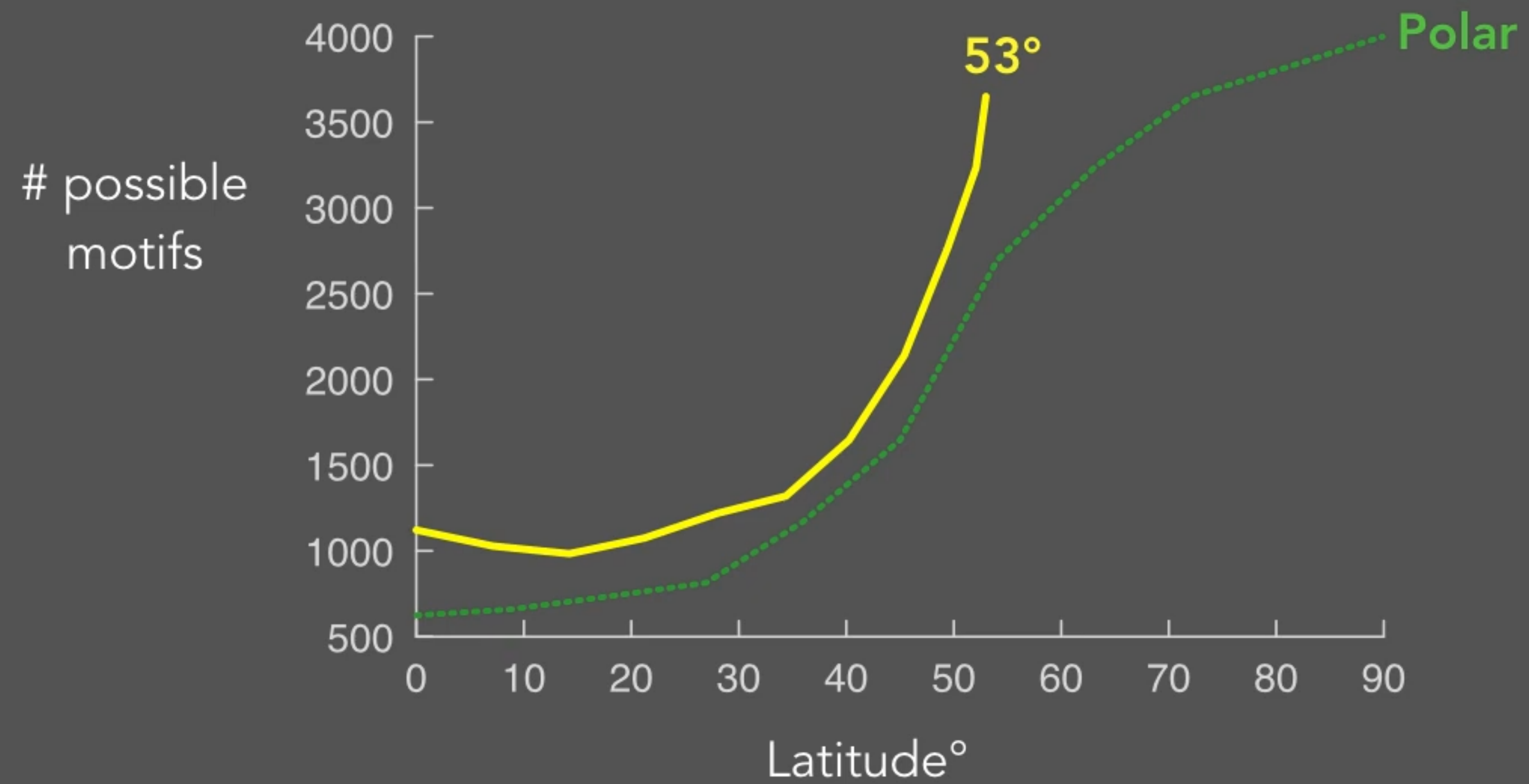


# Constellation Density



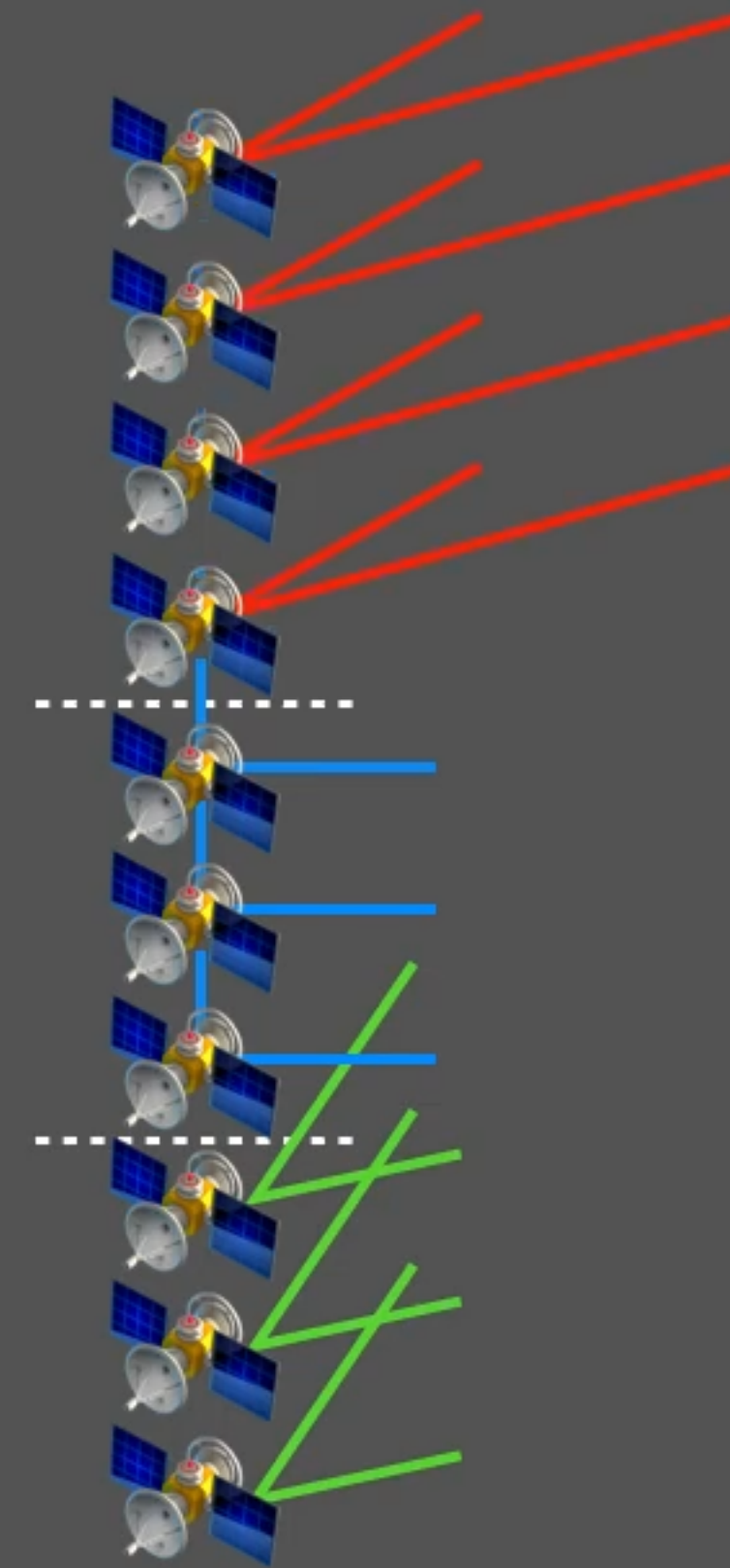
# Possible Motifs

## More options at higher latitudes



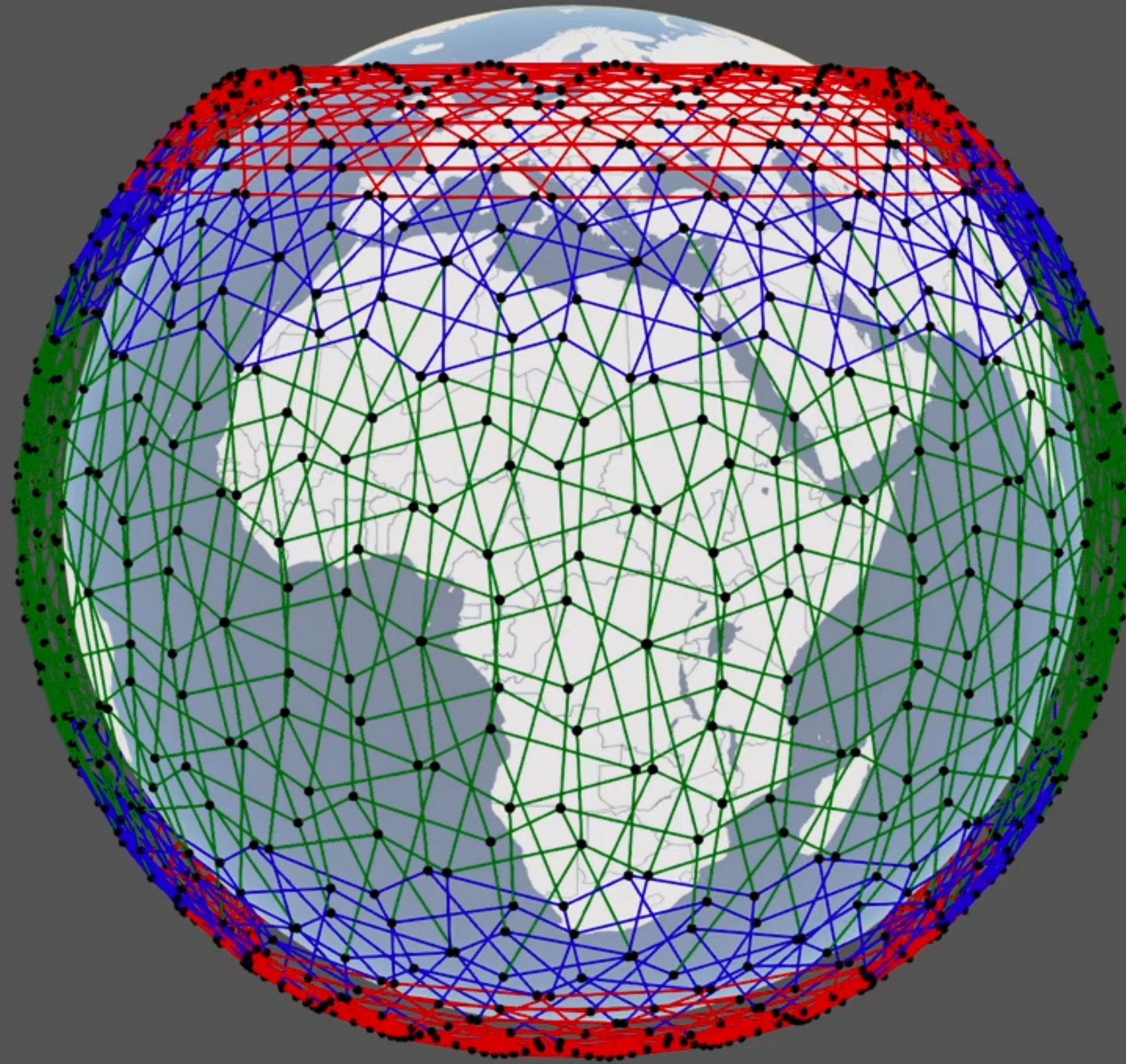


# Multi-motif



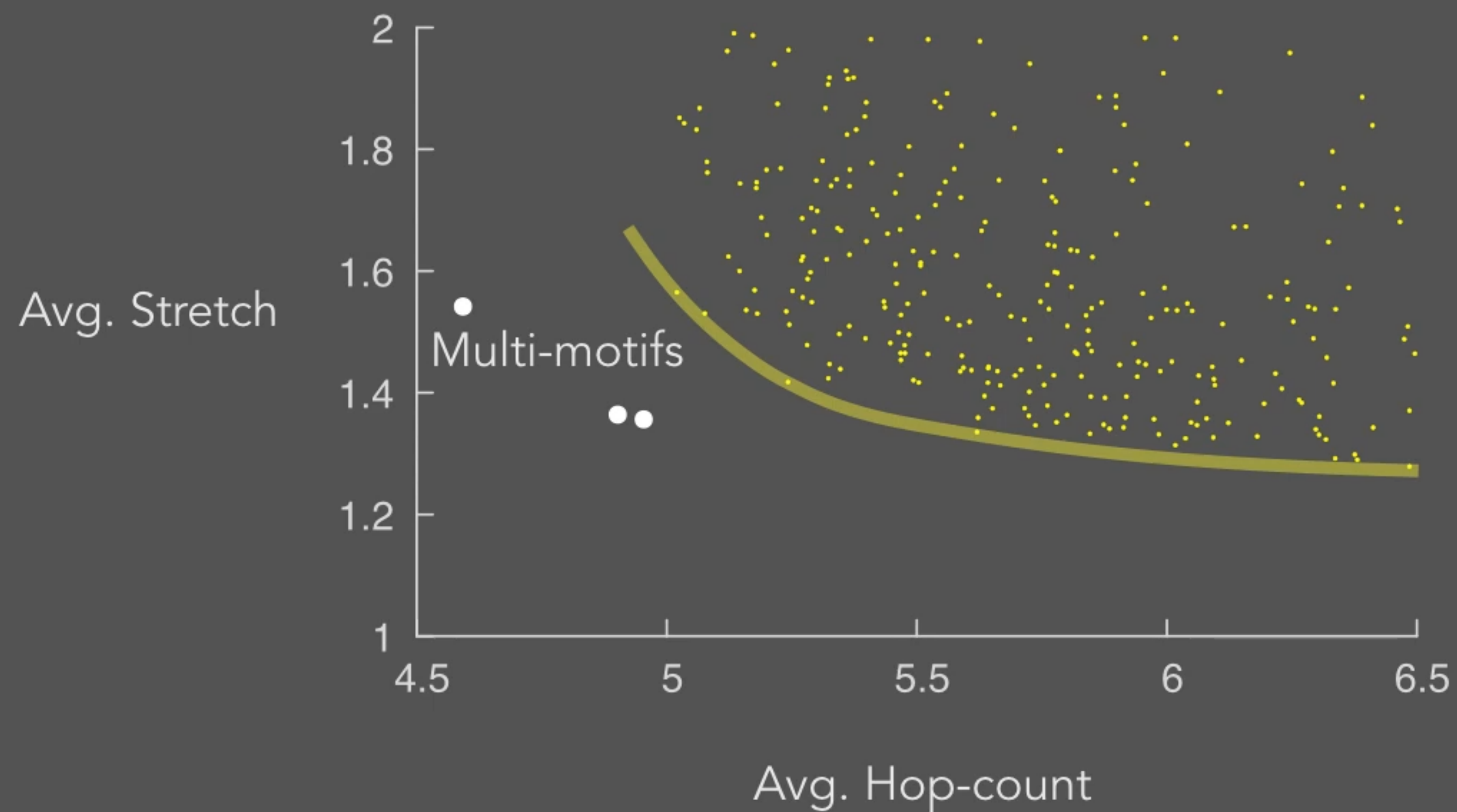


# 3-zone scheme





# Multi-motif Performance



# Open Challenges

- Topology design with multiple “shells”
- Inter-Satellite Routing
- Congestion Control
- Ground Station Deployments
- Satellite - Ground Station routing



Thanks!