LANCASTER UNIVERSITY

NTN Challenges Side Meeting @ IETF 117

An IETF Update on NTN and Satellite LEO Constellations Challenges

Daniel King
d.king@lancaster.ac.uk
July 26, 2023

Current Status of Largest LEO Constellations

Specifications / Company	SPACEX	OneWeb	TELESAT	amazon
System	Starlink	OneWeb	LightSpeed	Kuiper
Country of Origin	United States	United Kingdom	Canada	United States
Investment	$10 billion	$2.4 billion, Since Chap. 11	$5 billion	$10 billion
No. of SATs - Initial Phase (IP)	1,584 + 2,814 (total 4,408)	648	298	578 up to 1,600
System Throughput for IP	~10 Tbps	~1.5 Tbps	~7.5 Tbps	~9 Tbps
Data-Rate per Satellite (Avg.)	6 Gbps	2-4 Gbps	15-25 Gbps	~15 Gbps
Satellite Launched (IP)	1,665	218	1 (LEO 1 Testing)	0
Planned Constellations Size	12,000 + 30,000	7,000	1,671	3,236
Beginning of Service	2020	2021	2023	2026
Connectivity Coverage	N. America, N. Europe, Pacific	Northern Latitudes, above 50°	N/A	N/A
Throughput - Full Deployment	27 Tbps	25 Tbps	16-24 Tbps	53 Tbps
User Links (Band)	Ku	Ku	Ka	Ka
Gateway Links (Band)	Ka	Ka	Ka	Ka
Cross-links – Optical ISL	Yes, Future Launches	Not specified	Yes	Not specified
Operational Orbit	540 - 570 km	1,200 km	1,015 and 1,325 km	590, 610, and 630 km
Satellite Mass	260 kg	150 kg	750 kg	N/A
Satellite Lifespan	6 years	5 years	10 years	7 years
Satellite Manufacturer	SpaceX	Airbus (Arrow platform)	Thales Alenia Space	N/A
Target Markets	Consumer broadband	Enterprise, mobility, govt.	Mobility, backhaul, govt.	Consumer, businesses, govt.

SOURCE: ORBOFLEET WWW.ORBOFLEET.COM INFO@ORBOFLEET.COM

Satellite Deployments

Emerging Internet/IoT Constellations

UNIO ENTERPRISE

Constellation	# Sat's	Height (km)
Leosat	108	1400
Telesat	72	1000
Kepler	140	1200
Astrocast	150	600
Samsung	4600	1400
Hongyan	270	1100

SatCom Challenges
From Research to Deployment

- Architecting Network
  - Ground-Station and Space-Segment Connectivity
- Establishing the Connectivity
- Link Scheduling and Power Management
- Building and Maintaining the Network Graph
- User/Application Traffic Management
  - Path Steering and Traffic Engineering
- Role of Specifications and Standards

Establishing the connectivity

Physical link topology

- How will the optical links be established between the multitude of stationary and mobile nodes in the network?
- How will the subsequent network topology be disseminated throughout the network nodes?
- Laser links need planning and explicit pointing

Communication Link Challenges

Link Scheduling

- What is the link execution timeline?
- What is the balance between a planned link schedule versus a completely real-time link acquisition strategy?
- What is the minimum duration of a link in order to be considered viable?
- What are the decision criteria for a link that is broken versus interrupted versus degraded before switching to an alternative node?
- How are stationary links (e.g., to the ground) prioritized against links between mobile platforms (e.g., aircraft, satellites, HAPS)?
- How will links be powered down and scheduled for nodes to recharge batteries, or wait offline until additional capacity is needed?

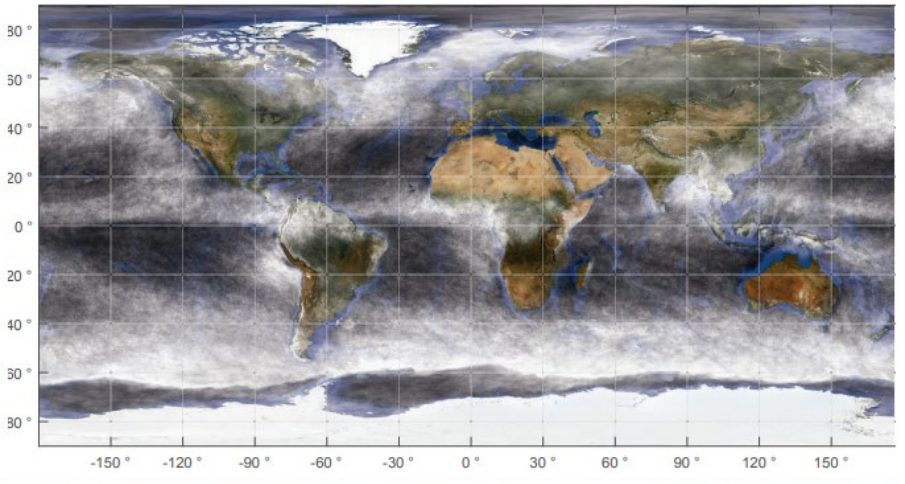
Space Communication Networks
Building the Network Graph

- Given
  - constellation's satellite trajectories and significant speed
  - small to medium number of inter-satellite connection units at each satellite
  - a target traffic matrix between terrestrial endpoints
- A goal might be to decide which satellite-satellite connections to build, we must:
  - minimize latency and hop-count in end-end paths
  - Consider fixed and static variants (satellite motion and Earth's rotation)
  - Utilise links efficiently and attach to gateways based on optimal delivery of traffic

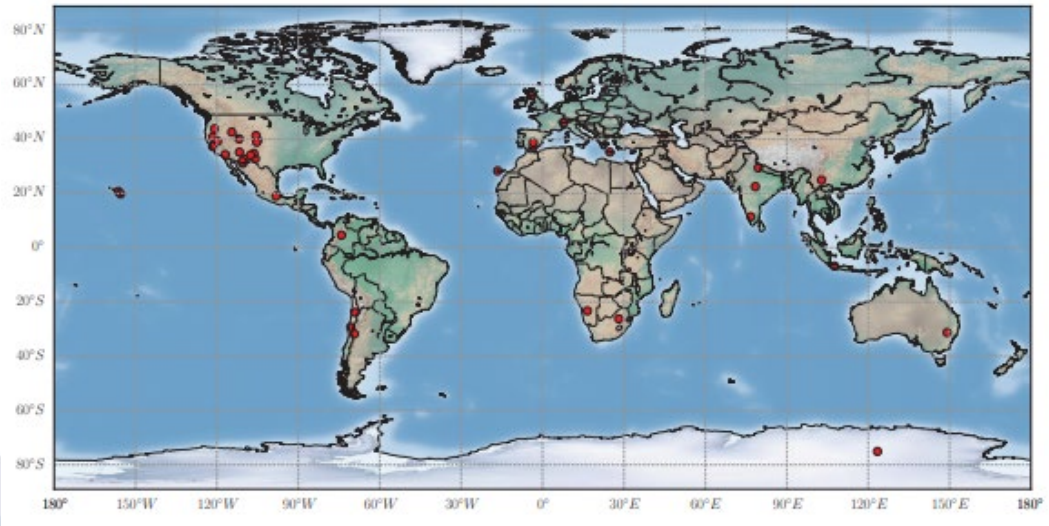
Space Communication Networks

Architecting the space-to-ground segment

- Significant challenges for direct Free-Space Optical (FSO) include:
  - downlinks from satellites are affected by cloud cover, aerosols, air turbulence and external object occlusion, which all determines the availability and speed of the downlinks.



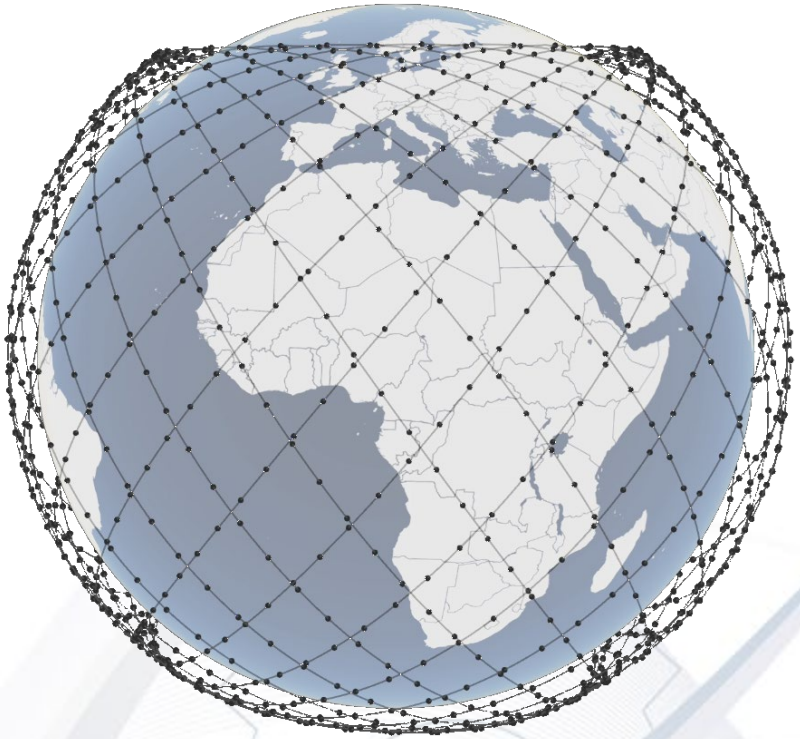
Some FSO ground stations will be mobile



Space Communication Networks

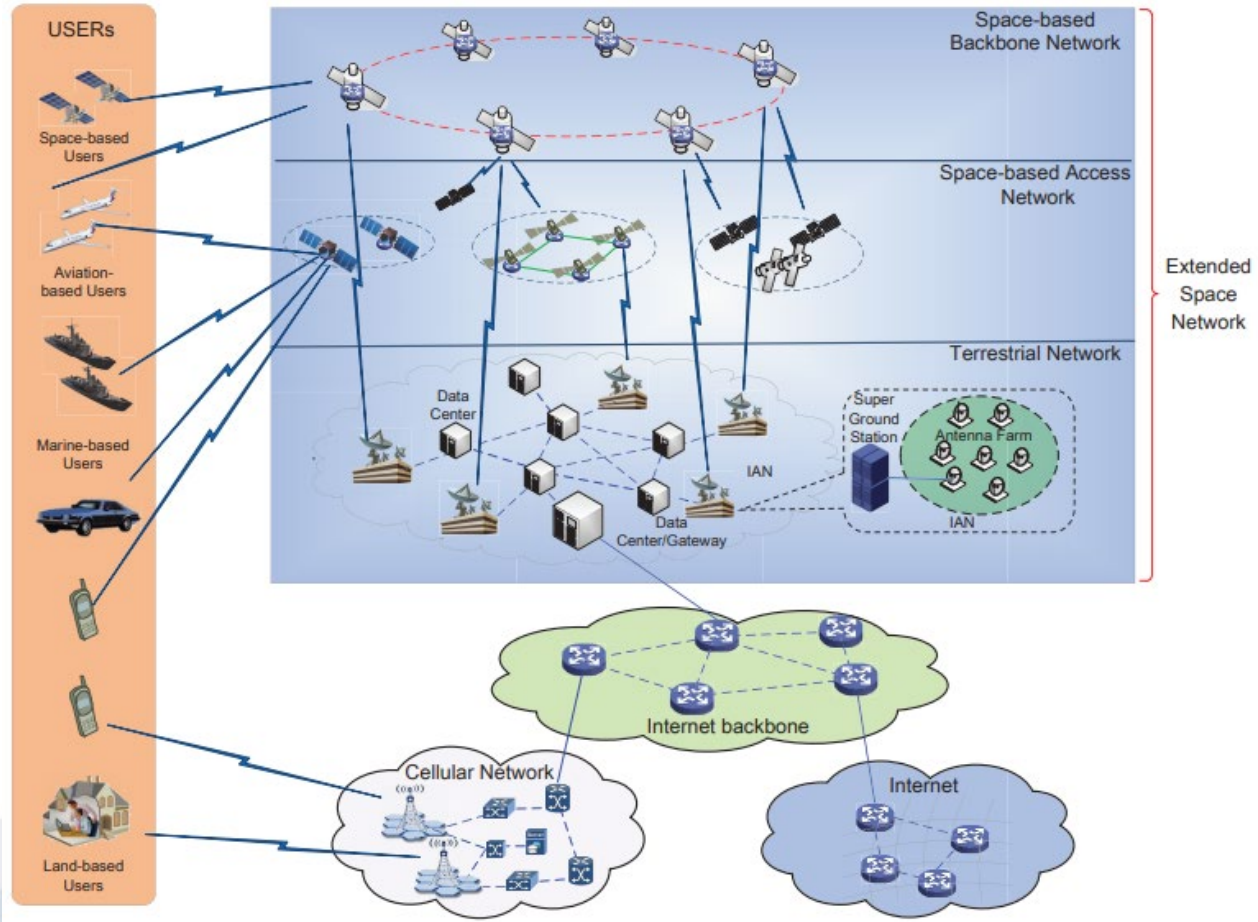
Architecting the space-to-space segment

- Acquisition and tracking of satellites as they move, and calculating relative velocity.
- Inter-satellite or inter-orbital links must cover larger distances; therefore, the transmission scheme has to be power-efficient with good sensitivity at the receiver.
- Need to consider power versus transmission costs, and path viability.
- Emerging technology of Steered Laser Transceiver (SALT)s that would need remote control capabilities.



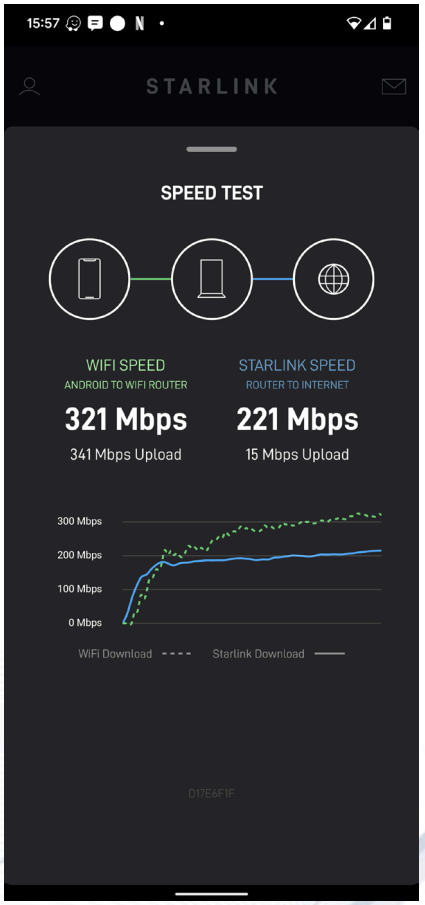
Space Communication Networks
User Types

- Mechanisms would also need to apply to different network users
  - Space-based
  - Aviation
  - Marine
  - Vehicles
  - Mobile



User Experience
My own Starlink Node

- Installed in March 2022
  - $650 for node
  - $130 monthly subscription



User Experience
My own Starlink Node

- The platform is not perfect, several observations,
- The problem is not availability,
- It's not bandwidth
  - But I wonder about although sustaining bandwidth as the customer base grows
- The main issues are latency and jitter, what could be causing these issues?
  - Due to Ground Station selection and switching?
  - Poor QoS and/or Buffering implantation on Space links?
  - Lack of ISL usage?

TUDOR Project
Use Case

- TUDOR
  - Towards Ubiquitous 3D Open Resilient Networks
    - Started in 2023
  - Partners
    - 5/6GIC (University of Surrey), AWS, AWTG, AMD, BAE, British Telecom, Ericsson, Imperial College London, IDE, King's College London, **Lancaster University**, Mavenir, Nokia, NPL, **OneWeb**, Qualcomm, Queen's University Belfast, Satellite Applications Catapult, University of Strathclyde, Toshiba, TWL, University College London, University of Glasgow, Viavi, and VirginMedia O2
  - A Satellite Use Case
    - Investigating rerouting IoT Sensor and User traffic onto satellite networks when train services are beyond 4G and 5G areas of connectivity.

Space Communication Networks
SDOs

- 3GPP
  - Non-Terrestrial Networks (NTN) & New Radio (NR) specs: Phase 3. Rel-19, TR 22.822, TR.38.811, et al.
- IETF
  - Time Variable Routing (TVR) WG defining use cases and requirements
  - Delay Tolerant Networking WG
  - Routing Area WG
  - BM WG
- IRTF
  - Global Access to the Internet for All (gaia)
  - Delay-Tolerant Networking Research Group DTNRG – **Concluded**
    - Published "Delay-Tolerant Networking Architecture" RFC 4838
  - Interplanetary Internet Research Group (IPNRG) - **Concluded**
  - Network Complexity Research Group NCRG - **Concluded**
  - Routing Research Group RRG - **Concluded**
- ITU-T
  - FG Network 2030 – **Concluded**
    - Focus Group on Technologies for Network 2030
      https://www.itu.int/en/ITU-T/focusgroups/net2030/Pages/default.aspx
- CCSA
  - Space Communications Technical Committee (TC12)

IETF Activity
Recent efforts

- Efforts ongoing (2023) at the IETF:
  - Time-Variant Routing Use Cases
  - Time-Variant Routing Requirements
  - Time Variant Challenges for Non-Terrestrial Networks
  - Problems and Requirements of Satellite Constellation for Internet
  - Routing and Addressing Challenges Introduced by New Satellite Constellations
  - LISP for Satellite Networks
  - Location/Identity Separation-based Mobility Management for LEO Satellite Networks
  - Addressing in Problems and Requirements of Addressing in Integrated Space-Terrestrial Network Space-Terrestrial Network
  - Satellite Network Routing Use Cases
  - Satellite Semantic Addressing for Satellite Constellation
  - Considerations for Benchmarking Network Performance in Satellite Internet Constellations

Side Meetings

- @ IETF 116: github.com/lh95129/IETF-116-satellite-network-side-meeting/tree/main/Materials