LEO satellite networking- An Infrastructure for Future Internet

For IETF114-HotRFC

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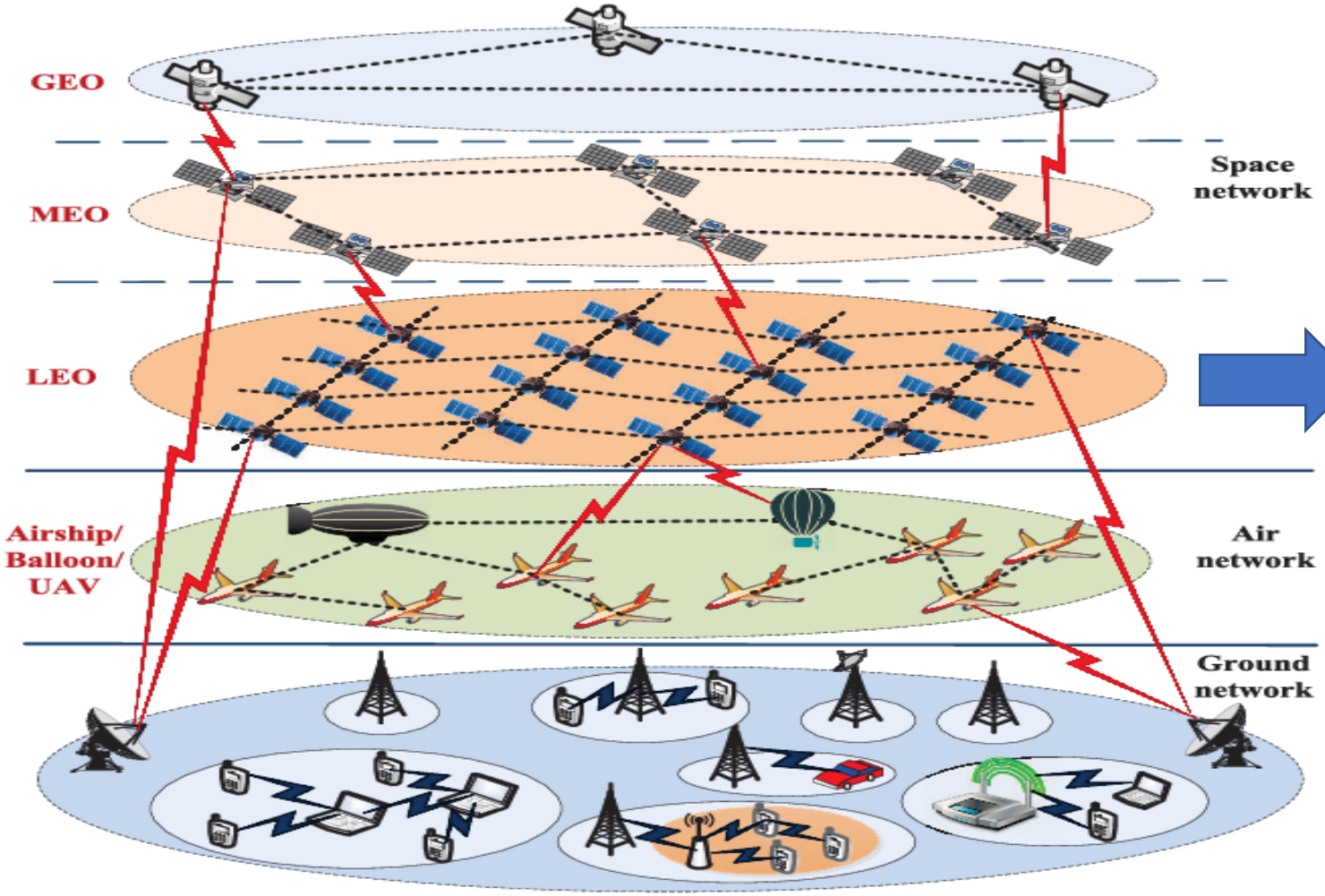
NTN Integration – Future Internet, Global Access with higher bandwidth and shorter latency



LEO satellite network (with ISL) is key infra due to its lowest altitude

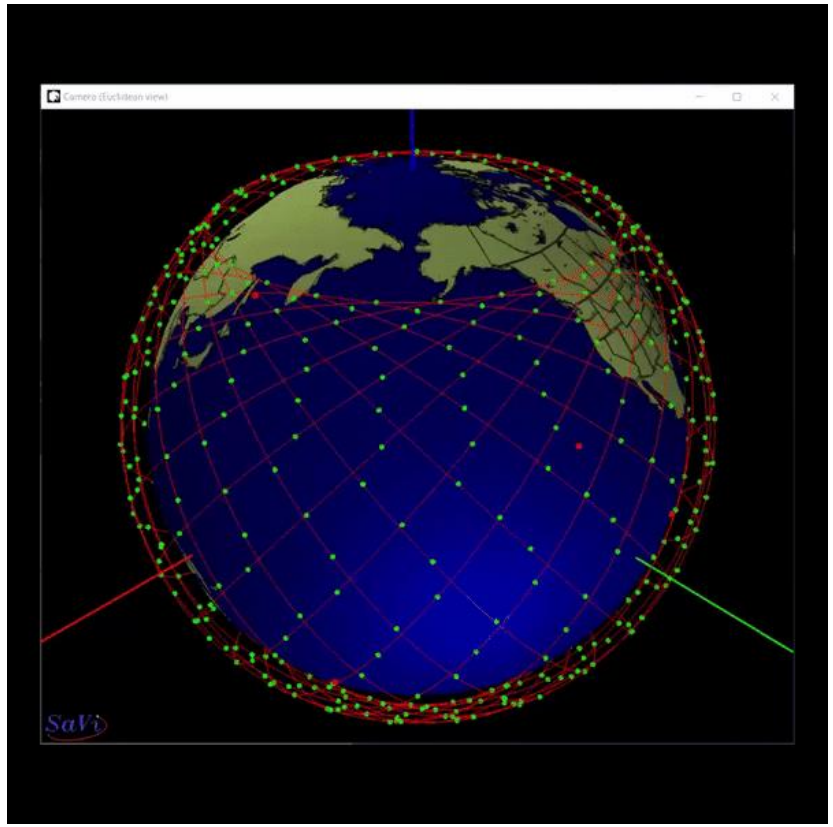
- Shorter Latency
- Higher Bandwidth
- Lower global coverage cost
- Lower Launching cost
- Lower Operation/management cost
- Lower power requirement for communication for both satellite and ground
- Lower Ground station and UE cost

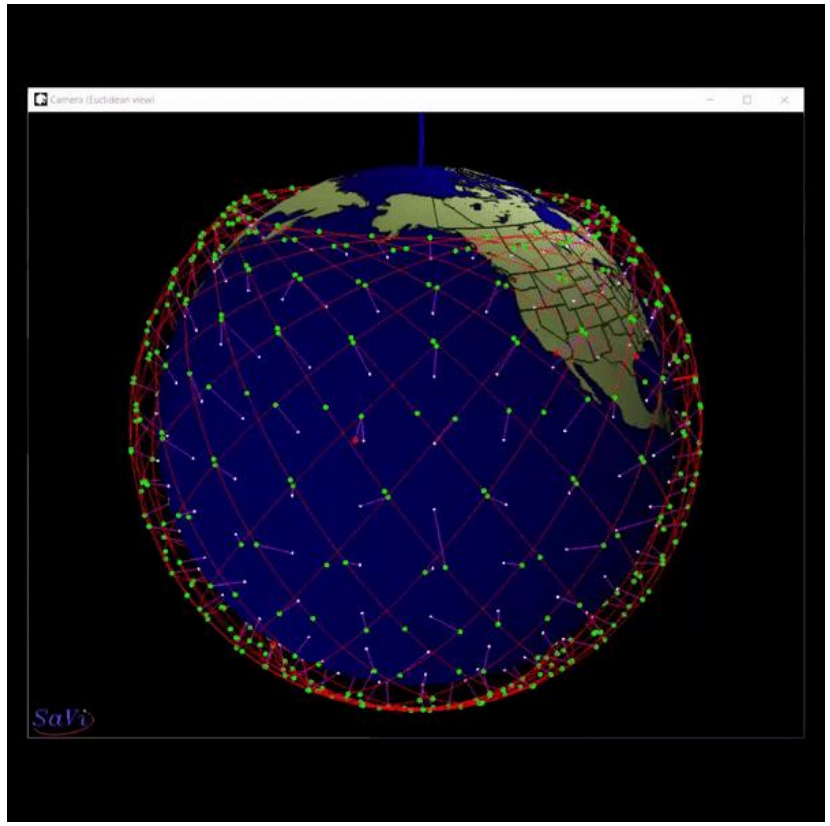
As of 2021, 37% population cannot access Internet
ITU: https://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

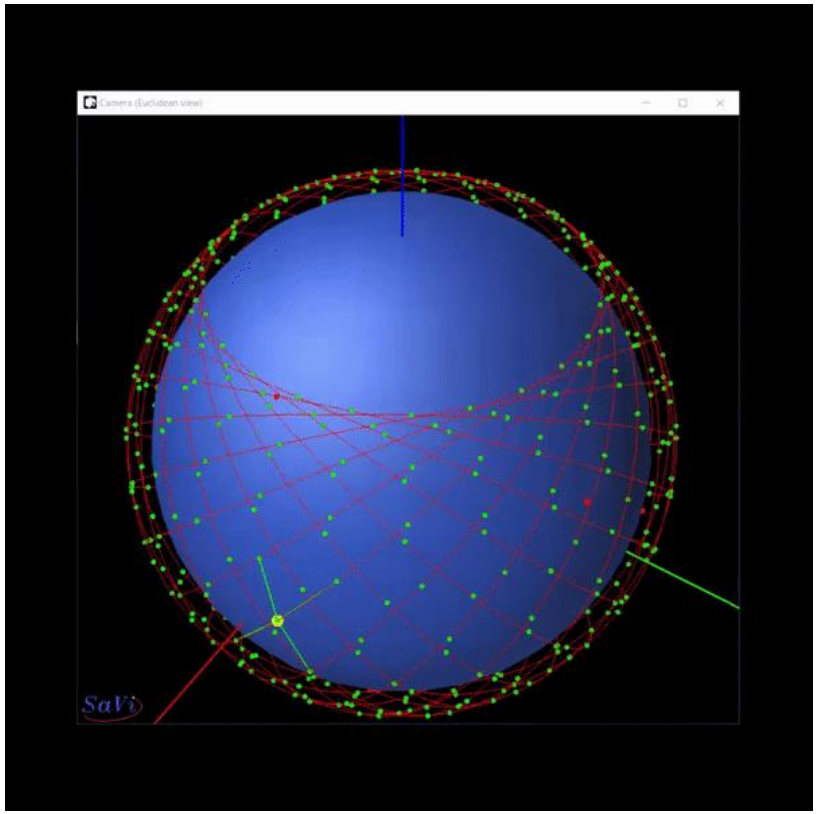
Shorter latency from LEO satellite network:
Mark Handley, University College London, “Delay is Not an Option: Low Latency Routing in Space”

Jiajia Liu, Yongpeng Shi, Zubair Md. Fadlullah, and Nei Kato. 2018. Space-Air-Ground Integrated Network: A Survey. IEEE Communica-tions Surveys & Tutorials 20 (2018), 2714–2741

LEO satellite dynamics – Challenging the current IP networking technologies







- LEO satellites move at ~7.x km/s with ~100min period
- 50% satellites move on different direction with another 50% satellites and form a dynamic interleaved network
- Earth is self-rotating at ~463m/s

- links between satellites and ground station (GS) will flip every ~5min for LEO satellites (~550 km altitude), distance keeps changing
- One satellite has multiple GS connected
- One GS has multiple satellites connected
- Huge number of Sat-GS links (> million)

- ISL distance for satellites on adjacent orbits keep changing
- ISL direction swaps on polar areas

Simulation is by savi: https://savi.sourceforge.io/

IETF works for Satellite

History and Current Work

- IP over Satellite Links (ipsat) WG: IP over GEO, closed for unknown reason, and no output.
- Delay/Disruption Tolerant Networking (DTN WG): for GEO and inter-planetary communication, not fitting for LEO (due to short delay, less tolerance for disruption)
- L4 work
  - TCP Over Satellite (TCPSAT WG)
  - RFC2488, RFC2760,
- Network Coding for Satellite System: RFC8975
- SATCOM side meeting on IETF111
- Current drafts related to satellite network not belonging to any existing WG:
  - draft-li-istn-addressing-requirement
  - draft-jliu-istn-savi-requirement
  - draft-lai-bmwg-istn-methodology
  - draft-lhan-problems-requirements-satellite-net
  - draft-retana-lsr-ospf-monitor-node
  - draft-lhan-satellite-semantic-addressing
  - draft-lhan-satellite-instructive-routing
  - draft-kw-rtgwg-satellite-rtg-add-challanges-00

IP networking for LEO?

- Why L3 networking is needed (more to see back up slides)
  - Large scale network with over 10k nodes and million links
  - Interworking with other networks in Internet
  - 3GPP expected satellite network as part of wireless access or back haul, must support IP and 5G functions (i.e, UPF distribution in satellites)
- Problems for current IP networking for LEO
  - Addressing
  - Routing
  - Traffic Engineering
  - Multi-path
  - Mobility
  - ….

What next

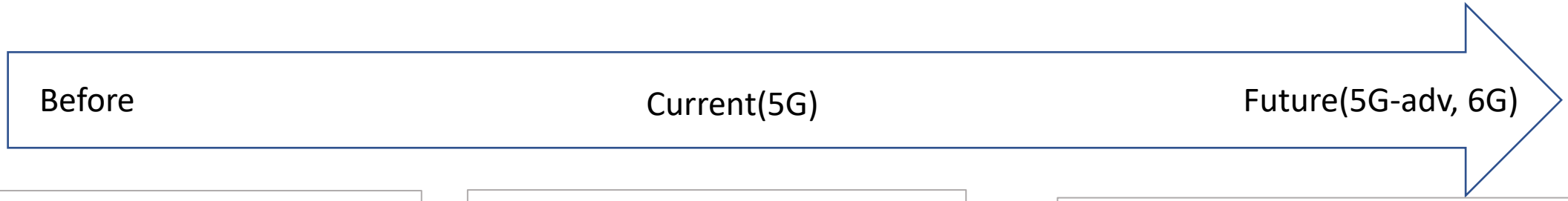
- We will have side meeting at IETF 115 (London)
- Reach out to me lin.han@futurewei.com or send to etosat@ietf.org, if you want to present something in the side meeting; or want to discuss details; or want to collaborate.

Thanks

Backup Slides

- LEO satellite network evolution
- Examples of LEO satellite network in service or in research
- 3GPP works for satellite network, IP networking is fundamental for the perspective of 3GPP NTN integration.

LEO Satellite network evolution

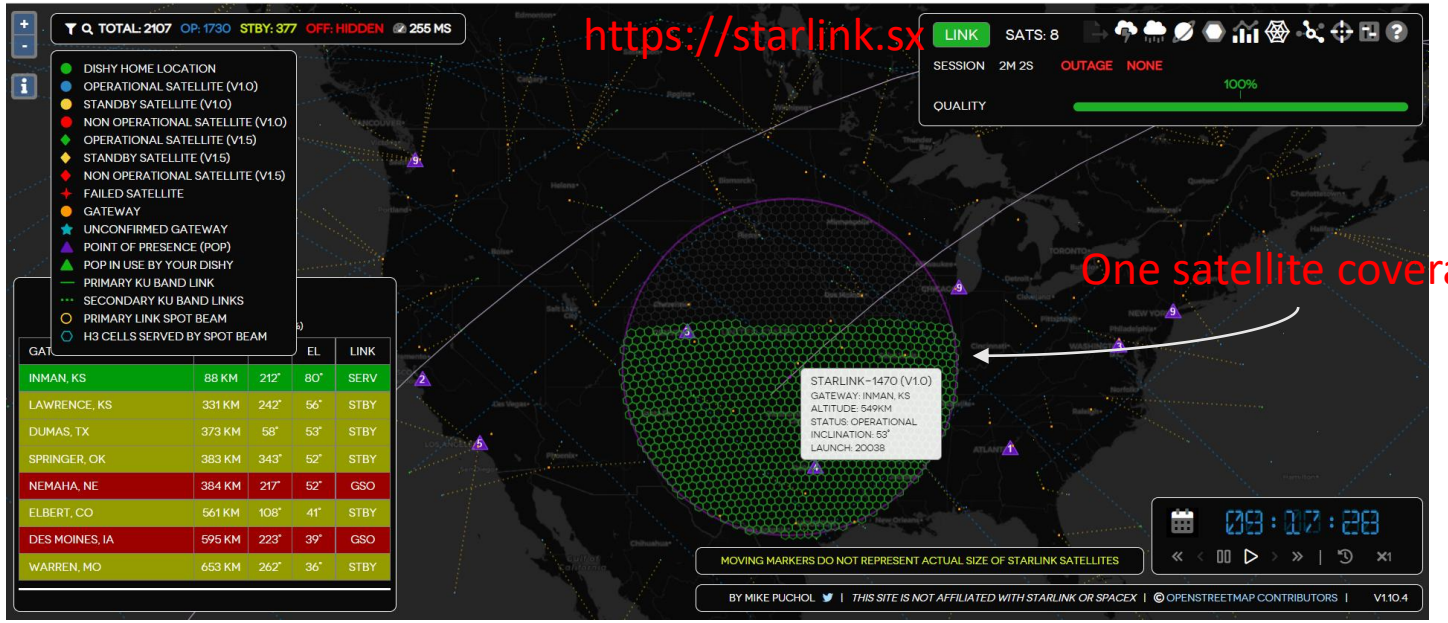


- Expensive
- Using GSO technologies
- Transparent Payload (Bent pipe)
- No ISL
- LEO Satellite only does L1 work
- Few satellites

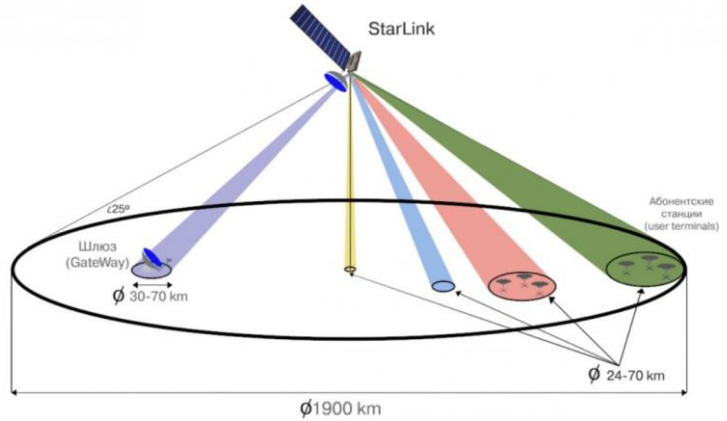
- More LEO satellites launched
- Transparent and Regenerative Payload
- ISL in experiment
- LEO Satellite does L2 work
- Small scale of LEO satellite network (ISL used)

- Regenerative Payload
- ISL widely used
- Satellites are network nodes connected by ISL,
- Satellites can provide most of functions of terrestrial network, i.e: gNB, routing, UPF, NV, etc.
- LEO Satellite network integrated with terrestrial network, HAPS, MEO, GSO
- Vertical applications on satellites

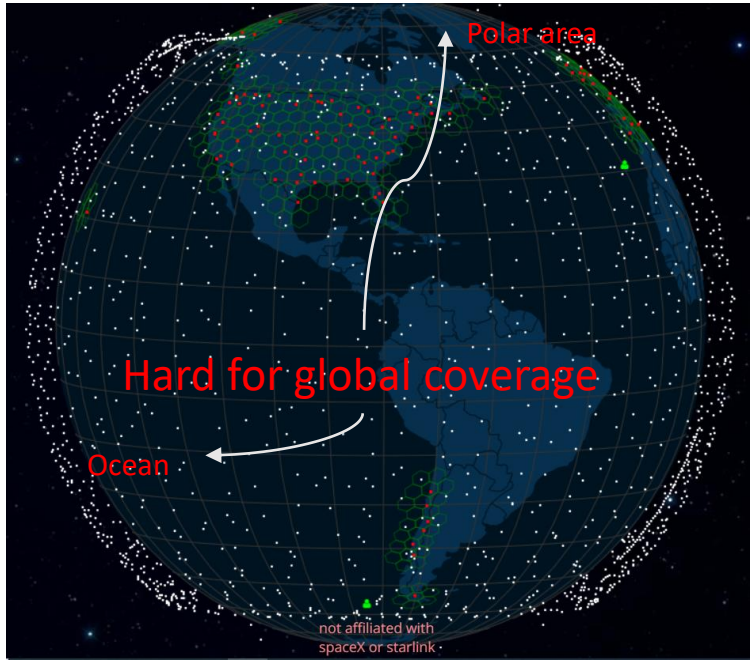
Example: StarLink



One satellite coverage



https://www.reddit.com/r/Starlink/comments/n9bas5/satellite_spot_beam_simulation_first_stab/



- Private technologies
- IP-less, pack overhead and complexity, (https://www.alphr.com/space/1008632/Elon-Musk-SpaceX-Starlink-internet)
- Started to test ISL for polar area users (https://www.connectivity.technology/2022/02/laser-inter-satellite-links-lisls-in.html)

Example: Tiansuan Constellation (天算星座)

- http://www.tiansuan.org.cn/index.html
- http://sguangwang.com/PDF/TiansuanFinal1203.pdf
- open satellite research platform, total 330 LEO satellites (two launched)
- Experiment the advanced technologies for 5G and beyond

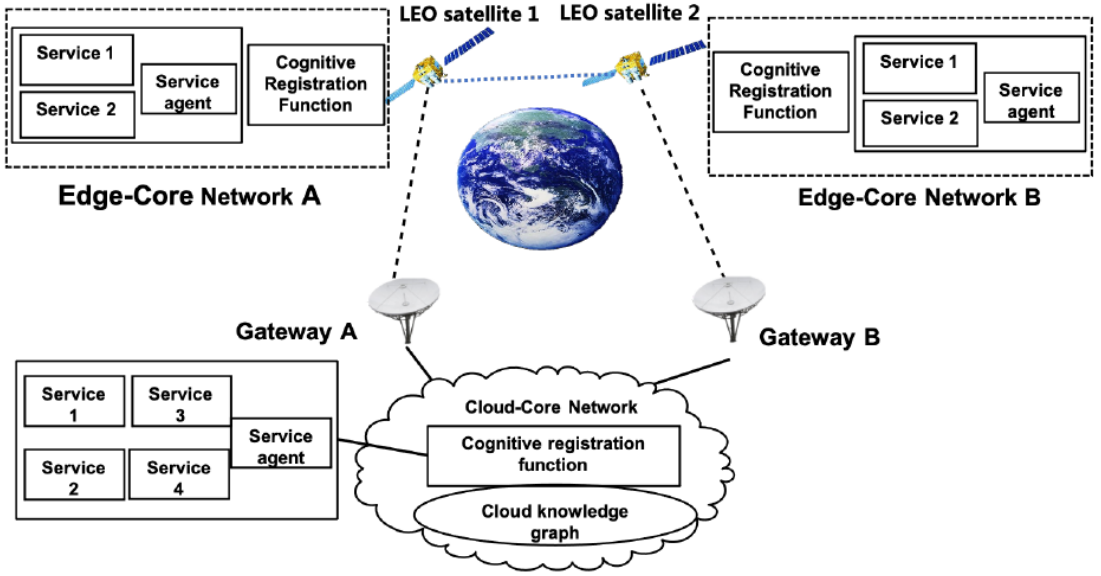


Fig. 2: Cognitive Service Architecture of 6G Core Network.

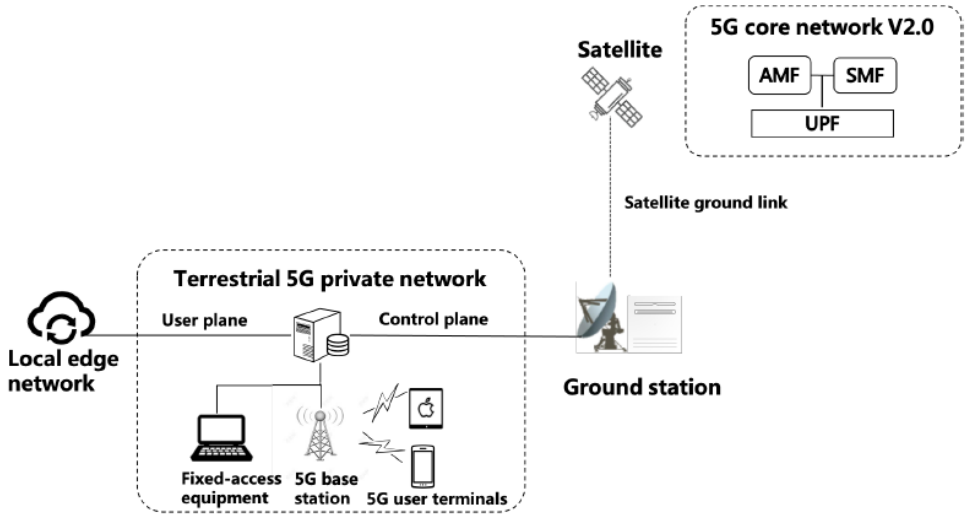
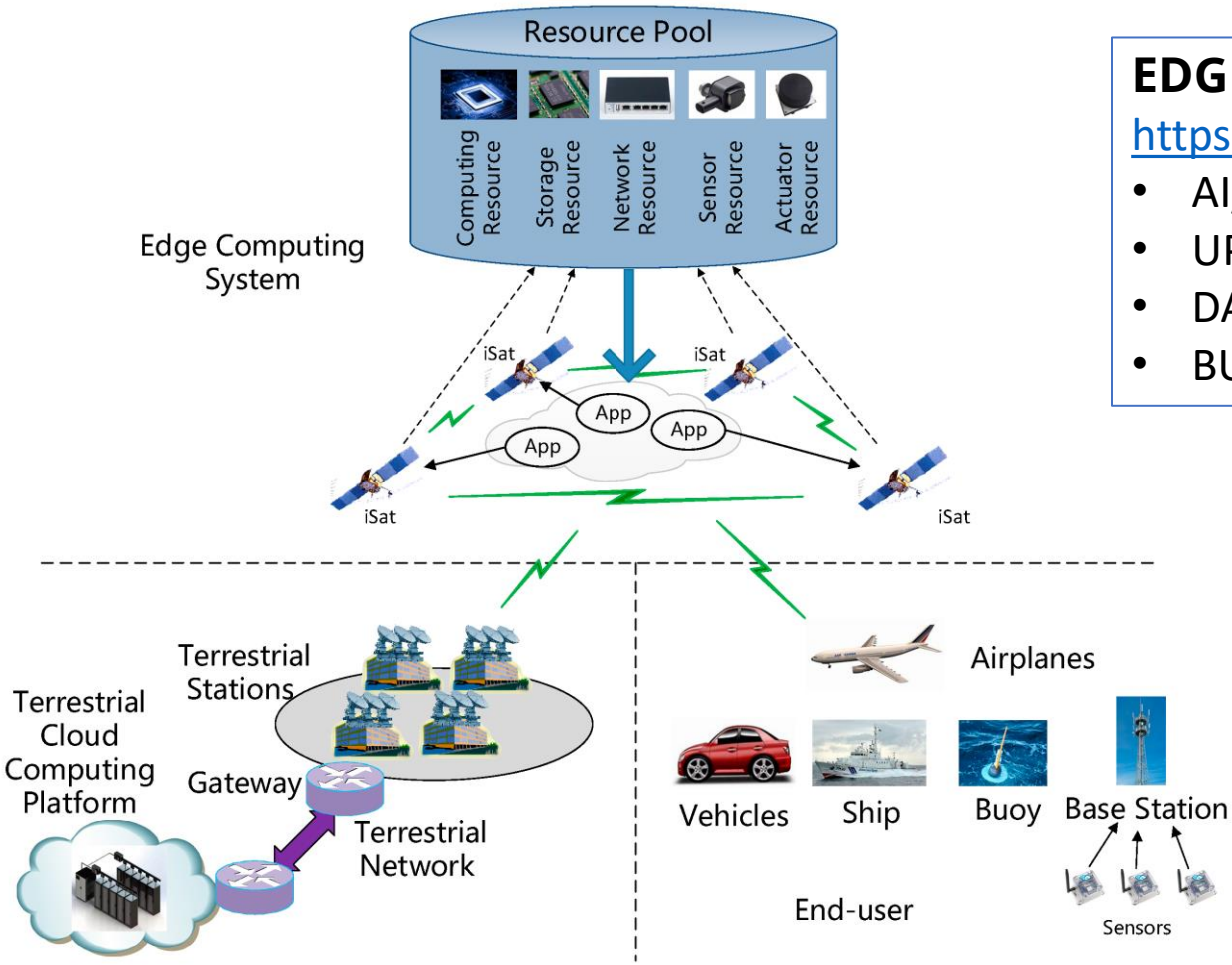


Fig. 3: Satellite-Borne B5G Core Network.

Figures are from above paper

Example: Application for LEO satellites – Edge Computing in Space



https://www.mdpi.com/1424-8220/19/20/4375

EDGE COMPUTING IN SPACE ALLIANCE

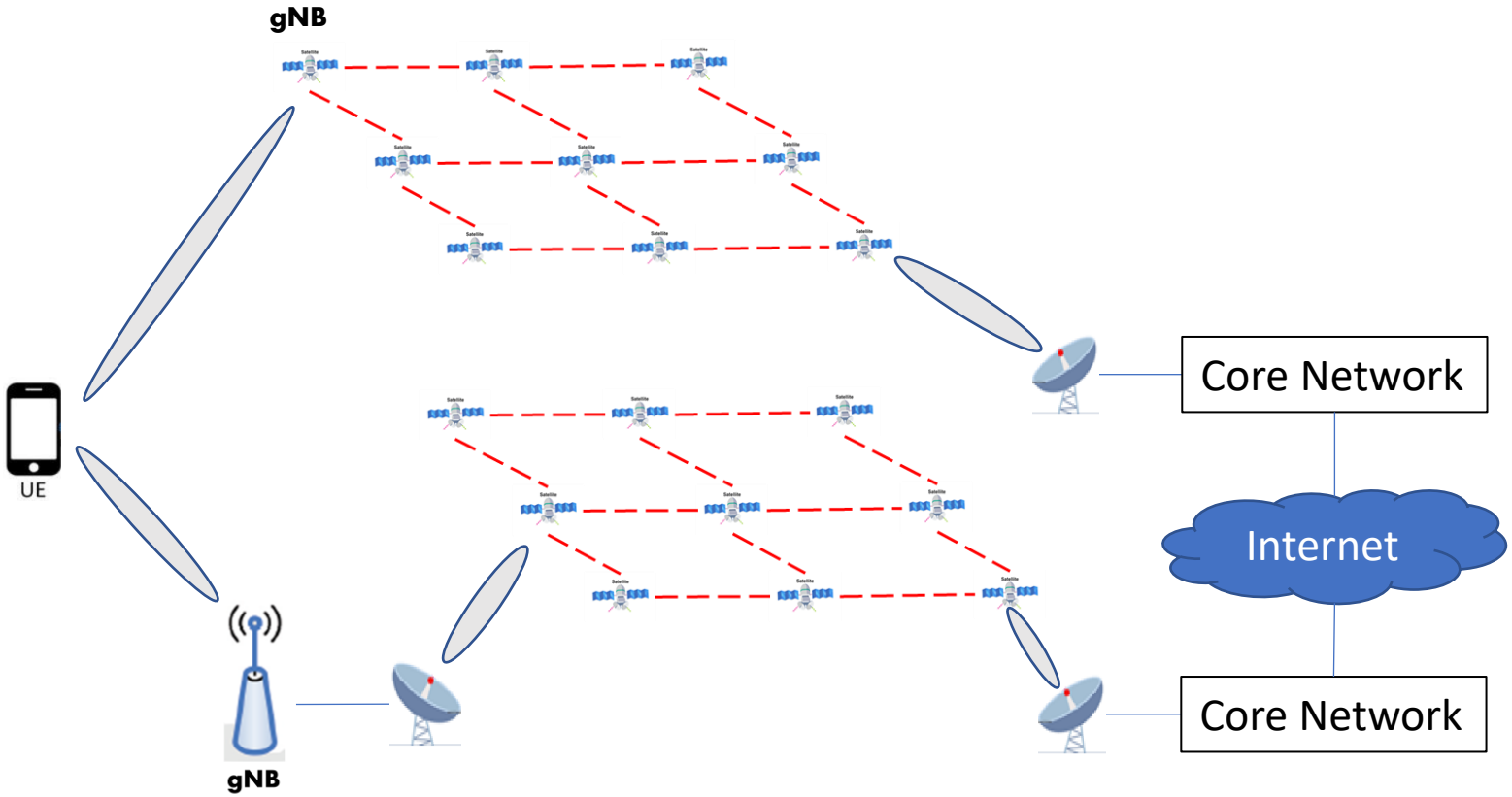
https://ecsa.space/

- AI/ML SOLUTIONS FOR SPACE INDUSTRY
- UPGRADEABLE SATELLITES
- DATACENTERS IN ORBIT
- BUSINESS INTELLIGENCE FROM SPACE

3GPP: Historical and current works

Rel	TR/TS number	TSG	Title	Status
15	TR.38.811	RAN	Study on NR to support NTN	Completed
16	TR 22.822	SA	Study on using satellite access in 5G	Completed
	TR 23.737 (phase-1)	SA	Study on architecture aspects for using satellite access in 5G	Completed
17	TR 23.737 (phase-2)	SA	Integration of satellite components in the 5G architecture	Completed
	TR 28.808	SA	Study on management and orchestration aspects with integrated satellite components in a 5G network	Completed
	TR 38.821	RAN	Solutions for NR to support NTN	Completed
18	5GSATB	SA	5G system with satellite backhaul	In progress
	5GSAT_Ph2	SA	5G Satellite Access Phase 2	In progress

3GPP: Two typical use case and variations for LEO satellite network



LEO satellite network as 5G Access Network

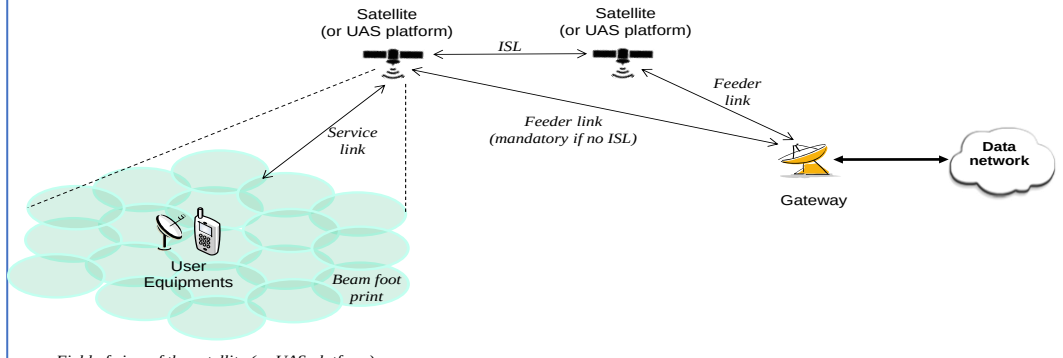
- gNB on satellite
- DU and CU can be separated on satellite and ground respectively
- CN can be completely or partially (i.e, UPF) on satellite
- Radio: Based on 5G NR for Ku, Ka band
- Architecture: SBA with enhancements
- Satellite network:
  - IP network to support 5G functions and interworking with other network in Internet

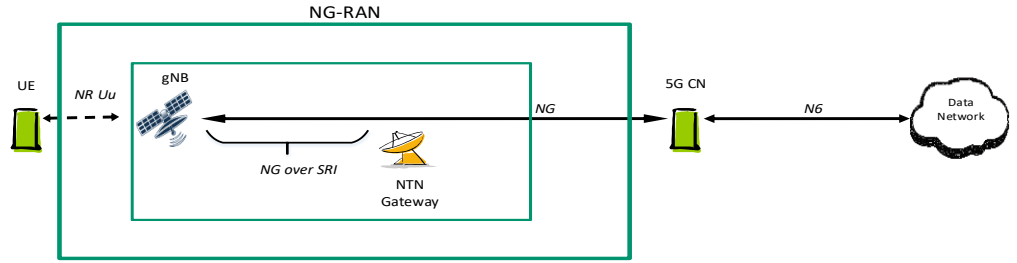
LEO satellite network as 5G Back haul

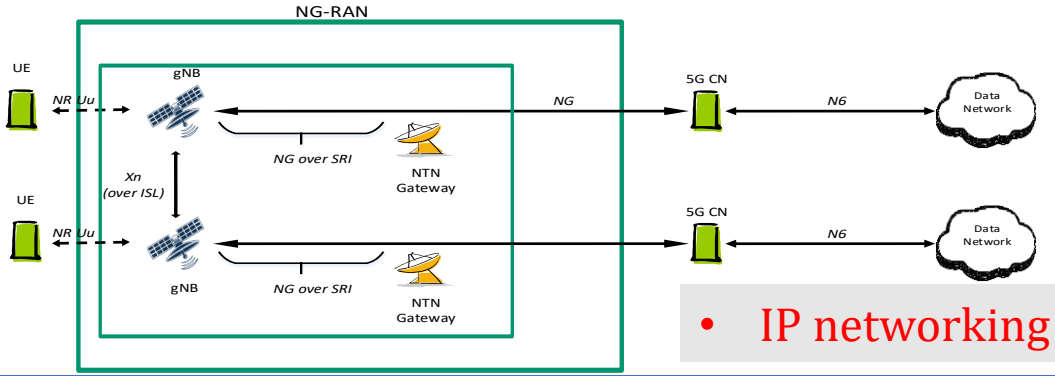
- gNB on ground
- CN can be completely or partially (i.e, UPF) on satellite
- Radio: 5G NR or other technologies
- Satellite network:
  - If want to support 5G functions and interworking with other networks in Internet, must be IP network

3GPP (TR38.821) : Satellite-based NG-RAN architectures, gNB on satellite

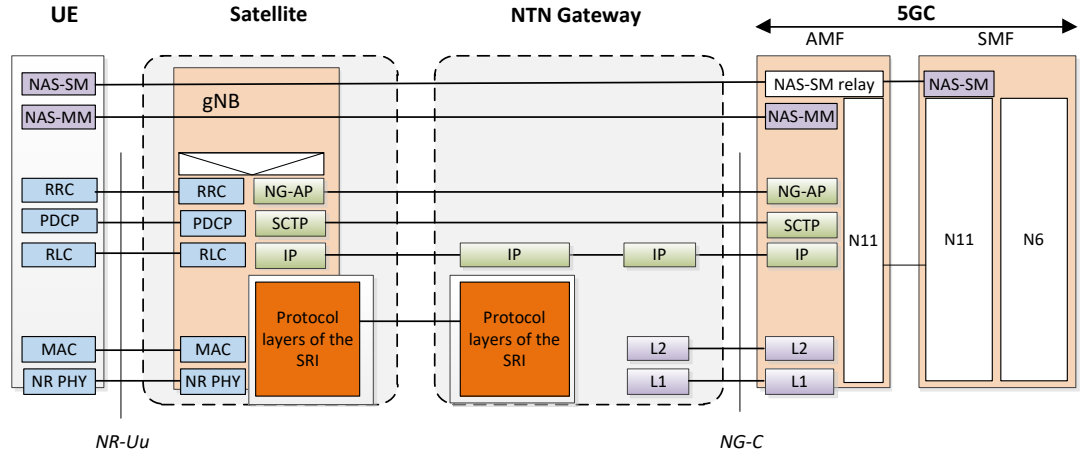
- Satellite with regenerative payload (gNB on board, with and without ISL)

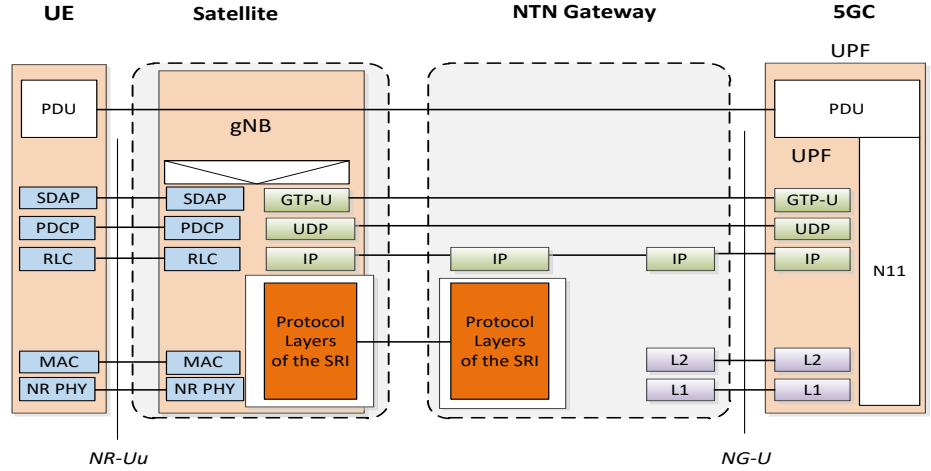






- Control plane and user plane stack

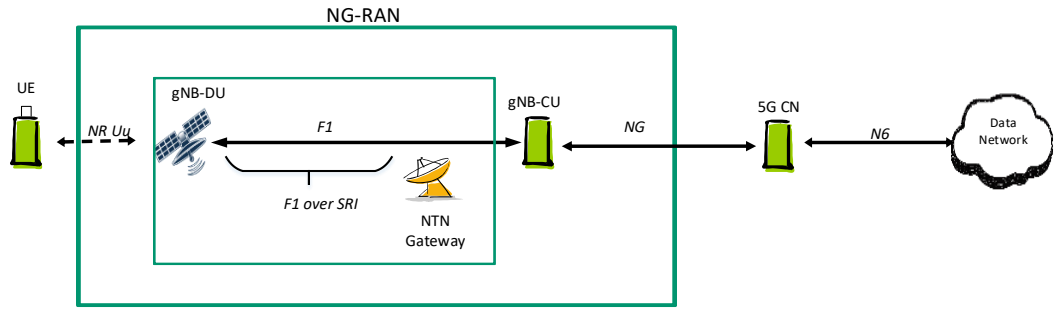




- IP networking is key requirements for infrastructure

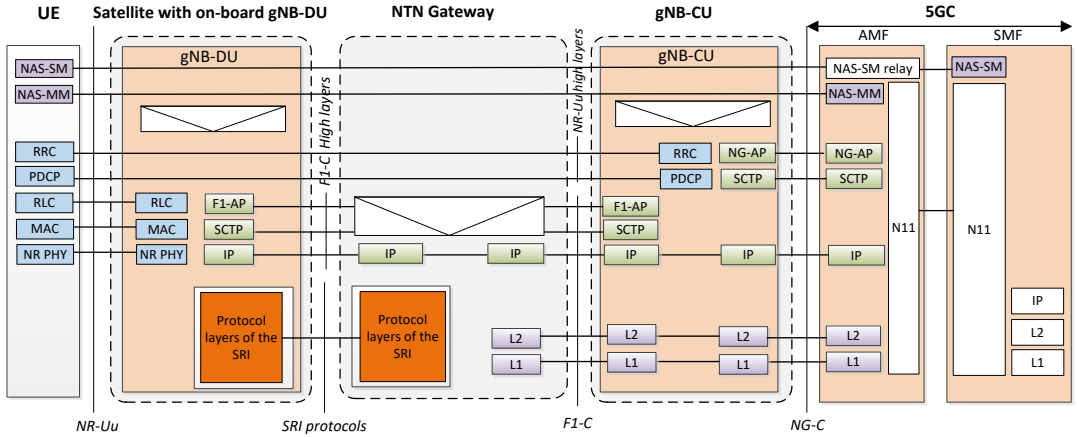
3GPP (TR38.821) : Satellite-based NG-RAN architectures, gNB-DU and gNB-CU separated

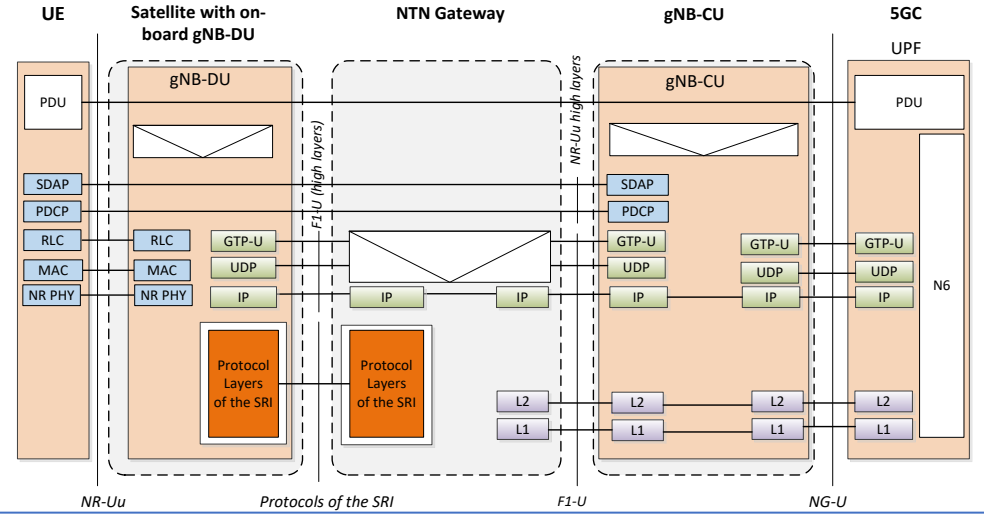
- Satellite with regenerative payload (gNB-DU on board, gNB-CU on ground)



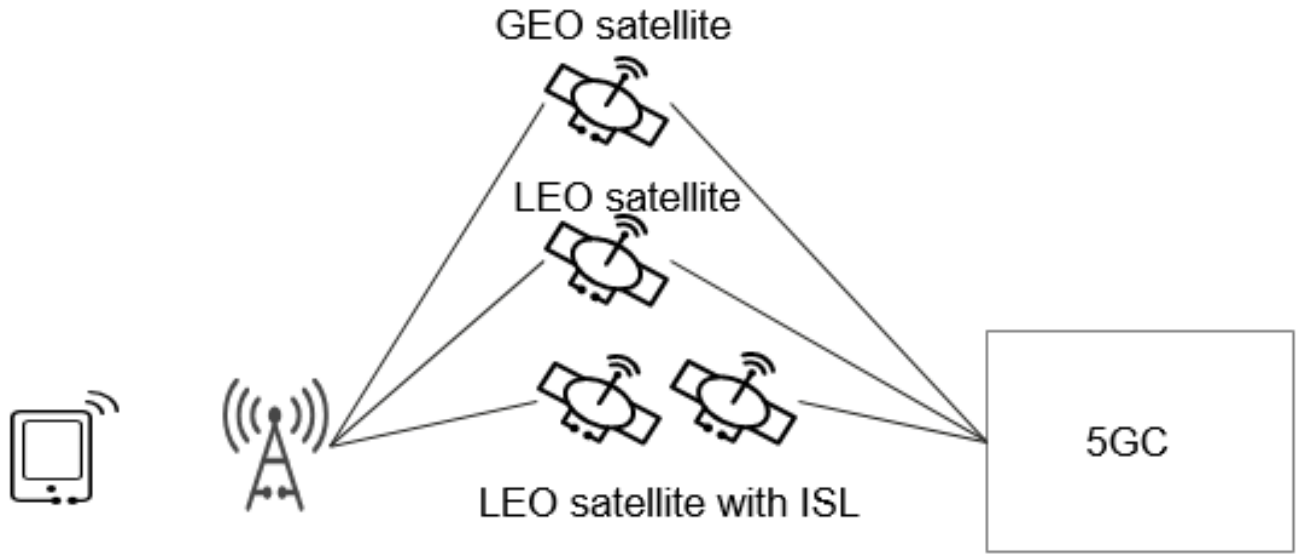
- IP networking is key requirements for infrastructure
- Higher requirement for IP in bandwidth and latency

- Control plane and user plane stack





3GPP(TR 23.700):
Study on 5G System with Satellite Backhaul (Release 18, in progress)



Three Key Items

KI#1: QoS control enhancements for dynamic satellite backhauling

KI#2: Support of Satellite Edge Computing via UPF on board

KI#3: Support of Local Data Switching via UPF on board

- IP networking is the fundament requirements for above support