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FUTUREWEI Technologies

Evolution to 6G for Satellite NTN Integration: From Networking Perspective

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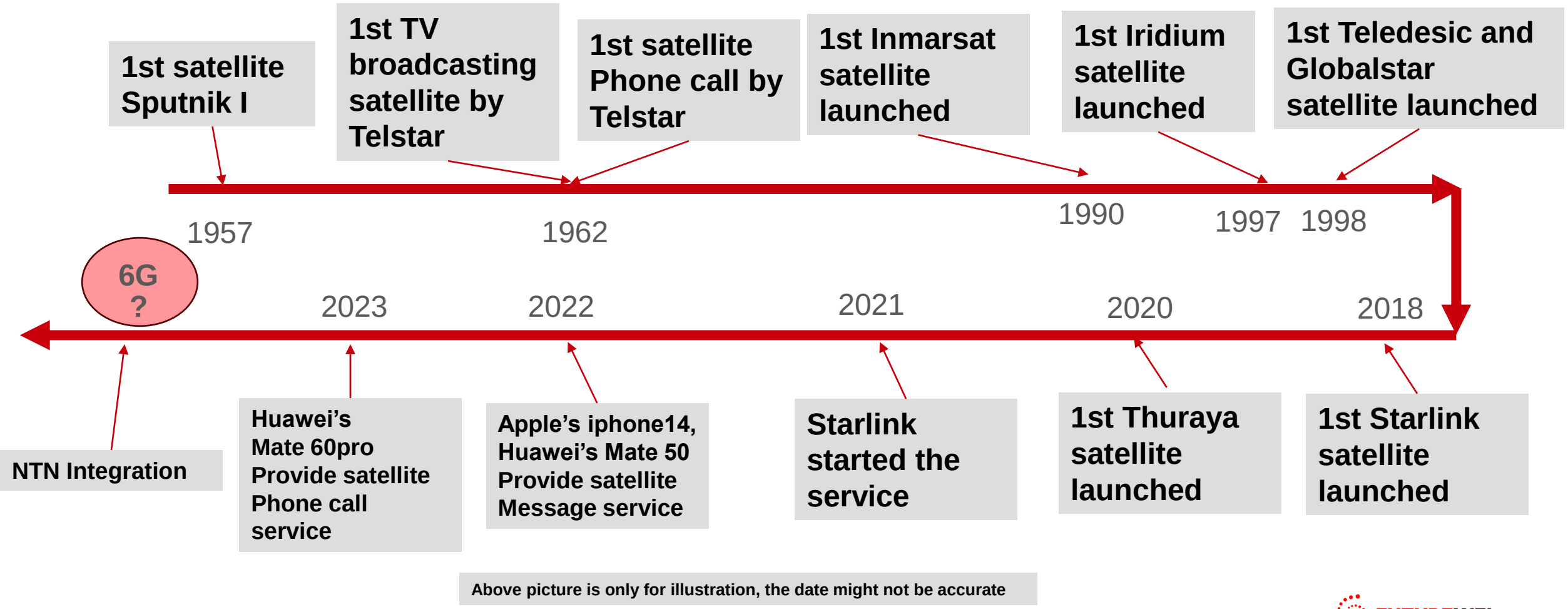
Agenda

1. Satellite Network – History, Current Status and Evolution
2. 5G, NTN Integration Evolution, and 6G
3. Technologies Paradigms, Challenges, and Problems
4. Status, Progress, and Future Works in 3GPP
5. Status, Progress, and Future Works in IETF

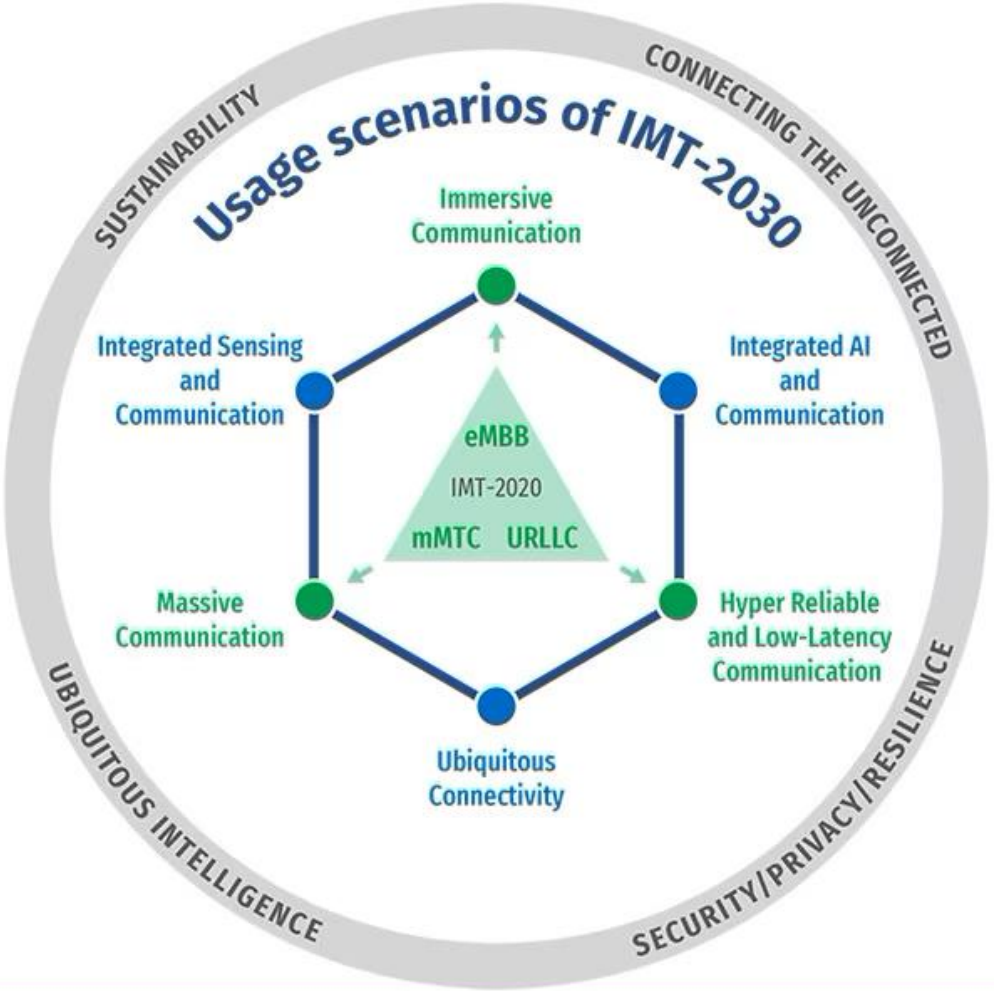
History of Satellite Service and Evolution Direction– TV Broadcasting -> Voice/data -> Internet Access -> NTN Integration



Above picture is only for illustration, the date might not be accurate

5G to 6G: IMT-2020 to IMT-2030

- IMT-2030 for 6G
  - Stage1: ITU completed the Recommendation Framework for IMT-2030 in Jun. 2023
  - Stage2: Requirements and evaluation methodology to be completed in 2026
  - Stage3: Specifications to be completed in 2030
- Visions
  - Connecting the unconnected
  - Security/Privacy/Resilience
  - Ubiquitous Intelligence
  - Sustainability
- Use Scenarios
  - Immersive Communication
  - Integrated AI and Communication
  - Hyper Reliable and Low-latency Communication
  - Ubiquitous Connectivity
  - Massive Communication
  - Integrated and Sensing and Communication



ITU-R, DRAFT NEW RECOMMENDATION, ”Framework and overall objectives of the future development of IMT for 2030 and beyond,” June, 2023.

6G Visions in Industries and Academia

- Next G Alliance, ”Next G Alliance Report: 6G Technologies,”
- The European Space Agency, ”Space for 5G and 6G,”
- ”6G White Paper on Connectivity for Remote Areas”. University of Oulu.
- Ericsson, ”6G – Connecting a cyber-physical world,”
- Nokia Bell Labs, "Communications in the 6G Era,”,
- Huawei, ”6G, The Next Horizon,”

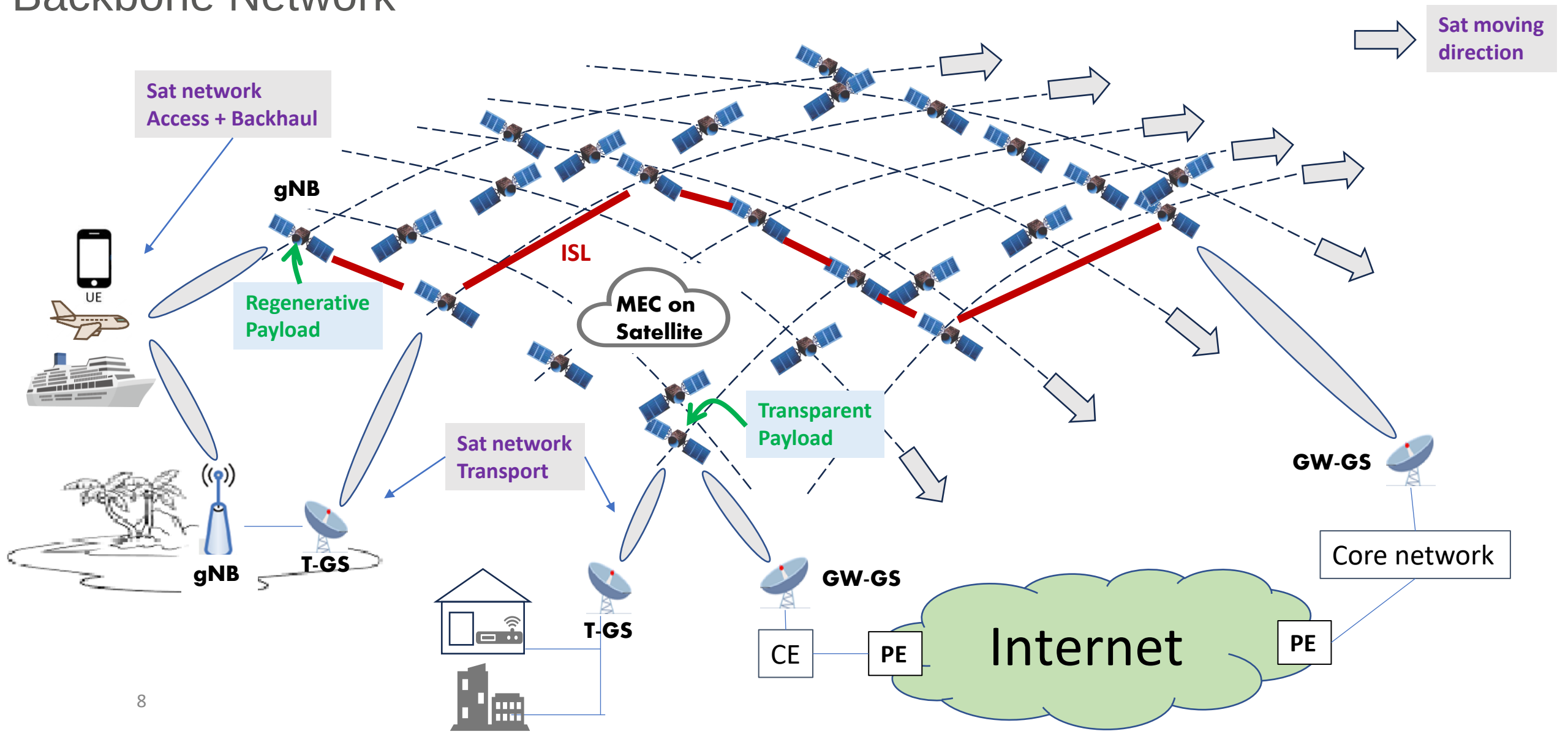
“Ubiquitous Connectivity” needs NTN Integration

- Terrestrial Network cannot cover entire Earth
  - Ocean, Space, remote areas.
  - Cost to cover
- NTN (Non-Terrestrial Network) Integration from 3GPP
  - High-Altitude Platform Station (HAPS):
    - balloon, drone, airplane, satellites (GEO/MEO/LEO)
  - Satellites:
    - GEO, MEO, LEO, VLEO
  - Best candidate
    - Large scale of LEO/VLEO satellite constellation
- Satellite NTN integration with 5G/beyond and Internet => “Space Internet”

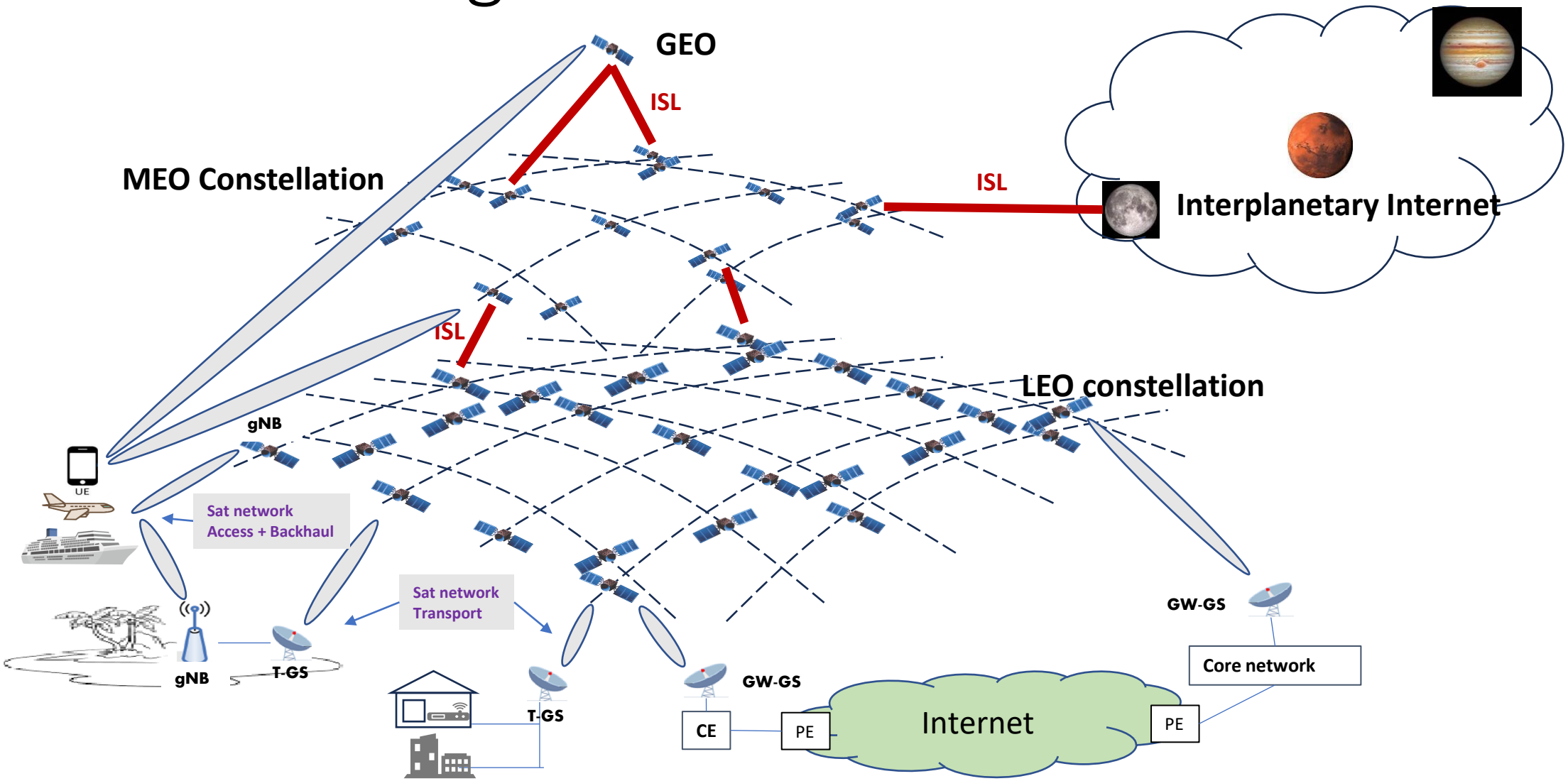
“Large Scale LEO/VLEO Satellite Constellation” is key

- Bigger coverage than non-satellite HAPS
- Lowest altitude in all types of satellites
  - Easier for direct communication between user terminal and satellite
    - Lower cost for antenna for UE and satellites
    - Lower cost for power supplier systems for UE and satellites.
  - Higher bandwidth
  - Shorter latency
  - Lower launching cost -> Repetitive launching-> Lower manufacturing cost-> Lower design cost (short life)
- Satellites move on their orbits
  - Steady and predictable position/speed
  - Lower management cost overall (compared with non-satellite HAPS) Bigger

Large LEO Satellite Constellation as Wireless Access and Backbone Network



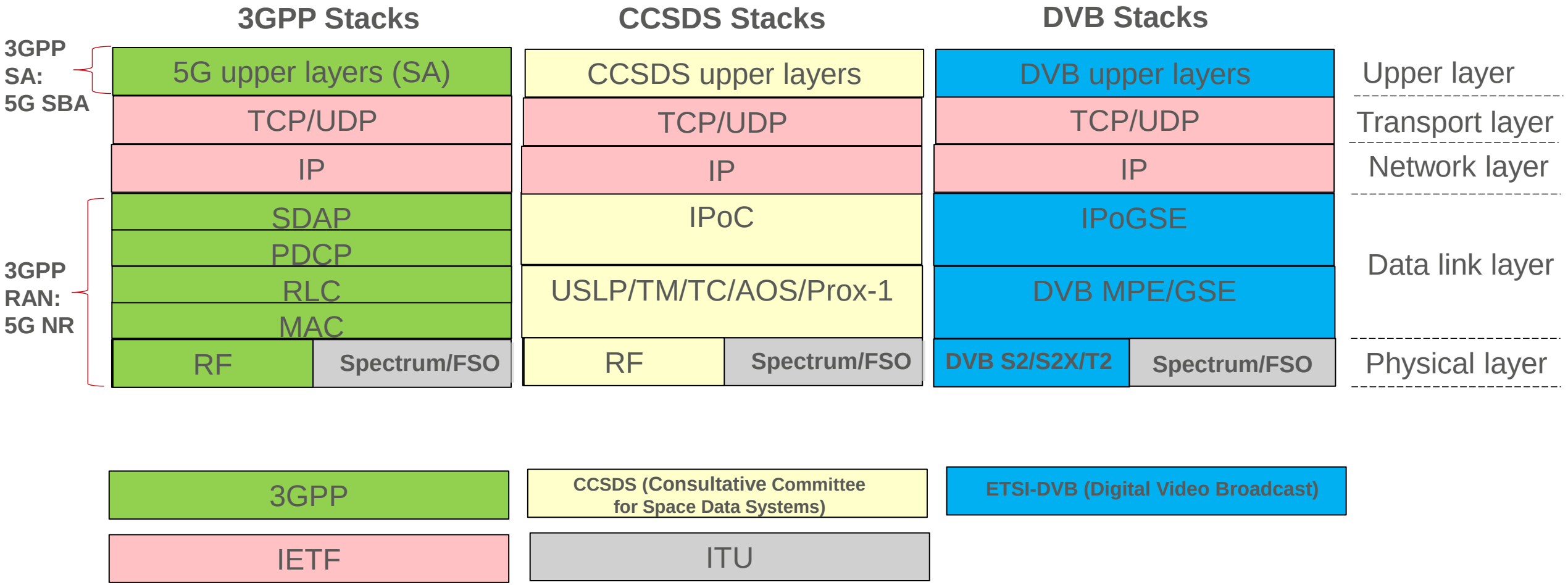
Future Internet: TN, NTN, and Interplanetary Internet all Integrated



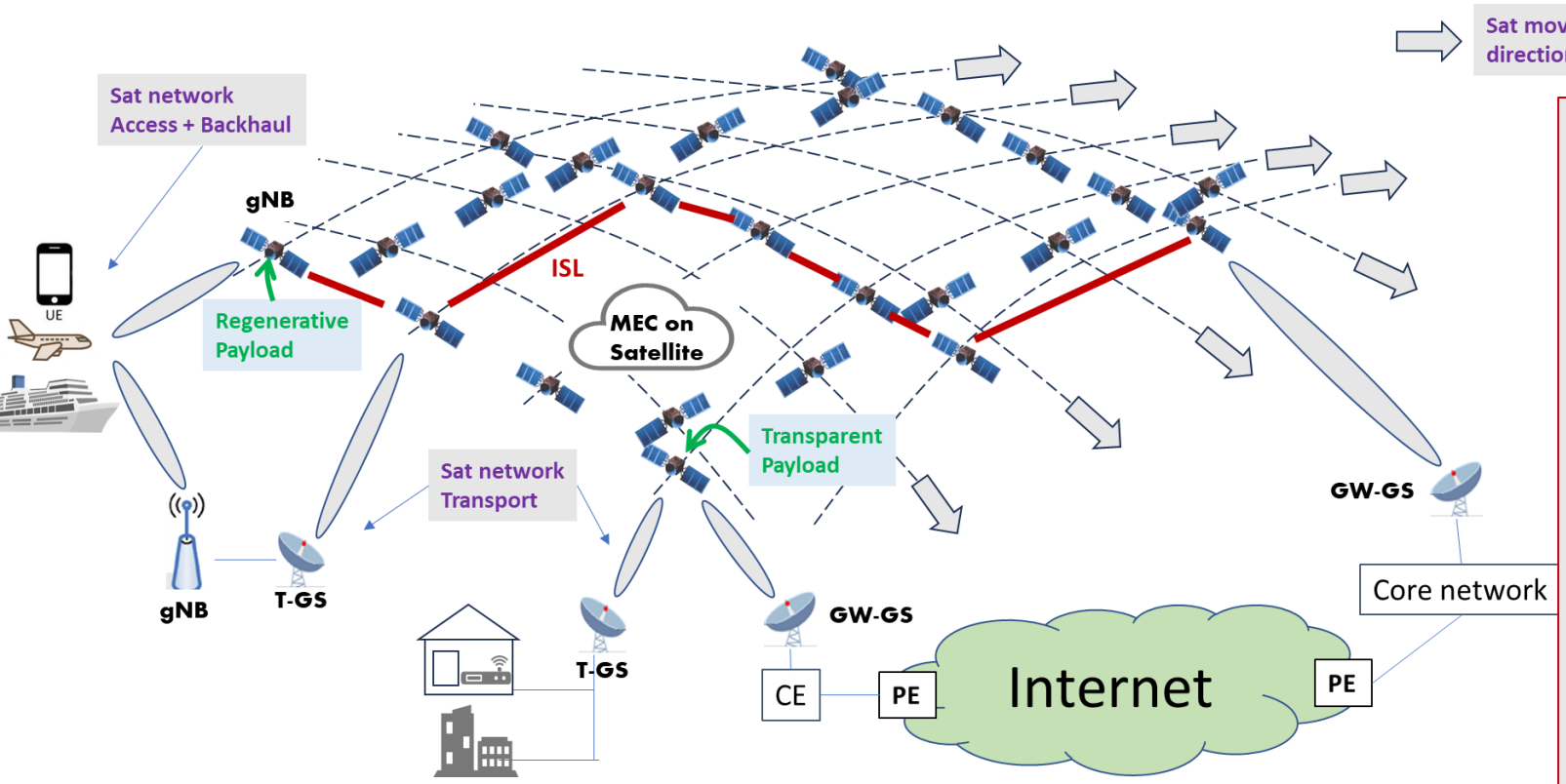
Use cases

- Complementary to the current Internet that is based on terrestrial network
- For the regions where terrestrial networks are not available
  - Unpopulated areas (suburbs, deserts, polar regions, etc.)
  - Ocean
  - Arial
- For the case that requires shorter latency than terrestrial network
- Examples:
  - Internet access for unpopulated areas, on ships, on airplanes, in the spaceship
  - MEC on satellite
  - IoT for unpopulated areas, even on other planets

Technology Paradigm and Protocol Stacks

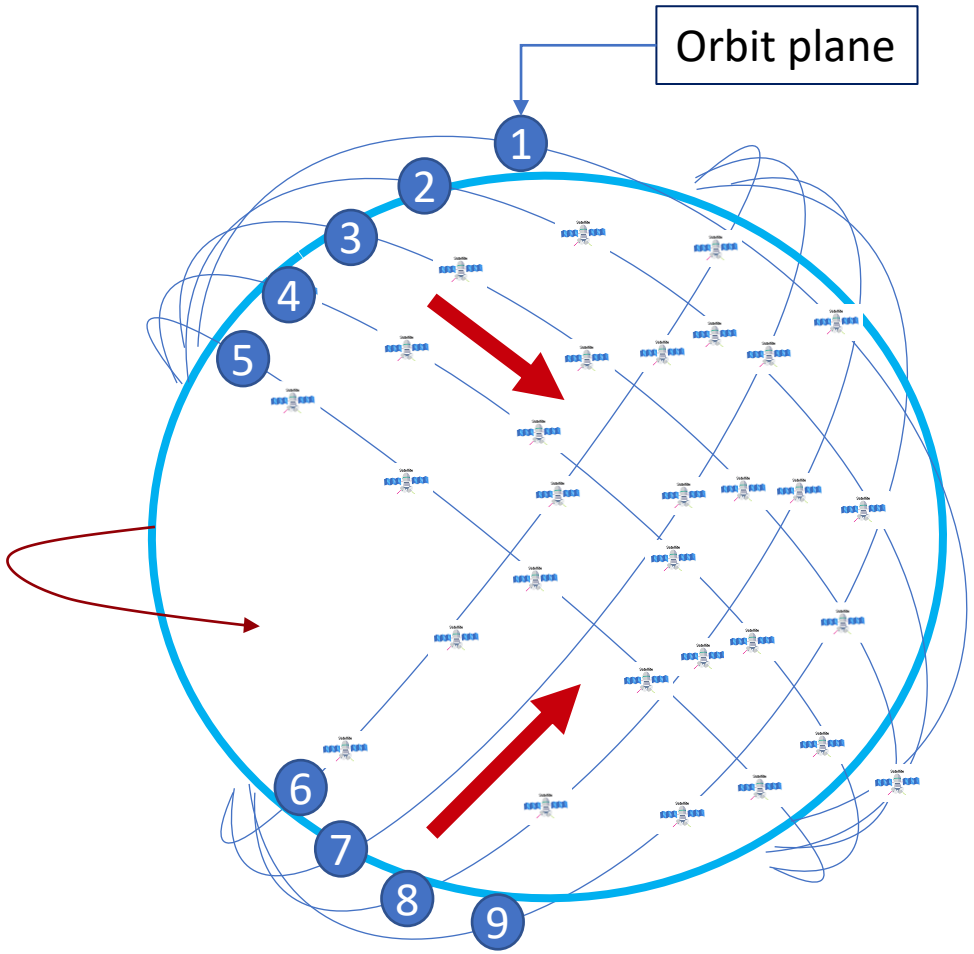


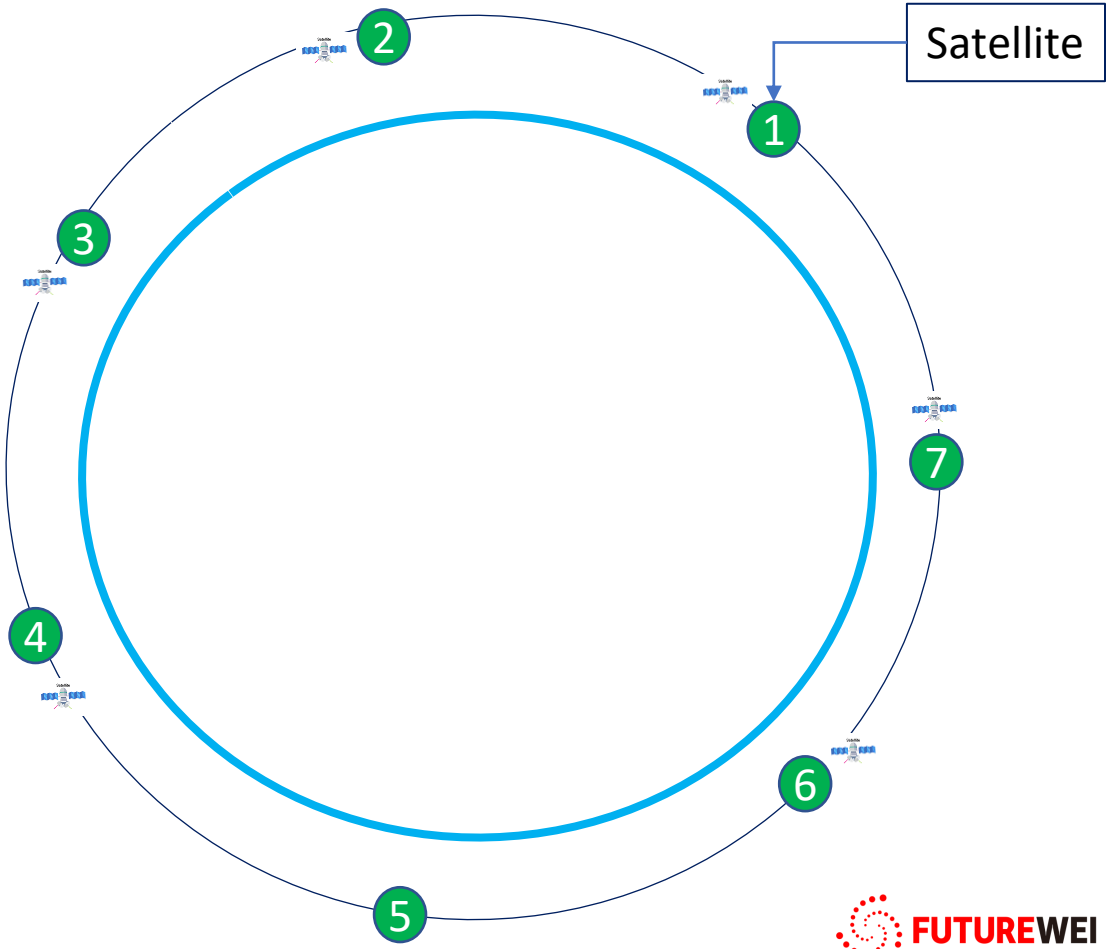
Extensive Technologies from Different Standard Organizations



- 3GPP provides
  - RAN (Radio Access Network)
  - SA (Service and System Aspects)
  - CT (Core network and Terminal)
- IETF provides:
  - Address, DNS
  - Routing, switching,
  - CC, TE, QoS, Load balance
  - L4 and Upper layer protocols
- ITU provides
  - Radio Spectrum
  - FSO
- ETSI
  - DVB, RF/Link
- CCSDS(Consultative Committee for Space Data Systems)
  - RF, Space Link
  - Other modules in Satellite

Orbit Plane and Satellite Movement





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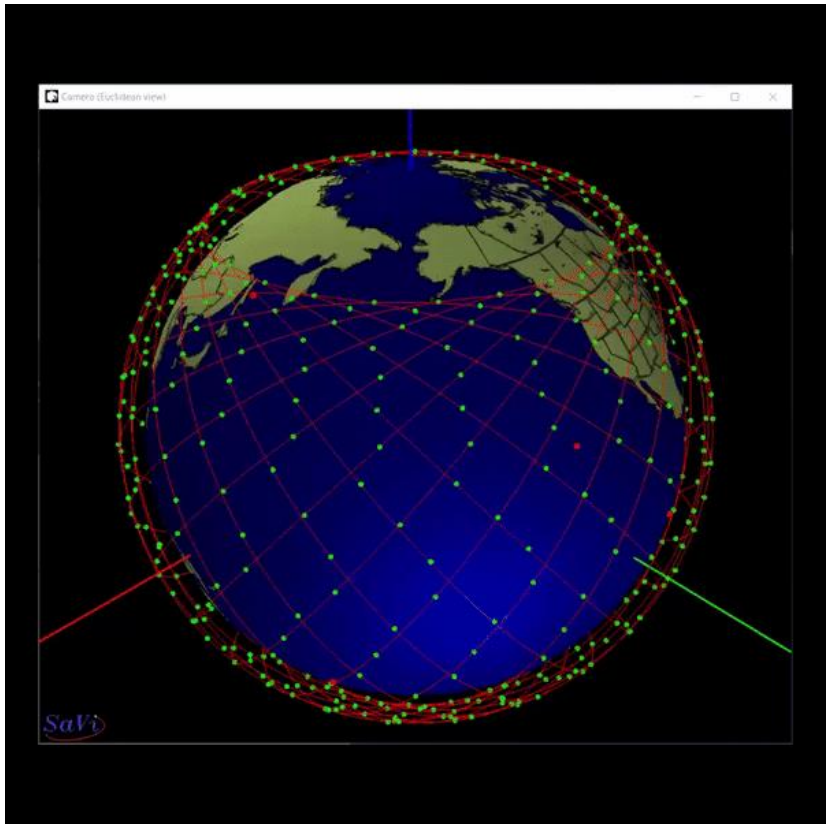
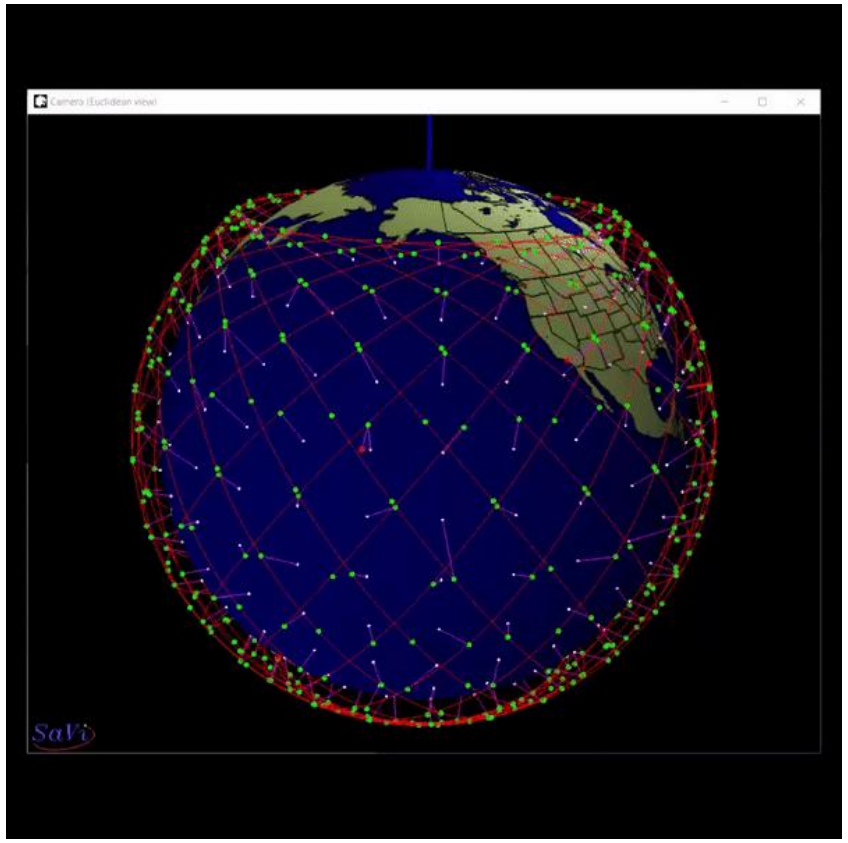
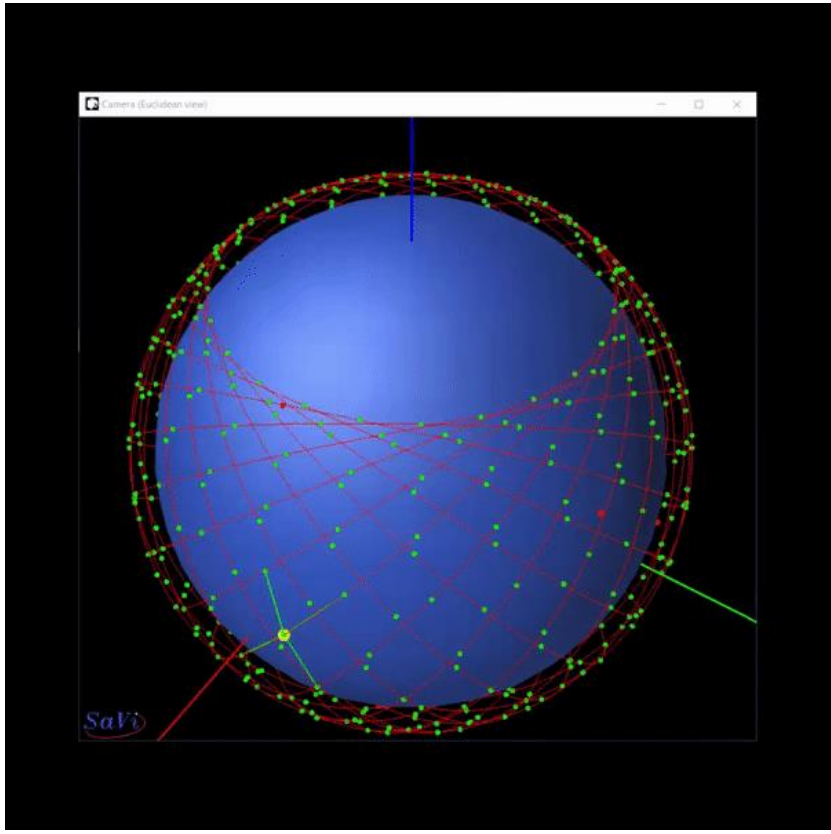
Simulation







- 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
- More: https://youtu.be/bUfO0Scd-j8

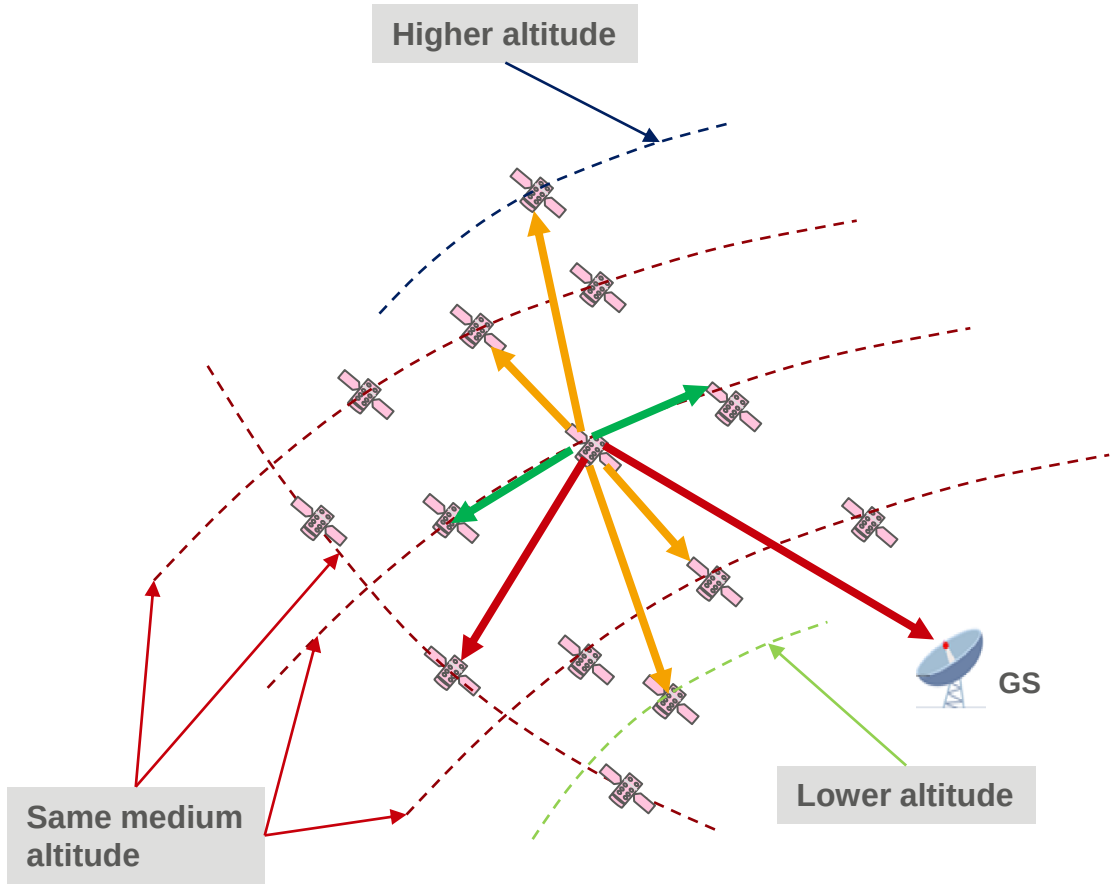
- links between satellites and ground station (GS) will flip every ~5min for LEO satellites (~550 km altitude), distance keeps changing
- One satellite has multiple GS connected
- One GS has multiple satellites connected
- Huge number of Sat-GS links (> million)
- More: https://youtu.be/qnqyfa46GZo

- ISL distance for satellites on adjacent orbits keeps changing
- ISL direction swaps on polar areas
- More: https://youtu.be/njSGghVRdGw

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

Consequence: Satellite network is very dynamic

Link type	Description	Link Life	Link Metrics
L1	Between adjacent satellites on the same orbit plane	Steady	Steady
L2	Between two satellites on the adjacent orbit	Unsteady, lasts tens of mins	Keep changing
L3	Between two satellites on the adjacent orbit shell	Unsteady, lasts tens of mins	Keep changing
L4	Between two satellites on the un-adjacent orbit	Unsteady, lasts couple of mins	Keep changing
L5	Between satellite and ground station	Unsteady, lasts couple of mins	Keep changing



Technologies Challenges and Problems

- Direct communication between UE and Satellite
  - Antenna design,
  - Power supply and management,
  - Doppler-shift compensation, Constant Tracking, etc.
- Communication between satellites by ISL
  - Coherent laser communication
  - Constant tracking
- Satellite network as 5G/6G Mobile access network
  - RAN and CT technologies
  - **Simplified/new architecture,**
  - **Constant mobility handling (attachment, hand-over, etc.)**
  - **Satellite Network Infrastructure Sharing**
- Satellite network as backhaul or transport network
  - **Addressing, DNS, DHCP, etc.**
  - **Routing/switching, IGP/BPG, etc.**
  - **TE, Load balance, Congestion control, etc.**
- Factors need to be considered for all solutions
  - Harsh environments for satellites in space (extreme temperature, radiation, sun interference to FSO)
  - Less powerful components than on Terrestrial Network (performance, memory size, etc.)
  - Less link capacity than on Terrestrial Network (~tens Gbps for FSO with ~2000km)
  - Strict and dynamic power supply (facing sun or in shadow)

Works in ITU, IEEE, and other SDO

Works in 3GPP

Network perspective

Works in IETF

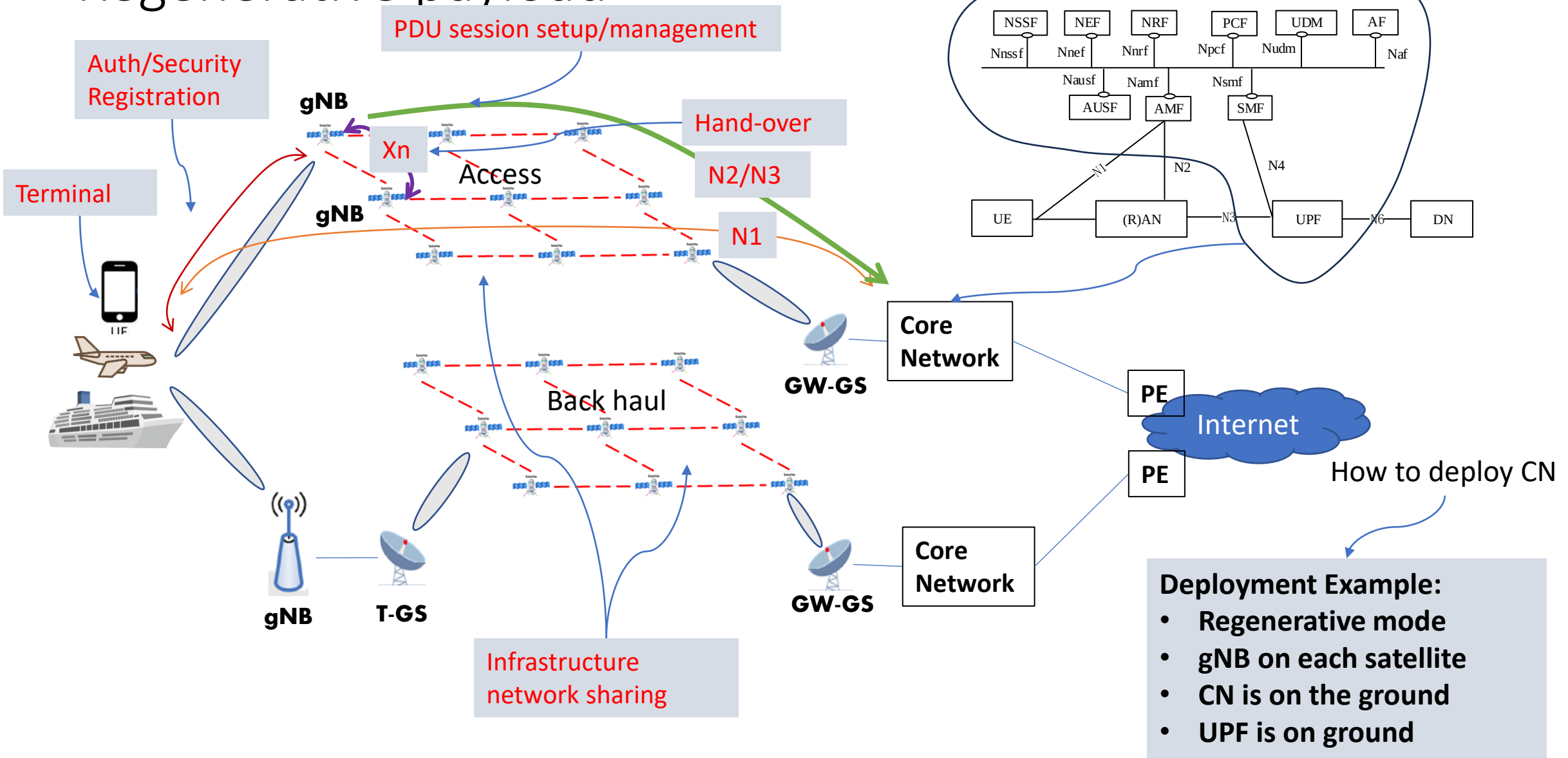
NTN studies in all 5G Releases

Pre-release:

- TR.38.811, RAN group, Study on NR to support NTN (Rel-15)
- TR 38.821, RAN group, Solutions for NR to support NTN (Rel-16)
- TR 22.822, SA group, Study on using satellite access in 5G (Rel-16)
- TR 23.737, SA group, Study on architecture aspects for using satellite access in 5G
- TR 28.808, SA group, Study on management and orchestration aspects with integrated satellite components in a 5G network (Rel-17)
- TR 22.926, SA group, Guidelines for extra territorial 5G systems (Rel-18)
- TR 24.821, CT group, CT aspects of 5GC architecture for satellite networks (Rel- 17)

- Rel-18:
  - TR 23.700-27 V18.0.0, ”Study on 5G System with Satellite Backhaul,”
  - TR 23.700-28 V18.0.0, ”Study on Integration of satellite components in the 5G architecture; Phase 2,”
- Rel-19:
  - Regenerative payload generic architecture study.
  - Store and Forward Satellite operation.
  - UE-Satellite-UE communication, 5GS.
  - Dual access or steer, TN-NTN and GSO/NGSO (Geo-
  - Stationary Orbit, Non-Geo-Stationary Orbit), 5GS (5G System).
  - GNSS (Global Navigation Satellite System) independent operation.
  - Multicast and Broadcast Service via satellite.
  - 5GC supporting IoT NTN.
  - Definition of Satellite Coverage Availability Information (SCAI).
  - Architecture for provisioning of SCAI to 5GS or EPS (Evolved Packet System) by a 3rd party A (Application Function).
  - IAB/MBSR (Integrated Access Backhaul, Multicast- Broadcast Service) applicability to the Satellite Access

Challenges to 3GPP technologies
Regenerative payload



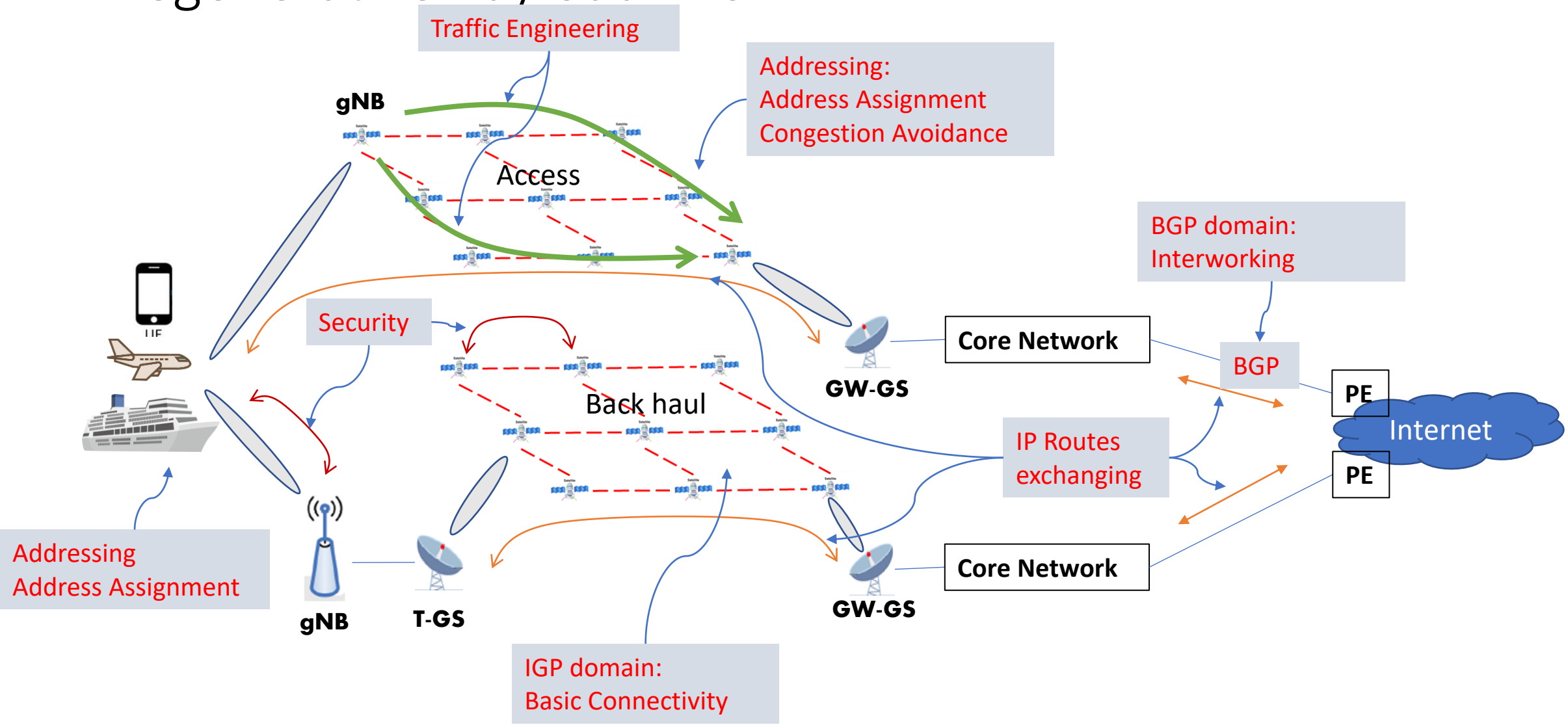
Issues to be Solved in 3GPP-SA

- 5G SBA (Service Based Architecture) was designed for terrestrial mobile access networks:
  - The network infrastructure (gNB, Transport network, and Core network) is steady, end device (UE) is moving
- Does SBA fit a large-scale LEO satellite network? Are any enhancements/improvements needed?
  - The network infrastructure is moving, and the end device keeps switching connections.
- Examples:
  - For regenerative mode, gNB is on each satellite, Where to deploy other CN modules?
  - Can the system handle very frequent attachments, hand-over, and messaging?
  - Can we have a lightweight architecture and protocols?
  - Is the current network-sharing protocols good enough?

IETF Related works: history, and current

- TCP Over Satellite WG (tcpsat)
  - Optimization of TCP over satellite links
- IP over Satellite Links WG (ipsat)
  - No output
- Mobile Ad-hoc Networks WG (MANET)
  - About Mobile ad-hoc network, does not applicable to satellite network
- Delay/Disruption Tolerant Networking (DTN)
  - For the scenario that delay/disruption is not issues, like interplanetary internet, does not apply to satellite network for 6G
- Time-Variant Routing WG (TVR) – new
  - Define information and data models that address time-based, scheduled changes to a network.
  - No protocol changes

Challenges to IETF technologies Regenerative Payload + ISL



Issues to be solved in IETF

- Basic connectivity for dynamic satellite network by IGP
- Interworking between satellite network and Internet by BGP
- Address and assignments for satellites and UE
- Traffic engineering (path selection, congestion avoidance, QoS, etc.)

Progress and Proposals

- IETF 116 Side meeting for satellite networking - https://github.com/lh95129/IETF-116-satellite-network-side-meeting
  - Problem statement and use case
  - Addressing, Routing and switching
  - Mobility, Handover, Multi-path
  - Integration with internet and routes exchanging
- Discussion at: sat-int@ietf.org

Thank You.