Routing in Satellite Networks:
Use Cases, Challenges & Consideration

draft-lj-rtgwg-sat-routing-consideration-00

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3GPP Rel-18: Satellite as ‘Transparent’ Relay (~June 2023)

- Satellite constellation network being the infrastructure for wireless access and backhaul, it provides the gNB, front haul and back haul transport functionalities.

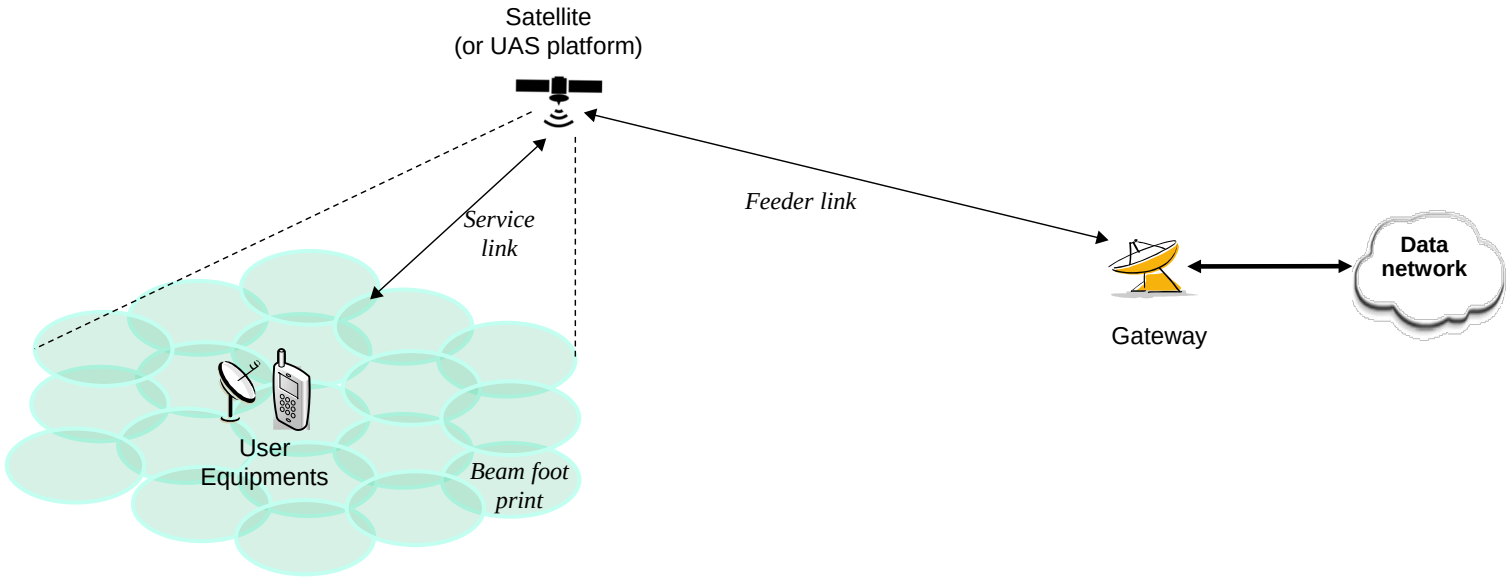
- Satellite Network for 3GPP Wireless **Access**

```
+--------------+   +---------+   +-------------+   +--------+
|    T or      |   |Satellite|   |Mobile Access|   |  WCN/  |
| Local network+---+ Network +---+  Network    +---+  DNN   |
+--------------+   +---------+   +-------------+   +--------+

     End user terminal or local network accesses DNN
     through Satellite Network and Mobile Access Network
```

- Satellite Network for 3GPP Wireless **Backhaul**

```
+--------------+    +-------------+    +---------+    +--------+
|    T or      |    |Mobile Access|    |Satellite|    |  WCN/  |
| Local network+----+  Network    +----+ Network +----+  DNN   |
+--------------+    +-------------+    +---------+    +--------+

     End user terminal or local network accesses DNN
     through Mobile Access Network and then Satellite Network
```

- Satellite as a transparent relay
- No Inter-Satellite-Link (ISL), i.e., so-called ‘bent-pipe’
- No layer-2/layer-3 packet processing, but only layer-1 functionalities like RF filtering, frequency

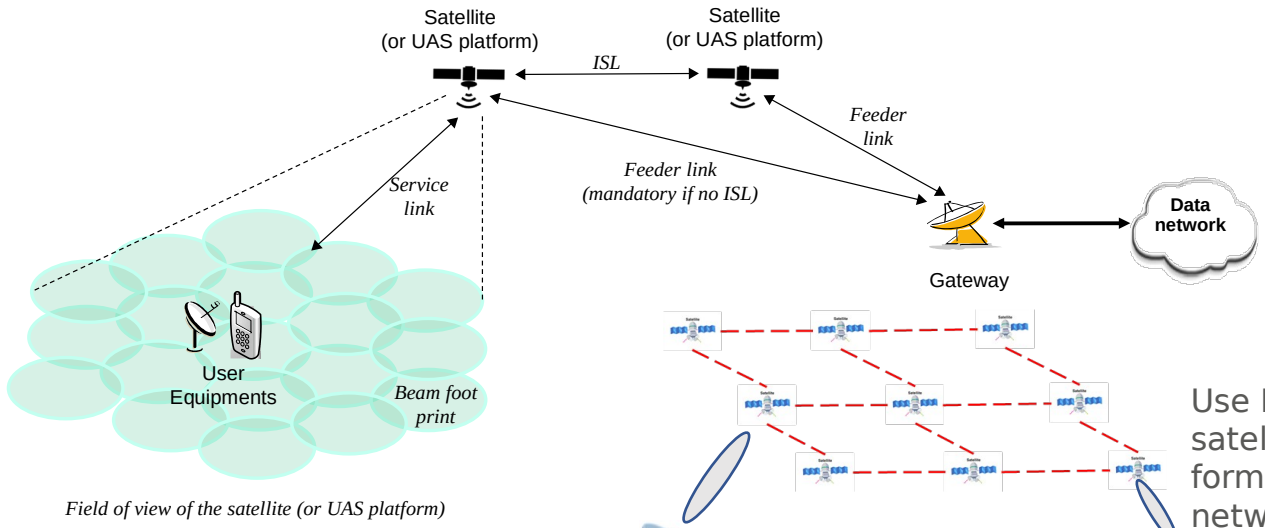


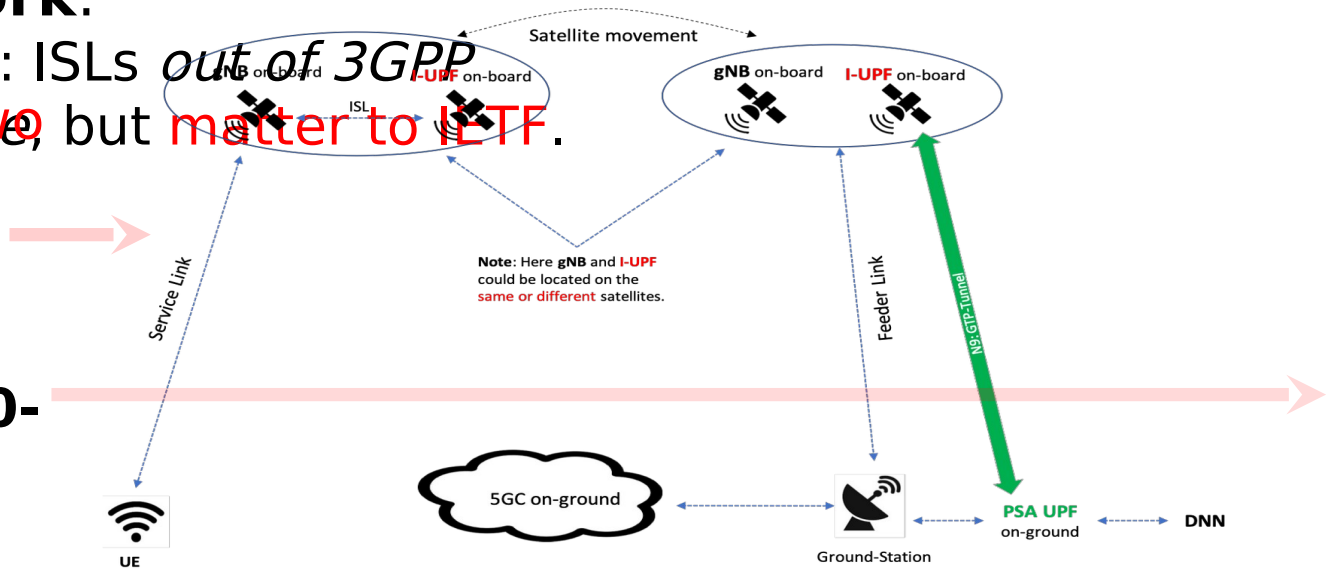
Field of view of the satellite (or UAS platform)

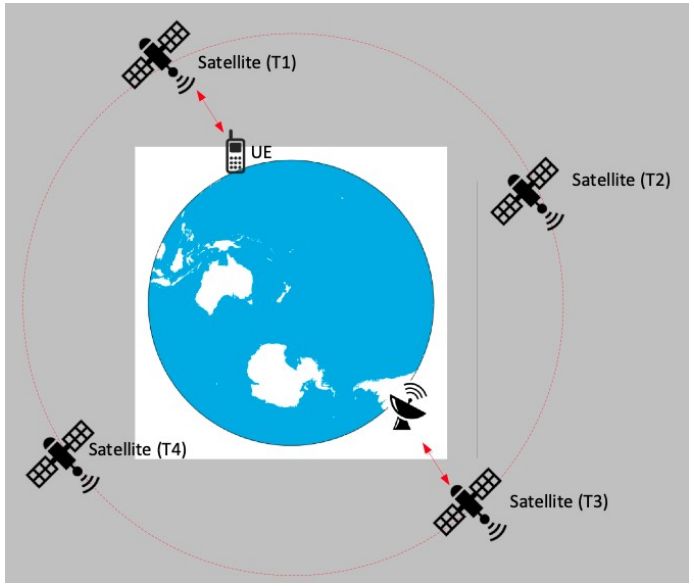
3GPP Rel-19 Satellite w/ Regenerative Forwarding (~March 2025)

- Satellite w/ regenerative payload (gNB on-board)
- Multi-satellites with Inter-Satellite-Links (ISLs)
- High-layer functionalities:
  - Packet processing, L2 or L3 networking, Large scale networking
- Criticalness of **ISLs** & **SAT-Network**:
  - Note: ISLs *out of 3GPP scope*, but matter to IETF.

* These two scenarios selected from the 3GPP SA2: TR **23.700-29**







eolocation Shifting of Satellite after One-round

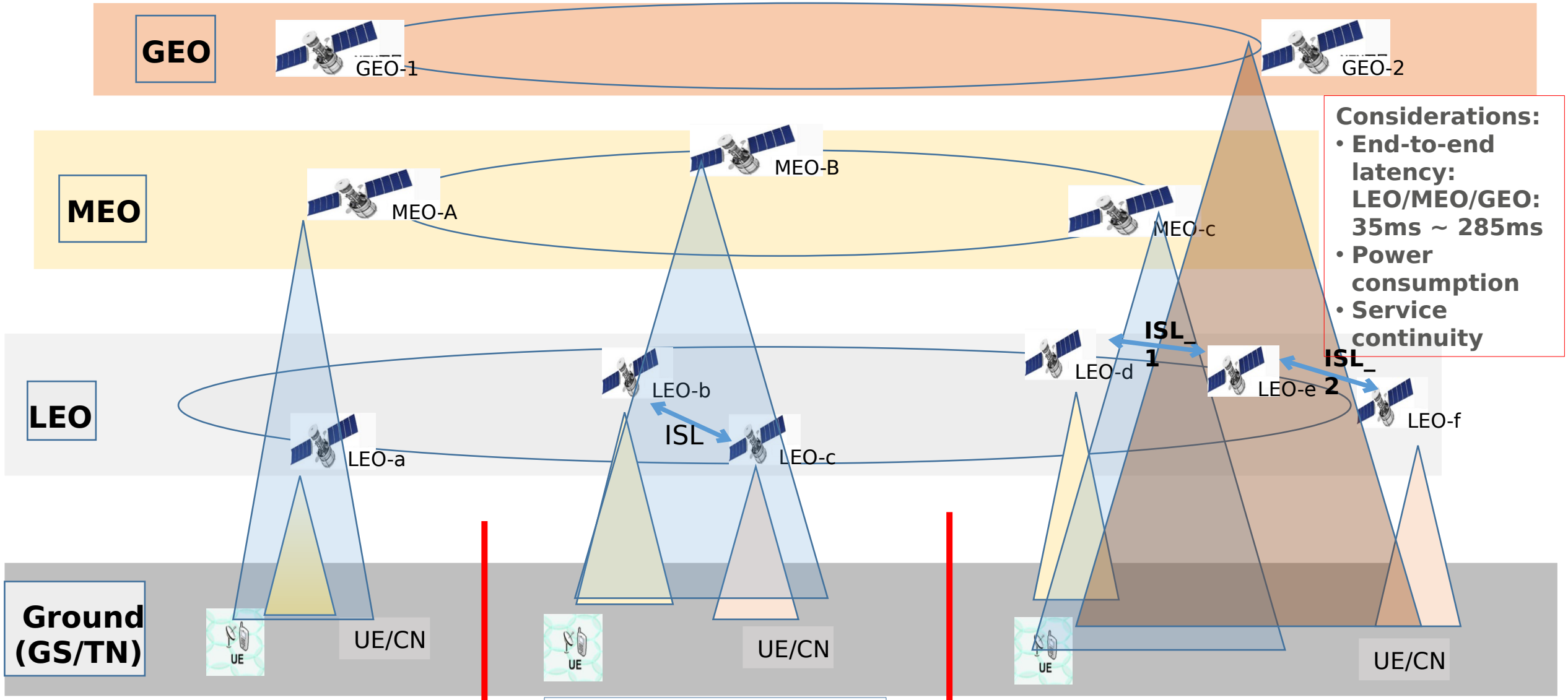
- Earth self-rotating at approximately 460 meters/sec at the equator
- Assuming a LEO satellite could rotate the Earth one-round in 95 mins (may depend on the satellite's rotation track):

```
Shift-distance on Earth = Earth-self-rotation-speed * Self-rotation-period
```

- Then, we have, 460 m/s * (95 mins * 60 sec/min) ~ 2600 KM.
- Indicating the geolocation-shifting at the equator (relative to Earth) after one round could be more than 2000 Km.
- This significant shifting is way beyond the coverage of a **RAN on-board** (i.e., regenerative) a LEO satellite.
- **Conclusion**:
    - A Satellite constellation network w/ inter-satellite links (or ISLs) is the necessary solution

* *Routing in Satellite Networks: Challenges & Considerations, draft-lj-rtgwg-sat-routing-consideration.*

Rel-20: Multi-orbit satellite access for service continuity (On-going



Scenario#1: UE – UE/CN covered by a single LEO and also

Scenario#2: UE – UE/CN Not-covered by a single LEO, but covered

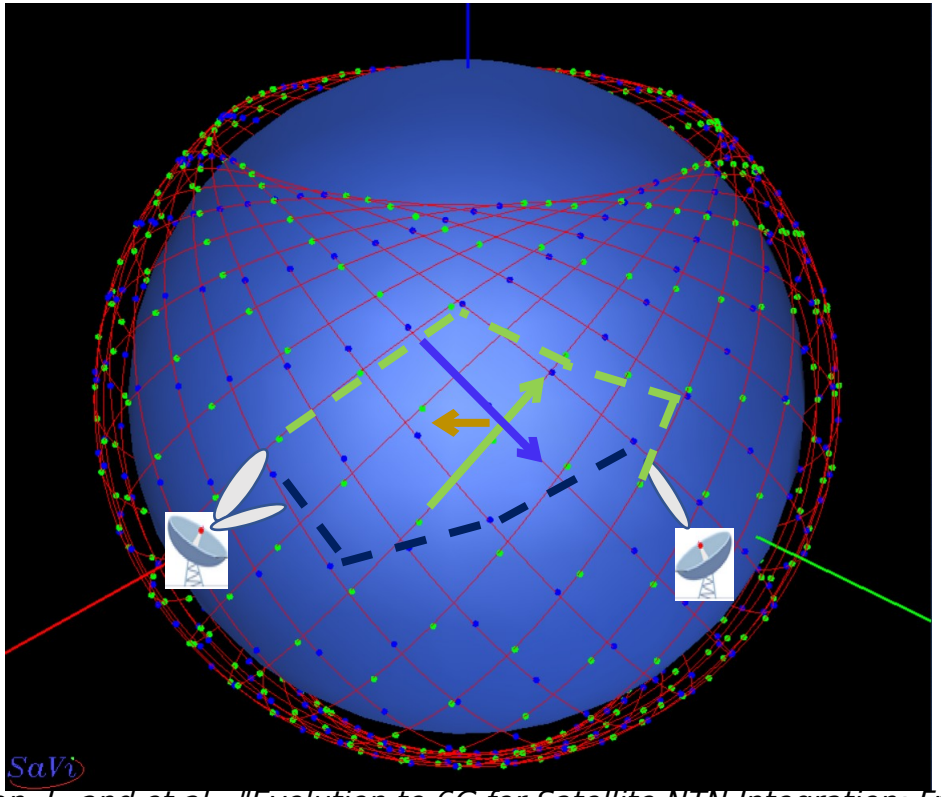
Scenario#3: UE – UE/CN Not-covered by a single LEO, nor covered by a single MEO, but

ulti-orbit SAT-Networks: Problems & Challenges

- **Challenge #1: The very dynamics of routing topology**
  - Dynamics between (on-ground) routing nodes and satellites: changing neighborship and varied distance (impacting ‘link cost’ associated with a routing protocol)
  - Dynamics among satellite nodes: Fast-moving satellites, on the same/opposite/angled directions, trigger the intermittent peering relationship.
- **Challenge #2: The limited bandwidth of peering links**
  - links between peering satellites and between satellites and ground-stations or (on-ground) MEs renders fairly limited link bandwidth (BW)
  - Data from field case-1: measured UL/DL rate via a GEO satellite only @ 10 Kbps
  - Data from field case-2: LEO at the orbit height 550 Km - measured rate UL @ 5 Mbps, DL @ 1 Mbps and ISLs @ 230 Mbps.
- **Challenge #3: The HW limitation & reduced capabilities**
  - Harsh & challenging environment: temperature, near-vacuum, radiation, etc.
  - Expensive to carry load upon rocket launch
  - RedCap HW to fulfill intra- and inter- satellite routing
- **Challenges:**
  - link-quality/cost, routing convergence, LSP exchange, LSDB sync-up, computational load, IGP/BGP advertise/withdraw, etc.

Satellite-Routing: Uniqueness, Considerations

- **Uniqueness**
  - Predictable & pre-determined satellite ‘footprint’ (i.e., trajectory, velocity, etc.)
  - Ephemeris: height, inclination, azimuth, time-changed track, etc.
  - Use case: (5G) ‘Predictable’ SAT-based QoS probing optimization for dynamic backhaul service
- **Routing Considerations for Multi-orbit SAT Network:**
  1. No full-set routing intelligence on-board satellites
  2. Adoption of layered routing structure: TN vs. NTN
     - A traditional routing scheme running for the 'overlay’ Terrestrial Network or TN, and
     - A novel switching scheme operating exclusively for the 'underlay’ Non-Terrestrial Network or NTN
  3. Impact of the ‘multi-orbit’ objective:
     - Different roles of LEO/MEO/GEO may impact the topology design and routing-logic selection.
  4. Simplified traffic forwarding logics on-board satellites via ‘predictable’ info.



Han, L. and et al., "Evolution to 6G for Satellite NTN Integration: From Networking Perspective", https://qualitativesemantic.wordpress.com/, Oc 2023.

Summary

- Use cases & evolutions from 3GPP:
  - 3GPP Rel-18: Satellite as **transparent** relay
  - 3GPP Rel-19: Satellite with **regenerative** forwarding
  - 3GPP Rel-20: **Multi-orbit** satellite access for service continuity

- Criticalness of SAT-network & ISL:
  - E.g., Geolocation Shifting of Satellite after One-round

- SAT-Routing: Problems, Challenges, Uniqueness, and Considerations
  - Problems & challenges
  - Uniqueness – predictable & pre-determined (e.g., Ephemeris)
  - Multi-orbit routing Considerations

Next step

- Any feedback from the community.
- Any motivation to continue this topic.

Thank you!