3GPP SA Satellite Use Cases: Update, Progress, Challenges & Routing Consideration

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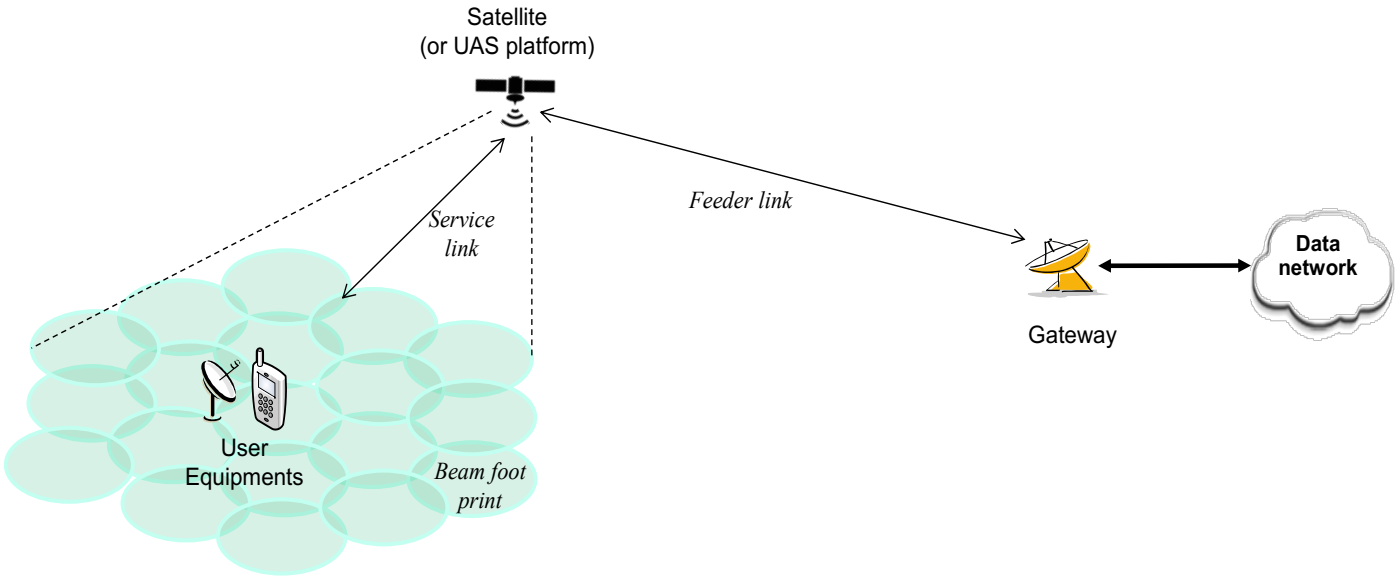
3GPP ‘Transparent’ Payload (Rel-18, Stage-2 Freeze by June 2023)

- Satellite constellation network being the infrastructure for wireless access and backhaul, it provides the gNB, front haul and back haul transport functionalities.
- Satellite w/ transparent payload
- No Inter-Satellite-Link (ISL), or so-called ‘bent-pipe’
- No packet processing, but layer-1 functionalities like RF filtering, frequency conversion, etc.



Field of view of the satellite (or UAS platform)

1. Satellite Network for 3GPP Wireless **Access**

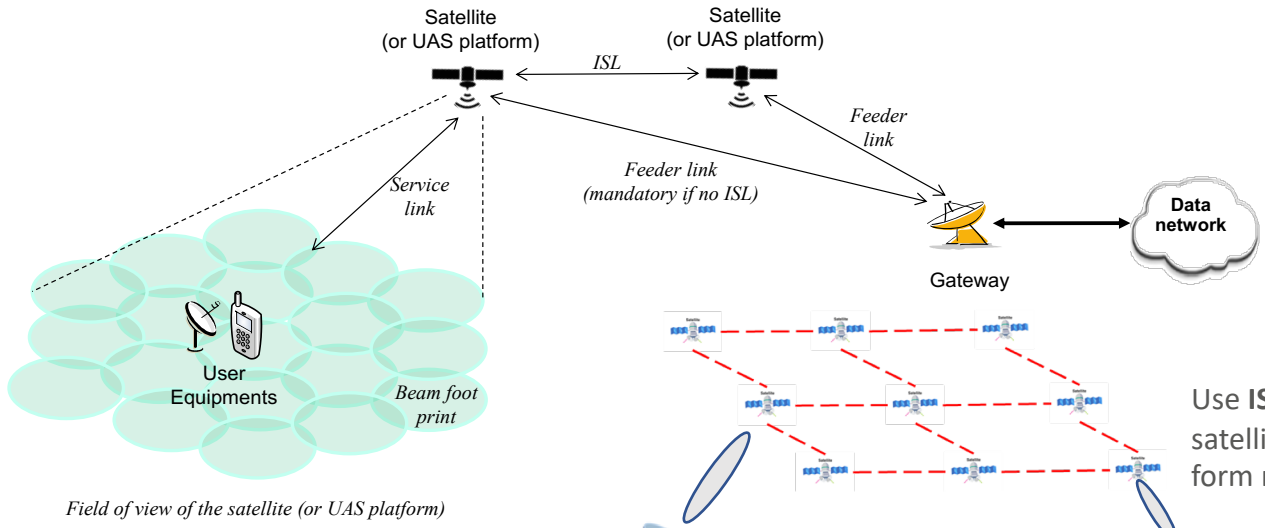
```
+--------------+   +---------+   +--------------+   +--------+
|    T or      |   |Satellite|   |Mobile Access|   |  WCN/  |
| Local network+---+ Network +---+  Network    +---+  DNN   |
+--------------+   +---------+   +--------------+   +--------+

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

2. Satellite Network for 3GPP Wireless **Backhaul**

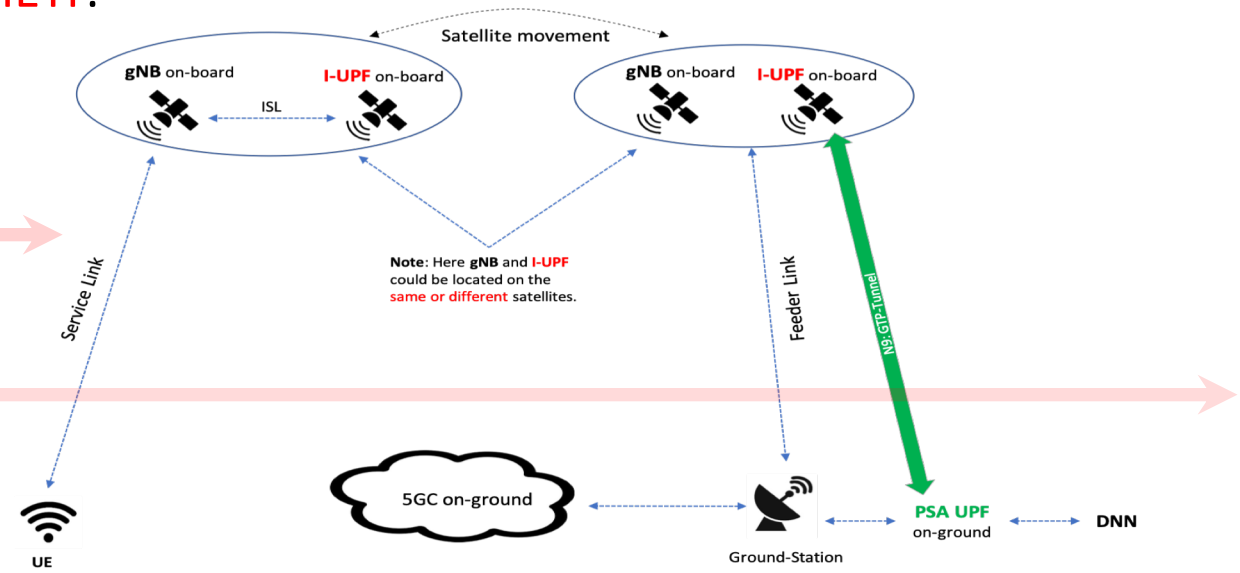
```
+--------------+    +-------------+    +---------+    +--------+
|    T or      |    |Mobile Access|    |Satellite|    |  WCN/  |
| Local network+----+  Network    +----+ Network +----+  DNN   |
+--------------+    +-------------+    +---------+    +--------+

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

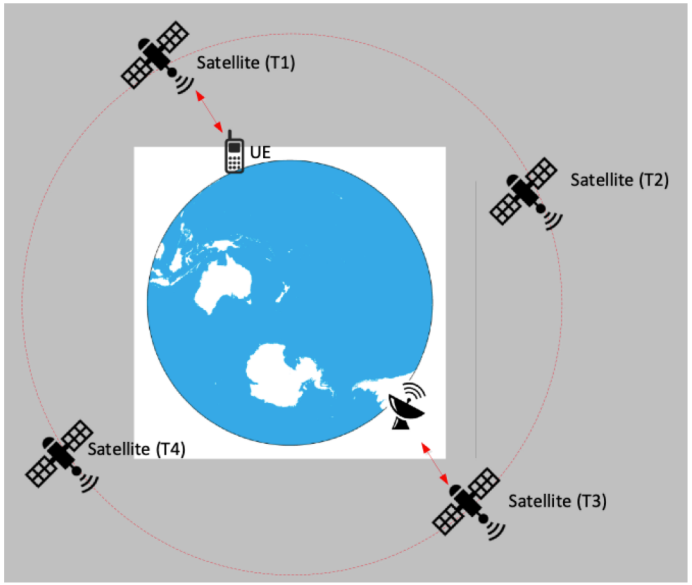
3GPP ‘Regenerative’ mode (Rel-19, SA2 projected to complete by Dec. 2024)

- 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
- Challenges & the **criticalness of ISLs**
  - Note: ISLs out of 3GPP scope, but matter to IETF.



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





Geolocation Shifting of Satellite after One-round

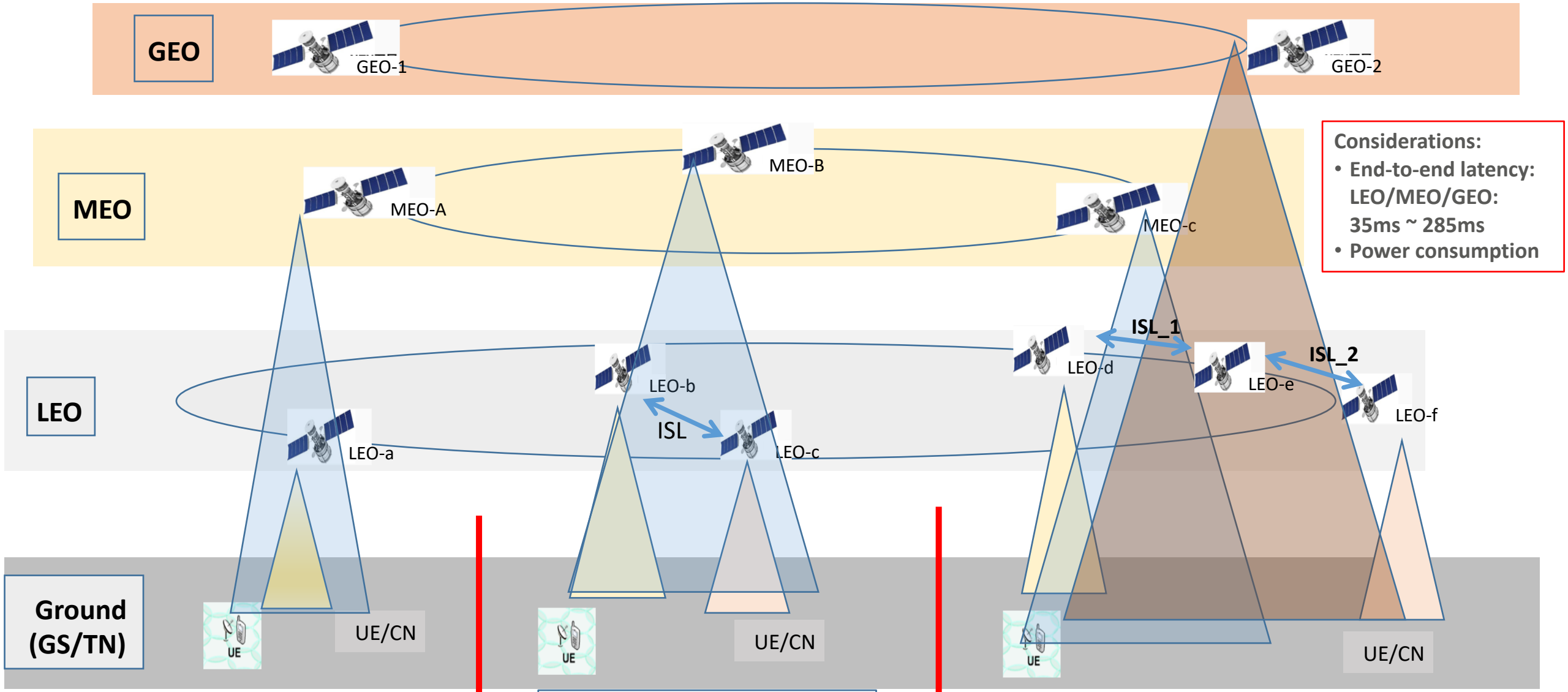
- Earth self-rotating at approximately 460 meters/sec at the equator
- Assuming a LEO satellite could rotate the Earth one-round in 95 mins (may depend on the satellite's rotation track):

```
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**:
  - Multi-satellite deployment with inter-satellite links (or ISLs) is the necessary solution

* "*Routing Consideration for Satellite Constellation Network", draft-jiang-tvr-sat-routing-consideration.*

3GPP Rel-20: Multi-orbit satellite access for service continuity (Stage-1 Study)



Considerations:

- **End-to-end latency: LEO/MEO/GEO: 35ms ~ 285ms**
- **Power consumption**

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

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

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

SAT-Routing: Restrictions & Challenges

- **Restriction#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.
- **Restriction#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.
- **Restriction#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.

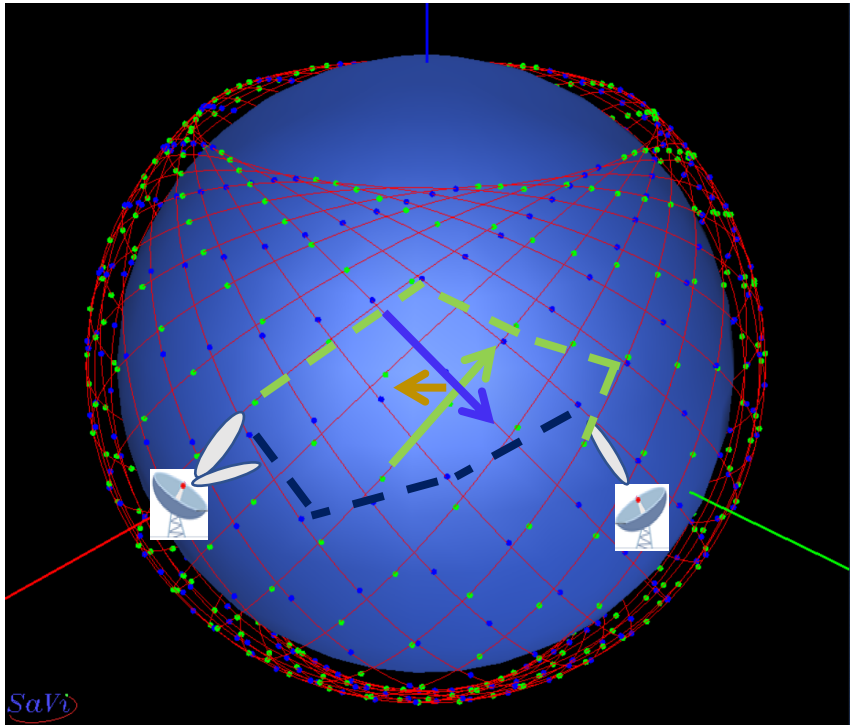
* "*Routing Consideration for Satellite Constellation Network", draft-jiang-tvr-sat-routing-consideration.*

SAT-Routing: Uniqueness, Design Considerations & Algorithmic Considerations

- **Uniqueness**
  - The trajectory and velocity of a satellite (‘footprint’) are predictable and can be pre-determined
  - Ephemeris: height, inclination, azimuth, time-changed track, etc.
  - 5G case: ‘Predictable’ SAT-based QoS probing optimization for dynamic backhaul service

- **Potential Design Considerations**
  1. No full-set routing intelligence on-board satellites
  2. Simplified traffic forwarding logics on-board satellites via ‘predictable’ info.
  3. Hierarchical routing structure
     - 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

- **Algorithmic Considerations**



Example*
- Shell
- Track
- index

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

Summary

- 3GPP scenarios & evolutions:
  - 3GPP ‘transparent’ payload (Rel-18)
  - 3GPP ‘regenerative’ challenges (Rel-19)
  - 3GPP ‘multi-orbit’ satellite access (Rel-20)

- Necessity of ISL: Geolocation Shifting of Satellite after One-round

- SAT-Routing: Restrictions & Challenges
  - Uniqueness - ‘predictable’ via Ephemeris
  - Potential design & Algorithmic Considerations