Routing Consideration for Satellite Constellation Network

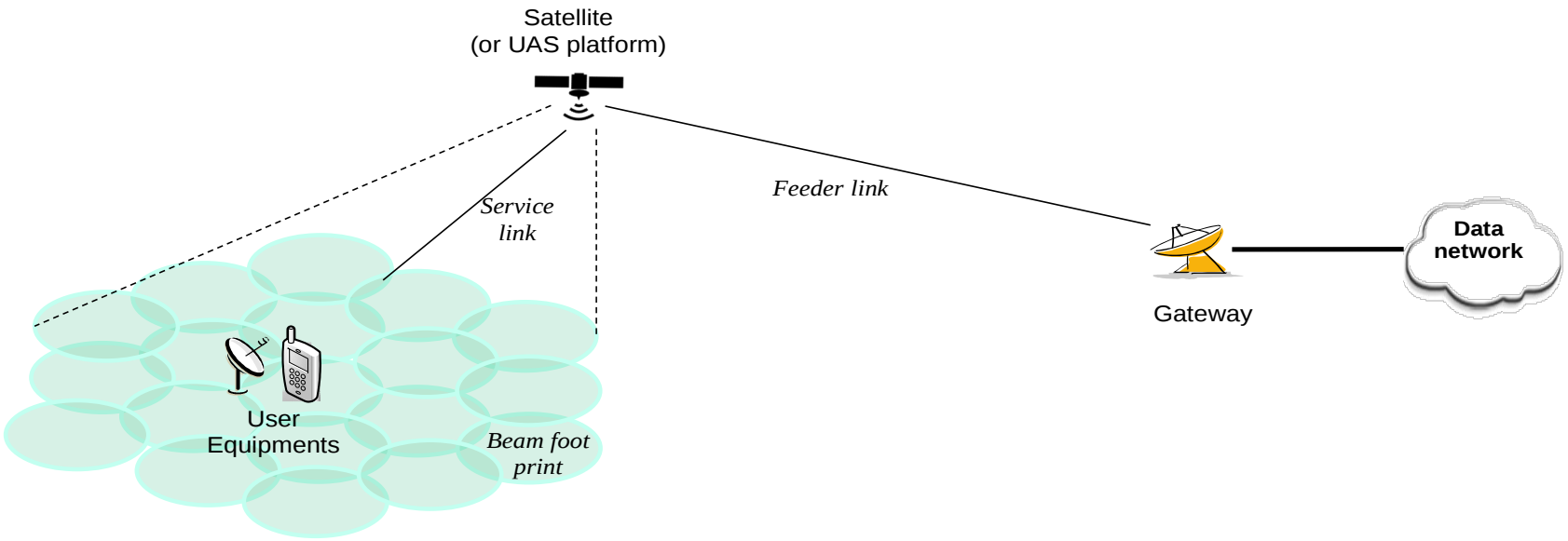
(draft-jiang-tvr-sat-routing-consideration-00)

Tianji Jiang, Peng Liu, Huaimo Chen

@IETF 119 (Brisbane, QLD, Australia)

Use Cases: Triggers from 3GPP (Rel-18)

- Satellite 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)



Field of view of the satellite (or UAS platform)

Satellite Network for 3GPP Wireless **Access**

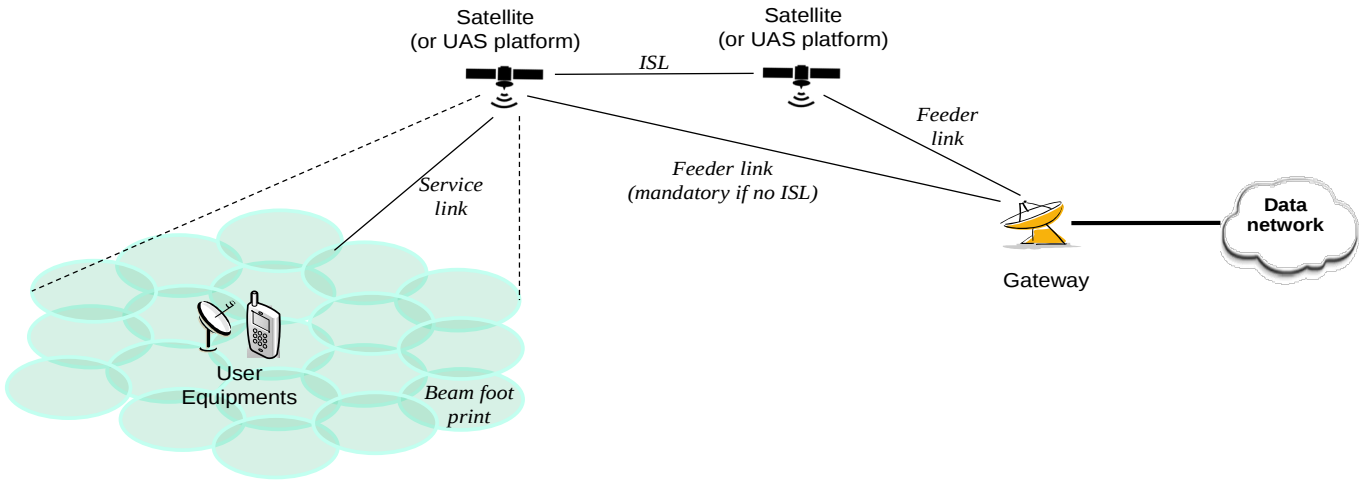
```
+--------------+   +---------+   +--------------+   +--------+
|    T or      |   |Satellite|   |Mobile Access|   |Internet|
| Local network+---+ Network +---+  Network    +---+        |
+--------------+   +---------+   +--------------+   +--------+

     End user terminal or local network access Internet
     through Satellite Network and Mobile Access Network
```

Satellite Network for 3GPP Wireless **Backhaul**

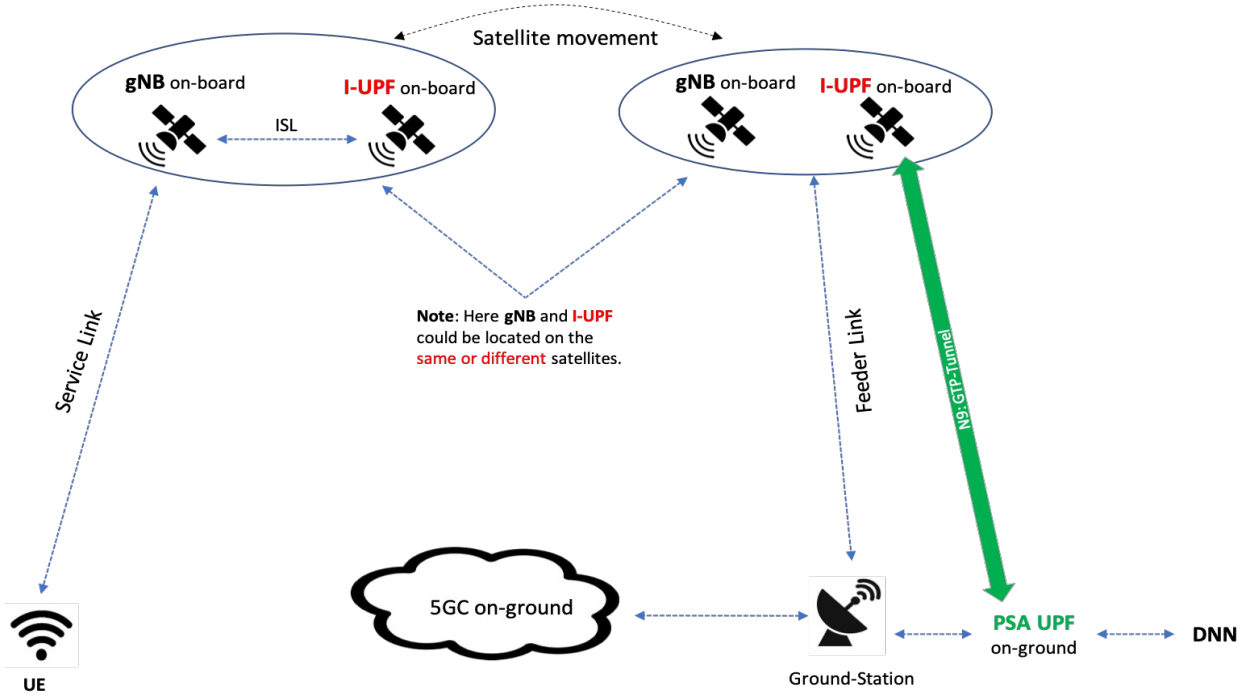
```
+--------------+    +--------------+    +---------+    +--------+
|    T or      |    |Mobile Access|    |Satellite|    |Internet|
| Local network+----+  Network    +----+ Network +----+        |
+--------------+    +--------------+    +---------+    +--------+

     End user terminal or local network access Internet
     through Mobile Access Network and then Satellite Network
```

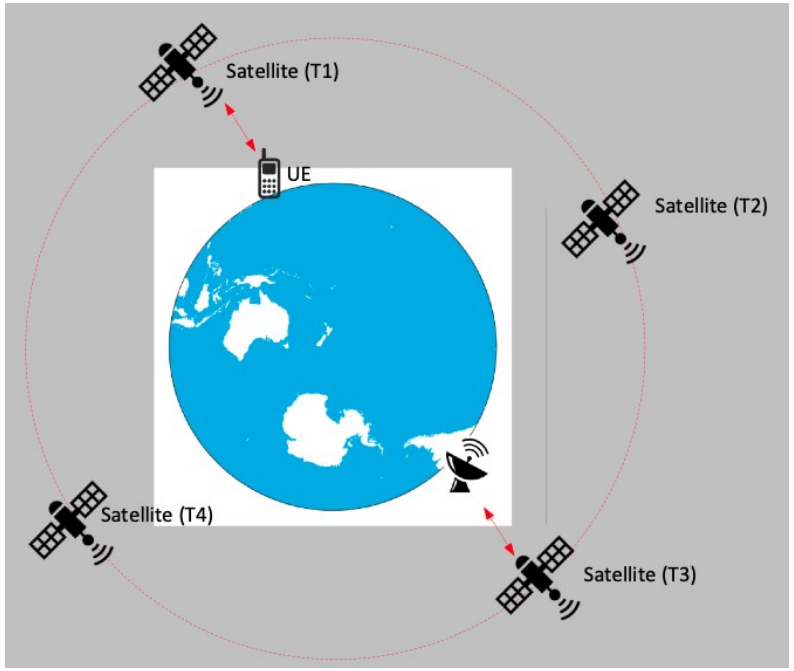
Use Cases: Challenges from 3GPP (Rel-19)

- Satellite w/ regenerative payload (gNB on-board)
- Multi-satellites with Inter-Satellite-Links (ISLs)
- A new (Rel-19) use case, i.e., *store & forward*, posts challenges & raises the **criticalness of ISLs**



Field of view of the satellite (or UAS platform)





**Picture borrowed from 3GPP SA2 document: S2-2400985*

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

SAT-Routing: Restrictions & Challenges

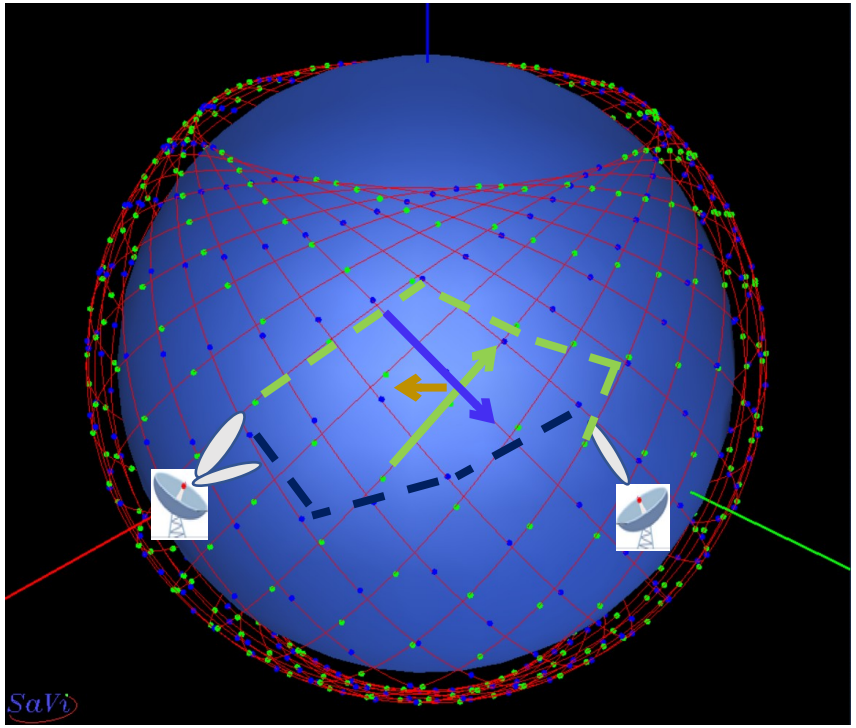
- **Restriction#1: The very dynamics of routing topology**
  - Dynamics between (on-ground) routing nodes and satellites: changing neighborship and varied distance (impacting ‘link cost’ associated with a routing protocol)
  - Dynamics among satellite nodes: Fast-moving satellites, on the same/opposite/angled 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.

SAT-Routing: Uniqueness, Design Principles & 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

- **Design Principles**
  1. No full-set routing intelligence on satellites
  2. Simplified traffic forwarding logics on-board satellites
  3. Adoption of layered routing structure, e.g., 2-layer routing
     - 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 & Next Steps

- Use Cases:
  - Triggers from 3GPP (Rel-18)
  - Challenges from 3GPP (Rel-19)
- Necessity of ISL: Geolocation Shifting of Satellite after One-round
- SAT-Routing Considerations:
  - Restrictions & Challenges
  - Uniqueness - ‘predictable’ via Ephemeris
  - Design Principles & Algorithmic Considerations
- Further expand & refine

Comments ?