Routing Consideration for Satellite Constellation Network

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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)

Satellite Network for 3GPP Wireless **Access**

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

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|    |Satellite|    |
| 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
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):

  \[
  \text{Shift-distance on Earth} = \text{Earth-self-rotation-speed} \times \text{Self-rotation-period}
  \]

- 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**

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 ?