A Routing Architecture for Satellite Networks

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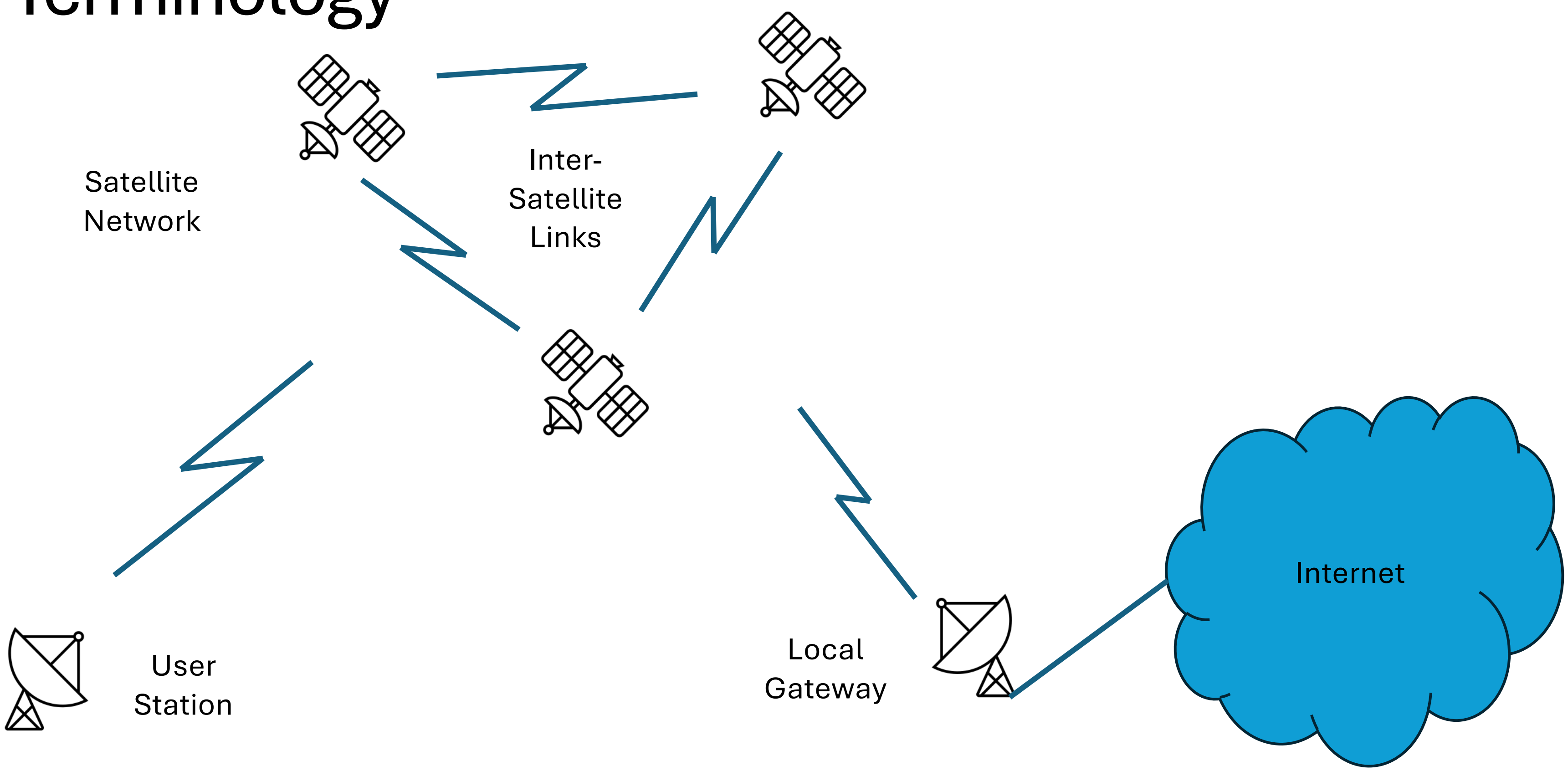
Disclaimers

- This is a work in progress, please pardon the dust.
- This is an engineering talk. Sorry, no pretty pictures.
- I'm a routing guy; if I get satellite stuff wrong, please be gentle.
- There's many ways to solve this problem, this is only one.
- No satellite operators were harmed as a part of this work.
- Please feel free to interrupt, this is a discussion.

Terminology



Issues to be addressed

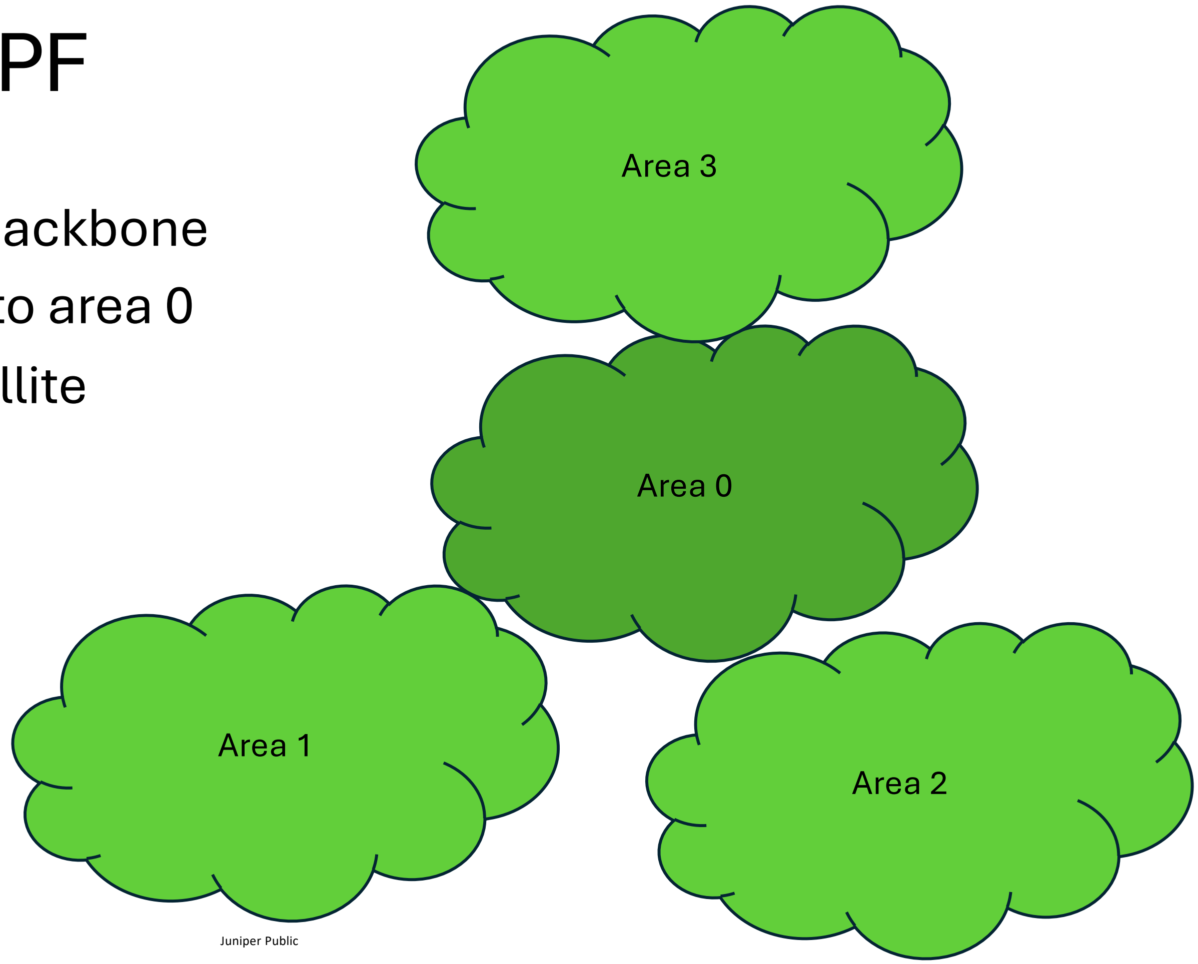
- Scale
  - Tens of thousands of satellites
  - Hundreds of gateways
- Links will frequently change
  - Uplinks and downlinks are continually changing
  - ISLs are very flaky
- Traffic engineering is a necessity
  - ISLs are a limited resource

Scale

- Hierarchy is the only solution for scalability.
- Link-state IGPs already have a two-level hierarchy.
- Hierarchy also helps contain link change churn.

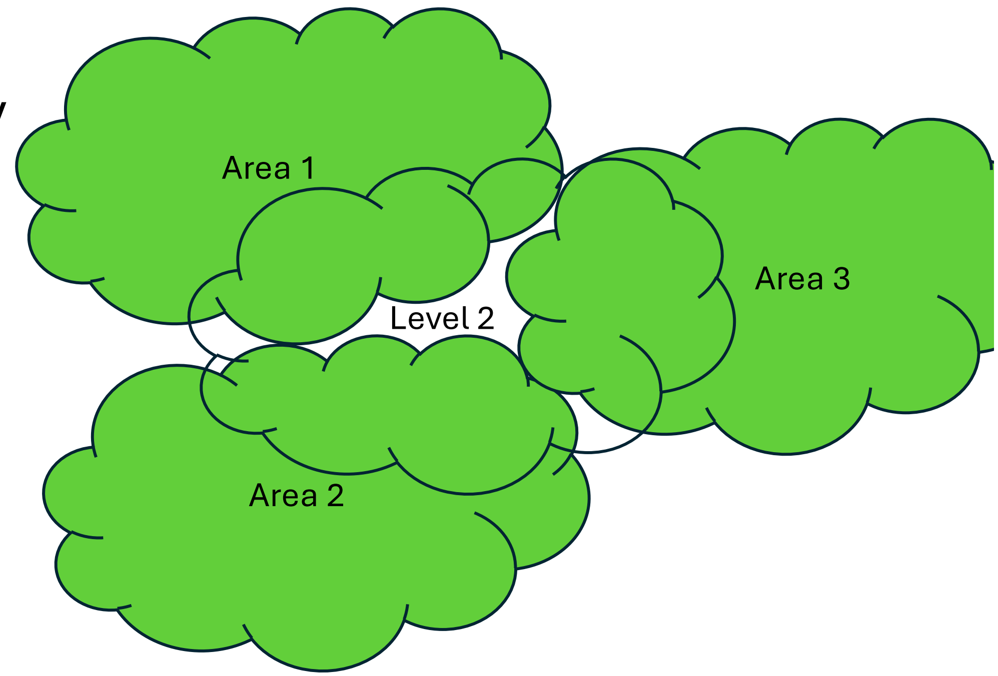
Hierarchy in OSPF

- Area 0 is the central backbone
- All areas are tangent to area 0
- Not a good fit for satellite topologies



Hierarchy in IS-IS

- IS-IS uses a two level hierarchy
- Areas are at level 1
- Level 2 can be a connected subset of all areas
- This allows areas to provide transit for one another
- More flexible: no need for a 'backbone'

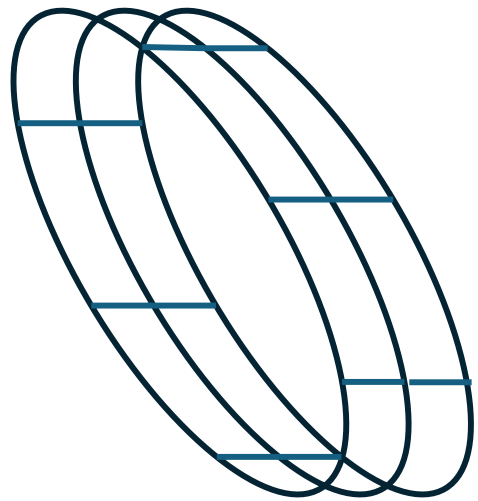


Issue: Area Partition

- If an area partitions, routing falls apart
  - Longstanding problem, no good fix
  - Not problematic in terrestrial deployments
- What about ISLs?
  - Intra-orbit is better than inter-orbit, but still not reliable

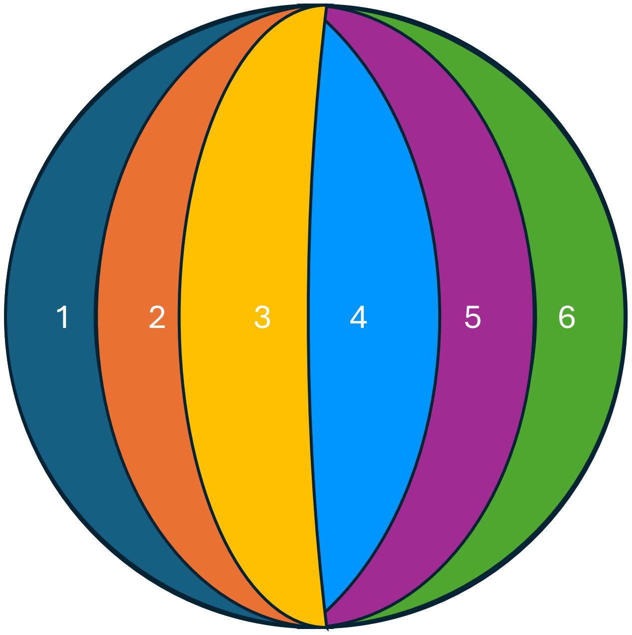
Stripes

- Group adjacent orbits into a 'stripe'
- A stripe is the basis for a level 1 area
- Assumption: for some number of orbits, we can form a stripe and avoid area partition



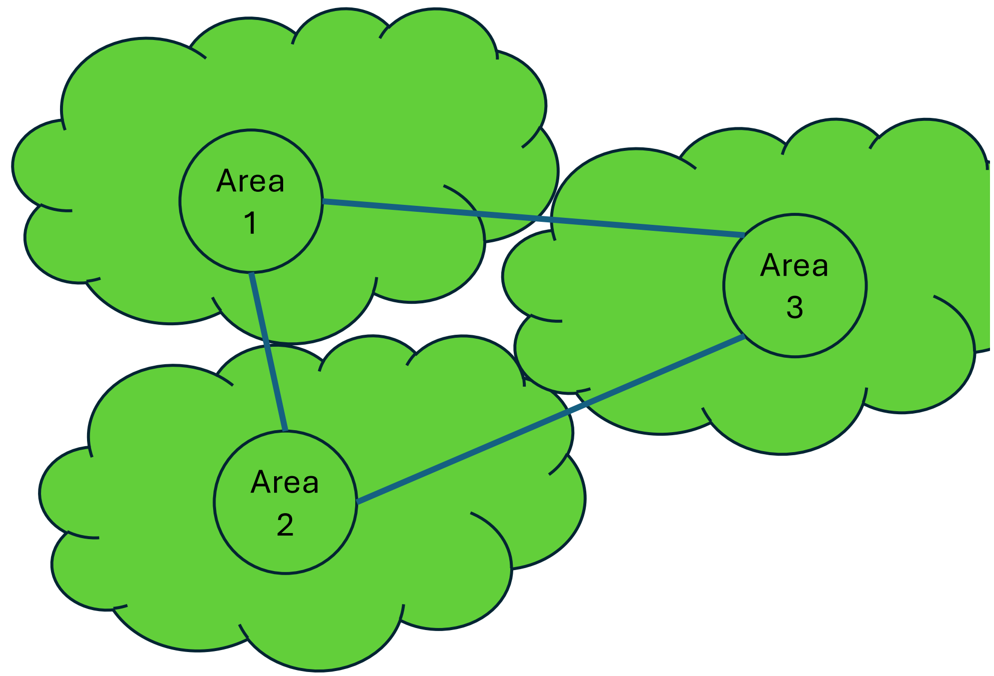
Topology

- Wrap the planet in stripes



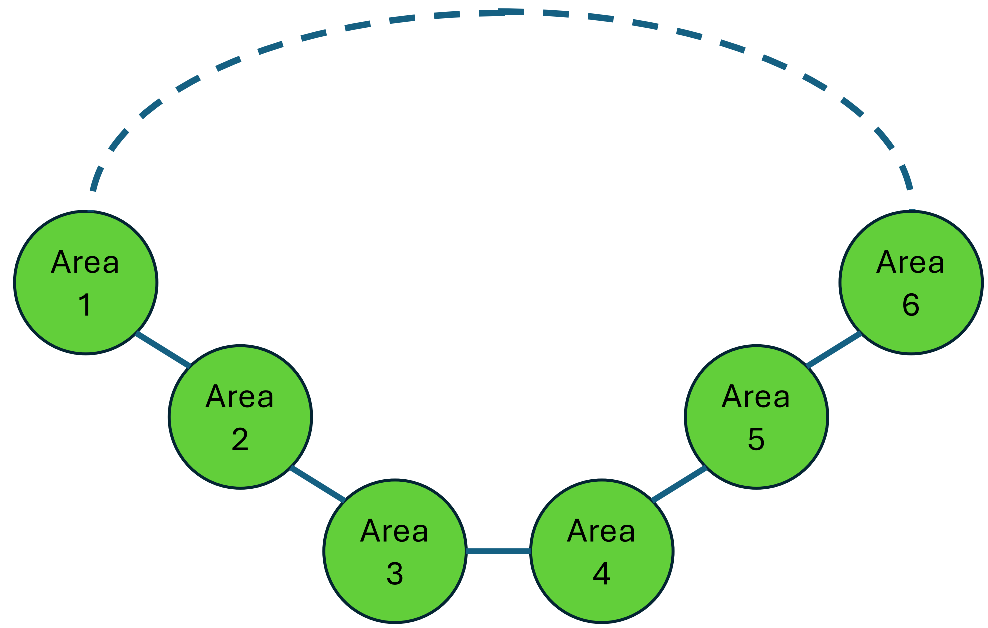
Area Proxy

- New extension to IS-IS
- Allows us to abstract an entire level 1 area as a single node at level 2
- Drastic improvement to scalability



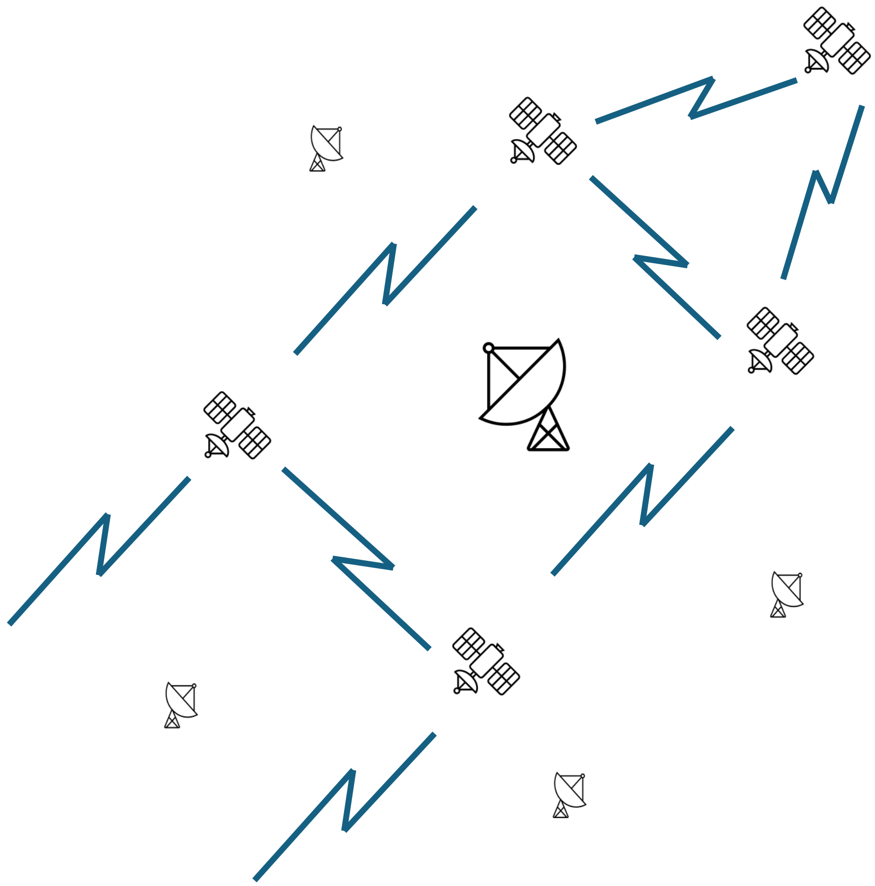
Topology with Area Proxy

- Level 2 routing now scales linearly with the number of areas
- More level 2 connectivity is possible and doesn't affect scalability



Traffic Engineering

- Links are not free
- Network capacity is limited
- Traffic engineering maps demand onto available capacity
- A gateway manages link bandwidth in its region
- For this, Segment Routing (SR-MPLS) seems appropriate

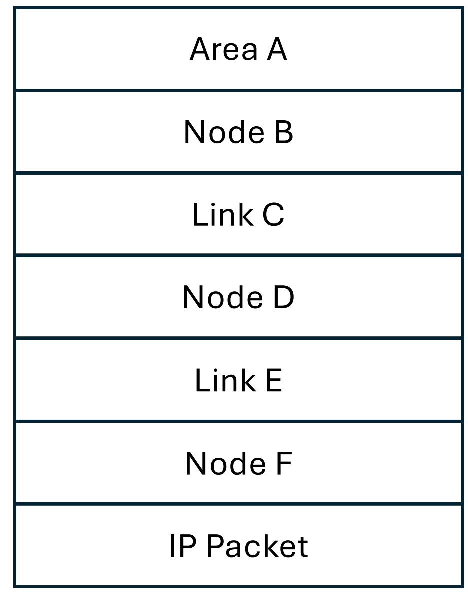


Traffic Engineering Details

- A gateway needs detailed topology information for stripes covering its region
  - Participate in level 1 IS-IS directly
  - Get IS-IS over a tunnel
  - Get topology via BGP-LS
- Monitor traffic to & from each user station to understand demand
- Compute paths per user station to optimize capacity and avoid link congestion
- Well established techniques in terrestrial networks

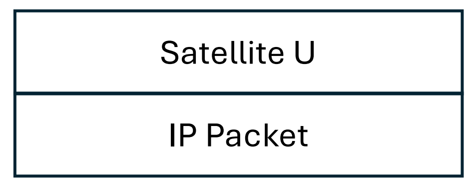
Segment Routing (SR-MPLS)

- Bandwidth management may need an explicit path on each packet
- SR allows us to specify areas (Area SID), nodes (Node SID), and links (Adj SID) on the path
- These turn into labels in the MPLS stack



On-Stripe Forwarding

- Case: user station is within the same stripe as the gateway
- Forward to satellite U for the user station
- Satellite downlinks the packet based on IP destination address
- User station registration with satellite is out of scope
- Add more labels as needed for TE



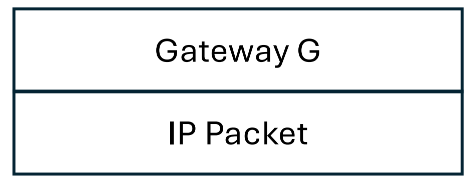
Off-stripe Forwarding

- Case: user station is in a different stripe from the gateway
- Use an Area SID to specify the area

Area A
Satellite U
IP Packet

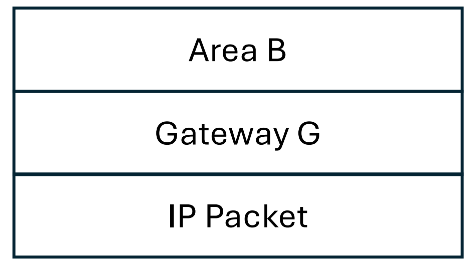
On-stripe Return Forwarding

- Case: user station returning a packet to its gateway
- Assign a node SID to the gateway
- Add TE labels as necessary
- Protocol with the user station is out of scope



Off-Stripe Return Forwarding

- Case: user station returning a packet to its gateway in a different stripe
- Add the area SID for the gateway's area



IP Addressing

- Satellites are not using IP addresses for transit traffic
- User stations are numbered from a prefix assigned by their gateway
- Gateways inject their prefixes into the Internet

- Rekhter's Law: Addressing must align with topology.

- Using MPLS for the forwarding plane finesses this issue: IP addresses are not part of the satellite topology

Summary

- Scalable routing for LEO satellites is not hard
- This approach uses existing off-the shelf, production software
- Scales to very large networks
- Low overhead in the forwarding plane
- Supports IPv4 & IPv6
- Supports full traffic engineering functionality