IETF 126

Towards Standardized Routing for LEO Satellite Networks: A Comparative Study

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Background and Objective

Background

- Current status on IETF
  - Scattered drafts and 3 side meeting
  - No consensus on whether new WG should be formed
  - No standard routing protocol yet
    - RFC9717 - not standard track
    - RFC9657 - TVR use case

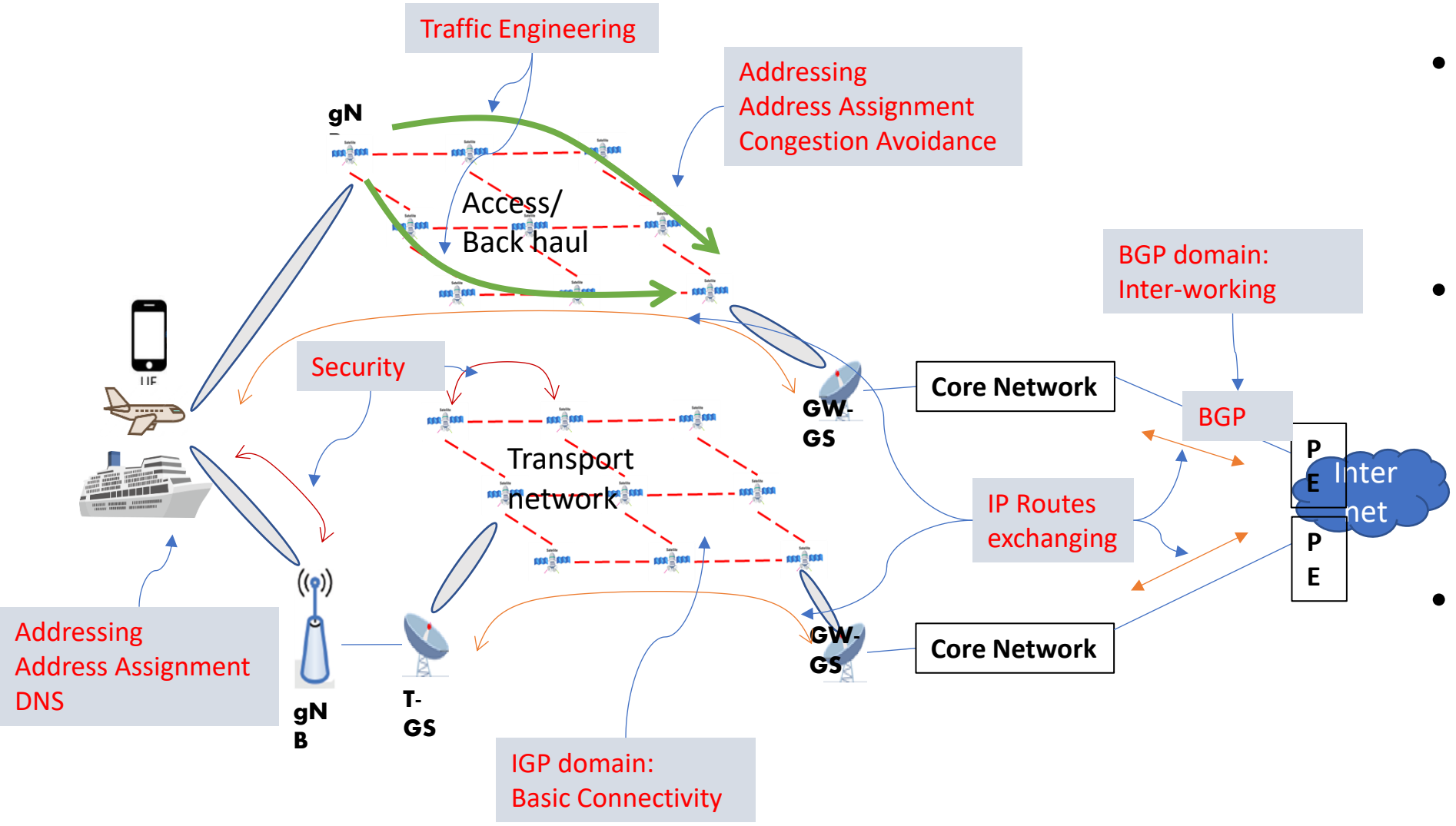
Objective

- Lay down the foundation for LEO satellite network routing
  - Determine which type of routing is the most viable candidate for future standard solution.
  - Determine which areas need to be enhanced/improved/studied.
- Driving Systematic solution

Proposed Solutions Analysis

Categories of Proposals	Pros	Cons
SDN	Easy to control all routers in the covered area	• One SDN controller controls limited area • Multiple SDN controller distributed globally • Synchronization of data plane programming
Reactive Routing	Adapt to dynamic network	• Routing on demand • Forwarding performance is limited by CPU, hard to reach line rate (> 100G bps)
Proactive Routing	Pre-programmed hardware based forwarding, best performance	• Does not fit to dynamic network
Emerging Solution (AI driven)	New way to solve routing issues	• No deployment

Why proactive routing is the most viable candidate



- LEO satellite is a carrier network to provide the wireless access and transport network functions.
- Its performance, scalability and reliability are most important factors to Service Provider. Only Proactive can satisfy such requirement.
- Proactive routing protocols (OSPF, IS-IS) were widely deployed in current Internet and proven to be successful.

For 3GPP 6G (Rel 20) NTN Regenerative Payload, gNB is running on Satellite, Core network runs on ground or other satellites

Current Proactive routing protocol cannot be used directly

- Designed for terrestrial network, relative steady network, LEO satellite network is very dynamic
- Scalability is not enough, ~ k nodes, LEO satellite network has ~10k nodes and millions of devices on ground
- Designed for hierarchy network, access, aggregation and core, LEO satellite network is not hierarchy.

Kept and Enhancements

Kept

- Architecture
  - LSDB
  - Adjacency establishment
  - SPF calculation
  - RT table and FW table
  - LSA flooding
- Messages
  - Hello
  - Some LSA

Enhancements

- Partitioning
- Convergence dependency
- Flooding reduction
- Key optimizations
- Source Routing and data plane

Other Critical Works

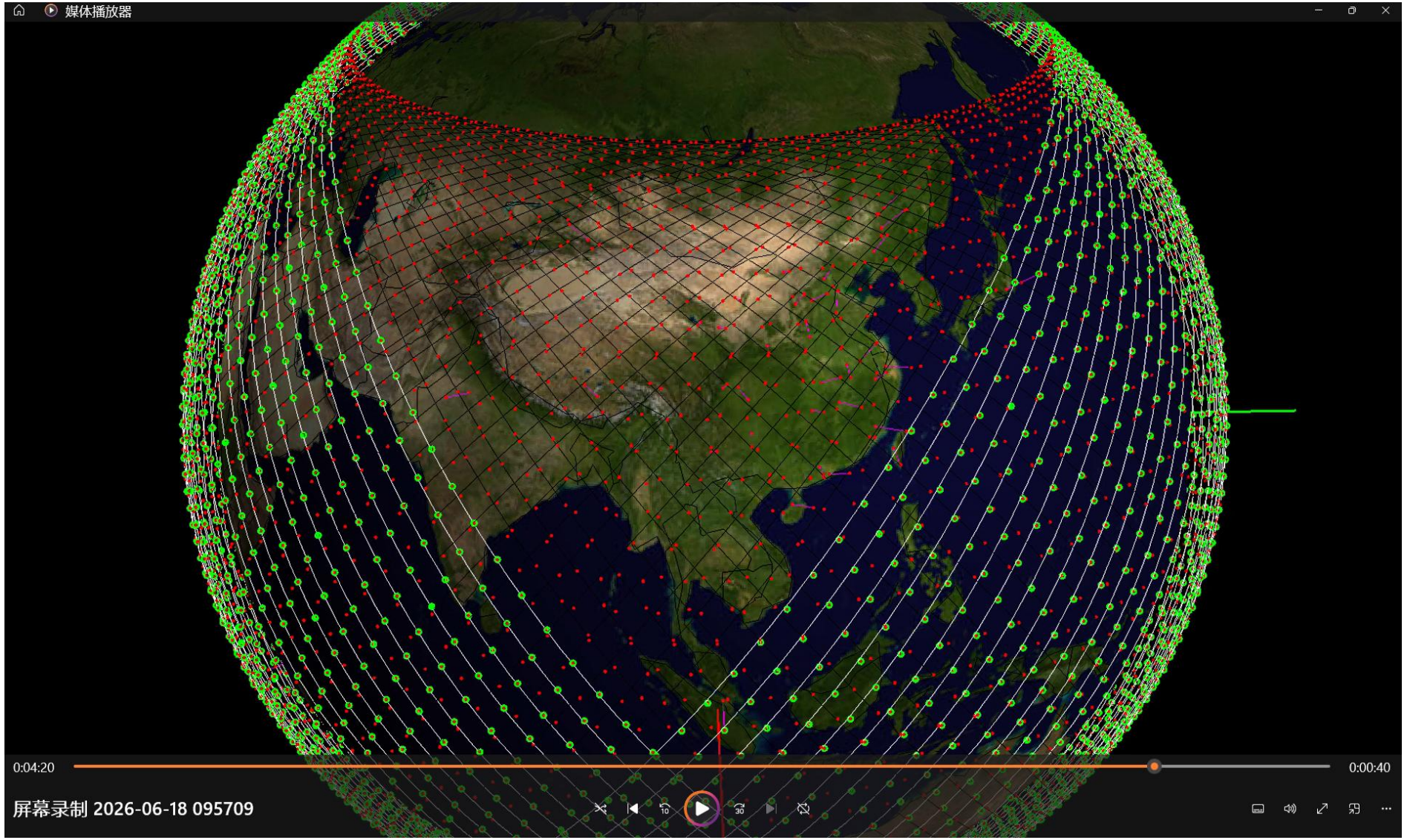
- Satellite Address
- Network state fast detection
- Simulation

Partitioning

- LEO satellite network is a flat network, and not hierarchical structure
  - All satellites are moving and will serve every place on earth, connect to each UE and Ground-station sooner or later
  - All satellites are equally important, provide same functions sooner or later depends on which type of node it connects to
    - connect to UE: gNB functions, forwarding between Satellite and UE
    - connect to GW-GS: forwarding between Satellite and GW-GS (and core function, depends on 3GPP 6g spec.)
    - not connect to UE and GS: forwarding between Satellites.
- Current static “backbone + non-backbone” partitioning:
  - limited improvement on the msg flooding
  - increase the complexity of area switching
    - UE/GS connect to a satellite that will switch between inside and outside of an area continuously.
- Better partitioning method is expected

RFC9717 – existing proposal

- Satellites on certain number of adjacent and continuous orbits form a L1 area, others form L2 areas.
  - Static partitioning based on orbits, UE-SAT and GS-SAT link will switch from L2 to L1 and vice versa frequently:
    - Every day, each UE-SAT/GS-SAT link will move from L2 to L1 twice, from L1 to L2 twice
    - StarLink has ~200 Gateway-GS, it means above link changing area will happen for every about ~108 sec, this does not count the UE-SAT link yet.
  - L1 and L2 area boundary is not as clear as static network, because UE-SAT/GS-SAT link can connect to any satellite inside and outside of an area, this means we cannot get the benefit of area partitioning (some msg exchanging only happens on the boundary network nodes)
  - Satellites moving on different direction (belonging to L2) will move cross the L1 area.
  - If the ISL between satellites moving on different direction are allowed, it means all L1 satellites are on edge, this is no benefit and more complexity for the partitioning.
  - For large scale satellite network, the area is still too big,
    - e.g., 10k LEO, the best partitioning is: 3k L1 area, 3k in two L2 area.
- See the video clip of simulation on next slide



10k satellites
50% (green) in L1 area
50% (red) in L2 area
GS-SAT links (purple)

simulated by modified open source software savi: https://savi.sourceforge.io/

Convergence Dependency

- Hop-by-Hop IP forwarding
  - Any network state change will trigger the re-convergence:
    - LSA flooding->SPF recalculation->RT/FW table update
    - service is interrupted
  - Satellite network is too dynamic
    - ISL distance changes continuously
    - UE-SAT and GS-SAT links only last < 10 mins, then switch
- Reducing Convergence Dependency
  - Source Segment Routing is current proposal, some issues to solve
    - What type of SR: MPLS or SRv6 or others
    - Head overhead: both MPLS and C-SRv6 (16bit SID) are not good enough because there may have over 100 segments for a long path (for 10k LEO network)

Flooding Reduction

- Flooding is necessary for network state population, cannot be eliminated.
- large scale LEO network has too many network state changes

  -> too many flooding -> CPU busy to process -> impact service availability and reliability
- Current proposals
  - Leverage the prediction of LEO position, radio/optical power, for link state
  - Just use limited type of LSA

Address

- Satellite address (and ISL address) should be static – not changing with its geo-position, and the connected gateway ground station.
- What type of address?

Simulation

- Powerful simulation is mandatory for any new proposal
- Expectation:
  - Simulate dynamics over “10k satellites + hundreds of GS + many UE”.
  - Simulate the dynamic state of radio interface of UE-SAT and GS-SAT for over thousands UE and GS.
  - Simulate the dynamic state of ISL links (one sat has > 3 ISL links).
  - Simulate Routing and other protocols
  - Simulate user traffic (sent, lost, received)

Other optimizations

- Adjacency faster state detection
  - Using BFD
  - Integration with lower layer info
- Flooding msg faster processing
  - Bypass the CPU for via flooding msg



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Thank you!

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