IETF 113

Satellite Network –
Problems and Solutions From L3 Perspective

draft-lhan-problems-requirements-satellite-net-02
draft-lhan-satellite-semantic-addressing-01
draft-lhan-satellite-instructive-routing-00
draft-retana-lsr-ospf-monitor-node-00

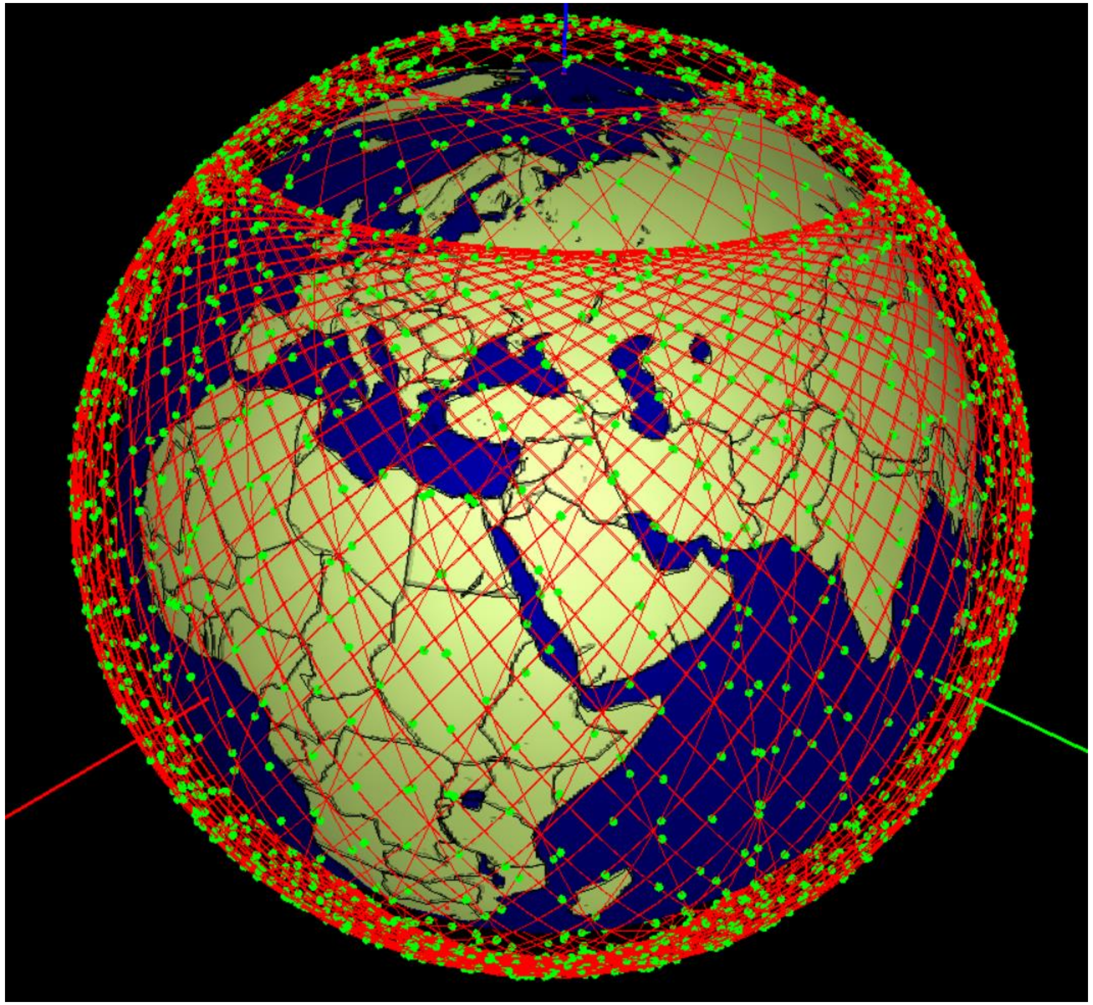
L. Han; A. Retana; R. Li (Futurewei Technologies, Inc. U.S.A)

M. Chen; L. Su (China Mobile, China)

N. Wang (Univ. of Surrey, U.K.)

Objectives of works

- Explore the open solutions (L3 layer) for Large scale LEO constellation for Internet access and NTN Integration
  - LEO/VLEOs, couple of k or over 10K, over million Ground-stations.
  - Inter-satellite-link (ISL) is used to connect satellites;
  - Global Coverage
  - Regenerative Mode (3GPP TR38.821)
    - IP is the infrastructure for NTN integration with 5G
- What we do/expect
  - Basic IP technologies for satellite network
  - Informational/experiment drafts.
  - Feedback from WG
  - This presentation does no cover all solutions. More drafts in future
- What we will not do
  - 3GPP related territories – wireless related protocols.



StarLink phase 1: https://en.wikipedia.org/wiki/Starlink
5 layers, 4396 satellites, finish by 2027, now: 1584

Problems

- For more explanation, See: Satellite Network Problem Workshop
  - Answers for collected questions in IETF meeting and mail discussions
  - 3GPP NR-RAN requirement for satellite network
  - Simulations for Mobility, Links, Path
- draft-lhan-problems-requirements-satellite-net-02
  - Add co-authors
  - Add use case for mobile access network integrated with satellite network (sec. 6)

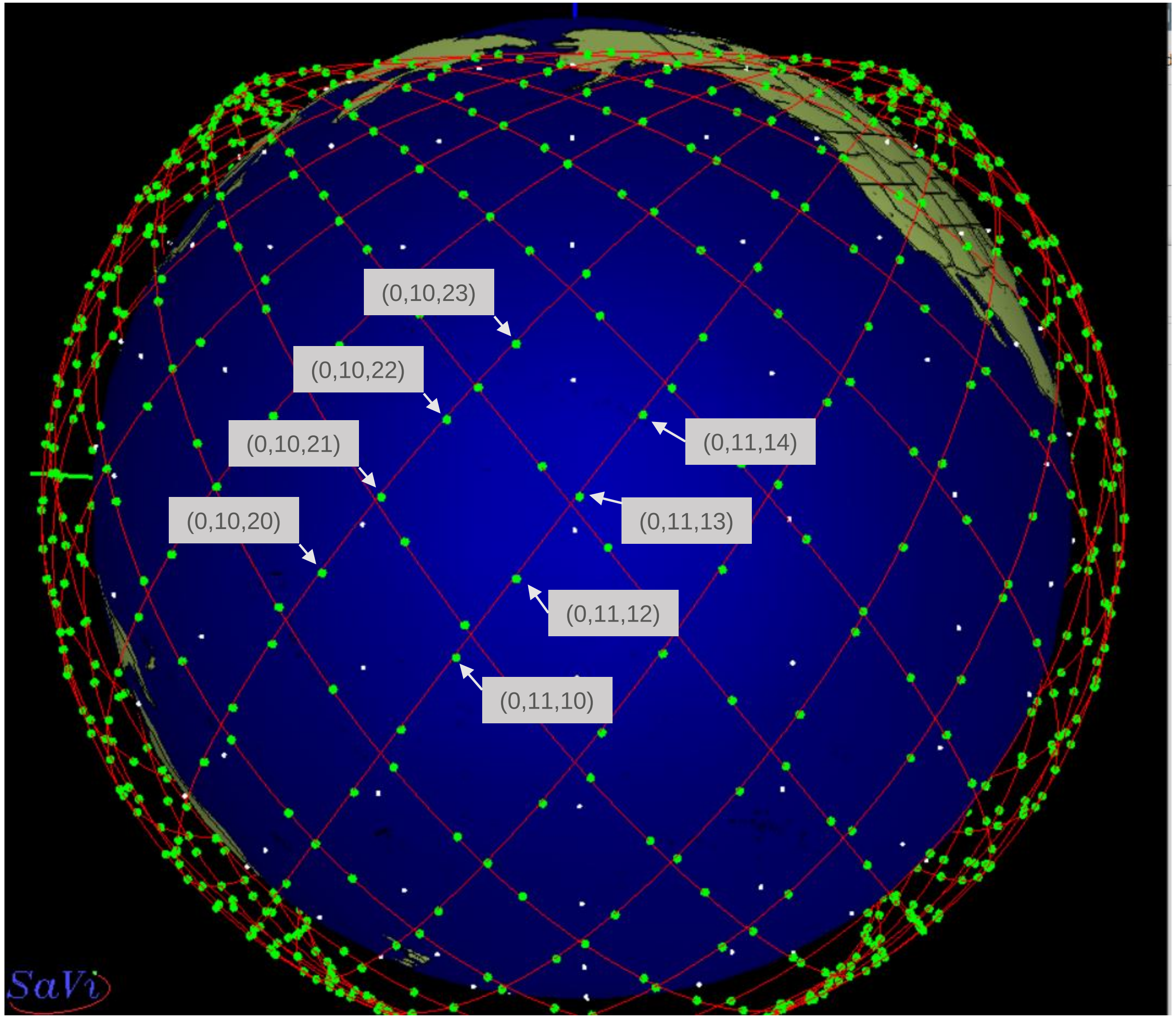
Semantic Address and update

- Satellite network
  - Multiple layer
  - Each layer is interleaved grid network
- Satellite can be identified by a new defined satellite address:

  (Shell_index, OrbitPlane_index, Satellite_index)

  Which layer — Which orbit plane — Which sat in orbit plane

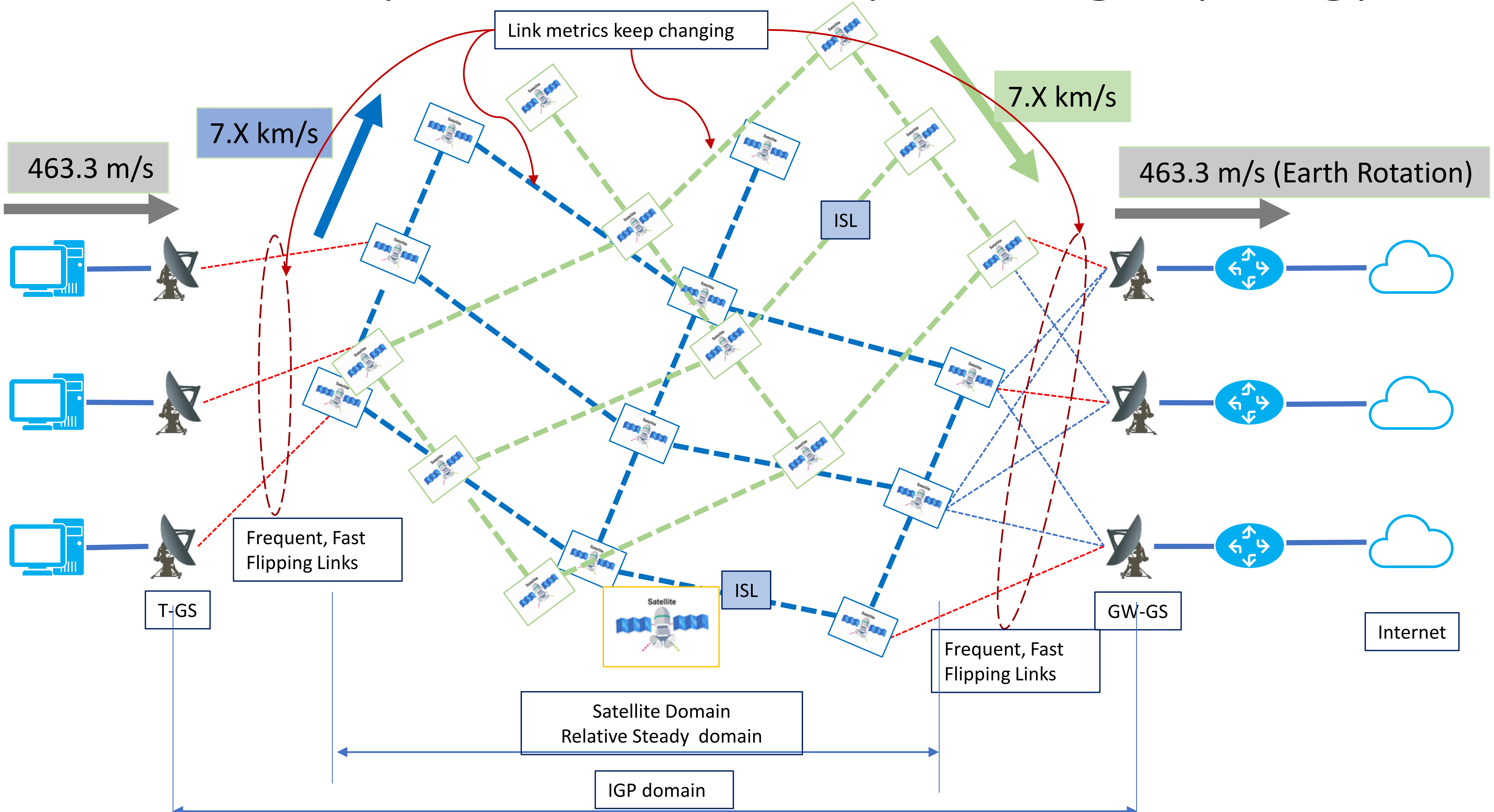
- Update for the latest version:
  - draft-lhan-satellite-semantic-addressing-01
  - Add co-authors
  - Add “32-bit Semantic Satellite Address” for sec. 5.4



draft-lhan-satellite-instructive-routing-00

- Purpose
  - Routing solution for satellite network
- Why
  - Current distributed routing mechanism (IGP/BGP) facing challenges
    - Constant Sat-GS link flipping (about every ~5mins)
    - Constant Link Metric changing (ISL links between adjacent satellites moving on the same direction)
    - Constant un-steady link flipping (ISL links between adjacent satellites moving on the different directions)
    - Possible link interruption at polar areas (ISL links between adjacent satellites moving on the same direction)
    - All above cause huge IGP protocol msg flooding, and reduce the service time dramatically.

Review: Complicated and Fastly Moving Topology



Review: Problem when using IGP for Satellite Network

- But we have critical Issues when using traditional IGP (OSPF) for satellite network
  - The number of (Sat, GS) links are huge, (i.e., > 1m for StarLink)
  - The (Sat, GS) links will flip in about 5 to 10 min (for LEOs with ~500km altitude). This cause the huge number of LSA flooding to whole network.
  - Math:
    - The number of (Sat, GS) links are the order of O(u), u is the total number of users using satellite network
    - For whole network, the frequency of link flipping (up and down) -> O(u)/T (T is the average life time of the links)
    - For a typical LEO constellation, It is about 1m/5min->3000 times/second, too much OSPF flooding info (Router LSA, Network LSA, Link LSA, etc) will be triggered.
  - Network usability dramatically reduced and not acceptable:

$$Network\ usability\ = 1 - \frac{routing\ re{-}convergency\ duration}{each\ satellite\ service\ duration} < 20\%$$

(“Internet in Space” for Terrestrial Users via Cyber-Physical Convergence, ***HotNets '21: Proceedings of the Twentieth ACM Workshop on Hot Topics in Networks***)

Special characteristics of satellite network

- Satellite network is a carrier network for Internet access and NTN integration with 5G (3gpp TR38.821, regenerative payload)
  - Satellite network (with ISL) is a transport network
  - Transporting traffic between ground-stations or satellite and ground-stations
- LEO Satellite constellation network has well ordered topology even it is extremely dynamic
  - Multiple-layer of grid networks, even interleaved and moving to different directions
  - Limited number of ISL
  - Self-explained Semantic address can be used to identify each satellite
- Satellite position is predictable (with time changes) when its orbit element is known
  - All satellite adjacency
  - All ISL Link metrics can be estimated (in space environment) without measurement

Principals for Hybrid Solution

- Maximize the usage of computation in routing to reduce the messaging from distributed protocols
  - Dynamic Network topology
  - Dynamic Link Metrics
  - Prediction of Satellite-to-Ground-station links
- Borrow the current IGP for satellite network topology and state detection
  - Isolate the extreme un-stable links: draft-retana-lsr-ospf-monitor-node-00
    - ISL Link state and network monitoring
  - More drafts for other purpose
- Utilize the special characteristics of satellite network
  - Semantic address: draft-lhan-satellite-semantic-addressing-01
    - Self-explained Semantic address
    - Limited forwarding directions
- Minimize the Routing overhead in control plane and data plane
  - Instructive routing: draft-lhan-satellite-instructive-routing
    - Use instruction lists instead of segments
    - Use semantic address to compress the instruction

Instructive routing Example

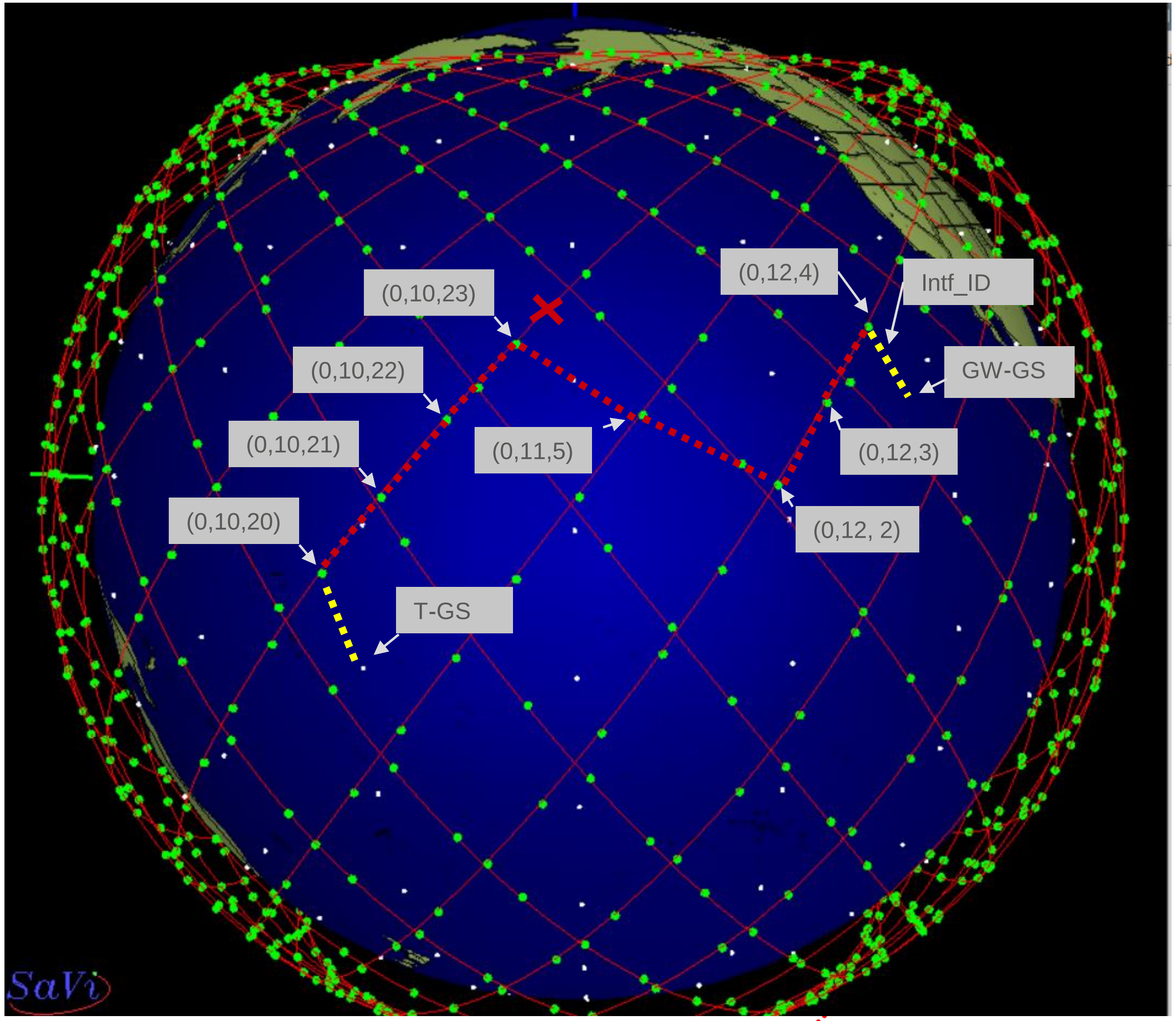
- Satellite address is described as
  (Shell_index, OrbitPlane_index, Satellite_index)
- Path calculation for T-GS to GW-GS will give the list of IP next hop:
  T-GS->Sat(0,10,20)-> Sat(0,10,21)-> Sat(0,10,22)-> Sat(0,10,23)-> Sat(0,11,5)-> Sat(0,12,2)-> Sat(0,12,3)-> Sat(0,12,4)->GW-GS
- The path can be compressed as:
  T-GS->Sat(0,10,23)-> Sat(0,12,2)-> Sat(0,12,4) ->GW-GS
- The converted instruction list:
  - Fwd.Inc.Sat_ID, 0x17
  - Fwd.Inc.Obp_ID, 0xC
  - Fwd.Inc.Sat_ID, 0x4
  - End.Intf_ID

Sat_ID = 23

Obp_ID = 12

Sat_ID = 4

Argument = Intf_IF



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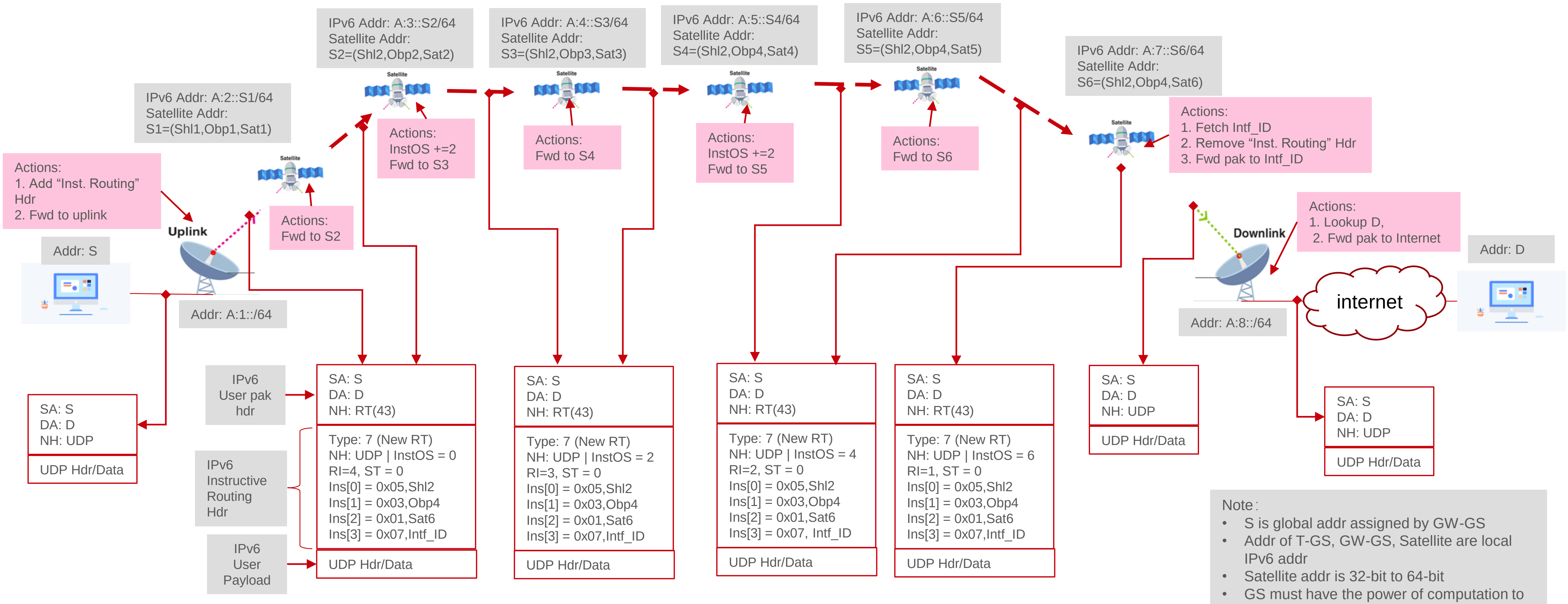
IPv6 Instructive Routing for Satellite – Tunnel-less solution
Packet Format and Actions



Note :
- S is global addr assigned by GW-GS
- Addr of T-GS, GW-GS, Satellite are local IPv6 addr
- Satellite addr is 32-bit to 64-bit
- GS must have the power of computation to compute the time varied positions of all satellites and distance to ground-stations after the time, the orbit parameters of satellites and the coordinates of ground-station are given

Summary of Instructive routing

- Fitting to the special requirement of satellite network
- Dramatically reduce the distributed protocol messaging that will be triggered by frequent changes in link state/link metrics
- Eliminate the population of huge number of Internet prefix and SRv6 SID
- Dramatically reduce the TCAM usage
- Less overhead for packet size compared with SRv6 or tunneling,
  - Overhead: (num of segments + 1) *2 octets
  - For regular satellite network without ISL broken, very limited number of segments
- Dramatically reduce the ISL link bandwidth consumption for control purpose.

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Q&A

Comments? lhan@futurewei.com