LEO satellite networking-
An Infrastructure for Future Internet

For IETF114-HotRFC

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NTN Integration – Future Internet, Global Access with higher bandwidth and shorter latency

LEO satellite network (with ISL) is key infra due to its lowest altitude
- Shorter Latency
- Higher Bandwidth
- Lower global coverage cost
- Lower Launching cost
- Lower Operation/management cost
- Lower power requirement for communication for both satellite and ground
- Lower Ground station and UE cost

As of 2021, 37% population cannot access Internet

Shorter latency from LEO satellite network:
Mark Handley, University College London, “Delay is Not an Option: Low Latency Routing in Space”

LEO satellite dynamics – Challenging the current IP networking technologies

- LEO satellites move at ~7.x km/s with ~100min period
- 50% satellites move on different direction with another 50% satellites and form a dynamic interleaved network
- Earth is self-rotating at ~463m/s

- links between satellites and ground station (GS) will flip every ~5min for LEO satellites (~550 km altitude), distance keeps changing
- One satellite has multiple GS connected
- One GS has multiple satellites connected
- Huge number of Sat-GS links (> million)

- ISL distance for satellites on adjacent orbits keep changing
- ISL direction swaps on polar areas

Simulation is by savi: https://savi.sourceforge.io/
IETF works for Satellite

History and Current Work

• IP over Satellite Links (ipsat) WG: IP over GEO, closed for unknown reason, and no output.

• Delay/Disruption Tolerant Networking (DTN WG): for GEO and interplanetary communication, not fitting for LEO (due to short delay, less tolerance for disruption)

• L4 work
  ➢ TCP Over Satellite (TCPSAT WG)
  ➢ RFC2488, RFC2760,

• Network Coding for Satellite System: RFC8975

• SATCOM side meeting on IETF111

• Current drafts related to satellite network not belonging to any existing WG:
  ➢ draft-li-istn-addressing-requirement
  ➢ draft-jliu-istn-savi-requirement
  ➢ draft-lai-bmwg-istn-methodology
  ➢ draft-lhan-problems-requirements-satellite-net
  ➢ draft-retana-lsr-ospf-monitor-node
  ➢ draft-lhan-satellite-semantic-addressing
  ➢ draft-lhan-satellite-instructive-routing
  ➢ draft-kw-rtgwg-satellite-rtg-add-challanges-00

IP networking for LEO?

• Why L3 networking is needed (more to see back up slides)
  • Large scale network with over 10k nodes and million links
  • Interworking with other networks in Internet
  • 3GPP expected satellite network as part of wireless access or back haul, must support IP and 5G functions (i.e, UPF distribution in satellites)

• Problems for current IP networking for LEO
  • Addressing
  • Routing
  • Traffic Engineering
  • Multi-path
  • Mobility
  • ....
What next

• We will have side meeting at IETF 115 (London)
• Reach out to me lin.han@futurewei.com or send to etosat@ietf.org, if you want to present something in the side meeting; or want to discuss details; or want to collaborate.

Thanks
Backup Slides

• LEO satellite network evolution
• Examples of LEO satellite network in service or in research
• 3GPP works for satellite network, IP networking is fundamental for the perspective of 3GPP NTN integration.
### LEO Satellite network evolution

#### Before
- Expensive
- Using GSO technologies
- Transparent Payload (Bent pipe)
- No ISL
- LEO Satellite only does L1 work
- Few satellites

#### Current (5G)
- More LEO satellites launched
- Transparent and Regenerative Payload
- ISL in experiment
- LEO Satellite does L2 work
- Small scale of LEO satellite network (ISL used)

#### Future (5G-adv, 6G)
- Regenerative Payload
- ISL widely used
- Satellites are network nodes connected by ISL,
- Satellites can provide most of functions of terrestrial network, i.e: gNB, routing, UPF, NV, etc.
- LEO Satellite network integrated with terrestrial network, HAPS, MEO, GSO
- Vertical applications on satellites
Example: StarLink

- Private technologies
- Started to test ISL for polar area users (https://www.connectivity.technology/2022/02/laser-inter-satellite-links-lisis-in.html)
Example: Tiansuan Constellation (天算星座)

- open satellite research platform, total 330 LEO satellites (two launched)
- Experiment the advanced technologies for 5G and beyond

Figures are from above paper
Example: Application for LEO satellites – Edge Computing in Space

EDGE COMPUTING IN SPACE ALLIANCE
https://ecsa.space/
• AI/ML SOLUTIONS FOR SPACE INDUSTRY
• UPGRADEABLE SATELLITES
• DATACENTERS IN ORBIT
• BUSINESS INTELLIGENCE FROM SPACE

https://www.mdpi.com/1424-8220/19/20/4375
# 3GPP: Historical and current works

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3GPP: Two typical use case and variations for LEO satellite network

LEO satellite network as 5G Access Network
- gNB on satellite
- DU and CU can be separated on satellite and ground respectively
- CN can be completely or partially (i.e., UPF) on satellite
- Radio: Based on 5G NR for Ku, Ka band
- Architecture: SBA with enhancements
- Satellite network:
  - IP network to support 5G functions and interworking with other network in Internet

LEO satellite network as 5G Back haul
- gNB on ground
- CN can be completely or partially (i.e., UPF) on satellite
- Radio: 5G NR or other technologies
- Satellite network:
  - If want to support 5G functions and interworking with other networks in Internet, must be IP network
3GPP (TR38.821) : Satellite-based NG-RAN architectures, gNB on satellite

- Satellite with regenerative payload (gNB on board, with and without ISL)

![Diagram of satellite-based NG-RAN architectures]

- Control plane and user plane stack

![Diagram of control plane and user plane stack]

- IP networking is key requirements for infrastructure
3GPP (TR38.821) : Satellite-based NG-RAN architectures, gNB-DU and gNB-CU separated

- Satellite with regenerative payload (gNB-DU on board, gNB-CU on ground)

- IP networking is key requirements for infrastructure
- Higher requirement for IP in bandwidth and latency
Three Key Items
KI#1: QoS control enhancements for dynamic satellite backhauling
KI#2: Support of Satellite Edge Computing via UPF on board
KI#3: Support of Local Data Switching via UPF on board

• IP networking is the fundamental requirements for above support