Protocols in ***S p a c e***

Discussed Topics

- **How do we integrate satellite networks with the Internet?**
- **Is the end-to-end principle enough or do we need to think in terms of segments?**
- **What are the problems with the transport protocols used today?**
- Do we benefit from compute/storage in the satellite network?
- How do we route packets?
- What falls apart when we go into deep space?

How do we integrate satellite networks with the Internet?

Two approaches:

- Satellite networks as an extension to terrestrial networks (see existing NTN, 5G discussions)
- Satellite networks as full-fledged Internet ASes

How do we integrate satellite networks with the Internet?

Assuming full-fledged IP space networks:

- Several Autonomous Systems, each one per satellite constellation (Starlink = AS14593)
- How to distribute IP addresses in each AS?
  - Currently Starlink uses Carrier-Grade Network Address Translation (CGNAT) for IPv4. Worse as the ratio of users to a single public IP address increases (Port Exhaustion and Conflict; Blocks unsolicited inbound connections; IP Reputation Issues)
    - The Long-Term Solution: IPv6 Adoption, granting every device on a user's network its own public IP address.
  - What is the impact of end-user mobility?
    - Starlink relies on the user terminal to quickly switch to a new Point of Presence (PoP) as it travels.. This design emphasizes connectivity over IP address stability.
    - Could IETF mobility management (MIP, HMIP, FMIP) may help to keep connectivity stability?
    - If Space AS can handle mobility efficiently, what is the impact on current cellular networks?
      - MNOs may end up focusing on dense, high-traffic areas (metropolitan areas).

How do we integrate satellite networks with the Internet?

Assuming full-fledged IP space networks:

- What is the impact on BGP?
  - Overall size and churn: Starlink's rapid global expansion means it continuously announces new IP prefixes via BGP as it brings up new PoPs and acquires new address blocks.
  - WIll Space AS peer to each other in the future? How?
  - Wil Space AS will operate as a Tier1?

Is the end-to-end principle enough or do we need to think in terms of segments?

- Right now, Starlink works with the end-to-end principle
  - But there are some problems: jitter, delay, periodic packet loss, throughput variability
- How to improve end-to-end performance?
  - Tweaking Congestion Control (generic vs access-technology specific CCA)
  - Adding ECN or something more than ECN signaling, e.g., part of the path has periodic packet loss.
- No more **transparent** PEPs, even for TCP
  - For GEO, we put transparent PEPs on two ends of a problematic segment to deal with latency
  - Do we need PEPs for LEO? Should this be application-specific?
  - QUIC, MASQUE, MoQ
- The path between endpoints is already segmented on the Internet
  - LEO can make use of segments to make things very fast (optical is faster than electrical)
  - Starlink uses satellite addressing possibly based on a large IPv6 space, or a specialized address format that may incorporates the satellite's orbital position. Will this support more intelligent routing inside the space AS (load balancing)?

Is this enough?

Technical, Governance and Business Challenges

Providers favoring IETF protocols over 3GPP cellular standards

Constellation operators:

- developing proprietary protocols
- stuffing LEO to block competitors
- discourage mobility (e.g., moving a Starlink antenna)

Latency not necessarily a selling point for end-users

- 70ms enough for most use cases.

Scalability issues: Starlink a “Global Network”, but running into issues with 7 million users

Radio Spectrum Issues - Frequency re-use

Satellite Proxies

Performance-Enhancing Proxies on satellites or on the border of the complex system

- Discovery: where, and which services?
- What is the role of middleboxes?
- Relation to Media over QUIC and Edge Deployments

Satellites as logical pipes to replace, e.g., sub-sea cables

Service identifiers instead of IP addresses identifying a location

End-to-end mechanisms are already difficult, satellites don’t make it easier

So we need middleboxes!