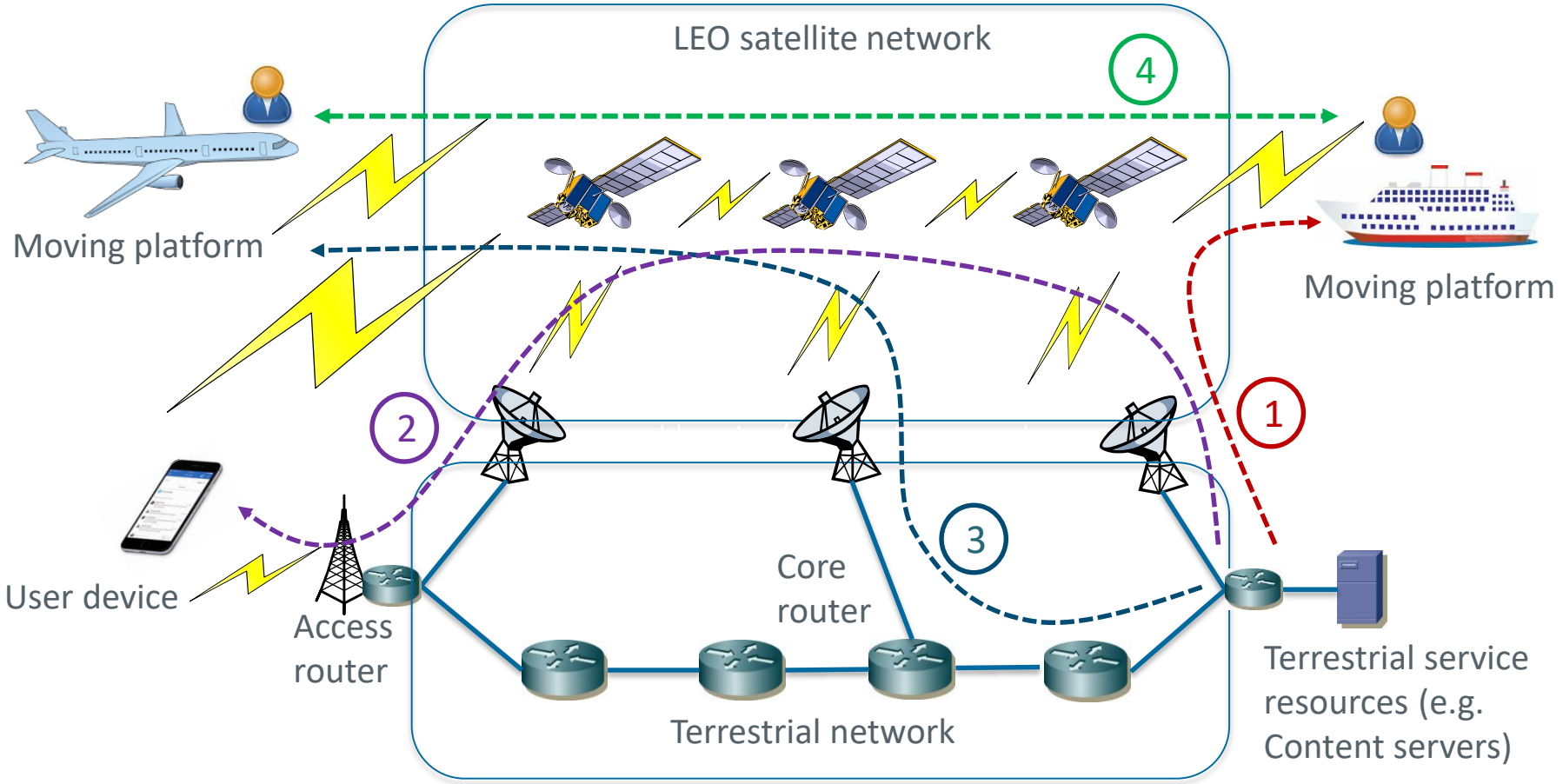
Space-Terrestrial Network Integration: Gap Analysis on Key Technical Issues

Ning Wang
University of Surrey

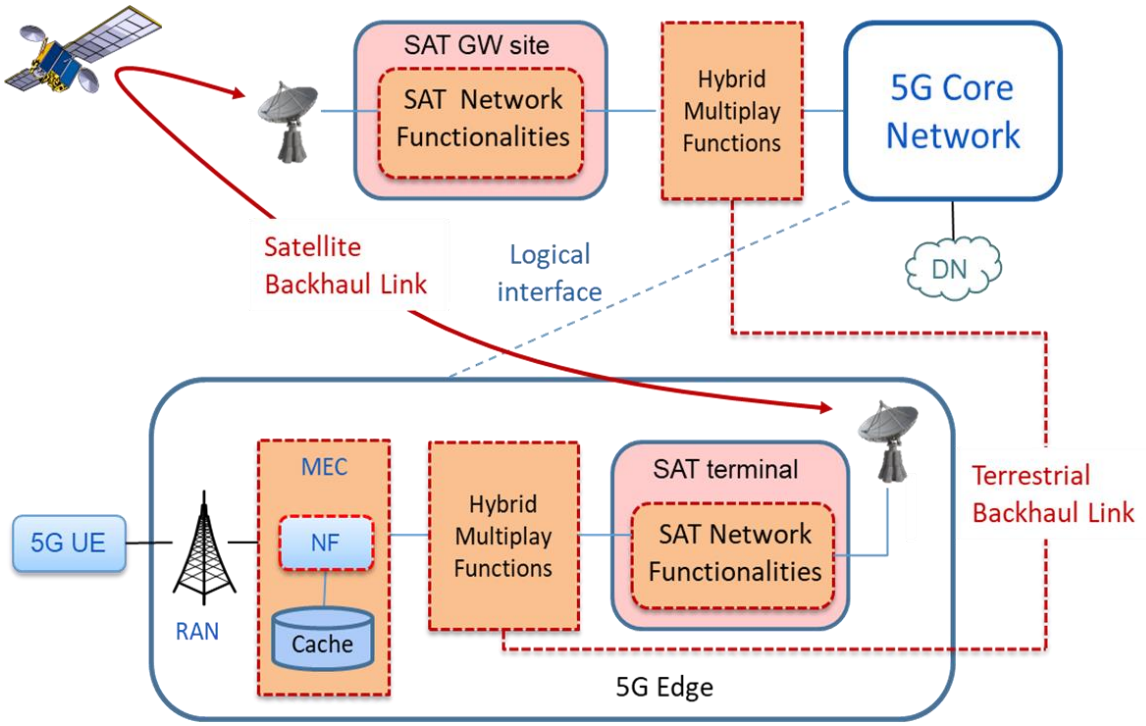
Integrating Networked LEO Satellites – Scenarios



STARLINK

- The most advanced LEO satellite network in operation that aims to provide global Internet access
- To our best knowledge:
  - ✓ Currently a “separate” network, not yet integrated with terrestrial network infrastructures
  - ✓ Sometimes known as “competitor” of 6G as a new type of access network
  - ✓ Existing proposals on using such a network infrastructure to provide transit services
  - ✓ Business model not yet known – have strong technical implications when integrated with the terrestrial infrastructure

Recent Progress in Integration in 5G

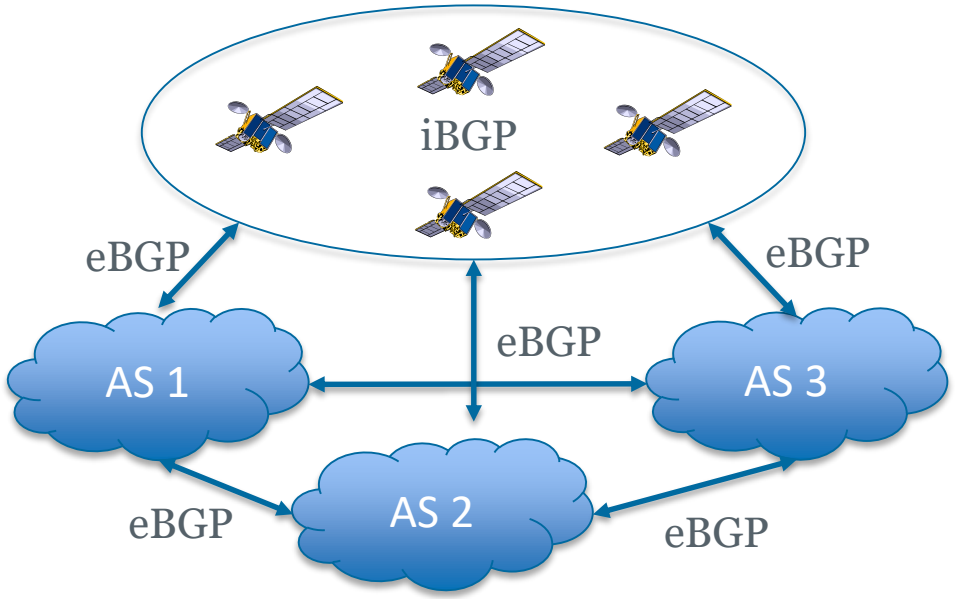


- EU 5GPPP-2 SAT5G Project (2017-2020)
- Key features
  - **Mainly on GEO satellite** only, no LEO constellation
  - Satellite taking the **backhaul role** in connecting 5G core with edge sites
  - Support of **multicast to edges**
  - Not focus direct access from end user devices
  - Not on the integration of fixed Internet

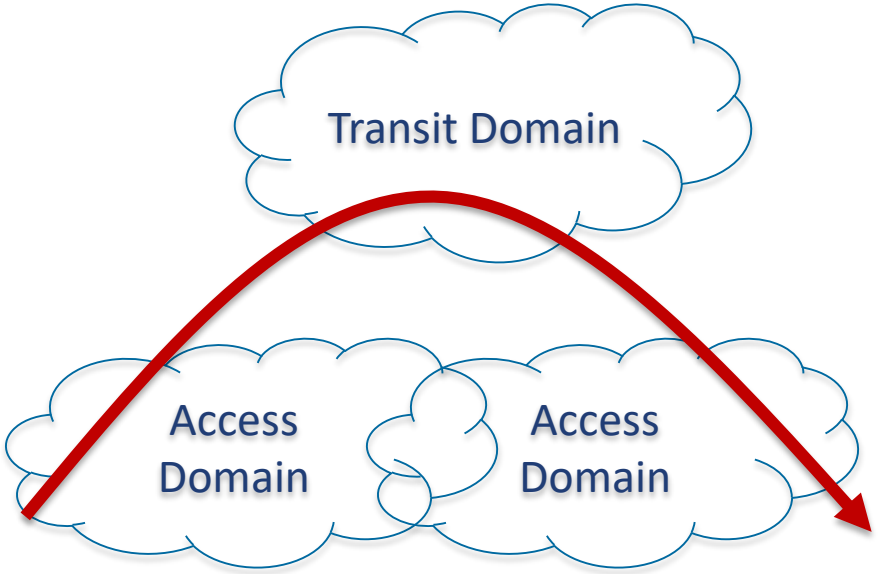
Technical Issues – Routing and Addressing

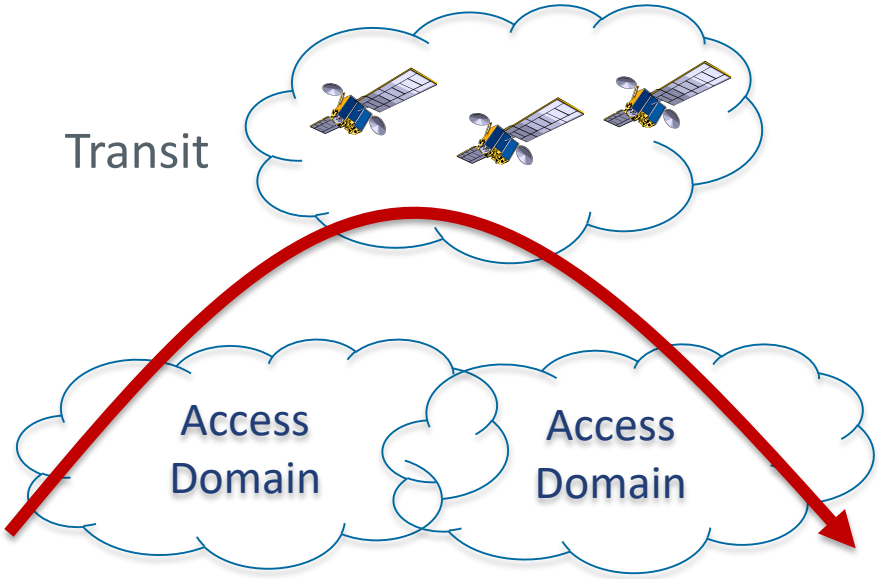
- Native IP or Something new?
  - Key challenge 1: **identify and maintain optimized paths** across satellites under constellation
  - Key challenge 2: impact on the **stability of BGP routing** over the terrestrial Internet – Essential for space-terrestrial network integration
  - Key challenge 3: **Addressing** of the dynamically changing, global network infrastructure

A possible scenario of using LEO satellites as a layer-3 network



- Global transit domain
  - Use LEO satellites as alternative provider/transit network to offload traffic from terrestrial provider

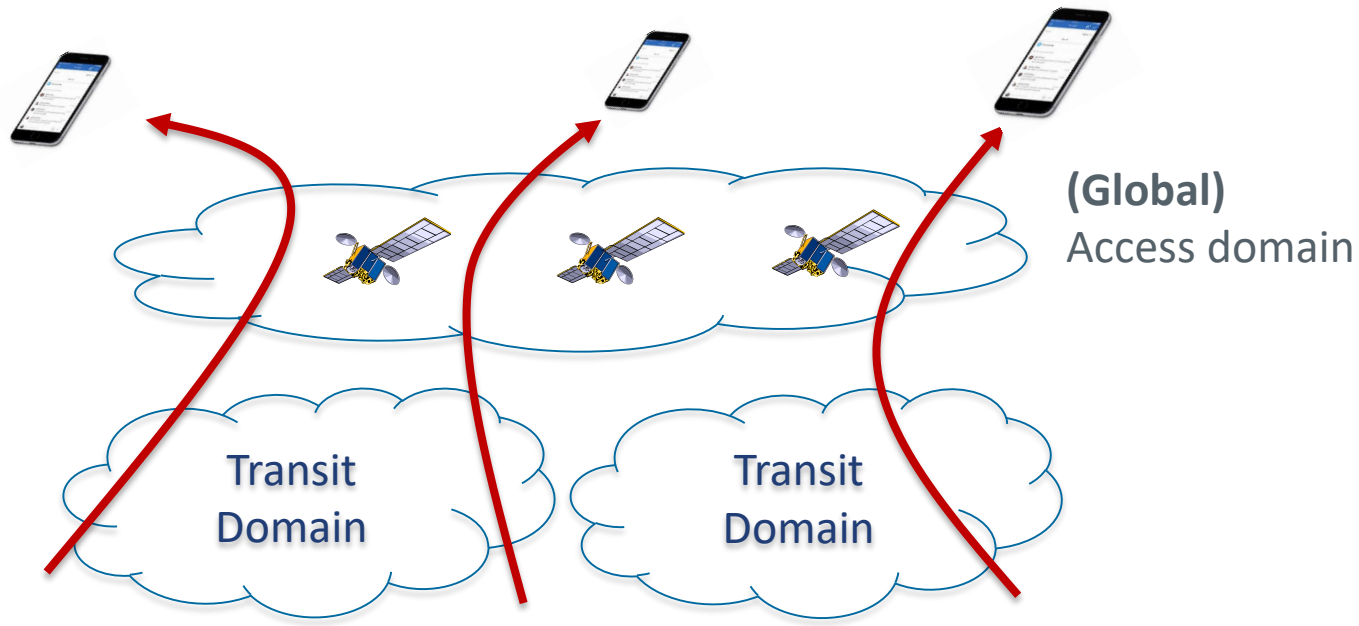




- **Issue:** topology change (including peering node (BGP next-hop) handover from the provider network will cause massive disruptions to customer domains

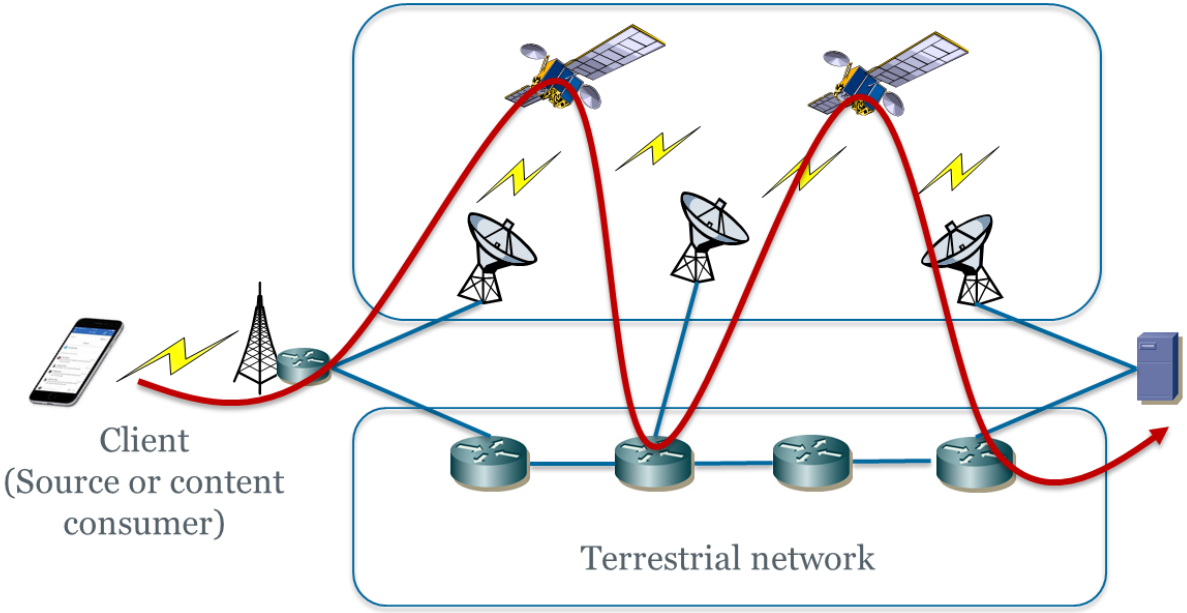
Technical Issues – Global Access

- Global access domain
  - Use LEO satellites as alternative access network (e.g. rural areas)
  - One "global" access network vs. logically partitioned "local" access network that is moving
  - Implication to addressing/routing
- **One network taking two (transit and access) roles – How?**



Technical Issues – Path flapping

- **Coupled routing** between LEO satellite and ground relay infrastructures
  - Allowing traffic flow to be routed across the two types of networks in the middle of journey
- Business scenarios
  - All belong to the same domain – Intra-domain routing stability
  - Different domains – How can BGP handle



M. Handley, "Using ground relays for low-latency wide-area routing in megaconstellations" Proc. ACM HotNets 2019

Implication to IP Addressing

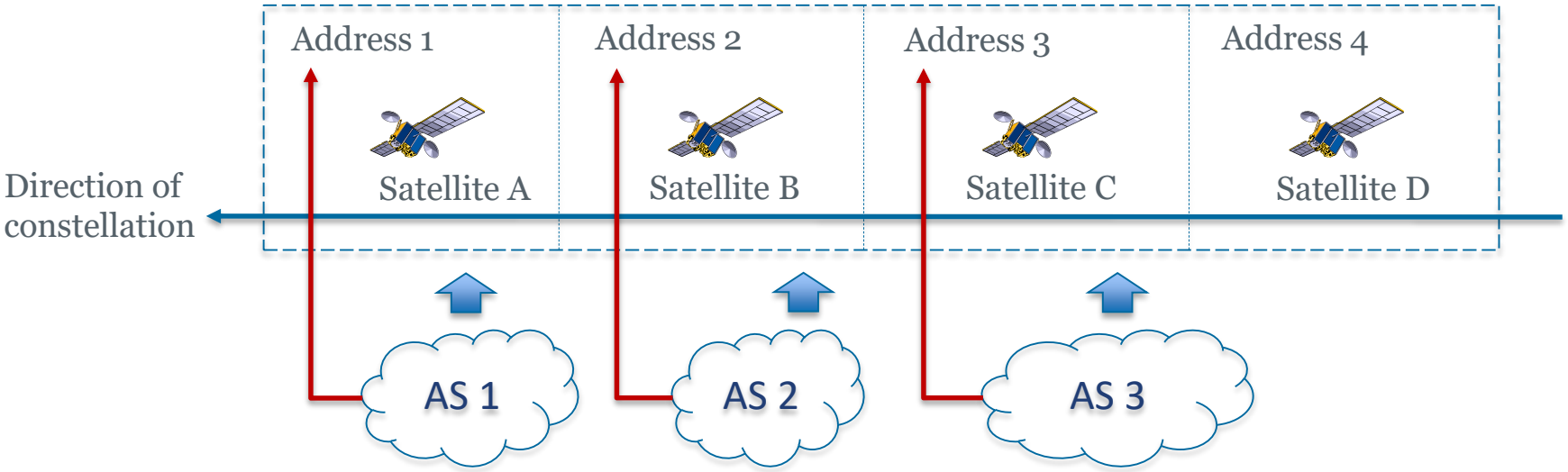
- Current IP addressing practice
  - For network elements such as terrestrial routers, the IP address is bound with specific physical hardware (e.g. interfaces)
  - Assuming routers are fixed at specific locations, the associated IP addresses are therefore fixed there
  - Entity-based IP addressing = Location-based IP addressing
- For LEO satellite networks
  - If individual LEO satellites “carry” physically bounded IP addresses and travel around the earth, IP addresses are not any more location-based, then

    Entity-based IP addressing <> Location-based IP addressing

    - A significant disruption to the underlying routing infrastructure base on existing IP

Implication to IP Addressing

- Making IP addressing genuinely location-based, even with LEO satellite constellation?
- Decouple IP addresses with (moving) network elements as a possible solution?
  - IP addresses are genuinely bound with fixed locations (geolocation grids)
  - The satellite in that grid instantiates the corresponding IP address
  - Infrastructures at the terrestrial side only see fixed IP address peer, without necessarily caring the physical satellite that instantiate it



G. Zheng et al, "Geosynchronous Network Grid Addressing for Integrated Space-Terrestrial Networks" Proc. IEEE ICNP NIPAA Workshop 2020

Summary

- Networking within a LEO satellite network might not be an issue, BUT making it seamlessly interface with terrestrial Internet infrastructures will encompass a systematic re-thinking of design strategies
- Implication to basics
  - Transit services vs access services
  - Routing policies and stability → end-to-end QoS
  - Semantic of IP addressing
- Geo-location based IP addressing?
  - Bind address with geo-locations but not physical network elements
  - Encapsulate complexity within the space network segments but no tunnels
  - Avoid massive routing disruptions on terrestrial network infrastructures

Thank You!