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IETF 115 TVR BOF Time Variant Routing Topology Management Challenges for Satellite Constellations

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Space Communication Networks

Emerging Constellations

- Space-based infrastructure is increasing its role in the Internet
- Concept of satellite backhaul (3GPP Release 18 and beyond) improves worldwide connectivity allowing service providers and operators to connect gateways and users all over the planet by creating orbital mesh networks to relay traffic
- The potential for lower latency over long distances stems from:
 - Being able to build low-hop-count paths instead of circuitous terrestrial fiber routes
 - Using Free Space Optics (FSO) transmitting at the speed of light in vacuum instead of in fiber
- New space infrastructure is rapidly expanding, additional challenges are placing new requirements on traditional network control technologies

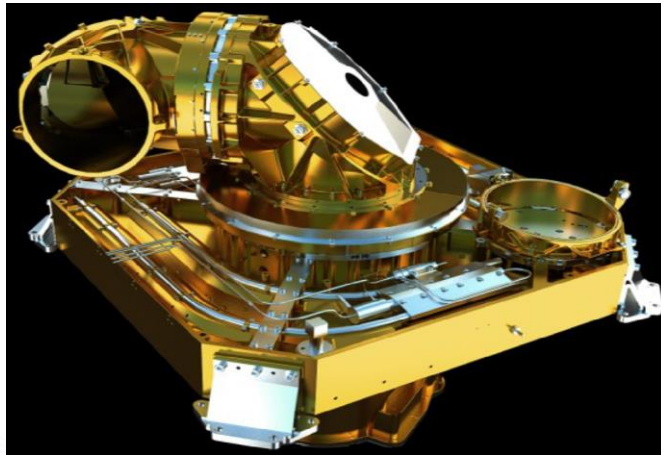
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Current Antenna Characteristics

- State-of-the-art:
 - Ka-, Ku-, L-, S-band
 - Near future Q/V-band
- Flat Panel Antennas
- Free Space Optics



Credit: Arianespace



Credit: Tesat

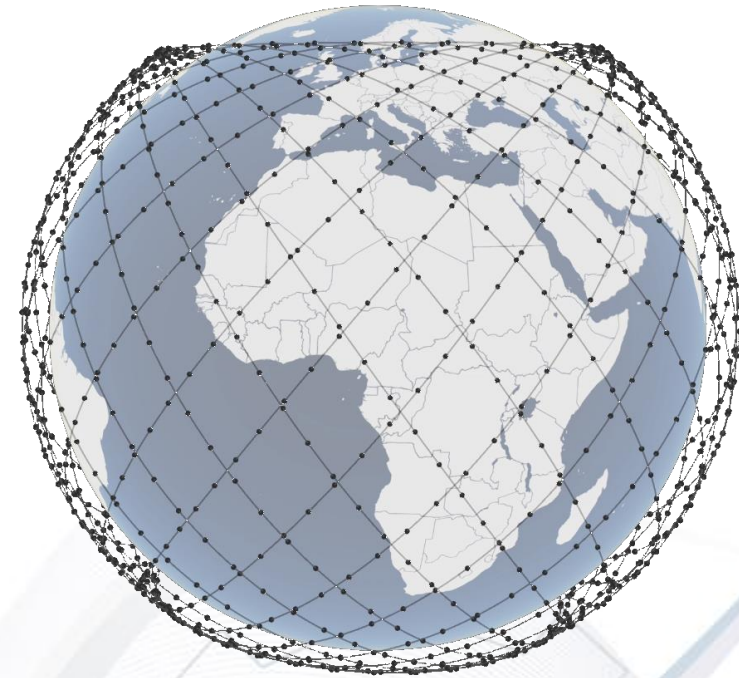


Credit: Kymeta

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Building the topology

- Topology will be created/managed based on knowledge of satellite position, available interfaces, bandwidth requirements, energy cost
- Centralized vs. decentralized approach
- Inter-satellite links must cover large distances → the transmission scheme must be power-efficient with good sensitivity at the receiver.
- Ground station selection is based on operational constraints/needs of the network
- Need to also consider power versus transmission costs, and path viability



Building the Connectivity

Physical link topology

How will the radio and optical links be established between the multitude of stationary and mobile nodes in the network? A few things to consider:

- Laser links need explicit pointing
- Power constraints may mean not all links will be in service all the time
- How will establishment of links be managed? Scheduled? Ad hoc?
- How will the subsequent network topology be disseminated throughout the network nodes?



Building the Connectivity To Link or Not To Link? That IS the question!



- What is the link execution timeline?
- What is the minimum duration of a link in order to be considered viable?
- What is the balance between a planned link schedule versus a completely real-time link acquisition strategy?
- What are the decision criteria for a link that is broken versus interrupted versus degraded before switching to an alternative node?
- How are stationary links (e.g., to the ground) prioritized against links between mobile platforms (e.g., aircraft, satellites, HAPS)?
- How will links be powered down and planned for nodes to recharge batteries, or wait offline until additional capacity is needed?

Building the Connectivity

The Network Graph

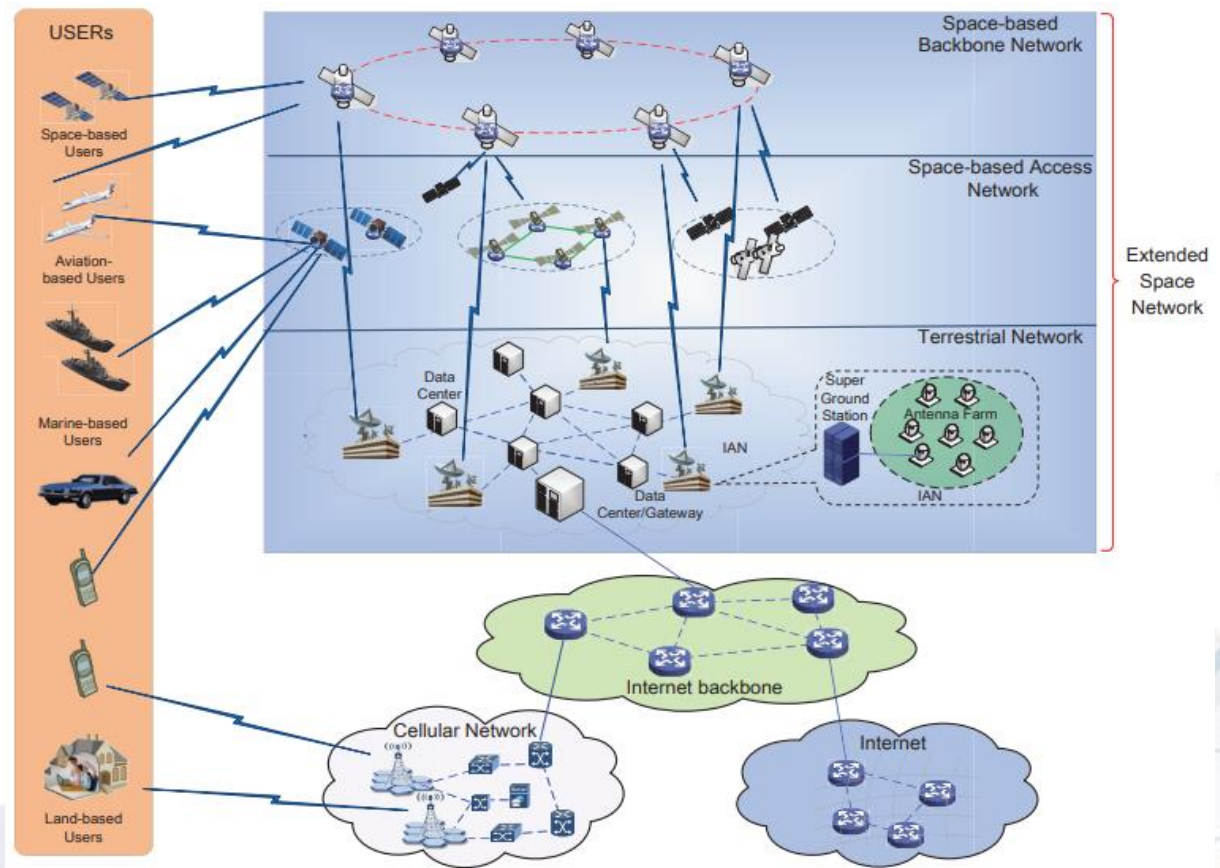
- Given
 - Constellation's satellite telemetry (e.g. two-line elements, TLEs)
 - Fixed number of inter-satellite terminals at each satellite
 - A target traffic matrix between terrestrial endpoints
 - Known energy costs for activation of links and the bandwidth they will provide
 - Link time activation and duration can be known
- The goal is to decide which inter-satellite and satellite-to-ground links to use, in order build a useful topology so that:
 - Minimize latency and hop-count in end-end paths, avoiding congested nodes
 - Consider fixed and static variants (satellite motion and Earth's rotation)
 - Utilise links efficiently and attach to gateways based on optimal delivery of traffic to meet the traffic requirements

Service Customers!!!

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User Types

- Topology mechanisms may also need to apply to different network users, with similar link management requirements
 - Space-based
 - Aviation
 - Marine
 - Vehicles
 - Mobile



In Conclusion

What do we need from TVR?

- Underlying engineering of the satellite network links
 - Determine relevant links between nodes
 - Establish links
 - Maximise the efficiency of service delivery on additional metrics such as bandwidth, link energy cost
- Improve satellite network operation
 - Efficient local resource management
 - Identify and disseminate interfaces that are shutdown to conserve power
 - Adapting to external conditions and traffic demands in the event of occlusion or planned and unplanned outages
- Managing scheduled mobility
 - Take advantage of predictability where appropriate
 - Making routing decisions for services, not packets
 - Creation of a virtual network topology based on link availability