Decentralized integration of non-terrestrial networks into 6G

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This presentation reflects my personal view on the topic and not Airbus position.
Starting point: Flexible satellite technology

OneSat can be fully reconfigured while in orbit – and it is capable of adjusting its coverage area, capacity and frequency “on the fly” to meet evolving mission scenarios.

Encompasses active antennas enabling several thousand beams.

- Multi-beam RF technology
- Free Space Optical Links
- Flexible payloads
## Throughput
Aggregate downlink capacity of the full Starlink deployment is estimated to be 240 Tbps.

## Latency
Telesat LEO simulations of traffic moving over only inter-satellite links.
Round-trip time at the network layer including processing latency for system and inter-satellite links.

### 3GPP TR 38.811 V15.0.0 – Study for New Radio (NR) to support non terrestrial networks (Release 15)

#### Round Trip Time – Telesat LEO Latency vs Terrestrial Latency

<table>
<thead>
<tr>
<th>Elevation angle</th>
<th>Path</th>
<th>LEO at 600 km</th>
<th>LEO at 1500 km</th>
<th>MEO at 10000 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>UE: 10°</td>
<td>satellite - UE</td>
<td>1932.24</td>
<td>6,440</td>
<td>12,158</td>
</tr>
<tr>
<td>GW: 5°</td>
<td>satellite - gateway</td>
<td>2329.01</td>
<td>7.763</td>
<td>13.672</td>
</tr>
<tr>
<td>90°</td>
<td>satellite - UE</td>
<td>600</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

**Bent pipe satellite**

- **One way delay**
  - Gateway-satellite_UE: 4261.2 ms
  - Satellite -UE: 1932.24 ms

- **Round Trip Delay**
  - Twice: 8522.5 ms
  - Satellite-UE-Satellite: 3864.48 ms

**Regenerative satellite**

- **One way delay**
  - Satellite -UE: 1932.24 ms

- **Round Trip Delay**
  - Satellite-UE-Satellite: 3864.48 ms
Target development: 3D networks at different altitudes

The SpaceDataHighway
The 1st Operational Optical Communication system

- We have achieved more than 50,000 successful relay links since 2016
- Outstanding service availability greater than 99.5%
- Up to 39 link sessions per day
- Downloaded more than 3,000,000 GB of data from space
- SpaceDataHighway can download data from space in near-real-time

What benefits does our services bring to our customers:
- Enabling last-minute satellite reactivity and tasking
- Real-time data access and high volume data transfer
- Improved data latency on a global scale
- Protected comms to support next-gen platforms and multi-domain operations
Challenge: Turn the Internet into a large scale 3D network
Turning the Internet into a large scale 3D network

**Vision**
Internet able to support a large scale of new services, such as (distributed) in-network computing (for instance for the coordination among autonomous vehicles), while transparently integrating 3D space/airborne networks.

**Motivation**
Need to devise a more decentralized, scalable and low cost way to operate and manage large scale networks.

**Potential Path**
Allow dynamic space/airborne networks to deliver services, and not just connectivity, based on different semantics (host, data, service, geolocation), while being self-sustainable by observing and acting autonomously in order to optimise their performance even in scenario with intermittent connectivity and resource availability.

**Goal**
Make a large number of new services accessible to all 7.3 billion people.
Challenge 1: Self-sustainable networks able to deliver services

4C-Agent capabilities:
- Communication
- Computing
- Caching
- Cognition, Autonomic
Road to Cognitive service-centric networks

**Potential starting point:**
- Information centric networking
- Edge computing

**Service centric networking**
- Placement and execution of service function chains among different 4C-Agents.

**Cognitive network functions**
- Self-managing distributed functions, adapting to unpredictable changes.
- Reinforcement learning algorithms to learn and predict best (scheduled) paths among function sets.
- Self-configuring trusted virtual networks used to exchange control messaging between all cognitive agents.

**Trust in cognitive networks**
- Functions capable of deciding how to optimally fulfill intents.

**Cooperative communication, computing, caching**
- Leverage the power of AI to deal with the fast changing heterogeneous environment

**Challenge:**
- Routing in cognitive networks: routing and TE parameters are almost exclusively implemented through a centralized set of (proprietary) SDN controllers configured by human operators.
- Cognitive intent-based networking: OAM evolved to define architectures consisting of ever-more-complex layers between human intents and all the parameters that need to be provisioned into each network device whenever there is any change.
Challenge 2: Global Networking based on different domains

Routing A Domain (Fixed)
Routing B Domain (DTN - Constrained)
Routing C Domain (DTN - Schedule)

Distributed Data Center
Content Distribution Domain

IoT Domain

Autonomic Vehicles Domain

Enterprise Communication Domain

IP Network
Challenge 2: Global Networking based on different domains

Future Scenario
In a large scale heterogeneous 3D Internet, with tens of billions of nodes being connected directly and indirectly, there is a trend towards network specific and local requirements, behaviors, and semantics.

Goal
How to reach global interoperability in a 3D Internet?

- Current limitations:
  - No transparency to IPv6 extension headers.
  - Unreliable path MTU discovery.
  - Problems with TCP maximum segment size.
  - Administrative domain boundaries:
    - Prone to leakage caused by human error.
    - May be difficult to define in dynamic domains.
  - Protocols with semantics limited to specific domain.

- Current management of (routing) domains:
  - Careful configuration of boundary routers and firewalls.
  - Careful management of address assignment to hosts.
  - Configuration errors can lead to unwanted traffic patterns.

- Future perspective on multiple domains:
  - Domains may extent throughout the Internet:
    - Based the notion of network segments.
  - Domains may overlap each other in an arbitrary fashion:
    - Network slices, service function chains.
  - Domains may operate based on different semantics:
    - HostID, DataID, ServiceID, GeoID.
  - Domains may be created and managed automatically:
    - Adaptation of boundaries over time.
    - Perform peer verification (identity and role).
Thank you!

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