Evolution of Non-Terrestrial Networks towards 6G Systems

Towards 6G - Drivers and State of Play

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TN/NTN convergence

Interworking before 5G

<table>
<thead>
<tr>
<th>TN</th>
<th>NTN</th>
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<tbody>
<tr>
<td>2G</td>
<td>• voice, SMS, limited data</td>
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<tr>
<td></td>
<td>• centralised network</td>
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<tr>
<td>3G</td>
<td>• Video calls</td>
</tr>
<tr>
<td></td>
<td>• centralised network</td>
</tr>
<tr>
<td>4G</td>
<td>• MBB, streaming, VoLTE</td>
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<td></td>
<td>• decentralised network</td>
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Integration 5G and 5G-A

<table>
<thead>
<tr>
<th>5G/5G-A</th>
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<tbody>
<tr>
<td>• eMBB, URLLC, mMTC</td>
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<td>• decentralised network</td>
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<td>• network virtualization</td>
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First 3GPP NTN Release

• seamless TN/NTN combination
• 5G support across various RATs

Independent TN/NTN optimisation

• Backhauling support
• Roaming for special satellite phones

• Backhauling service
• Interworking at IP

TN optimisation minimum impact to support NTN

A. Guidotti - The evolution of NTN from 5G to 5G-Advanced and the path to 6G
3GPP NTN in Rel. 17

- NTN-based GEO/LEO with implicit HAPS/ATG compatibility

- Main characteristics
  - transparent payload architecture
  - coverage type
    - Earth-fixed
    - Quasi-Earth-fixed
    - Earth-moving
  - FR1: S-band and L-band
  - handheld terminals with GNSS capabilities
  - FDD
  - Earth-fixed tracking

- Massive normative work to adapt the NR system to the NTN characteristics

3GPP NTN beyond Rel. 17

Source: A. Guidotti et al., “Role and Evolution of Non-Terrestrial Networks towards 6G systems,” submitted to IEEE Access, 2023
3GPP NTN Rel. 18-19

- **NR radio protocols enhancements**
  - support FR2 and mobile/nomadic VSAT
    - transparent payloads
    - co-existence analysis on-going (adjacent channel)
  - network verification of the GNSS coordinates determined by the UE
  - optimise mobility procedures in idle/connected modes

- **NB-IoT/eMTC radio protocols enhancements**
  - optimise mobility procedures
  - improve the support of small constellations providing discontinuous service over a given area

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- **NR-NTN**
  - coverage enhancements (DL and possibly UL)
  - NTN/TN mobility enhancement in connected mode (e.g., CHO)
  - support of HD mode RedCap UE (Reduce Capabilities) in FR1
  - support of regenerative payloads (i.e., with ISL)
  - support of UE with GNSS independent operation for UL time and frequency synchronization in NTN based access (idle/connected modes)

- **IoT-NTN**
  - regenerative payload = Store and Forward (i.e., eNB + ePC network elements)


A. Guidotti - The evolution of NTN from 5G to 5G-Advanced and the path to 6G
The role of Non-Terrestrial Networks in 6G

- 6G will target a fully unified T-NT infrastructure based on multi-dimensional multilayer architecture
The role of Non-Terrestrial Networks in 6G

• No distinction between TN and NTN nodes: they are all nodes of the same infrastructure, to be jointly optimised and exploited
The role of Non-Terrestrial Networks in 6G

**Architecture and system design**
- Multi-layered constellation from GEO to drones, Innovative LEO and vLEO orbits, optical
- inter and intra node-links design, cell-free MU-MIMO, traffic-driven coverage

**Networking, edge computing and communications**
- Softwarization, virtualization, and orchestration of network resources, functional
- split, advanced IP, routing in the sky, resource management, integrated edge
- communication and computing

**Flexible and integrated waveforms**
- Low PAPR and low OOBE solutions, Non-orthogonal techniques to increase the
- connection density, novel RA procedures to allow multiple transmissions per
- beam, multipoint transmission from the sky, distributed beamforming

**Dynamic Spectrum Access and new spectrum**
- Coordinated and uncoordinated sharing among different access technologies, inter and intra layer, higher frequency bands, Q/V and above

**Positioning**
- Network based positioning

**AI/ML**
- Network and system orchestration, Radio Resource Management, Network traffic
- forecasting, Physical layer management, Channel estimation

**Antennas and components**
- Active antennas for link budget and flexible coverage, Refracting RIS for
- indoor coverage, regenerative payload, high-parallel energy efficient HW
- Optical devices

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Conclusions

• The integration of an NTN component into 5G is a reality since Rel. 17

• However, both *evolutionary and revolutionary technologies* are needed towards a true fully integrated NT-T system infrastructure for 5G-Advanced and 6G communication systems

• **NTN** will play a **pivotal** role in future fully unified systems, leading to a **ML-MO-MB 6G NTN**

*For future NTN systems, we need to make a further technology leap now!*
Current funded projects on NTN...

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