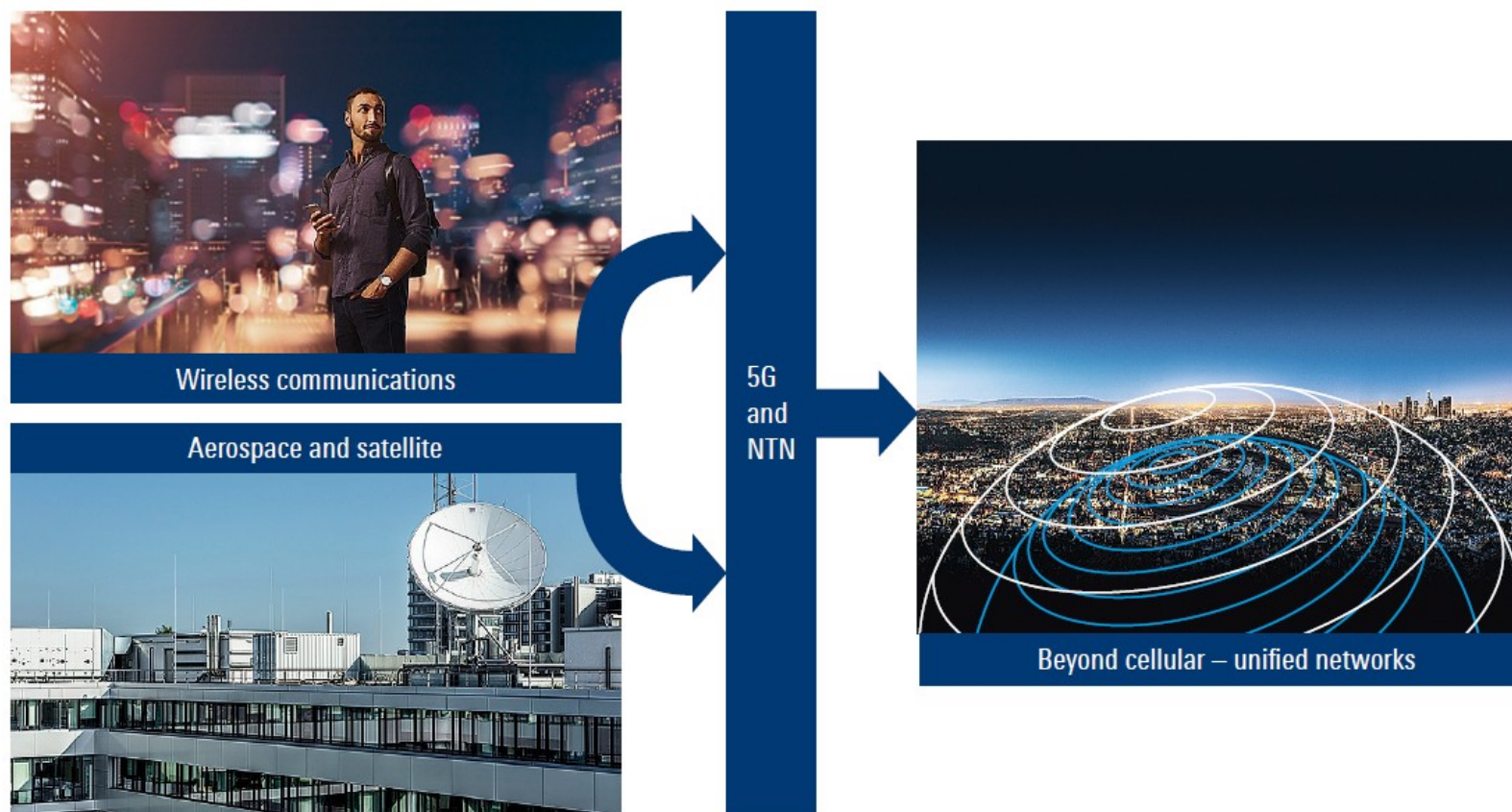


5G Non Terrestrial Networks NTN - Introduction and State of the Art

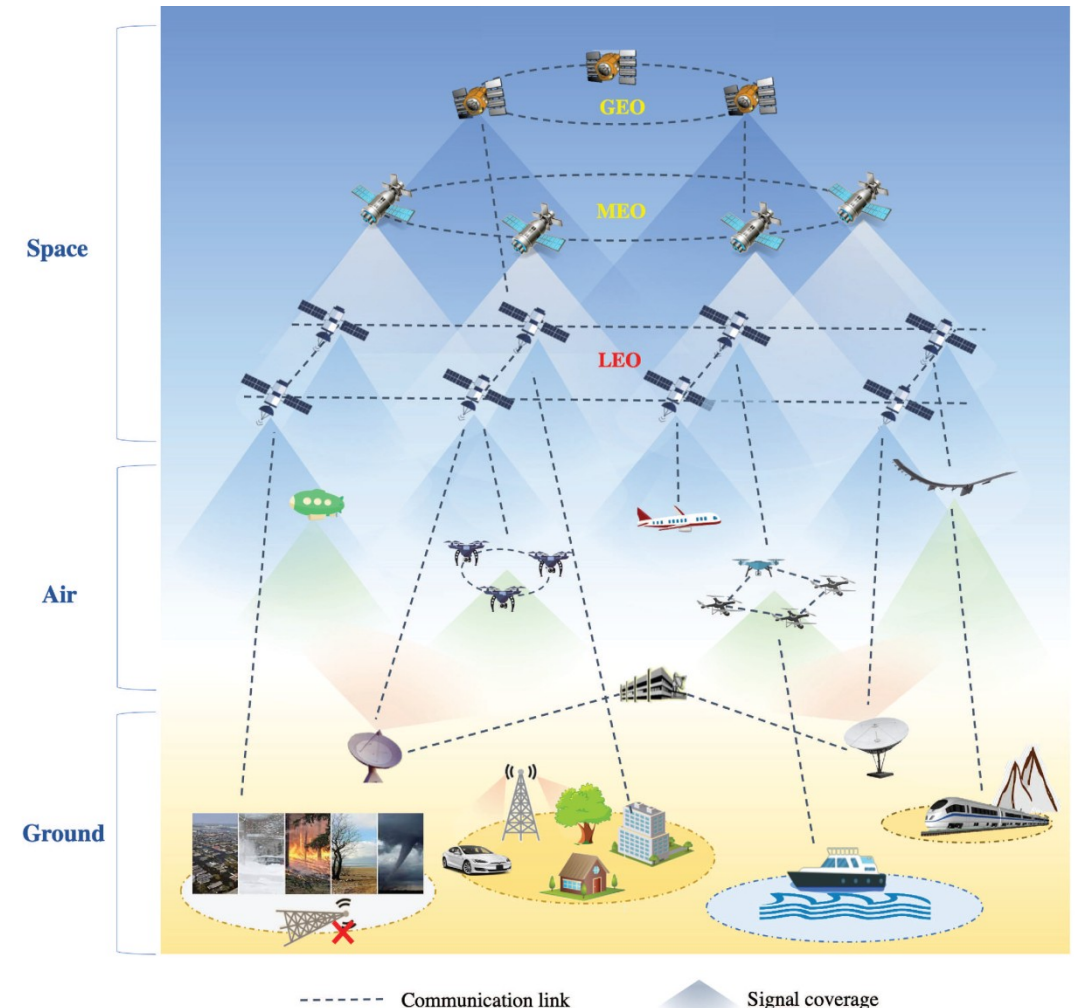
16° December 2024 - Ing. Giovanni Nicolai
Consigliere Ordine Ingegneri della Provincia di Roma



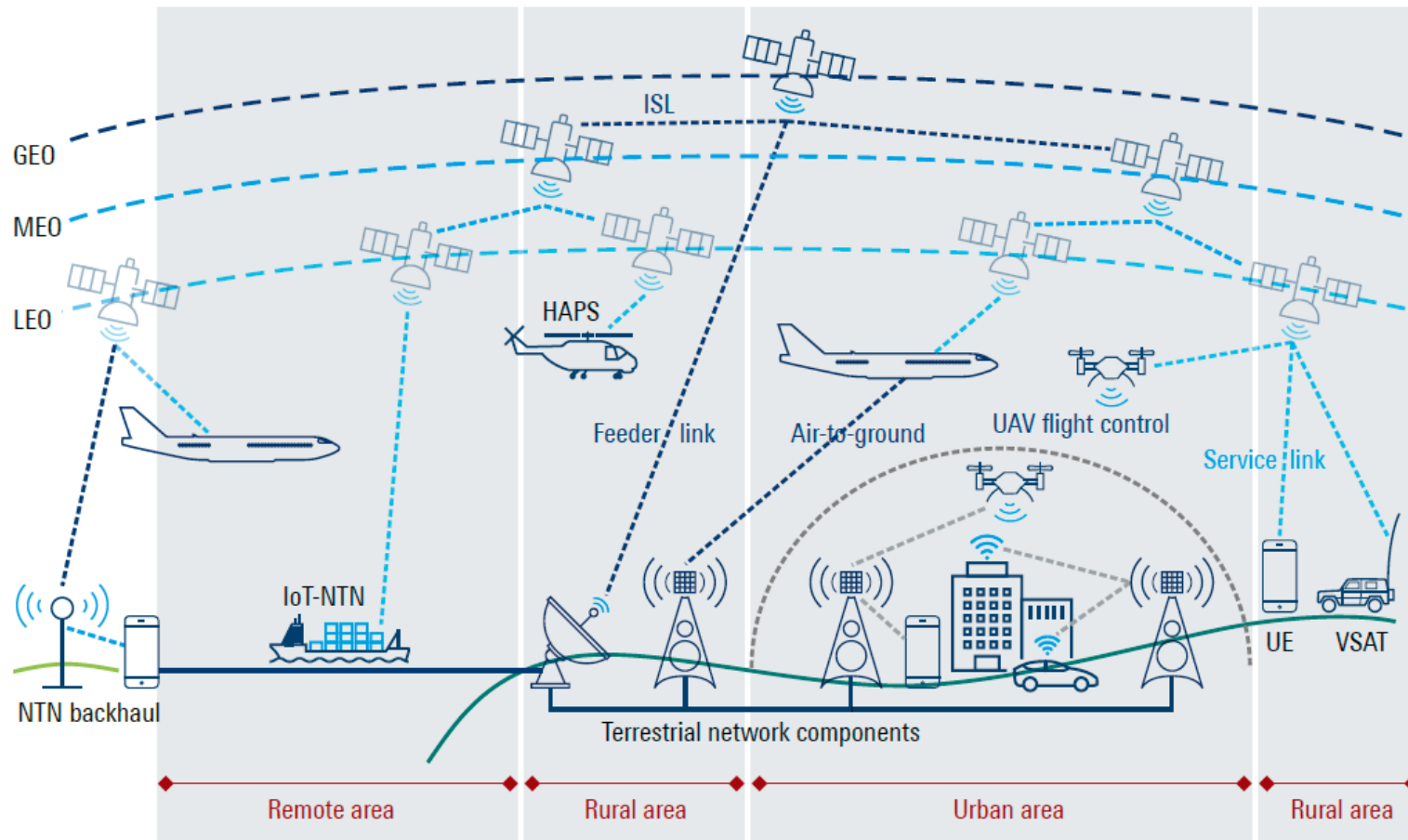
Space Air Ground Access Networks

The Space Air Ground Access Networks is generally composed by the hierarchical satellites in the space GEO-MEO-LEO, multiple vehicles in the air, and basic infrastructures on the ground.

The air vehicles include airships, HAPs, aircrafts, and UAVs, on the basis of different heights and functions. Besides, most users come from ground, such as emergency areas, ocean, deserts, and remote areas without services of ground base stations.



Introduction to NTN Concept

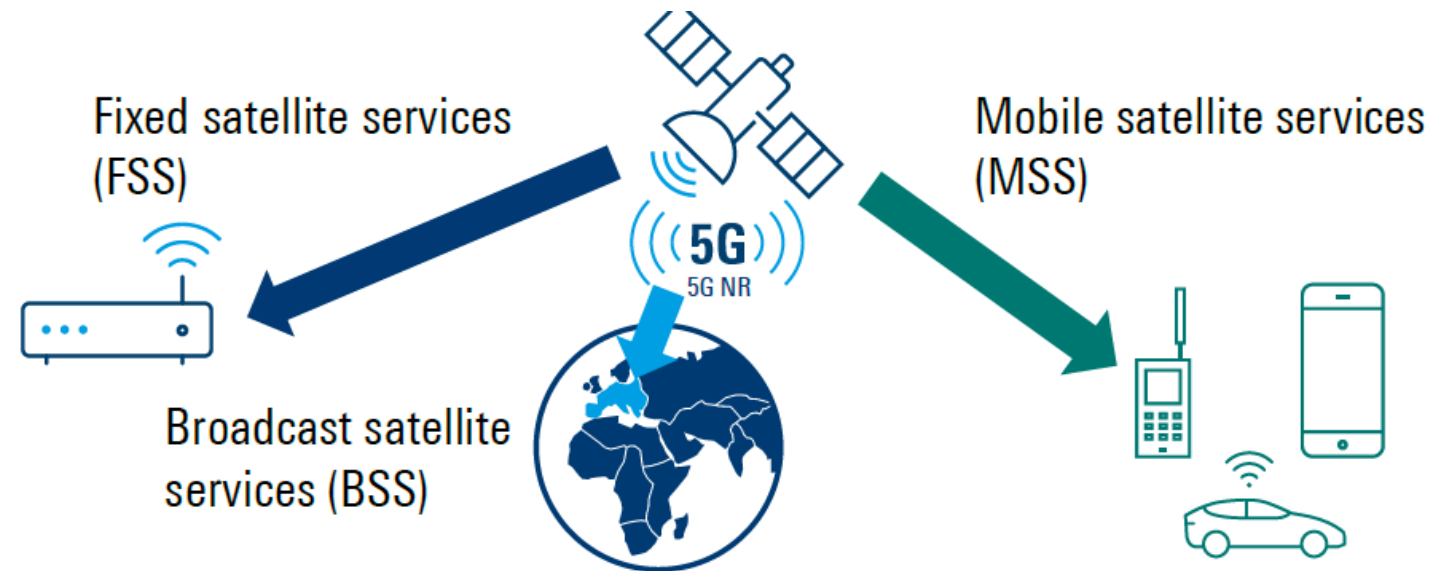


General connectivity overview of non-terrestrial networks

Non-terrestrial networks (NTN) are networks or segments of networks that use either Uncrewed Aircraft Systems (UAS) operating typically between 8 and 50km altitudes, including High Altitude Platforms (HAPs) or satellites in different constellations LEO, MEO, GEO and HEO to carry a transmission equipment relay to a node or to a base station.

NTN Use cases

1. Overlay and traffic offload, hotspot on demand, network resilience and emergency, fixed wireless access;
2. Network resilience and emergency, fixed wireless access, wide area connectivity, public protection and disaster relief (PPDR);
3. Network resilience, backhaul, PPDR and emergency, wide area connectivity;
4. Aeronautical, Maritime, Remote Hotspots, PPDR and Emergency.



Non-Terrestrial Networks – Migration to 3GPP Standardization

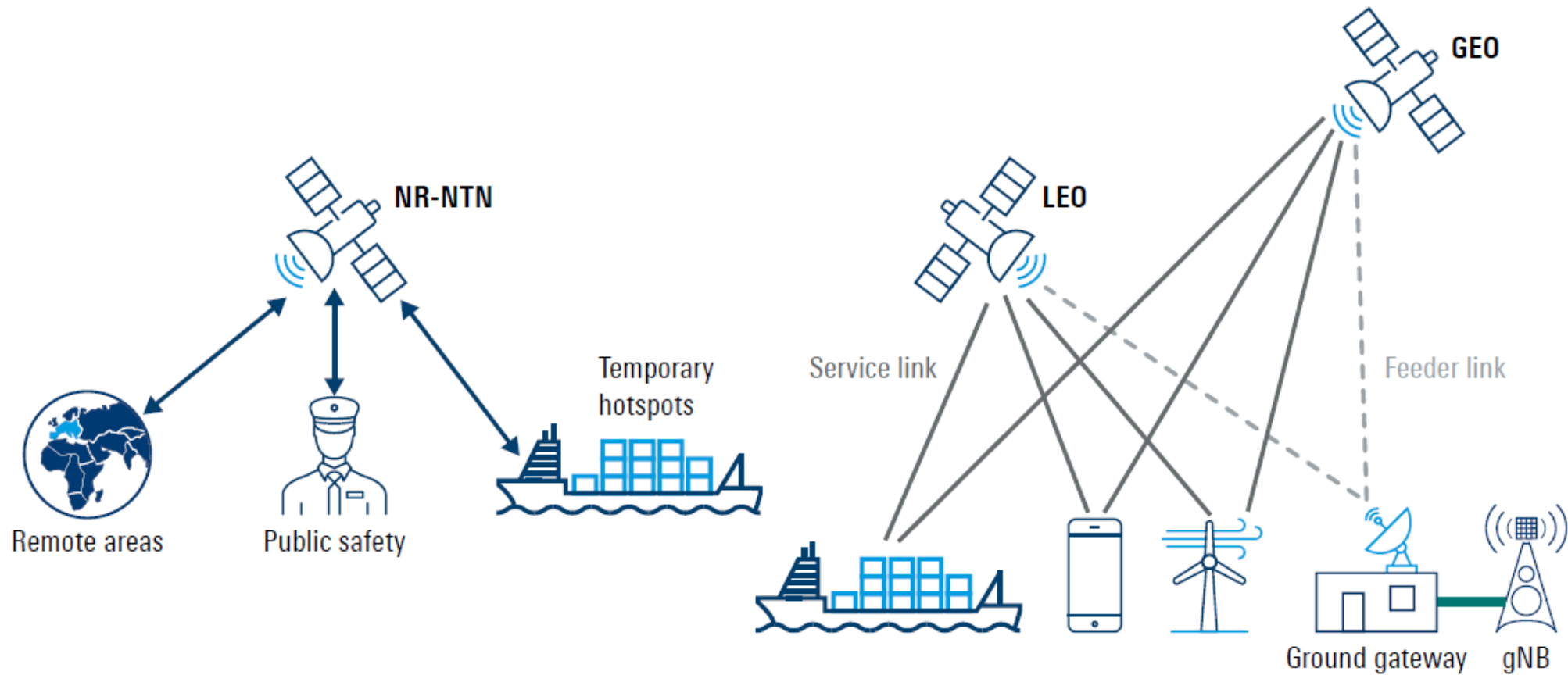
The Migration involves the physical layer aspects, protocols and architecture as well as the radio resource management, RF requirements, and frequency bands to be used.

The primary focus is on transparent payload architecture with earth-fixed tracking areas and frequency-division duplexing (FDD) systems where all UEs are assumed to have global navigation satellite system (GNSS) capabilities.

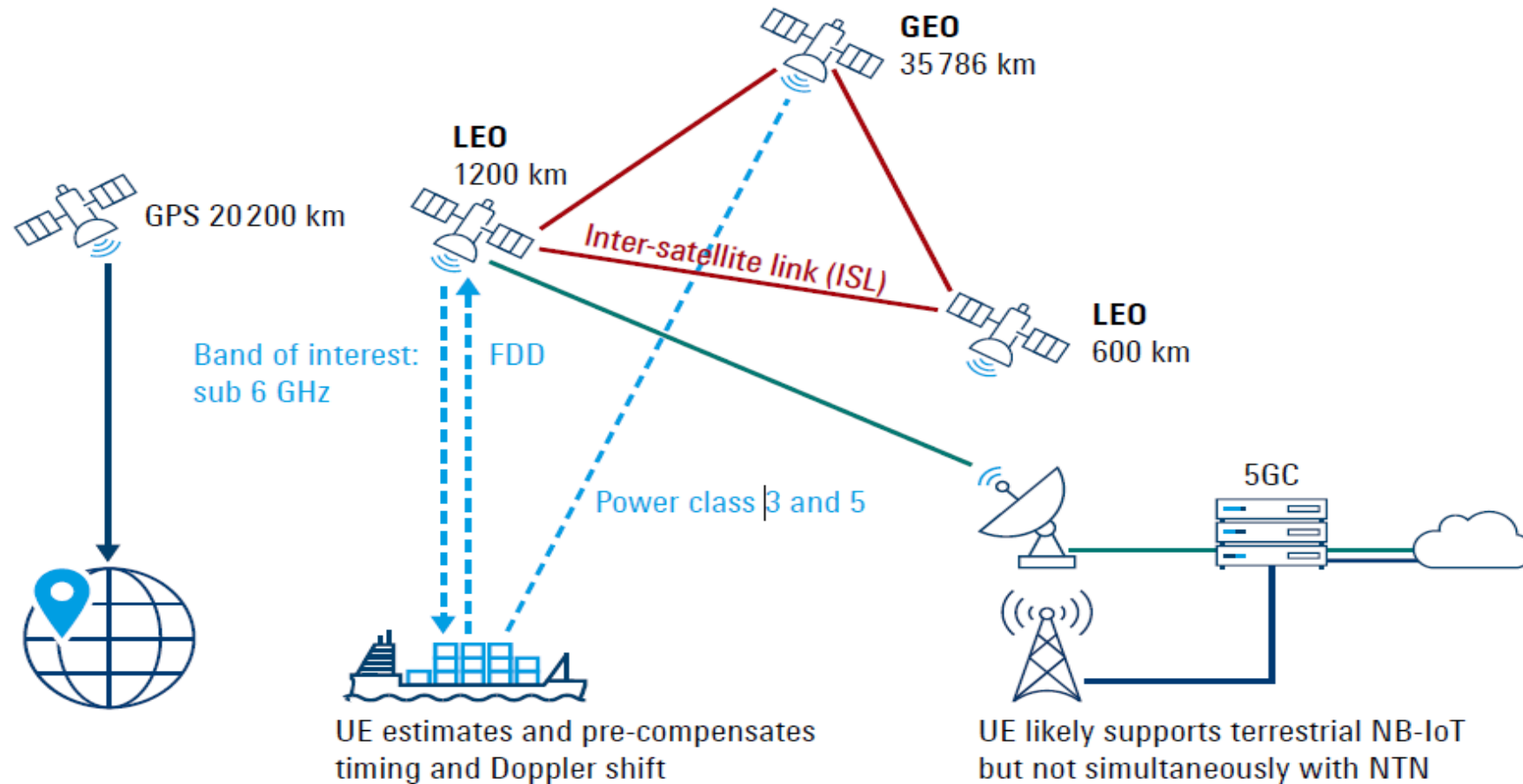
In a simplified service-oriented perspective, the vision of 3GPP goes into two deployment and service scenarios:

- One is the support of 5G NR for NTN (NR-NTN), which mainly focuses on mobile broadband services.
- The second service aspect is the motivation to support low data rate, mainly Internet of Things IoT via satellite (IoT – NTN).

NR-NTN - New Radio - Non-Terrestrial Networks



IoT-NTN – Internet of Thing - Non-Terrestrial Networks



NTN – Current Situation in the 3GPP Standardization

The main motivation for 3GPP to have started a study to include non-terrestrial networks in the 5G system is to create an open standard for a common Radio Access Technology RAT and system access allowing operators, system vendors and device manufactures to incorporate NTN into their service offerings.

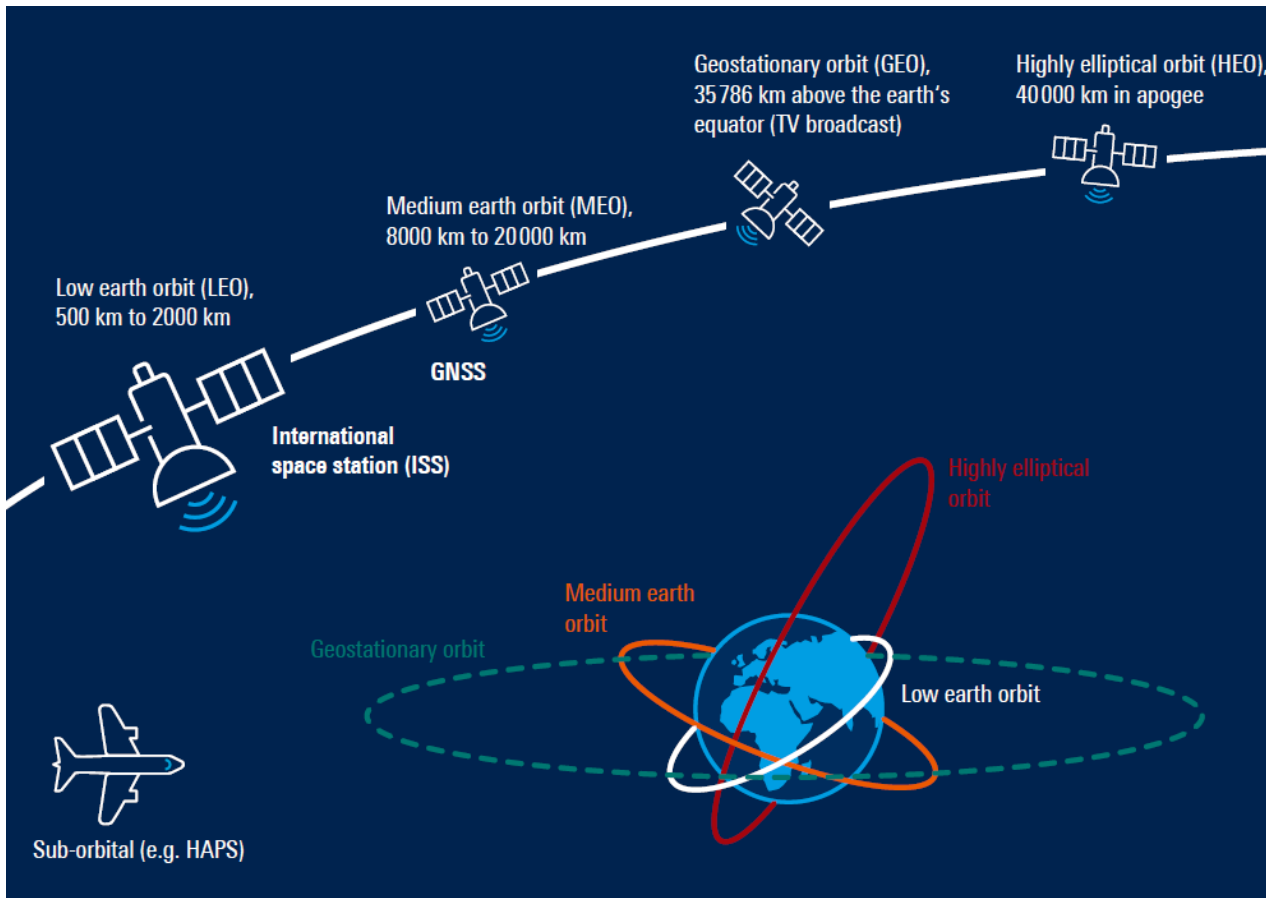
As the incorporation of NTN represents a technology evolution, 3GPP started the study in **Release 15** [TR 38.811] with the focus on channel models and deployment scenarios. After completing the study on scenarios and channel models, 3GPP continued with a follow-up **Release 16** study on solutions for adapting 5G New Radio NR to support NTN.

The main objective of **Release 16** study [TR 38.821] has been the identification of a feature set that enables NTN within the 5G system with the motivation to reduce the impact on the existing 5G system to a minimum level. The feature set in the study includes architecture aspects, protocol layer enhancements and physical layer aspects.

Based on the successful outcome of the Release 16 study, 3GPP decided to start a work item on NTN in **Release 17** [TR 38.863]. The major objective has been to specify enhancements necessary for LEO and GEO based NTN while targeting implicit support for HAPS and air-to-ground networks for future deployments.

Recently the **Release 18** [TR 38.882] has been finalized by the 3GPP Study Group. The main objective has been to specify NR based NTN_solutions to support 5G via satellite.

Satellite Constellations considered for the NTN 5G Networks



The Satellite Constellations that have been considered for integration into the Network NTN 5G are the following: :

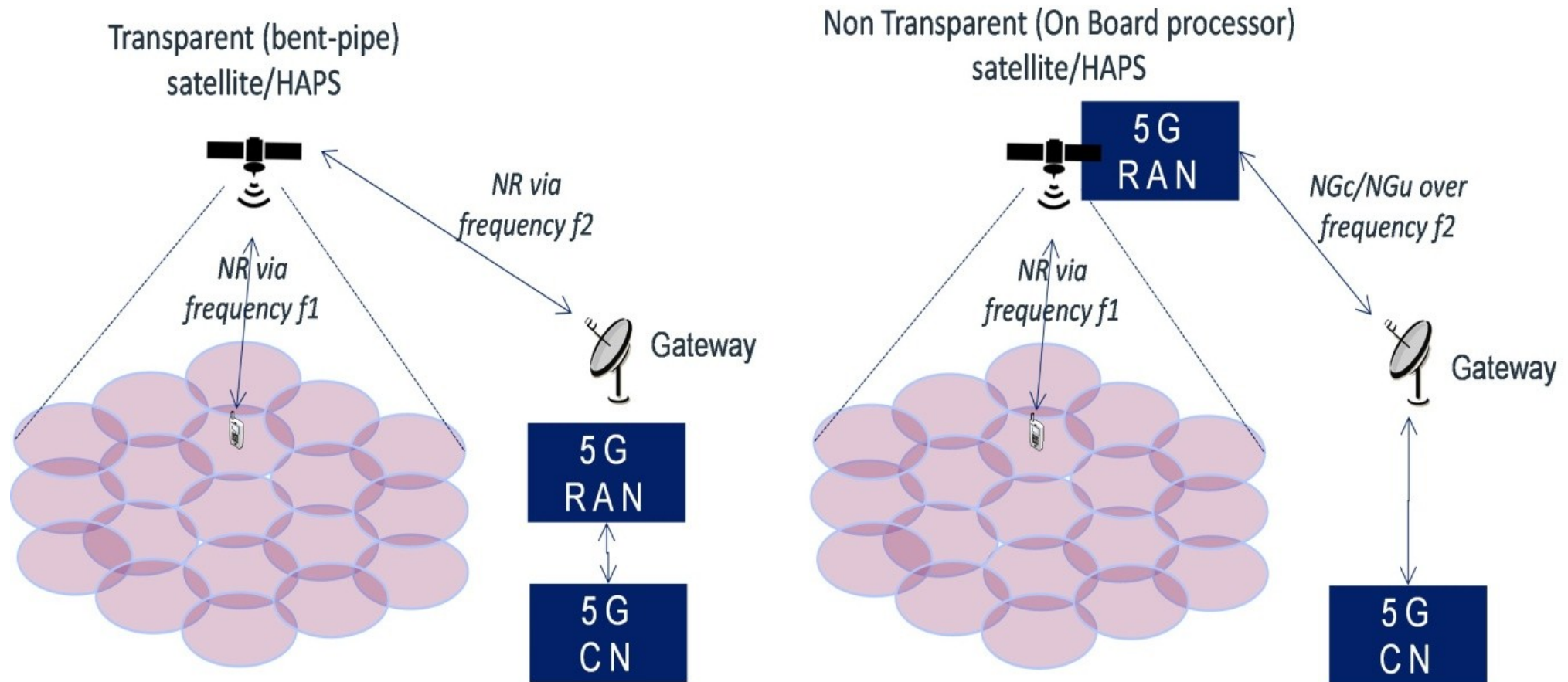
- **LEO (Low Earth Orbit)**: Circular orbit in altitudes of typ. 500-2.000km (lower delay and better link budget but larger number of satellites needed for coverage)
- **MEO (Medium Earth Orbit)**: Circular orbit in altitudes of typ. 8.000-20.000km
- **GEO (Geostationary Earth Orbit)**: Circular orbit 35.786 km above the Earth's equator (Note: Due to gravitational forces a GEO satellite is still moving within a range of a few km around its nominal orbital position).
- **HEO (Highly Elliptical Orbiting)**: Elliptical orbit around the earth.

Satellite Payloads considered for the NTN 5G Networks

Two types of modes or "payload" can be distinguished:

- **Non-Regenerative Payload** (considering the path from the gateway via spaceborne platform or "transparent mode"): A spaceborne platform with no on-board processing capabilities that changes the frequency carrier of the received uplink RF signal, filters and amplifies it before transmitting it on the downlink, i.e. the platform corresponds to an analogue RF repeater;
- **Regenerative Payload** (or non-transparent mode): a spaceborne platform that has on top of RF filtering, frequency conversion and amplification also on-board processing capabilities (for demodulation/decoding, switching and/or routing, coding/modulation) so this spaceborne platform has 5G base station functions on board.

Transparent and Non Transparent (Regenerative) Satellites



Applied Frequencies for Transparent and Non Transparent Satellite

UHF-band (400-900 MHz): Satellite Mobile Military Communication carriers for satellite global coverage.

L-band (1–2 GHz): Satellite Mobile Communication carriers for satellite mobile phones such as Iridium, Inmarsat (providing communications at sea, land and air), NTN 5G (3GPP); Global Positioning System (GPS and Galileo) carriers.

S-band (2–3 GHz): Weather radar, surface ship radar, and some communications satellites.

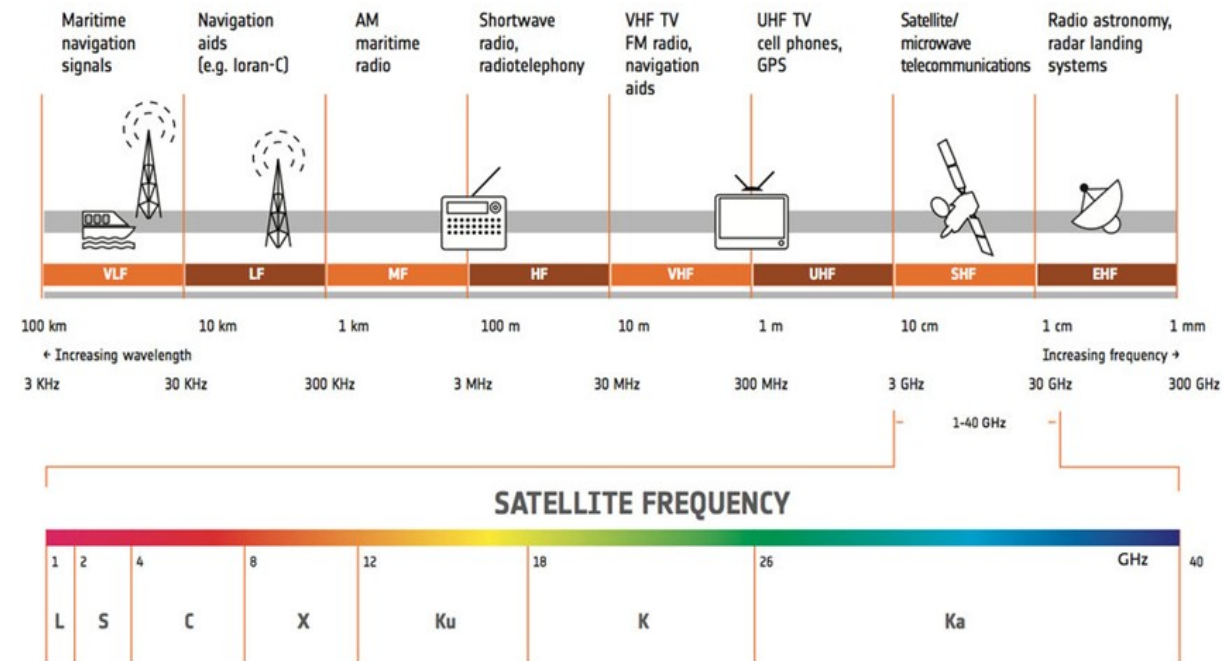
C-band (4–6 GHz): Primarily used for satellite communications, for full-time satellite TV networks or raw satellite feeds.

X-band (7–8 GHz): Primarily used by the military. Used in radar applications including continuous-wave, pulsed, single-polarisation, dual- polarisation, synthetic aperture radar and phased arrays (Earth Observation -EO- applications).

Ku-band (10–14 GHz): Used for satellite communications.

Ka-band Commercial (20–30 GHz): Communications satellites, uplink in either the 27.5 GHz and 31 GHz bands, and high-resolution, close-range targeting radars on military aircraft.

Ka-band Military (21-44 GHz): Used for military and government applications in single and dual- polarization.



Operators of NTN Constellations in LEO Orbits

The Operators of NTN networks need to regulate their spaceborne station via their local regulatory body. Actually have been approved the following LEO Constellations:

SpaceX Starlink

Starlink is an US private company planning long term up to 30.000 satellites. Actually about 12.000 in LEO satellites in orbits. Operational.

OneWeb

OneWeb was in origin a British company planning to deploy up to 650 satellites in orbital planes in LEO satellites in orbits. Recently since 28 September 2023 is part of the Eutelsat Group. Operational.

Amazon Kuiper

Kuiper is an US private company with the objective to launch up to 3.236 satellites in a LEO constellation. Planned next.

Telesat Lightspeed

Telesat is a Canadian company and currently the fourth largest satellite constellation aiming to provide internet access services with about 298 satellites in LEO orbits. Planned next.

NTN Constellations in LEO Orbits – Operational

SpaceX Starlink

Starlink is an US private company planning long term up to 30.000 satellites. Actually about 12.000 LEO satellites in orbit. The satellites are deployed in different orbital planes with altitudes ranging between 540 km to 1300 km. The Starlink User Terminal provides a stationary VSAT with about 60 cm phased-array antenna. Starlink achieves data throughputs up to 93 Mbps for individual users, approximately 16 Gbps capacity per satellite and latency values of 31 ms.

OneWeb

OneWeb was in origin a British company planning to deploy up to 650 satellites in orbital planes. OneWeb uses an altitude of about 1207 km and in contrast to Starlink and Kuiper, the orbital planes also include coverage of the polar regions (SSO) . With such a constellation architecture, OneWeb achieves elliptical beam footprints with a wide inner axis and low height. In January 2023, OneWeb had 542 satellites being fully operational .Recently since 28 September 2023 is part of the Eutelsat Group.

NTN Constellations in LEO Orbits – Planned next

Amazon Kuiper

Kuiper is an US private company with the objective to launch up to 3.236 satellites in a LEO constellation with altitudes between 590 km to 630 km. Data rates envisaged reach up to 400 Mbps. Kuiper uses the frequency spectrum in the Ka-band, 17.8 GHz to 20.2 GHz for downlink direction and 27.5 GHz to 30 GHz for uplink direction. The User Terminal can operate with a phased array antenna. Kuiper has not yet deployed any satellites .

Telesat Lightspeed

Telesat is currently the fourth largest satellite constellation aiming to provide internet access services. The overall constellation consists of about 298 satellites in two shells, one with 1000 km altitude and one with 1248 km altitude. The advantage of such a constellation is a uniform and evenly distributed coverage or satellite visibility across the earth's sphere.