Networks for the 3D future and path to 6G

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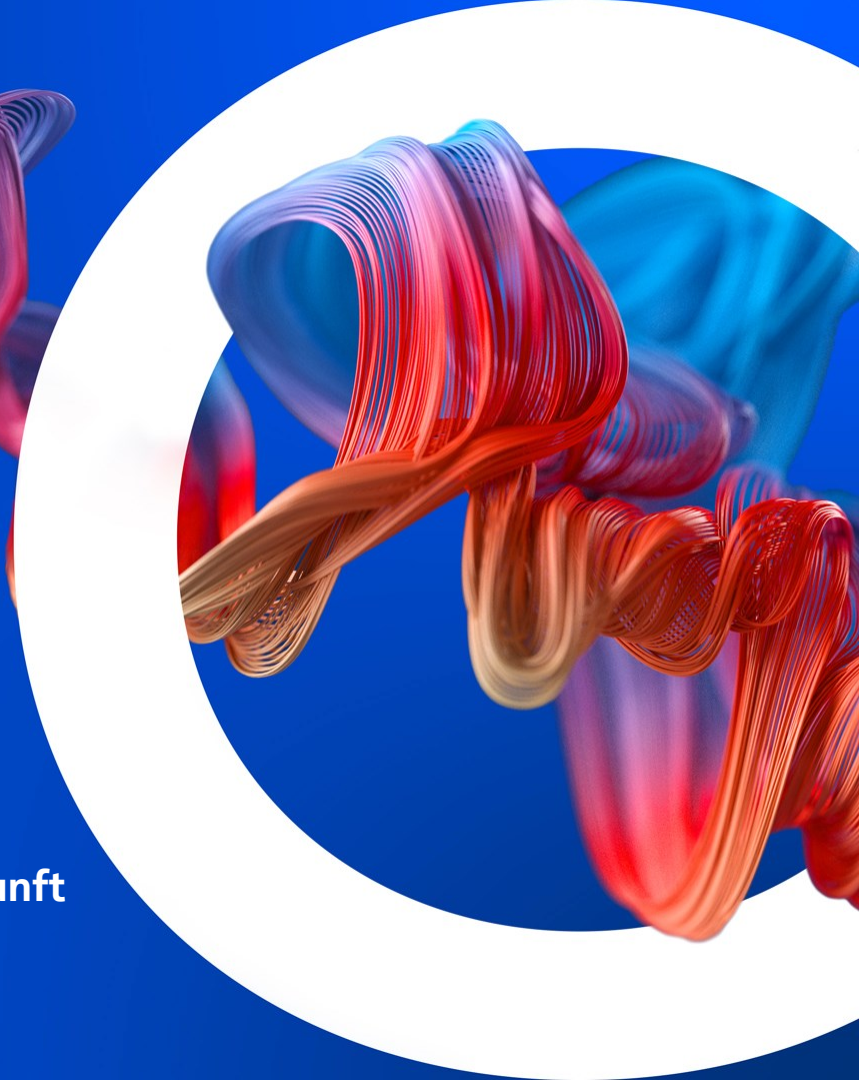
February 1, 2023

Workshop: Antennenkonzepte 3D Netze der Zukunft

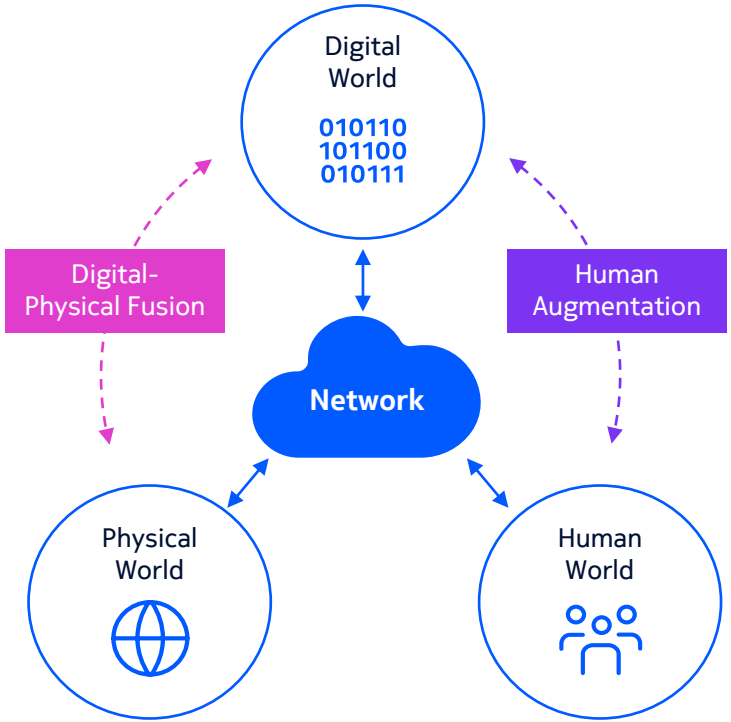
Organized by VDE ITG and Rohde & Schwarz



Agenda

1. **What is 6G?**
2. The value creation
3. NTN in 6G
4. 6G timeline
5. Leading the early 6G ecosystem

6G is framed by digital-physical fusion & human augmentation



Digital-Physical Fusion

Dynamic, network-connected representations of real-world things in the digital world

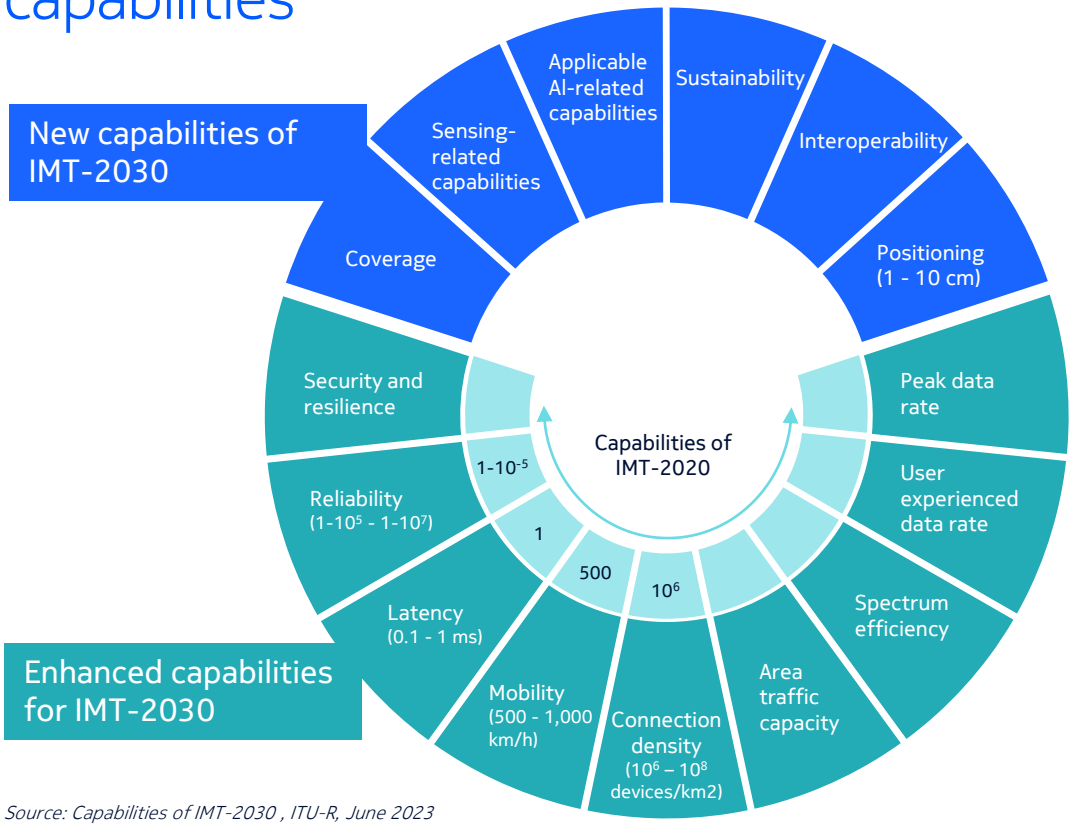
Allows the physical world to be replicated, simulated and automated within the digital world - opening doors to a wealth of new possibilities for human benefit.

Human Augmentation

Extensions that enable people to interact with and within the digital world

Evolves the digital world from being a source of two-dimensional experiences and information, to a focal point of immersive and productive interaction

This transformation will require enhanced and new network capabilities

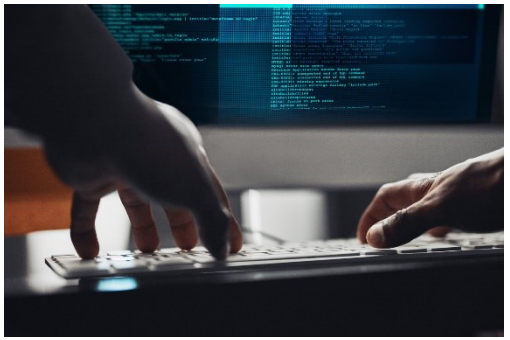


IMT-2030 as important enabler for the following characteristics:

- Inclusivity
- **Ubiquitous connectivity**
- Sustainability
- Innovation
- Enhanced security, privacy and resilience
- Standardization and interoperability
- Interworking

Source: Capabilities of IMT-2030 , ITU-R, June 2023

...to be done in a sustainable, digitally inclusive and resilient way



Green by design

- 10X capacity increase with 50% power reduction, compared to 5G

Digital inclusion

- Aims to address three key factors: accessibility, affordability and consumability

Security and privacy

- Increasing security and privacy risks require higher levels of control

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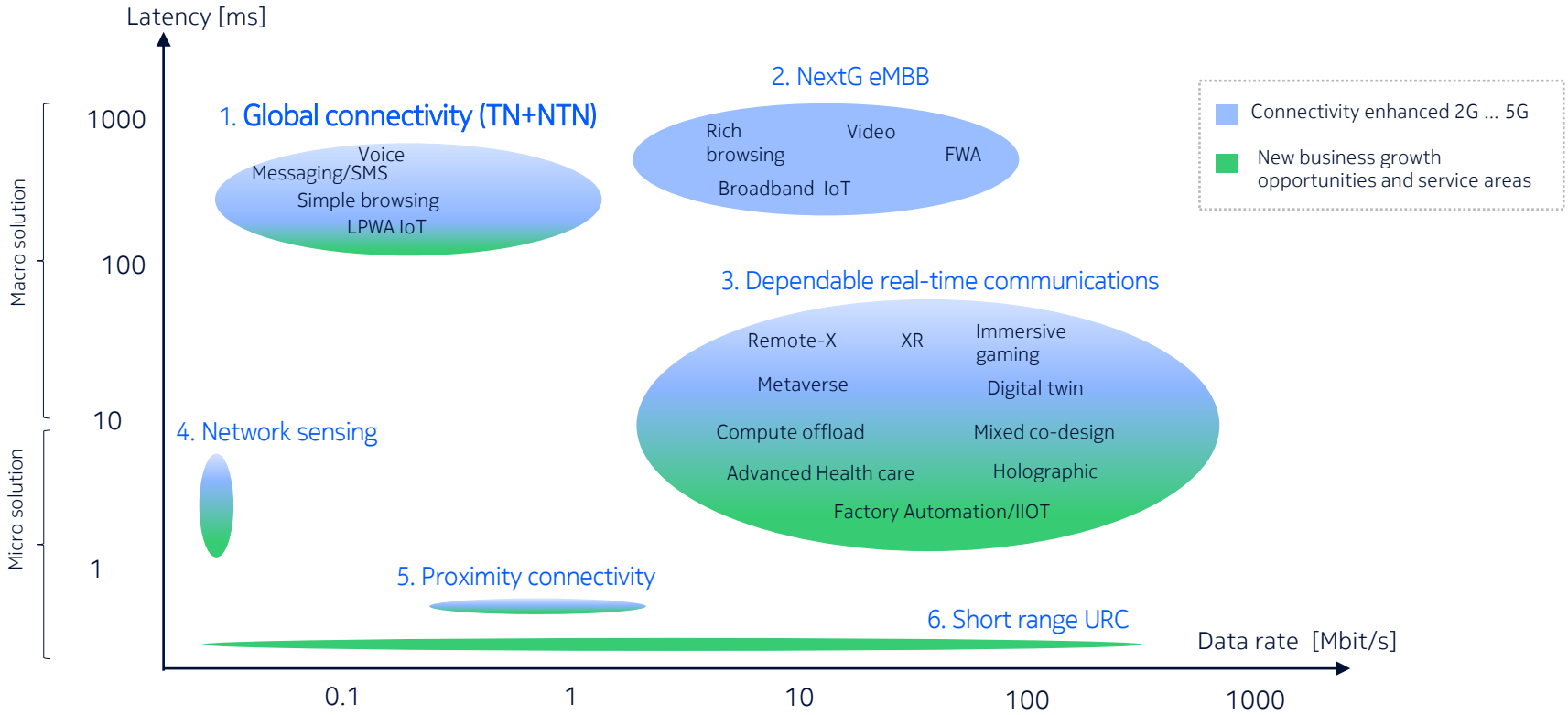
Evolutionary or revolutionary? **Both!**



6G capabilities and services are coming in multiple steps

Illustrative examples

6G day-one focus

- Energy efficient
- New frequency bands
- Dependable real-time communications
- **Integrated TN+NTN**
- IoT expansion
- API Exposure for monetization
- ML/AI framework
- Basic network as a sensor
- Zero-touch network optimization

➕ **Porting successful 5G-A features**

6G to build on 5G success and do so in a more efficient, economical, scalable and sustainable way

6G in full swing

Potential services that take us:

- From connectedness to **togetherness** (e.g., immersive holographic experience, connect the unconnected)
- From information to **knowledge** (e.g., cognitive and complete context awareness, leveraging ambient IoT, digital twins, sensing)
- From efficiency to **purpose** (e.g., mission & life-critical services supported by subnetworks)

➕ **Extreme and yet unknown services**

The full realization of digital-physical fusion and human augmentation

Use Cases for NTN

- Global coverage for search and rescue
- Maritime coverage
- Consumer handheld connectivity in remote areas
- NTN for connectivity in high mobility
- NTN as backup for disaster relief
- Global IoT coverage for full range of IoT devices
- Solving the digital divide

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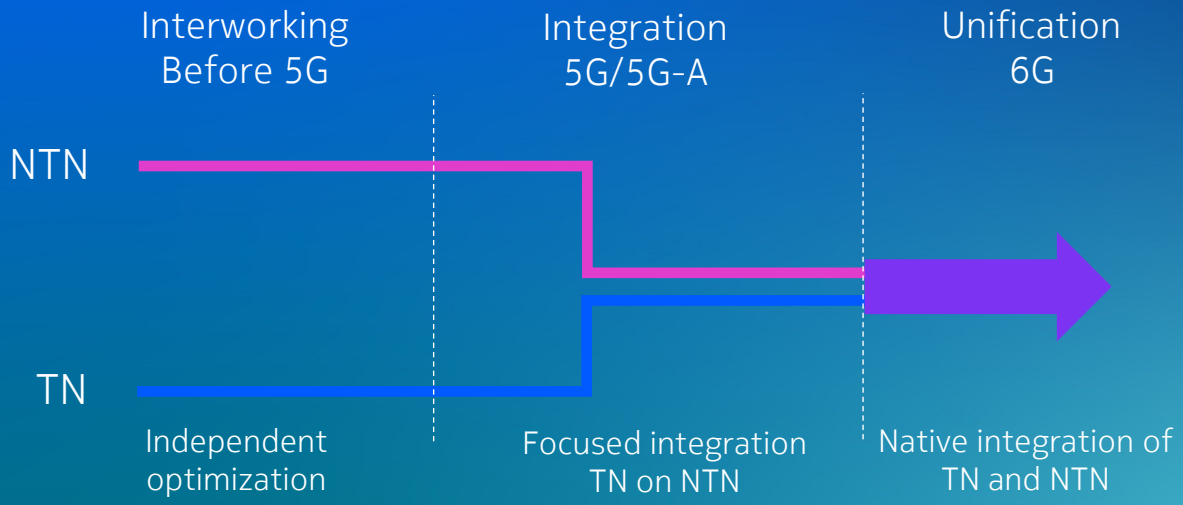
Convergence between Terrestrial and Non-Terrestrial Networks

- Ubiquity, continuity and resiliency
- 3GPP Standard protocol



Rel. 17: Recap of LEO at 600 km/ 1200 km

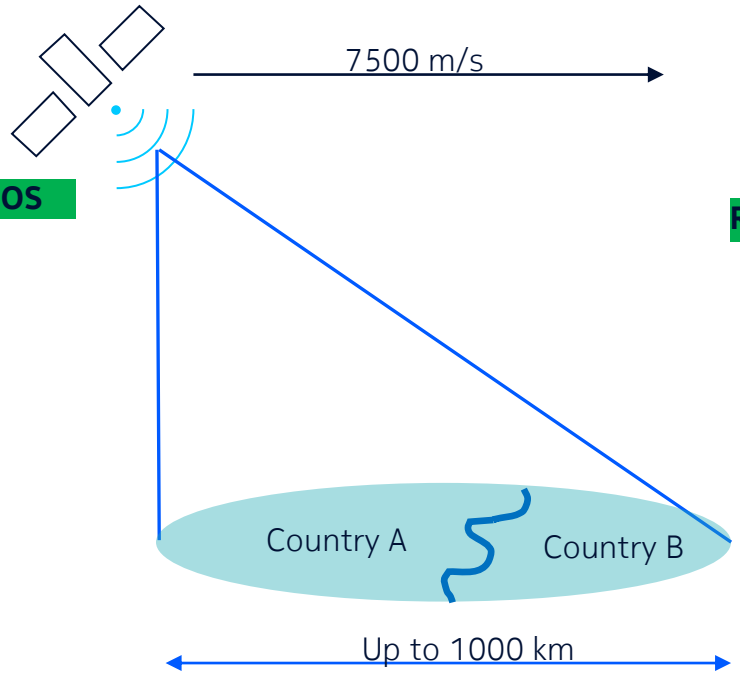
Challenges and Rel-17 solutions

Large Distances:
- Up to 1932 / 3131 km
- Link Budget

Rel.17: Assumed LOS

Large Delays:
- Up to 12.9 / 20.9 ms
- AMS may be out-of-date
- Large HARQ buffer required

Rel. 17: Adjust timers
Rel. 17 HARQ: increased number and optional turn-off



High Speed:
- Mobility: inter/intra satellite
- Timing Advance (UL Sync)
- Doppler

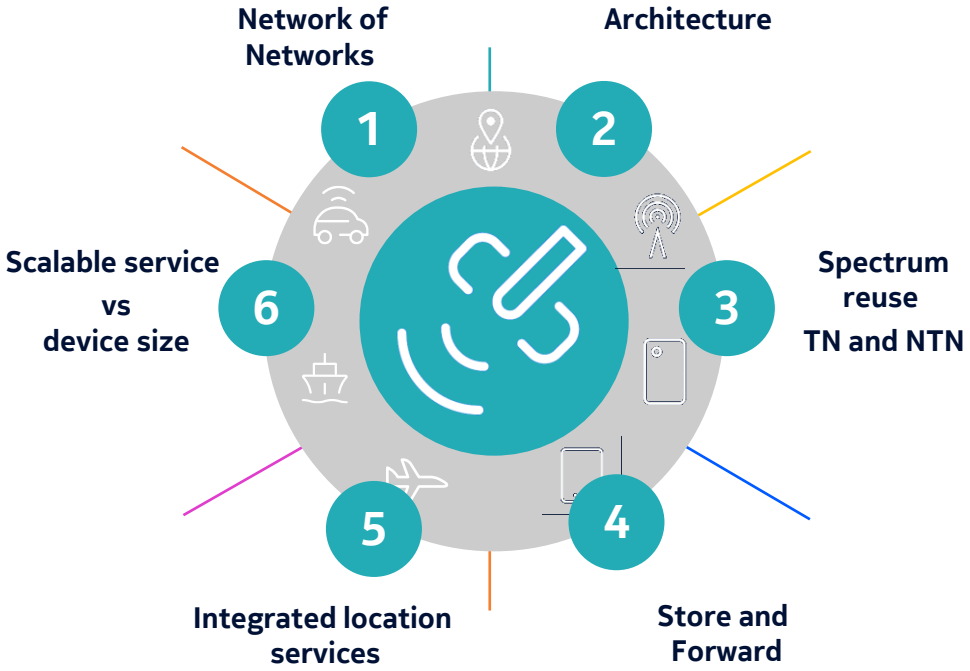
Rel.16: CHO

Rel. 17: UE has GNSS and is responsible for synchronization

Cell size:
- RACH/TA Range
- Country Identification

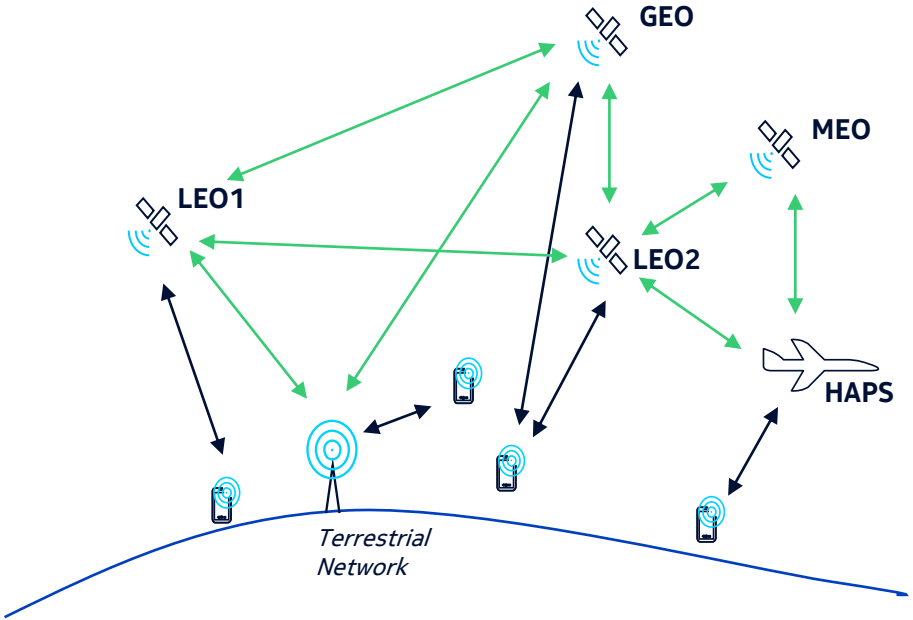
Rel. 17: UE chooses correct PLMN

Six key enablers for 6G NTN



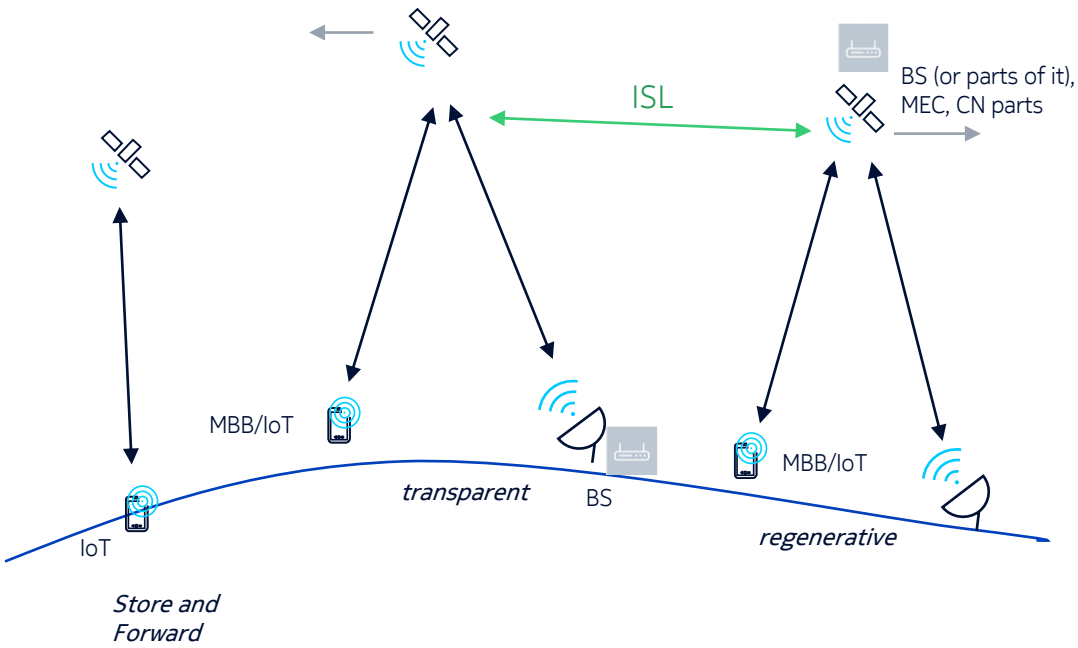
- high level of integration with TN
- flexible system in terms of architecture
- Larger system capacity and increased user throughput compared to 5G-Advanced
- Improved coverage than 5G-Advanced.

Network of Networks



- Efficiency from complementary usage advantage
- Fit each service (with different requirements) to suitable networks
- “Route” optimization of users (load balancing)
- Resilience
- Decrease of CO2 by turning of TN network and serving users from space at times of low load

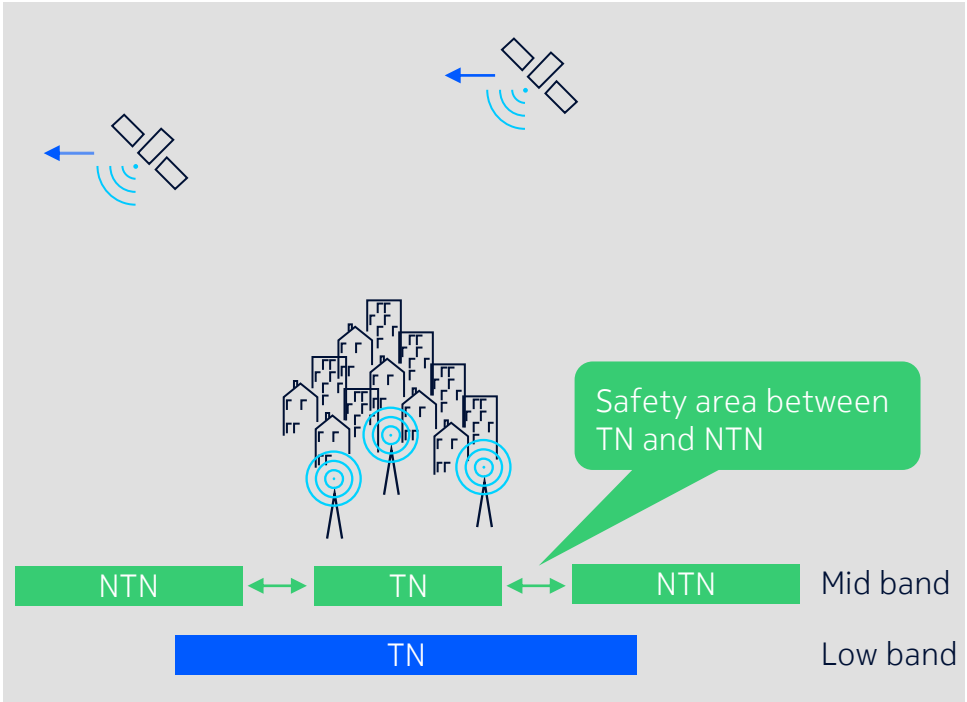
Co-existence of 6G NTN architecture options



- Transparent architecture
- Regenerative architecture
  - Full BS on satellite
  - Part of BS on satellite
  - CN partly on satellite
- Inter Satellite Links (ISL)
- MEC on the satellite
- Store and Forward

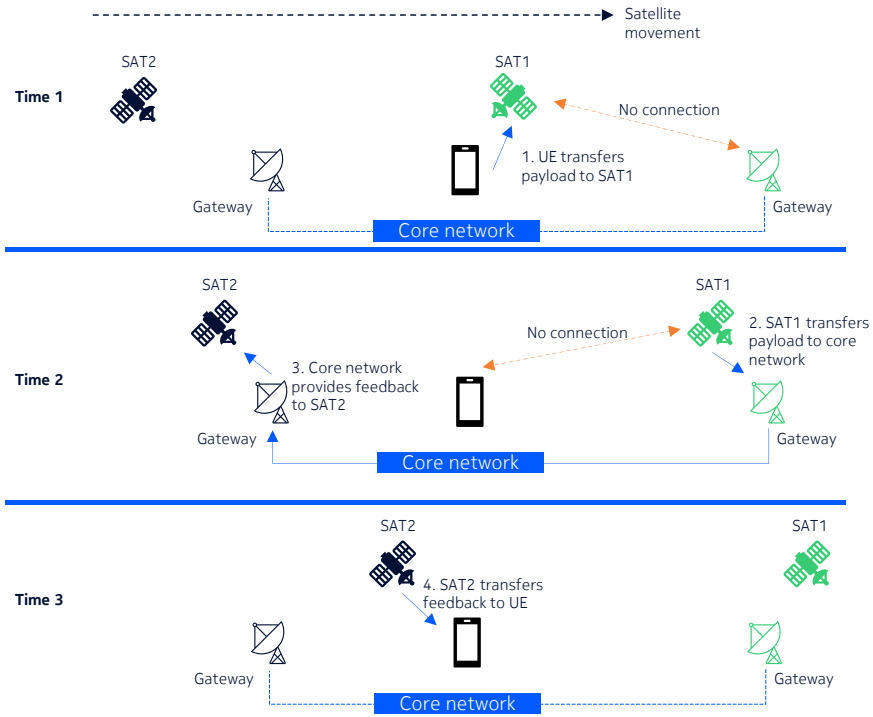
Spectrum Re-use

- FCC opens up for use of terrestrial spectrum from space *
- Spectrum reuse requires that interference is taken care of through
  - Safety margins
  - Interference Coordination
  - Beam control of satellites
- Country borders complicate the design.
- Spectrum needs to be coordinated between the different NTN systems (LEO, GEO) which may share frequencies.
- Complexity from moving cells from moving satellites in LEO constellations
- New bands may come into play for NTN



* FCC: "authorized non-geostationary orbit satellite operators to apply to access terrestrial spectrum if certain prerequisites are met, including a lease from the terrestrial licensee within a specified geographic area"(2023)

Store and Forward



- store data when the satellite is not in position to connect with a ground station, forwarding it as entering the coverage range; relevant for delay-tolerant IoT services and early-adopter constellations with limited number of satellites
- To be included with Rel. 19
- Option of new design from scratch with 6G

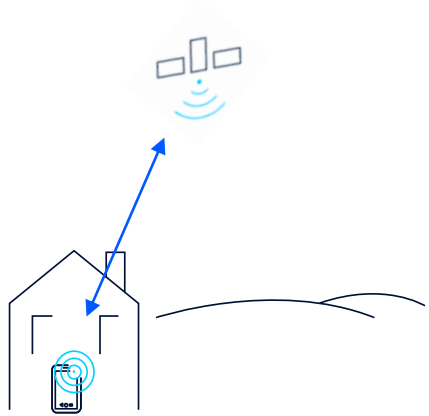
Integrated Location services

- GNSS requirements in Rel-17 and 18 limits coverage to outdoor locations.

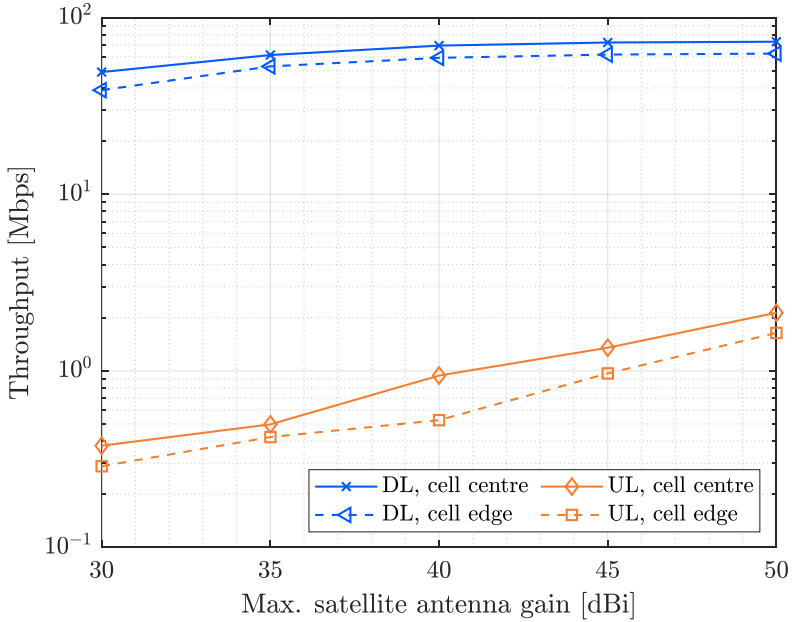
- Making the system independent from GNSS to enable (light) indoor coverage and lowers the price and energy consumption (relevant for low cost IoT devices).

- Therefore, we need integrated location services in 6G.

- As location is used for initial access there is a tradeoff between accuracy and initial access efficiency



Scalable Service vs Device Size



- Coverage and throughput improvements are challenging in NTN due to poor link budget
- Larger antennas at the satellite helps in both directions
- UEs with different power classes or more directionality may appear (for instance in the context of connecting vehicles)
- Waveforms optimizing PAPR and OOBE
- Network coding schemes and in combination with HARQ may also lead to better coverage

LEO 600 km, BW: 30 MHz, 25% background load, 2GHz, 34 dBW/MHz, 50 km(diameter) cells

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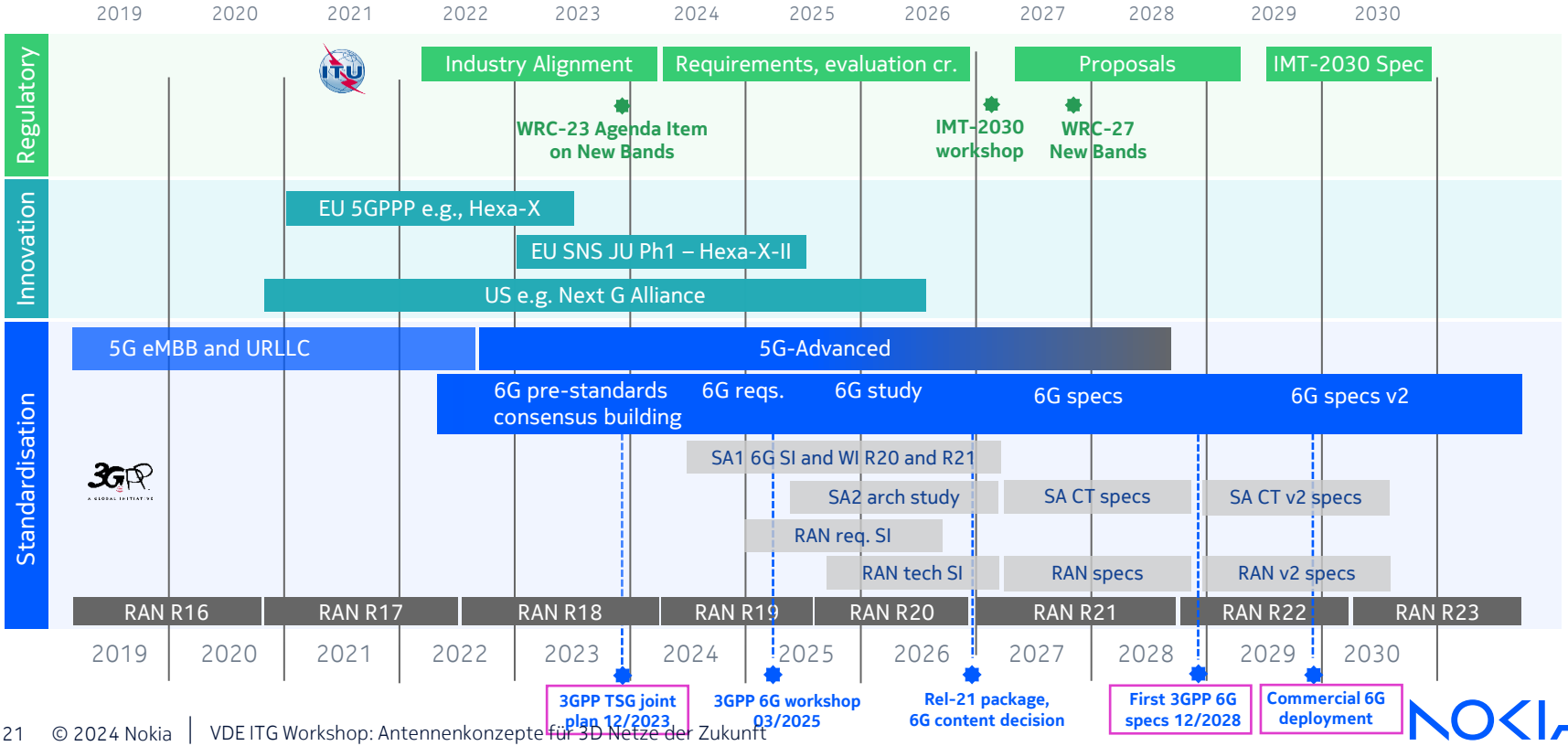
6G success depends on a global unified approach

Different regulatory, innovation, standardization timelines to be brought in harmony



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We are leading the way to make 6G a reality

Ecosystem engagement


NOKIA