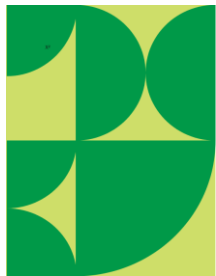


Non-terrestrial Networks (NTN): Boosting 6G from the Sky

CONASENSE 2021 Symposium
04-05 October 2021

Speaker: Tomaso de Cola

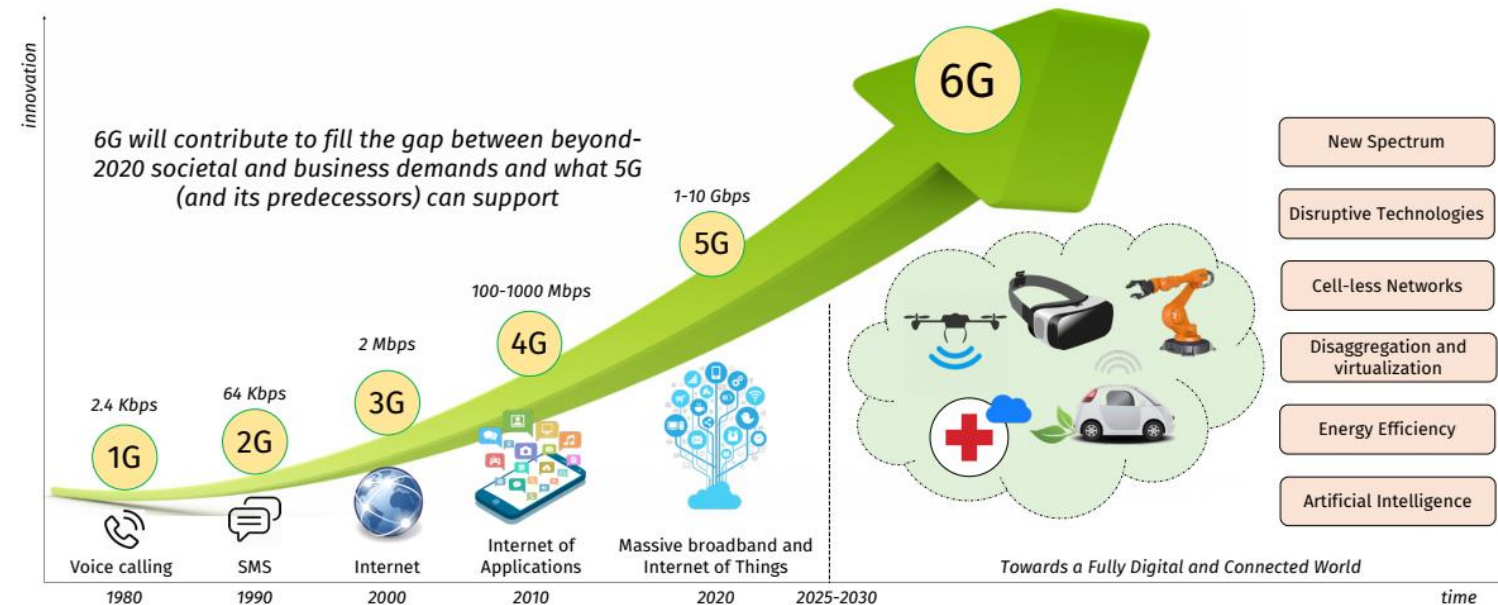


Knowledge for Tomorrow



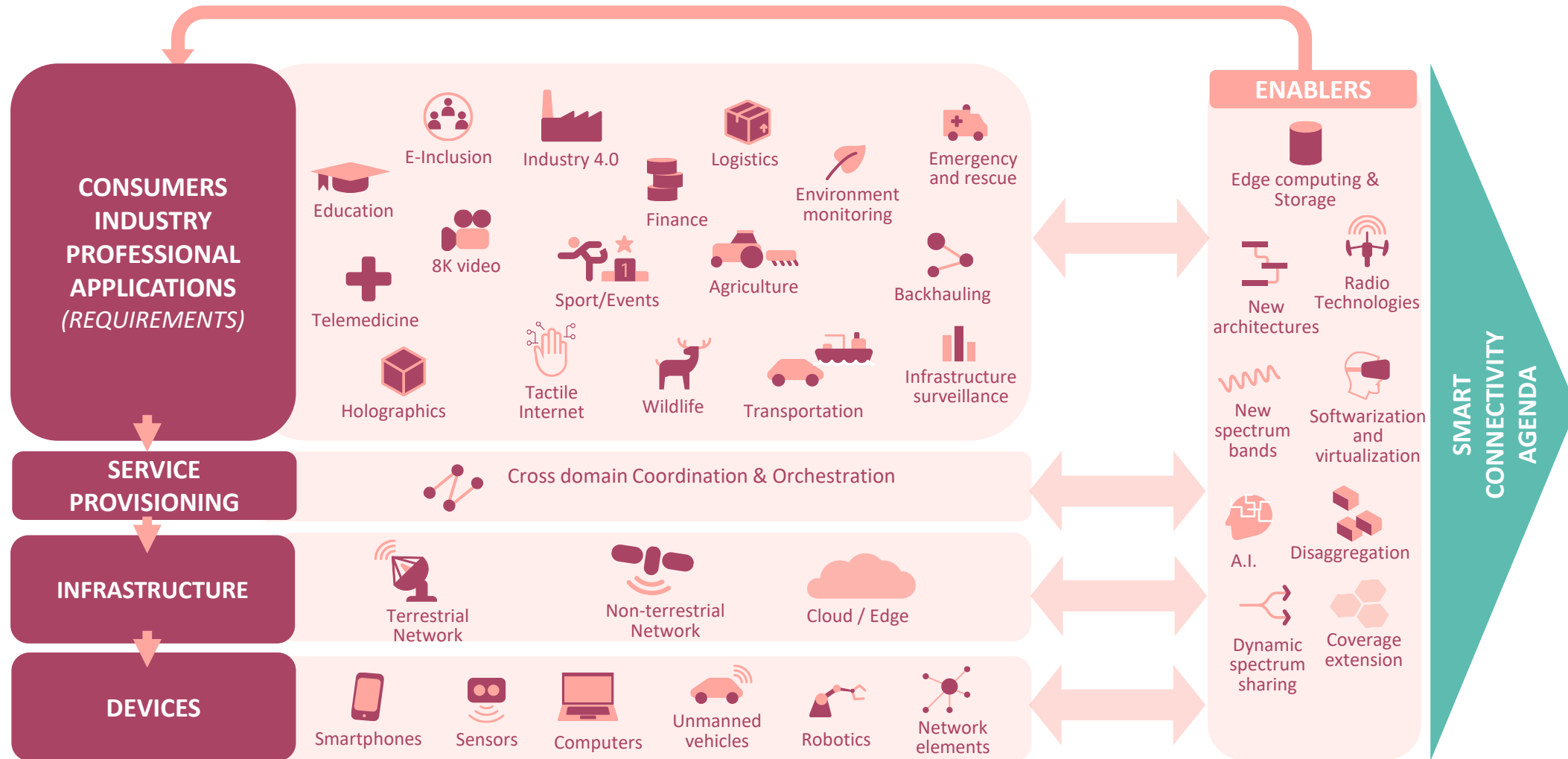
6G: Vision and Services

- B5G and 6G are expected to bring substantial evolution of the architecture and services envisioned for 5G:
 - Deep use of ML/AI concepts
 - New frequency bands (i.e. THz+)
 - Energy efficiency
 - Full system softwarisation
 - Edge computing capabilities on demand
- New services will be enabled:
 - AR/VR/MR
 - Holographic telepresence
 - E-health with haptic applications
 - Pervasive connectivity
 - Unmanned mobility



from M. Giordani *et al.*, "Toward 6G Networks: Use Cases and Technologies," in IEEE Communications Magazine, vol. 58, no. 3, pp. 55-61, March 2020 (with IEEE courtesy)

6G Ecosystem



6G Enablers and Technology Areas

Technological Areas	Indicative list of promising research areas
ubiquitous availability	<input type="checkbox"/> Integrated fixed mobile architecture <input type="checkbox"/> Satellite communications
infinite network capacity	<input type="checkbox"/> Spectrum re-farming and Reutilization <input type="checkbox"/> mmWave, Terahertz, VLC communications <input type="checkbox"/> Satellite communications <input type="checkbox"/> Ultra-massive MIMO <input type="checkbox"/> Flexible capacity scaling
Throughput	<input type="checkbox"/> Ultra-massive MIMO <input type="checkbox"/> Enhanced modulation and coding <input type="checkbox"/> Optical wireless integration
Ultra-low e2e latency	<input type="checkbox"/> Media access control <input type="checkbox"/> Edge/fog computing
Security	<input type="checkbox"/> Software defined security <input type="checkbox"/> Network wide security <input type="checkbox"/> Slice-specific and convergence on common software defined patterns <input type="checkbox"/> Distributed trust systems
Energy efficiency	<input type="checkbox"/> extended bandwidth adaptation <input type="checkbox"/> improved RF
Massive IoT Service management	<input type="checkbox"/> Scalable management of massive deployment <input type="checkbox"/> Distributed autonomous and cooperative computing

NTN key contributions

NTN key enabler
see NB-IoT in 3GPP

Enablers

AI/ML

Data Analytics

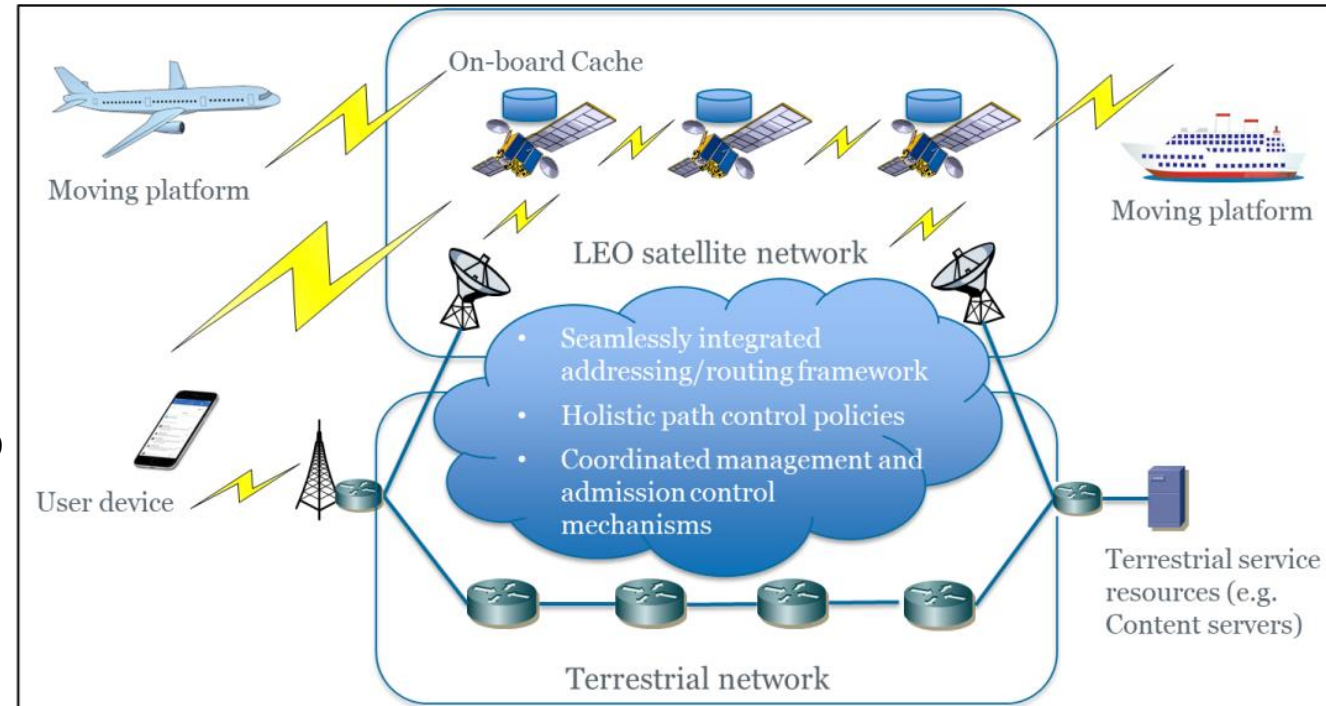
Real-Time Zero-Touch Service Orchestration

High Performance Distributed Computing



Role of satellite in B5G/6G

- Satellite will certainly be pivotal to the effective deployment of B5G/6G technologies, in order to:
 - Guarantee ubiquitous coverage with limited infrastructure
 - Exploit effective multicast functionalities for data distribution
 - „connecting the unconnected“
 - Easily push content to the edge for quasi-zero latency perception
- Explosion of LEO satellite market can certainly further revamp the role of satellite in the B5G/6G ecosystem:
 - Reduced latency
 - Capability of onboard storage
 - Inherent edge computing capabilities

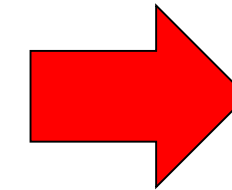
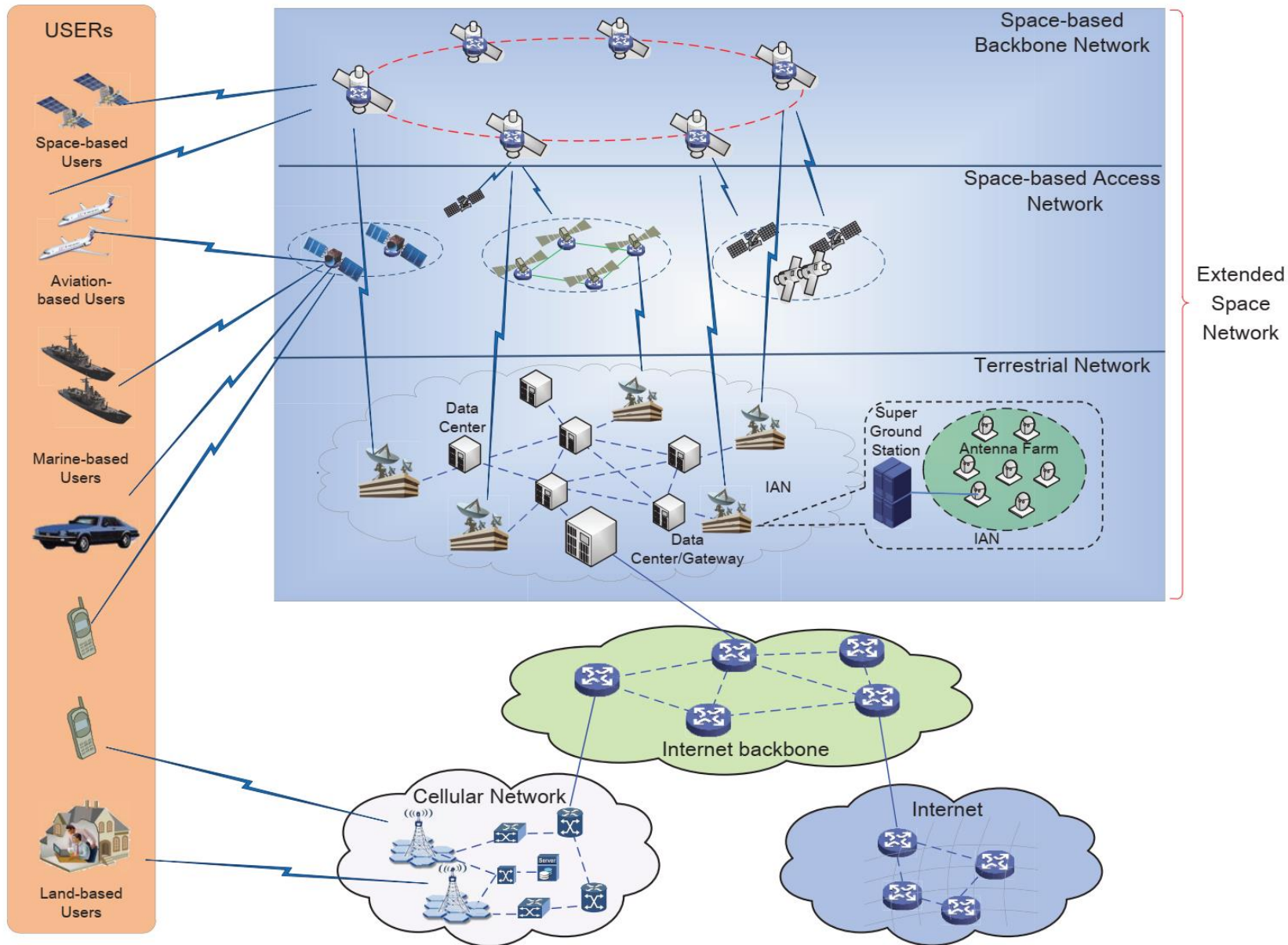


From ITU Technical Report, “Representative use cases and key network”
Focus Group on Technologies for Network 2030 (FG NET-2030)
FG NET-2030 Sub-G1 (with ITU courtesy)

RESEARCH AREAS	RATIONALE AND IMPACTS
SYSTEM ARCHITECTURE: <i>a single access network</i>	<ul style="list-style-type: none"> • Full integration of T and NT, and of hierarchical layers • Softwarization, Virtualization, and Disaggregation • Processing and communication in the sky (Inter-node links) - Edge computing and storage
CONSTELLATIONS: <i>hierarchical design</i>	<ul style="list-style-type: none"> • Hierarchical constellations: from single (layers) to multiple orbits (layers) • Incomplete constellations • Nodes platooning
RESOURCE OPTIMIZATION: <i>infrastructure as a resource</i>	<ul style="list-style-type: none"> • Beyond the bandwidth, time, power, and space concepts: infrastructure as a resource • Infrastructure reconfiguration: a network of networks • Autonomous and intelligent Predictive optimization
DYNAMIC SPECTRUM MANAGEMENT <i>coexistence and sharing</i>	<ul style="list-style-type: none"> • Coexistence and Sharing: inter-segment (T & NT) and inter-layer • New spectrum (THz and Optical): user/feeder/inter-node • Spectrum sensing, predictive (see also AI)
BEAMLESS COMMUNICATIONS: <i>user-centric coverage</i>	<ul style="list-style-type: none"> • Beyond beam-centric: user-centric beamless communications • Dynamic creation of communication links that follow the users • MIMO and beam forming
UNIFIED ACCESS NETWORK DESIGN: <i>flexibility and adaptability</i>	<ul style="list-style-type: none"> • 3GPP waveform designed for T/NT channels: Doppler/Delay/vertical handover • New numerologies for flexibility and adaptability • Quantum based communication for security
ARTIFICIAL INTELLIGENCE: <i>exploitation of NT dynamics</i>	<ul style="list-style-type: none"> • System Complexity management, including security • Network predictive configuration and Predictive maintenance • New physical layers, medium access layer, etc. approaches
PROPAGATION CHANNELS & ANTENNAS: <i>beyond large scale arrays</i>	<ul style="list-style-type: none"> • Higher frequency bands (Q/V, W, ...) & Wavelength (including optical) • Propagation channel characterization • Beamless communications • Large scale antenna arrays, Distributed arrays (node cooperation)
COMPONENTS: <i>developing the supporting technologies</i>	<ul style="list-style-type: none"> • Antenna, Amplifiers • THz & Optical devices (Rx & Tx)



NTN as enabler for 3D systems



**Multidimensional
Multi-layered
Unified**

H. Yao, L. Wang, X. Wang, Z. Lu and Y. Liu, "The Space-Terrestrial Integrated Network: An Overview," in IEEE Communications Magazine, vol. 56, no. 9, pp. 178-185, Sept. 2018.

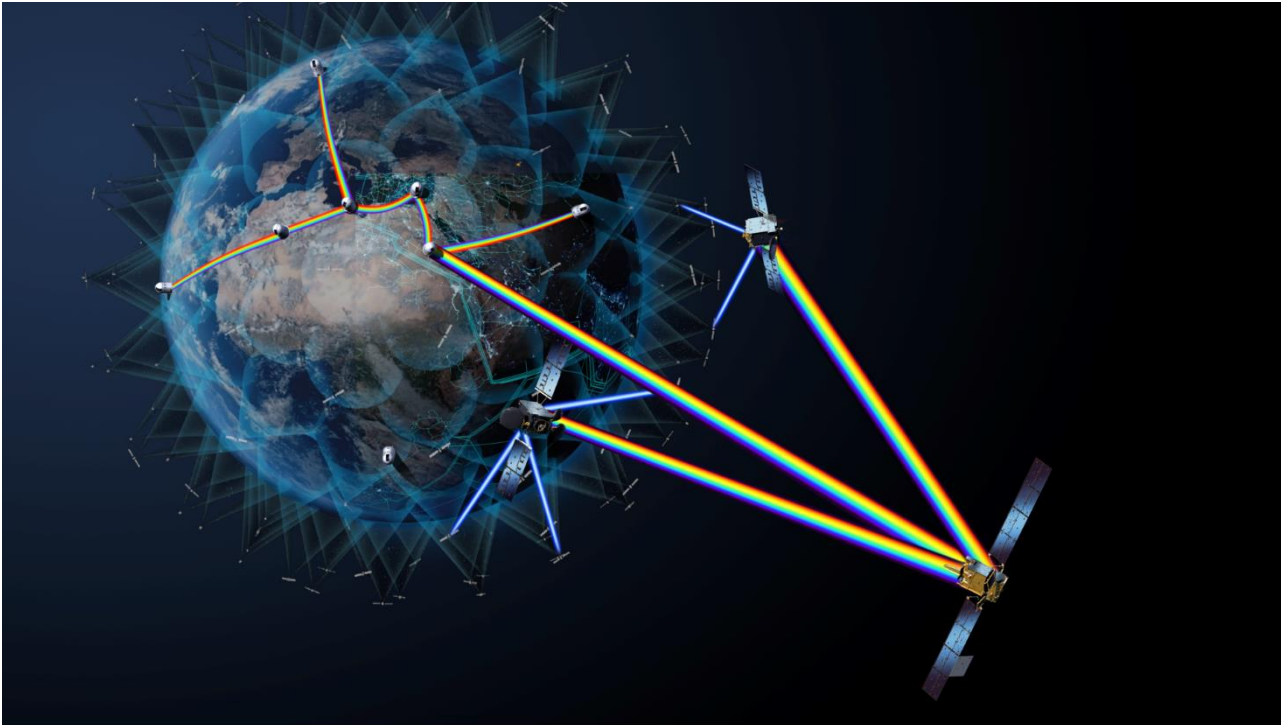


Optical links for global NTN connectivity?

- Global connectivity
 - Space communications network as an extension of the ground network
 - LEO, GEO satellite communications: downlinks, feeder-links...
 - Fiber-coupling is essential for using fiber based-components
 - Needed when targeting ~+10Gbps
 - It enables pre-amplification, coherent communications, wavelength division multiplexing...
 - Availability is key in offering competitive services
 - Clouds: ground network of optical ground stations (OGS)
 - Turbulence: phase corrections
 - Adaptive optics:
 - Research on alternative approaches
- Technology demonstration
 - Optical free-space communications testbed at DLR
 - 13.16 Tbit/s with 16QAM in 2017 together with ADVA



Optical links for global NTN connectivity?



Conclusions

- 6G will introduce further technology evolution with respect to 5G with new technologies and unprecedented QoS/QoE requirements
- Terrestrial infrastructure alone will not suffice to meet all envisioned requirements:
 - Technology heterogeneity and convergence will be the clue to meet all new use cases from civil society and Industry 4.0
 - Role of NTN pivotal to achieve all the planned connectivity objectives and allow for more sustainable communication models
- NTN and TN expected to symbiotically and interchangeably live in the 6G body
- Evolution of NTN in the form of new systems and thereof components (e.g., optical link technology) will be the key factor to enable more NTN-oriented digital connectivity agenda of industry and governments



Take-home Message 😊



Thank you for the attention!

For any questions please contact me at:
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