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Satellite COMMUNICATIONS

and their role in enabling 6G

The value of technology advancement ultimately lies in the benefits it brings to citizens. As researchers define 6G as the Internet of Everything, key requirements emerge for users to have a meaningful, reliable and secure experience. Satellite is key to making that a reality.

Global Challenges | Satellite Answers

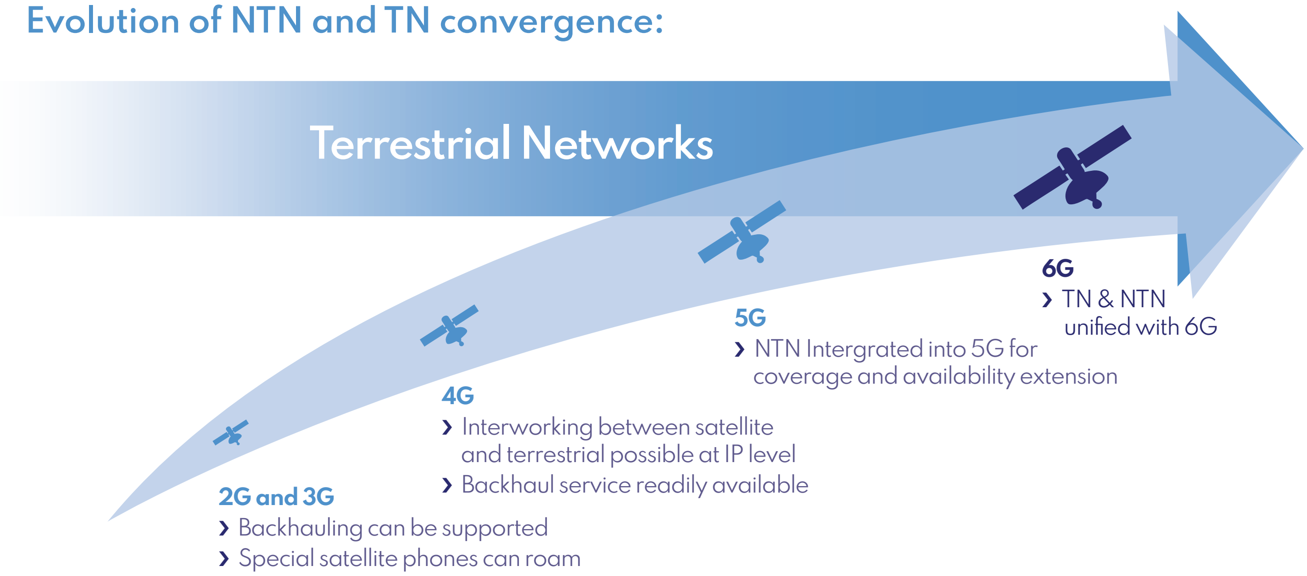
With an anticipated launch around 2030, 6G brings promises of the "internet of senses" and the "internet of everything" to the world.[1] Proponents claim that communication experiences will include data transmission for all five senses: sight, sound, smell, taste, and touch. Increasingly rapid advances in wireless technology should enable 6G-supported applications such as advanced virtual reality, holographic communication, and distributed artificial intelligence. Accordingly, 6G should merge the real and digital world and open a host of opportunities to users across the globe. These human-centric use cases should be complimented by advanced sensing and machine type communications, for example controlling robots in hard-to-reach locations, Earth observation and deep integration of sensing with communications.

6G will build on the important work being undertaken to bring 5G to the world. While it remains to be seen which 6G use cases will become reality, 6G will need to incorporate the full range of terrestrial and non-terrestrial technologies if its benefits are to be enjoyed by all. As all previous generations of wireless technologies have demonstrated, the use of non-terrestrial technologies is essential for maximizing reach. This means that the standards for 6G must include terrestrial and non-terrestrial network (TN and NTN) technologies from the outset.

The GSOA Vision for satellite in 6G

While 5G optimizes terrestrial network design to allow the integration of satellite for coverage and availability extension, 6G will optimize network design, implementation and operation considering the characteristics of terrestrial *and* satellite communications to create unified networks. By building on the integration of NTN into 5G, 6G will leverage the most advantageous characteristics of satellite communication and sensing systems. Different types of 6G devices will be able to access satellite-based networks with service capabilities suitable for their specific use cases.

Evolution of NTN and TN convergence:



1 https://www.ericsson.com/en/6g/internet-of-senses

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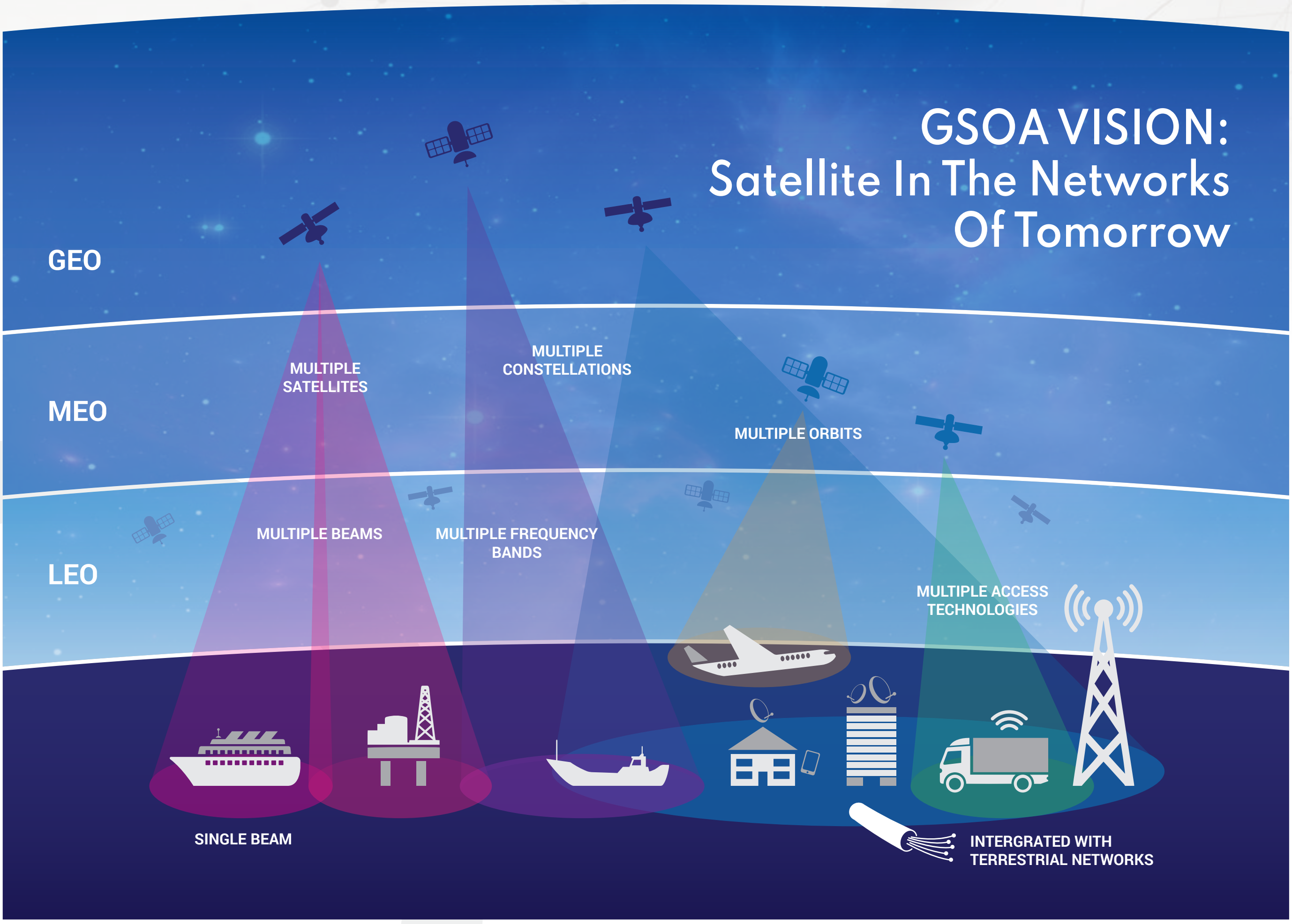
The studies defining the goals for 6G are developing a range of Key Value Indicators (KVIs). Potential KVIs that NTNs and especially satellite networks can contribute to are:

UBIQUITY | **CONTINUITY** | **SCALABILITY** | **RESILIENCE**

A range of Key Performance Indicators (KPIs) will emerge from these KVIs for varying types of equipment and use cases to cover aspects such as positional accuracy, data rates and power consumption.

This leads to a future where multiple TNs and NTNs work together, e.g. through enhanced AI/ML techniques, to deliver connectivity whenever, however, and wherever needed.

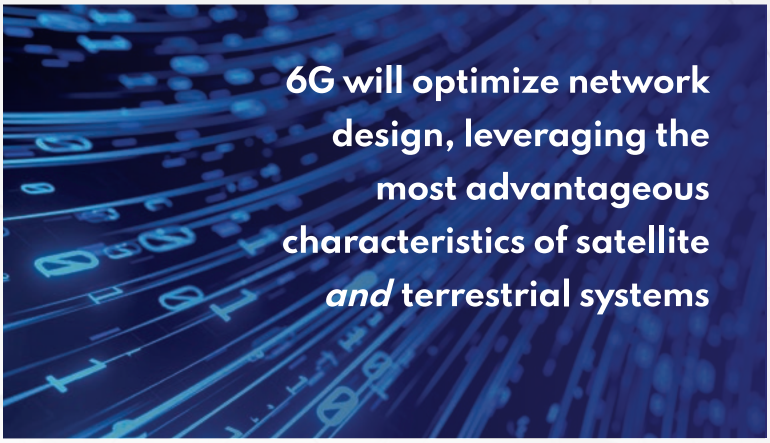


The Role of Satellites in 6G

6G will need to rely on the combined benefits of multiple communications technologies for 6G use cases to be meaningful for broader society. As such, the KVIs of satellite communications being ubiquity, continuity, scalability & resilience stand to play a central role in 6G networks. Satellites already play an important role in expanding the reach of 4G network services, and are poised to expand 5G network services as well.

Specifically, the capabilities of satellite communication networks highlighted below make it particularly well-suited to allow 6G to deliver on the KVIs and KPIs that will ultimately be agreed:

› Global Coverage



Satellites connect all parts of the world from the densely populated to areas that are otherwise unreachable. This includes providing mobility services on planes, ships and land-based vehicles, and their supporting infrastructure. Building on the Internet of Things conceived around 4G, and further expanded in 5G to support NTN, 6G networks will link sensors everywhere to create the Internet of Everything. As a result of their location in space and differing orbits, communications satellites are particularly well-suited for distributing critical information in 6G networks over wide areas.

› Sustainability

Satellite communications will support TN to address global sustainability goals. For example, satellites can provide communications directly to locations where the embedded carbon costs for a TN solution are excessive. In addition, satellites should increasingly be seen as 'base stations in the sky', from which content and data can be accessed at anytime from anywhere, relying on solar power rather than requiring huge amounts of energy to both run and cool them as is the case with land-based data centers. Satellite communications can connect widely dispersed sensors used for essential environmental and climate monitoring, e.g. providing early warning of possible wildfires. They will also connect systems requiring large scale energy to operate such as railways to enable the operational energy requirements to be reduced.

› Reliability

The use cases around unifying the physical, digital, and biological worlds foreseen for 6G highlight the need for 6G networks to be highly **reliable**, **resilient**, and **secure**. Some mobile operators have experienced first-hand how the integration of satellite communications into their networks significantly increases the uptime of their networks. This is due to the higher availability of NTN, so when unified, NTN and TN can maximize service reliability, for example by using the NTN to provide a backup connection for the primary TN connectivity.

› Resilience

With climate change and geo-political tensions on the rise, the world is becoming increasingly susceptible to natural and man-made disasters while at the same time becoming increasingly dependent on connectivity. Leveraging the 'always on' capability and inherent resilience of space-based networks, 6G networks are set to be the most resilient networks of all time, as long as they are conceived as unified networks from the start, building on 5G developments based on NTN and TN technologies.

› Security and authentication

With the ambition of being an Internet of Everything, 6G users will rightfully demand an unprecedented level of security, trust and authentication. The inherent security features of satellite communications make hacking or eavesdropping data transmission over these networks extremely difficult, particularly in point-to-point or private circuit operations.

As the capabilities of quantum computers grow towards having a stable environment offering reliable quantum supremacy able to break today's encryption schemes in near-real-time, the need for enhanced security and authentication grows. This is both in terms of secure 6G networks (including satellite communications networks) and for delivering quantum resilient security as a service, e.g. Quantum Key Distribution (QKD). Satellite QKD may pave the way to a global quantum internet network, where satellite naturally addresses path length limitations that arise due to fiber absorption.

› Meeting Capacity Requirements

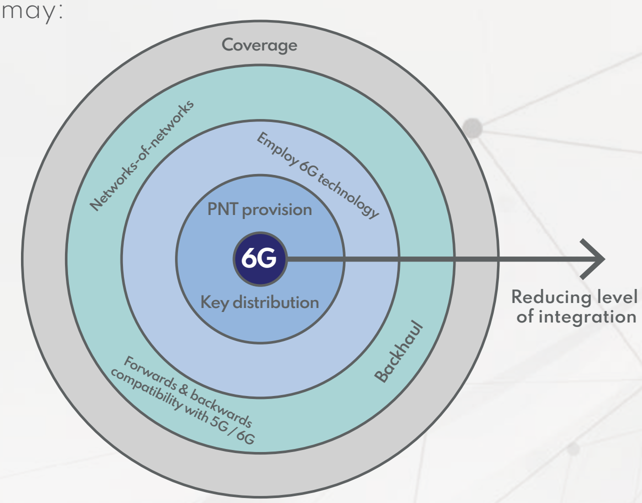
6G's multi-sense data transmissions are likely to require significant capacity. Unlike the tenfold increase from 4G to 5G, there may be a hundred-fold jump in speed, requiring extensive integration among technologies in order to support anticipated demand. Placing this transmission load on terrestrial networks alone will put great strain on even the most advanced systems and thus affect the quality of service and ultimately the adoption of 6G. Accordingly, to meet these data needs, multiple networks will be required. Satellite connectivity can offer a competitive alternative or complement to terrestrial technologies by offering connectivity where it is not available or additional bandwidth to ease bottlenecks and carry the extra traffic. Each wireless technology, including satellites, will need spectrum to play their respective roles in the 6G ecosystem.

› Positioning and Timing Services

Delivery of many of the services envisaged for 6G will require even higher resolution, positioning and timing than that of 5G. This will enable position-dependent services relating to the metaverse and sensing, as well as supporting the higher fidelity QoS and data rates for 6G. Satellite networks will need to support these requirements as well as deliver them as a service in outdoor locations for which they are perfectly suited.

This figure illustrates the various 'touch points' satellite communications is expected to have with '6G'. With '6G' technology and services at the centre, each ring shows reducing levels of uniqueness and level of integration to 6G. For example, satellite communications may:

- offer the precision of PTN services necessary for supporting 6G where and when terrestrial provision is unavailable thus enabling 6G services when and where it would not otherwise be possible.
- employ 6G technology as the communications technology of choice for a satellite communications network.
- provide backhaul to connect a network-of-networks and be backward compatible with previous generations of communications networks.
- provide global coverage if desired.



The use of satellite systems can help accelerate 6G deployment. By encouraging terrestrial telecom operators to use satellite communications, nations can reduce time lag for the adoption of new technology between urban and rural populations. They can also begin to enjoy the advantages of a connected population and economies, avoid creating a 5G and 6G divide, and meet development goals far sooner than expected.

With work on 6G already under way, it is critical that governments begin to consider the wide range of technologies that will be required to realize the vision of 6G. For 6G to be socially and economically inclusive, governments and regulators will have to ensure their policies and regulations are also technologically inclusive so that each technology can play its role in the 6G ecosystem.

The building blocks for satellite-terrestrial integration have been put in place with 5G. 6G will build on these to deliver unified networks with inbuilt ubiquity, continuity, scalability & resilience.

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