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6G NTN & Space Communications

Non-terrestrial networks offer standardized high performance satellite communications at global scale.

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July 2026

Direct-to-device and NTN standards

In lead markets, direct-to-device satellite services are now widely available for purchase. They offer compelling utility to end customers by providing coverage in remote areas underserved by terrestrial networks (TNs). Mainstream adoption is on the horizon.

This report makes the case for adopting 3GPP standardized non-terrestrial networks (NTNs) based on 5G Advanced (Release 17 onward) and proposes options to evolving NTNs in the 6G era.

Current services have been effective at demonstrating direct-to-device satellite technology and rapidly scaling to a wide customer base. Over the long term, these proprietary narrowband and adapted 4G terrestrial systems are likely to be superseded by higher performance, standardized, and purpose-built NTN systems.

Standardized and purpose-built NTNs

NTN is standardized in 3GPP from Release 17 onward and includes a narrowband Internet of Things (NB-IoT) NTN variant and a New Radio (NR) NTN variant for data devices such as smartphones and satellite terminals. The specifications can therefore scale services from very low to moderately high data rates (see **Table 1**).

NTN—specifically NR NTN—is expected to offer better system performance and data rates than today's proprietary narrowband and adapted 4G systems because

- The NR NTN device uses GNSS to determine its position and, at connection setup, receives the satellite's position and velocity (ephemeris).
  - In this way, the device can compute timing and frequency corrections to its uplink transmissions, a process that compensates for delays and Doppler shifts and extends the usable part of the beam footprint.
- The NTN mobility framework leverages the deterministic nature of the satellite movements to trigger time-based and location-based handovers.

Combined with various other enhancements (e.g., enhanced HARQ to optimize retransmissions), these features should make the NTN system deliver better customer experience than adapted 4G systems and proprietary systems designed for messaging. The leading provider of direct-to-device satellite services (Starlink) has said it will adopt NTN in its next-generation constellation. Although not confirmed, it is widely reported that Apple will move from its current proprietary system to NTN in the medium term.

NTN is initially specified to use mobile satellite spectrum (MSS), such as L- and S-band, for direct-to-device services (Ka- and Ku-bands are also specified for dedicated satellite terminals). The MSS bands are internationally regulated by the ITU-R and are licensed for cross-border use. In many regions—for example, in Europe—it is difficult not to overlap (and potentially cause interference) at national borders using repurposed terrestrial spectrum.

Table 1: NTN satellite services

	NB-IoT NTN	NR NTN	
		Direct-to-device	Broadband
Example device types	IoT modules, devices, and gateways	Smartphones, cars, embedded eSIM devices	VSAT terminals, mobile gateways, vehicles, rail, maritime, aerospace, industrial routers
Performance	Narrowband (10s to 100s of kbps)	1–10Mbps	Broadband (50Mbps+)
Example use cases	Utilities, agriculture, mining, oil & gas, logistics, environmental monitoring, messaging	Direct-to-device: smartphones, public safety, defense, agriculture, utilities, transportation	Cell backhaul, enterprise access, on-demand connectivity, transportation, public safety, defense, etc.
Spectrum	L- and S-bands (n254, n255, and n256)	L- and S-bands (n254, n255, and n256)	Ka- and Ku-bands (n510, n511, and n512)

Source: Omdia

Satellite operators need stable technology ecosystems that can serve customers over long periods. NTN deployments based on 5G Advanced standards (R17 onward) will continue to evolve; for example, GNSS-resilient features, voice over NTN NB-IoT, and regenerative payloads are all in the development pipeline.

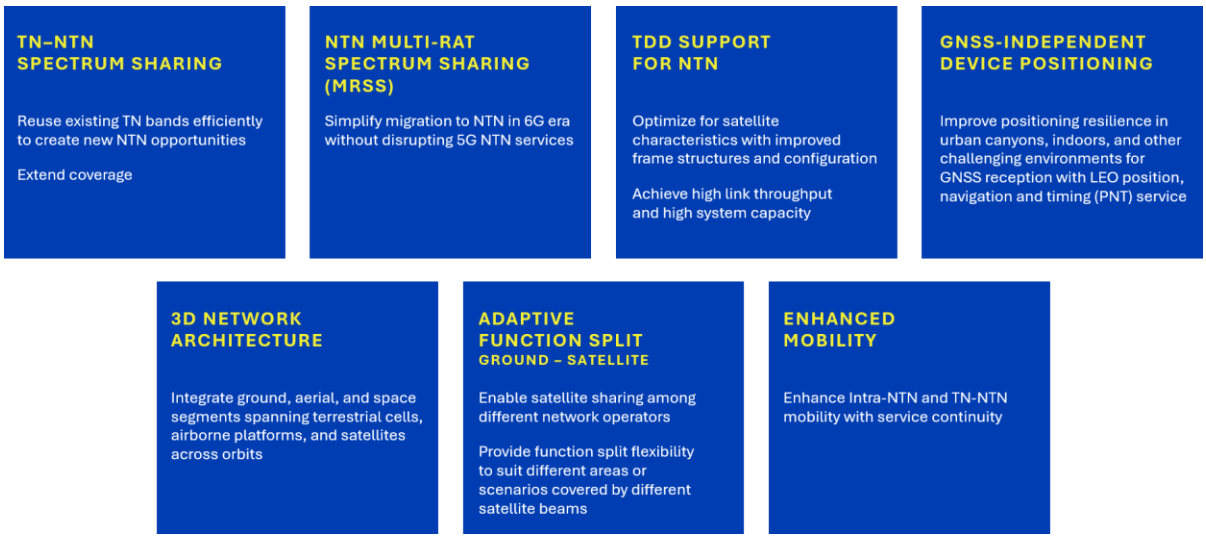
The 3GPP preferred approach, therefore, is to continue with NR NTN as today's primary deployment option and work on 6G NTN standards for future networks.

Vision to extend NTN in the 6G era

Before committing to large NR NTN constellations, satellite operators must understand potential NTN evolution paths into the 6G era to design future-proof networks. A unified TN-NTN system is a realistic outcome for 6G at some point in the 2030s. Potential NTN innovations are shown in **Figure 1**.

The 3GPP R20 Studies on 6G Radio Access Networks and System Architecture both include NTN. The aim is that the radio and protocol design of 6G will ultimately be harmonized across TN-NTN (unlike NR NTN, which was introduced years after the first 5G release). This would allow 6G features such as multi-radio access technology spectrum sharing (MRSS) and integrated sensing and communications (ISAC) to be deployed in space, enabling deeper integration of TN and NTN for better mobility, access network selection, service continuity, and so on.

Figure 1: Evolving NTN in the 6G era



Source: Qualcomm

One strong area of interest—ironically—is to look again at reusing terrestrial spectrum for satellite access. This topic is due to be discussed at the upcoming ITU World Radio Conference in 2027. (As noted, some national regulators already allow this, such as the Supplementary Coverage from Space regulation in the US, and license modifications in the UK allow satellite use in terrestrial spectrum). In 6G, there is a chance to extend NTN further; for example, to underused terrestrial licensed mmWave TDD spectrum.

Conclusion

Satellite-based direct-to-device services offer strong customer value and are starting to scale globally. Today's satellite operators have pioneered a fundamentally new connectivity model and introduced innovative technologies and architectures into commercial use. This ecosystem has set the stage for the next phase of satellite communications.

There are strong technical and regulatory reasons to pursue NR NTN as the next evolution of direct-to-device. A purpose-built standards-based architecture should deliver both efficiency gains and better customer experience. It is true that there is currently no commercial NR NTN constellation in operation; however, this is expected to change in the coming years.

NR NTN is a state-of-the-art architecture that is mature enough to deploy. To prepare for the future, it is now time to investigate what 6G NTN might look like and to identify the key innovations that can build on NR NTN later in the 2030s.

With NTN, satellite communications can offer global economies of scale. The winning operators potentially have a very strong commercial opportunity. For the first time in history, for standard smartphone users, we may see the emergence of planet-scale mobile operators.

In the vast majority of cases, however, satellite will be a supplemental service that fills coverage gaps and serves use cases not addressed by TN. For most users, most of the time, TNs will remain their primary access mode. The best customer outcome, therefore, will be to integrate satellite direct-to-device communications with terrestrial operations.

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