RADCOM

White paper

Quality Assurance for the Next Frontier:

Non-Terrestrial Network (NTN) Services

Contents

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Executive Summary

As the telecommunications industry pushes the boundaries of global connectivity, Non-Terrestrial Networks (NTNs) are emerging as a transformative force. By integrating satellite, high-altitude platforms, and other space-based communication systems into traditional terrestrial networks, NTNs are redefining what it means to be connected, anywhere, any time.

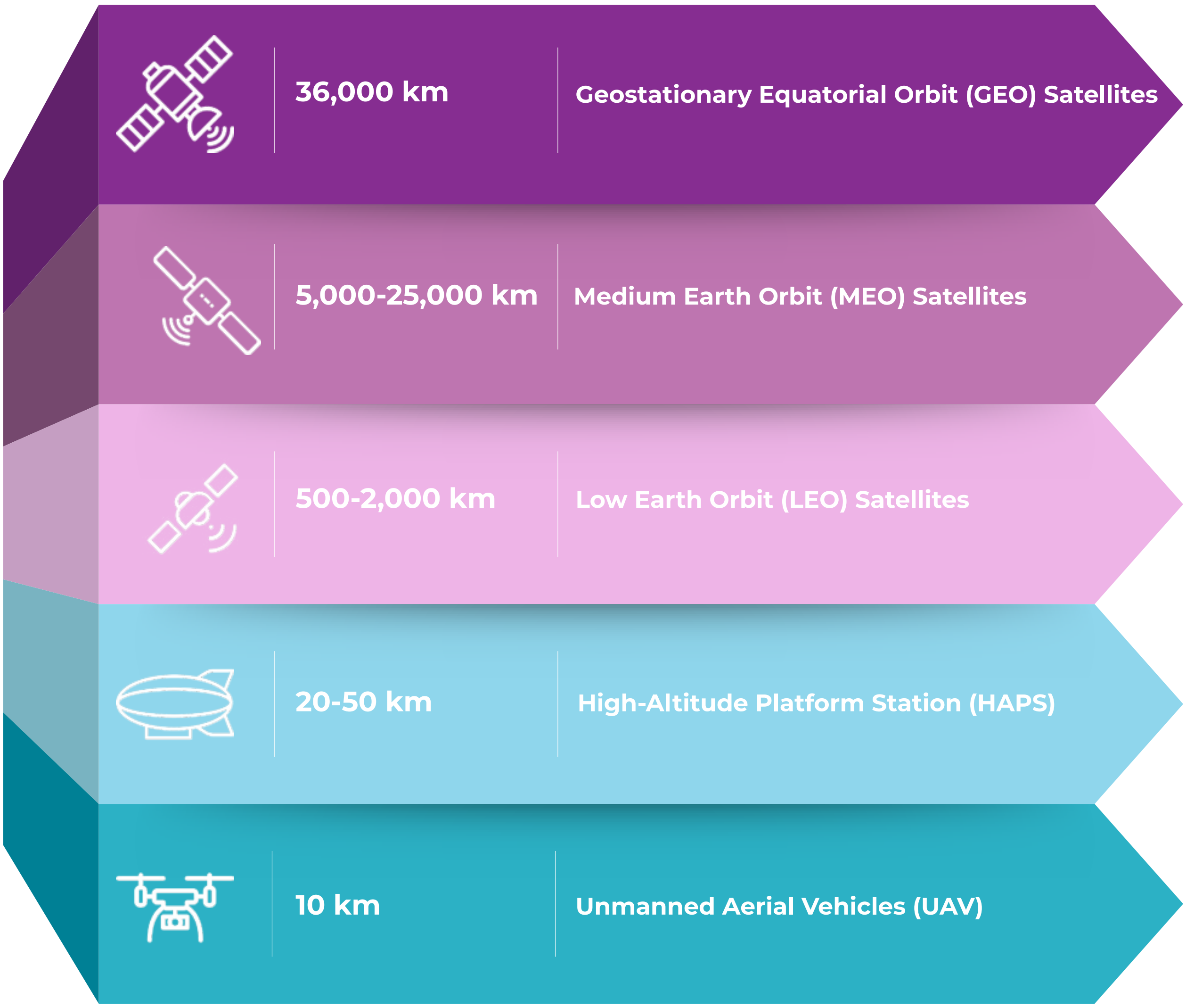


Figure 1: Satellites, UAVs, and HAPS can extend network coverage

Driven by the demand for ubiquitous coverage, seamless mobility, and resilient infrastructure, NTNs are poised to play a critical role in extending network reach to underserved and remote regions, enhancing connectivity during natural disasters and emergencies, and supporting the growing needs of industries such as maritime, aviation, and defense.

This white paper explores the evolving NTN landscape, its technological and operational challenges, and how service providers can harness advanced service assurance and monitoring solutions to deliver consistent, high-quality experiences across hybrid network environments. From enabling robust roaming between terrestrial and non-terrestrial domains to capturing real-time performance data and quality of experience (QoE) metrics, the path to monetizing NTNs relies on intelligent, end-to-end visibility and automation.

What are Non-Terrestrial Networks?

NTNs are wireless communication systems that operate above the Earth's surface, as opposed to traditional ground-based (terrestrial) networks. NTNs are a key component of the broader 3GPP 5G standards (with Release 17 being the first to include mandatory NTN requirements), designed to extend coverage to remote, underserved, or hard-to-reach areas where terrestrial infrastructure is limited or unavailable.

Integrating satellite, high-altitude platforms, and other communication systems that orbit the Earth at various altitudes into traditional terrestrial networks ensures seamless mobility, interoperability, and service continuity across both terrestrial and non-terrestrial domains. Technically, this involves enhancements in radio protocols (NR-NTN), Doppler compensation, delay management, and link budget adaptations to account for the high altitudes and orbital dynamics of NTN platforms.

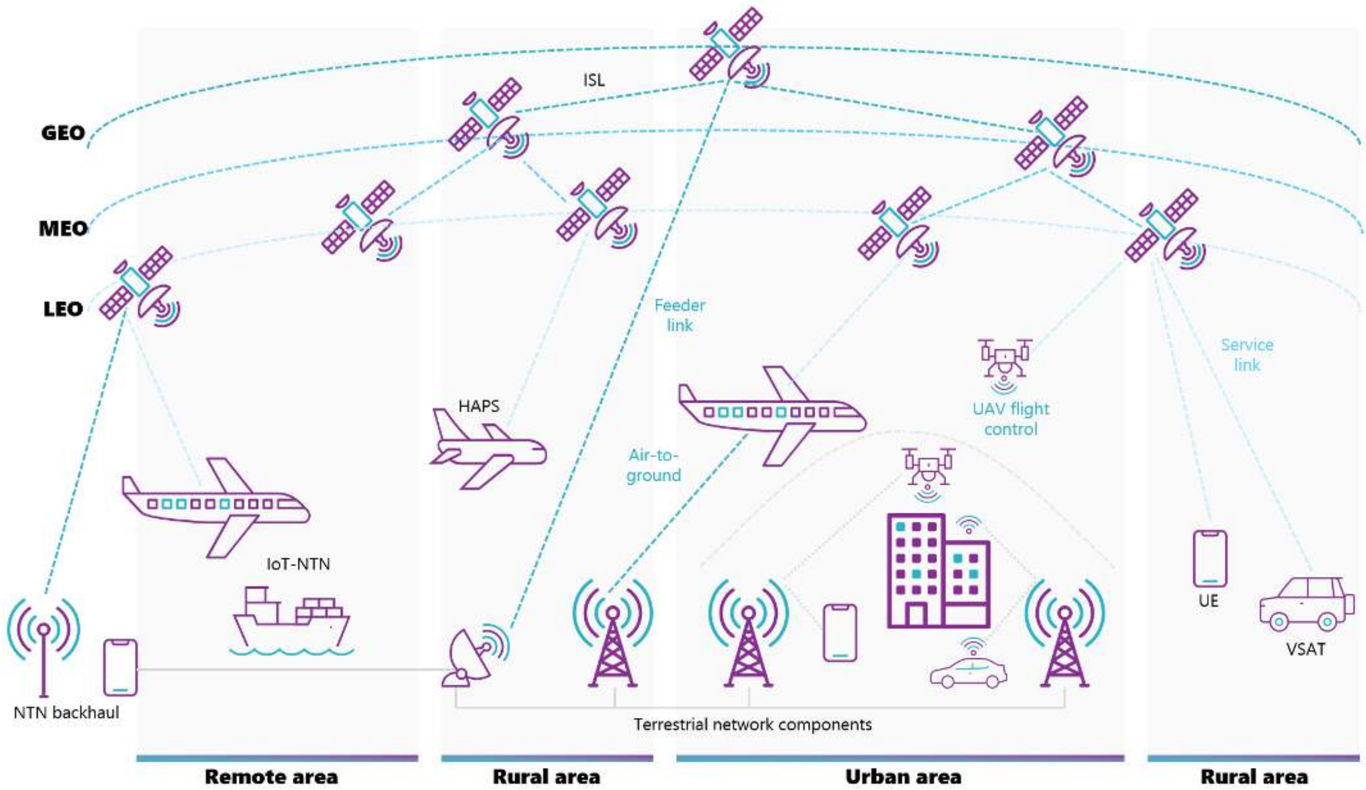


Figure 2: Incorporating non-terrestrial networks aims to offer complete coverage anytime, anywhere

NTNs are designed to complement and extend traditional terrestrial networks by providing seamless connectivity in areas that are underserved, remote, or difficult to reach, such as rural regions, oceans, and disaster zones. By leveraging satellites, high-altitude platforms, and unmanned aerial vehicles, NTNs ensure continuous coverage beyond the limits of ground-based infrastructure. This enhances network resilience, supports global mobility, and enables mission-critical applications, such as emergency response, maritime and aviation connectivity, and remote IoT deployments. NTNs are becoming increasingly relevant with the rise of 5G Advanced and 6G, which aim to unify terrestrial and non-terrestrial connectivity into a seamless global network.

Platform	Type	Orbit Altitude	Advantage	Use Cases	Vendors
Satellite-Based Communications	Geostationary Orbit (GEO) Satellites	36,000 km	Fixed position over the Earth, ideal for continuous coverage over a region	Broadcast TV, backhaul, emergency communications	Traditional TV and internet satellites Thuraya
	Medium Earth Orbit (MEO) Satellites	5,000-25,000 km	Larger coverage area than LEO, fewer satellites needed	Navigation (e.g., GPS, Galileo), high-capacity data transport	O3b
	Low Earth Orbit (LEO) Satellites	500-2,000 km	Low latency, global coverage with constellations	Low-latency broadband (e.g., Starlink), Direct-to-Device (D2D), IoT	Starlink, OneWeb. AST, Iridium
High-Altitude Platform Systems (HAPS)	Airborne vehicles (e.g., balloons, solar-powered drones)	20-50 km	Lower latency than satellites, reusable platforms, targeted coverage	Rural broadband, disaster recovery, surveillance, IoT	Balloons or drones operating in the stratosphere
Unmanned Aerial Vehicles (UAVs)	UAVs, drones	10 km	Rapid deployment, flexible coverage, real-time recovery	Tactical communications disaster response, temporary coverage	Drones providing ad hoc or emergency coverage
Hybrid NTN-Terrestrial Systems	Combining satellite, HAPS, and terrestrial networks	N/A	Optimized cost and performance, extended reach of mobile networks	Seamless connectivity, 5G NTN, roaming support	AT&T T-Mobile Telstra Rakuten Iridium

Figure 3: Type of NTN Platforms

3rd Generation Partnership Project (3GPP) Standardization

3GPP first introduced NTN support in Release 16, laying the groundwork for integrating non-terrestrial networks into the mobile ecosystem, specifically to enable 5G connectivity via satellite. This included adapting the 5G New Radio (NR) air interface and related technologies to address the unique characteristics of satellite communications such as increased propagation delays and varying Doppler shifts.

Building on this foundation, 3GPP Release 17 introduced two key specifications: NB-IoT NTN and eMTC/LTE-M NTN for IoT use cases, as well as NR NTN for data and voice-centric applications. These developments marked a significant step toward extending mobile connectivity beyond terrestrial infrastructure. Further enhancements and expanded capabilities are expected with the ongoing rollout of Releases 18 and 19, which will support a broader range of use cases and improve NTN performance and interoperability.

While some satellite operators actively participate in 3GPP standardization for NTN, the situation regarding dedicated Mobile Country Codes (MCCs) and Mobile Network Codes (MNCs) is still evolving and not universally established.

- 3GPP has been working on NTN specifications since Release 16, with ongoing work in Release 18 and beyond. These specifications cover various aspects, including network architecture, frequency bands, and integration with terrestrial networks.
- Satellite operators and related companies are engaging with 3GPP to define standards for NTN. This is evident in the development of technical specifications (TS) and reports (TR) related to NTN.

Dedicated MCC and MNCs for Satellite Operators

- MCC (Mobile Country Code): Typically, MCCs are assigned to specific countries. However, 3GPP has defined MCC 901 for worldwide services, which global satellite operators could use.
- MNC (Mobile Network Code): MNCs identify a specific mobile network operator within a country (or MCC 901, a global network).

Currently, there isn't a widespread allocation of dedicated, country-specific Mobile Country Codes (MCCs) and Mobile Network Codes (MNCs) exclusively for satellite NTN operators, as is common with terrestrial mobile network operators. Some satellite providers may experiment with existing MCCs and MNCs through roaming agreements or special arrangements with terrestrial operators.

In some instances, global MNCs under the worldwide MCC 901 can be assigned to satellite operators offering global NTN services, for example, MCC 901 MNC 05 is designated for the Thuraya RMSS Network. Additionally, 3GPP specifications outline scenarios in which a satellite network might broadcast either a global or shared Public Land Mobile Network (PLMN) ID using an MCC in the 9xx range or the operator's standard PLMN ID based on the MCC of its home country.

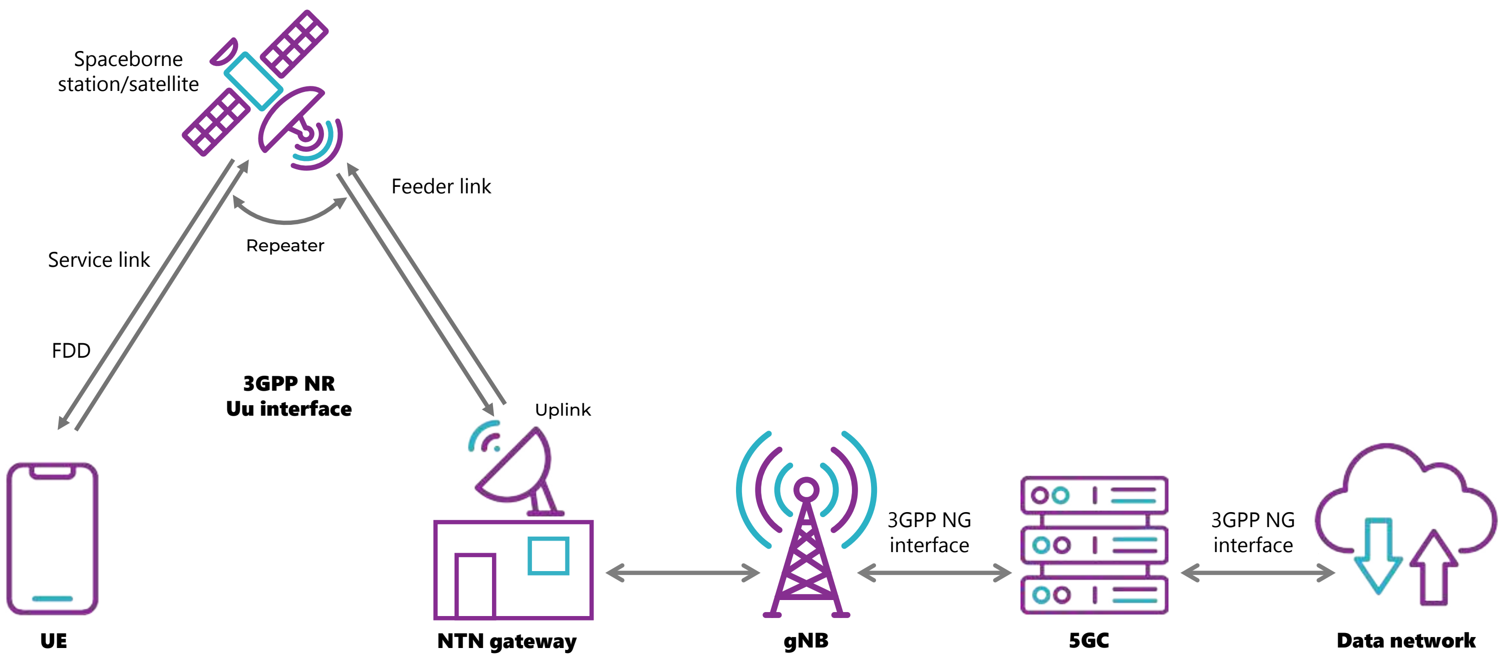
Devices

Devices designed for NTNs are evolving rapidly to meet the unique demands of satellite and high-altitude communication environments. Unlike traditional terrestrial devices, NTN-enabled equipment must support seamless connectivity across varying altitudes, latencies, and coverage areas. This includes ruggedized terminals, mobile handsets, IoT modules, and user equipment with integrated satellite modems or multi-mode capabilities, enabling automatic handover between terrestrial and non-terrestrial links.

Some devices are also designed to operate in challenging conditions, such as remote, maritime, or disaster-prone areas, where reliable connectivity is crucial. As NTN standards mature and satellite constellations expand, the ecosystem of compatible devices will play a pivotal role in driving adoption and delivering consistent user experiences across hybrid networks.

Spectrum

There are two primary spectrum categories leveraged for NTN: International Mobile Telecommunications (IMT) spectrum and Mobile Satellite Service (MSS) spectrum. The IMT spectrum, standardized by the International Telecommunication Union (ITU) for International Mobile Telecommunications, includes frequencies traditionally used for terrestrial 4G and 5G services. Its use in NTNs enables seamless integration and interoperability between terrestrial and non-terrestrial components of 3GPP-based networks, supporting global mobility and service continuity.



Note: The gNB can be terrestrial, as deployed by AST Space, or integrated directly into the satellite, as in the case of Starlink.

Figure 4: An example integration between the non-terrestrial network and 5G RAN

In contrast, the MSS spectrum is allocated explicitly for satellite communication services, often in the L-band, S-band, and occasionally in the Ka-band. The MSS spectrum is well-suited for NTN applications due to its favorable propagation characteristics, which allow for reliable coverage in remote or obstructed environments. Together, IMT and MSS spectrum bands provide the flexibility needed to support a wide range of NTN use cases—from consumer broadband to IoT, public safety, and mission-critical communications.

Part of the IMT spectrum is Frequency Range 1 (FR1) and Frequency Range 2 (FR2)

- FR1: Covers sub-6 GHz frequencies (typically 410 MHz to 7.125 GHz) and is part of Release 17. Used in legacy communications.
- FR2: Covers millimeter-wave (mmWave) bands (24.25 GHz to 52.6 GHz) part of Release 18 and offers broadband speeds.

NTN Use Cases

NTNs enable a wide range of use cases across multiple industries by delivering connectivity beyond the reach of terrestrial infrastructure. In the maritime and aviation sectors, NTNs provide continuous broadband coverage over oceans and in-flight, supporting navigation, real-time communications, and passenger services.

For emergency response and public safety, NTNs offer rapid-deployment connectivity in disaster zones where terrestrial networks may be damaged or unavailable, ensuring mission-critical communications. In the agriculture and mining industries, NTNs support remote IoT applications, including equipment monitoring, environmental sensing, and predictive maintenance, thereby enhancing operational efficiency in challenging and remote areas.

Telecom operators benefit from NTNs by extending mobile coverage to rural and underserved areas, thereby closing the digital divide and enabling universal access to services. Meanwhile, defense and government agencies utilize NTNs for secure and resilient communications in remote and hostile environments.

Use Case	Overview
Direct-to-Cell (DTC)	This enables unmodified cell phones to connect to low-Earth-orbit (LEO) satellite constellations directly through IMT spectrum or mobile satellite service (MSS) spectrum (for more details on spectrums see Frequencies)
Disaster Communications	Satellite communication can be used as fall back if cellular infrastructure is damaged
Mobile Backhaul	This service operates by transmitting signals from mobile cell towers to orbiting satellites, which then relay the signals back to Earth. Once received, the signals are routed through the service provider's infrastructure to connect the mobile network to the core network. Satellite mobile backhaul also serves as a resilient backup to traditional terrestrial backhaul, ensuring continued connectivity in the event of network outages or equipment failures
Rural and Enterprise Broadband	Extending wireless coverage with satellite networks in uncovered or under-covered areas
Satellite IoT and M2M	Using 3GPP Release 17 IoT-NTN for hybrid connectivity (i.e., small amounts of data (often in remote areas) are exchanged, and communication is optimized for low power usage)
Voice and Data Services	These services can be delivered via specialized satellite phones or cell phones that transmit signals directly to orbiting satellites. The satellites then relay the signals back to Earth, where they are routed through the service provider's ground stations and integrated with traditional networks to reach the call recipient Satellite voice services are especially valuable in remote areas regions with limited terrestrial infrastructure and in emergency situations where traditional networks may be compromised or unavailable

The Role of Telecom Operators

According to the Global Mobile Suppliers Association[1], as of March 2025, forty-eight operators have partnered with satellite providers to deliver Direct-to-Cell (DTC) services. Of these, thirty-four are planning to launch services, sixteen are conducting trials or evaluations, and eight have already launched commercial offerings.

Additionally, sixty-eight operators are exploring rural and enterprise use cases. Among them, forty-eight are planning services, seven are in the evaluation or trial phase, and thirteen have already launched offerings. Starlink continues to gain momentum, while new constellations, such as Amazon Kuiper and Thousand Sails, are entering the market.

As NTN adoption accelerates, telecom operators will play a critical role in the deployment, integration, and commercialization of these networks. NTNs will be an essential component of the broader 5G and future 6G ecosystem, supporting a range of verticals including consumer connectivity, enterprise solutions, government applications, and mobile backhaul.

Key Roles of Telecom Operators in NTNs:

Telecom Operator Activity in the Space

As operators increasingly extend their networks via NTNs, the following examples illustrate some of the current partnerships and services offered in the telco segment:

Operator	Partner	Orbit	Service
T-Mobile	Starlink	LEO	Direct-to-Cell (DTC)
AT&T	Starlink	LEO	Direct-to-Cell (DTC)
Vodafone Group	AST SpaceMobile[3]	LEO	Direct-to-Cell (DTC) in all European markets , USA, Canada and Japan
Verizon	Starlink	LEO	Direct-to-Cell (DTC)
Kyivstar (VEON)	Starlink	LEO	Direct-to-Cell (DTC)
Telstra	Starlink	LEO	Direct-to-Cell (DTC)
Optus	Starlink	LEO	Direct-to-Cell (DTC)
One NZ	Starlink	LEO	Direct-to-Cell (DTC)
Vodafone	Starlink	LEO	Direct-to-Cell (DTC)
Reliance Jio	Starlink	LEO	Direct-to-Cell (DTC)
Bharti Airtel	Starlink	LEO	Direct-to-Cell (DTC)
Airtel Africa	Starlink	LEO	Direct-to-Cell (DTC)
MTN Zambia	Starlink	LEO	Direct-to-Cell (DTC)
PLDT	Starlink	LEO	Direct-to-Cell (DTC)
Any operator where the service is available	Globalstar	LEO	Direct-to-Satellite (DTS) For Emergency SOS via Satellite, Apple's iPhone connects to Globalstar's satellites directly when there is no available cellular network. Available: Australia, Austria, Belgium, Canada, France, Germany, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Portugal, Spain, Switzerland, the U.K., and the U.S
Etisalat, UAE	Quantum	GEO	Extend 5G coverage to areas currently unreachable by terrestrial connectivity.

Operator	Partner	Orbit	Service
Telstra, Australia	OneWeb	LEO	Extend rural coverage
Deutsche Telekom, Germany	Intelsat	GEO	Satellite-as-a-service offerings for business
	Skylo	LEO/GEO	NB-IoT applications
Telefónica, Spain	Sateliot	LEO	IoT capabilities for agriculture, shipping and wind farms
NTT, Japan	SES	MEO	Edge-as-a-Service, aimed at companies operating in hard-to-reach areas and acts as an expansion of NTT's existing private 5G offering
Vodafone, Ghana	Lynk[2]	LEO	Direct-to-Cell (DTC) in rural areas Delivers mobile coverage to the entirety of the Ghanaian population across the Vodafone Ghana network, via the 'cell towers in space' concept

Major Players in the Satellite Broadband Market

Name	Founded	# of Satellites Launched[1]	# of Subscribers	Focus Areas
Starlink (SpaceX)	2002 (SpaceX) / 2015 (Starlink)	8,094	6 million (across 140 countries)	Direct-to-consumer internet service
Eutelsat OneWeb (formerly OneWeb)	2012	652[2]	Subscriber count not publicly disclosed	Enterprise, government, and backhaul solutions
Project Kuiper (Amazon)	2018	100[3]	Service not yet commercially launched	Aiming to provide broadband internet access. Commercial services have not yet started
Iridium NEXT	1997	80	2.3 million	Voice and data connectivity anywhere, including remote and hard-to-reach regions
Orbcom	2012	51	2.4 million	
Globalstar	2006	48	0.8 million	Commercial maritime; Forestry; Construction; Energy; Transportation; Government & public safety; Agriculture
Inmarsat	1980	20	Subscriber count not publicly disclosed	Satellite communications to enhance maritime safety
AST SpaceMobile	2017	6	Service not yet commercially launched	Cellular connectivity to existing smartphones via satellite
Viasat	1986	4	0.6 million (estimate)	An established GEO satellite provider
Thuraya	1997	4	Subscriber count not publicly disclosed	Voice and data connectivity across industries including energy, government, maritime, and humanitarian aid
HughesNet	1996	3	Estimated in the hundreds of thousands (exact number not disclosed)	An established GEO satellite provider

[1] Note: All figures are approximate and represent the total number of satellites launched. These totals do not exclude satellites that are no longer in orbit or currently inactive.
[2] https://oneweb.net/our-network
[3] https://www.investors.com/news/technology/amazon-stock-project-kuiper-spacex-starlink

Quality Assurance for NTN Services

Why Assurance is Mission-Critical for NTN?

Service assurance is critical for NTNs because these networks operate in highly dynamic, hybrid environments where consistent performance, reliability, and quality of experience (QoE) are essential.

As users and devices transition between terrestrial and non-terrestrial domains, such as satellites, high-altitude platforms (HAPS), and UAVs, operators must ensure seamless connectivity without service degradation. Real-time monitoring, intelligent analytics, and proactive issue resolution are essential for managing the unique challenges of NTNs, including latency variation, Doppler effects, and intermittent coverage.

Without robust service assurance, operators risk poor user experiences, service disruptions, and lost revenue, especially in mission-critical scenarios such as emergency response, maritime communications, and rural connectivity.

NTNs are well-positioned to bridge coverage gaps in areas underserved by terrestrial infrastructure. However, to support this evolution, telecom operators must gain end-to-end visibility across both terrestrial and non-terrestrial domains. As users and devices seamlessly transition between these networks, maintaining uninterrupted service requires the ability to anticipate network demands, optimize data routing, and dynamically configure the network, especially in mission-critical scenarios where performance and reliability are paramount.

As a leading provider of intelligent assurance solutions with integrated AIOps capabilities, RADCOM is uniquely positioned to support the evolving needs of the NTN market. Our capabilities are further enhanced through our participation in the TM Forum Catalyst 25.0.766 – SATCOM with an EDGE, which demonstrates how real-time service monitoring and KPI insights can drive smarter business decisions. This project earned the Outstanding Catalyst Award at DTW 25 for Tech for Good.

In Phase III, the focus was on introducing intelligent orchestration, dynamic routing, and autonomous service assurance to maintain service quality and optimize network performance.

Key innovations included:

- On-Demand Service Activation: Customers can effortlessly launch SATCOM+5G services using natural language prompts, with the system automatically handling all provisioning, thereby accelerating time to service and reducing operational overhead.
- Intelligent Connectivity Optimization: Leveraging SD-WAN and multi-orbit satellite networks, the system autonomously selects the best path to ensure performance and meet SLAs, maximizing efficiency and user experience.

- Unified Service Assurance: A single monitoring layer delivers end-to-end visibility across hybrid networks, enabling proactive management and ensuring reliability at scale.

This approach empowers operators to rapidly deploy flexible, resilient connectivity solutions, ideal for high-impact scenarios such as emergency response, remote operations, and enterprise-grade communications.

Whether supporting roaming across terrestrial and satellite networks, deploying our User Plane solution at the satellite operator level (including the satellite RAN for real-time radio

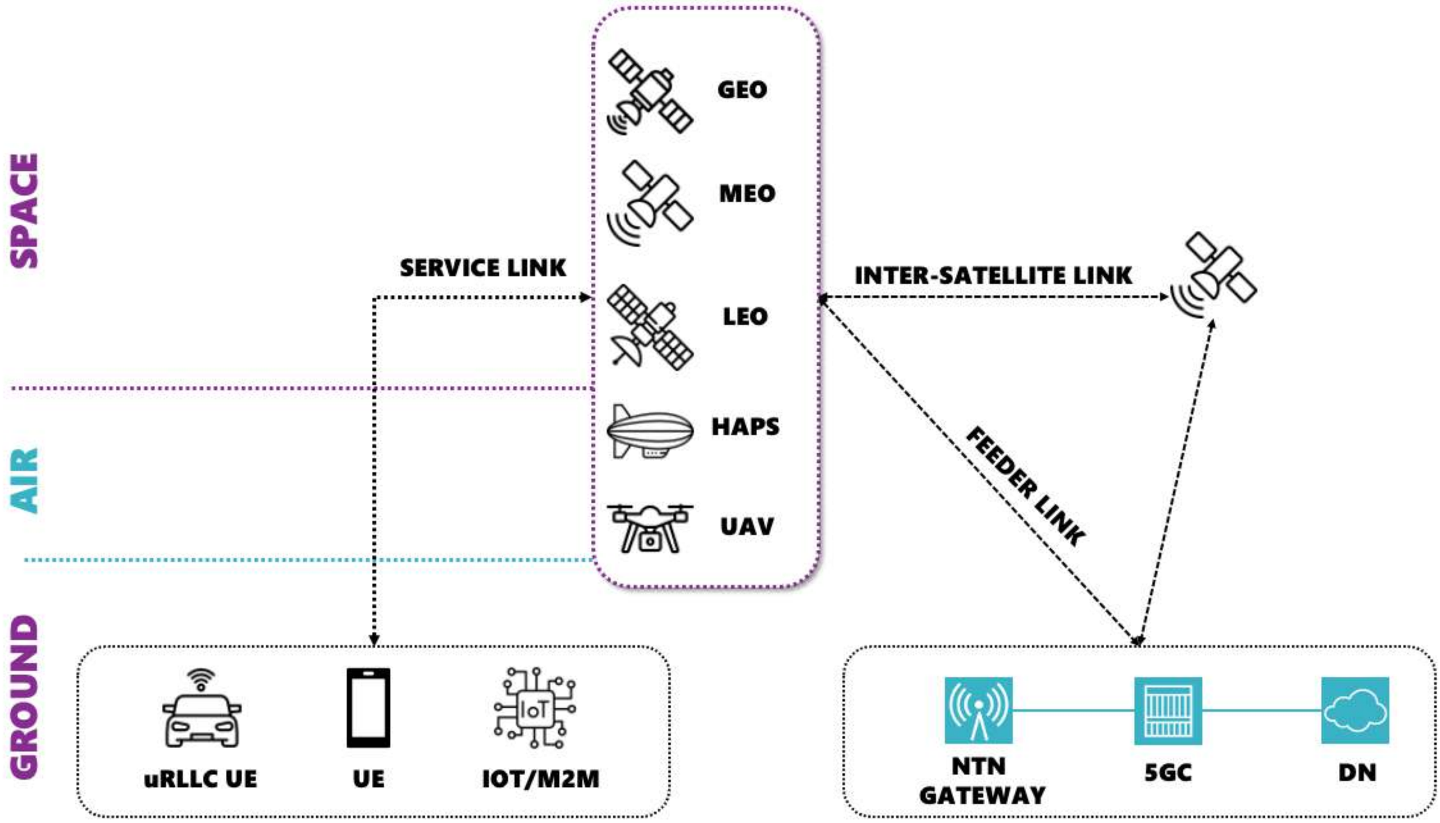


Figure 5 – Hybrid 5G and NTN network

This powerful platform enables a wide range of use cases — from proactive troubleshooting to revenue optimization — helping operators unlock the full value of their NTN investments.

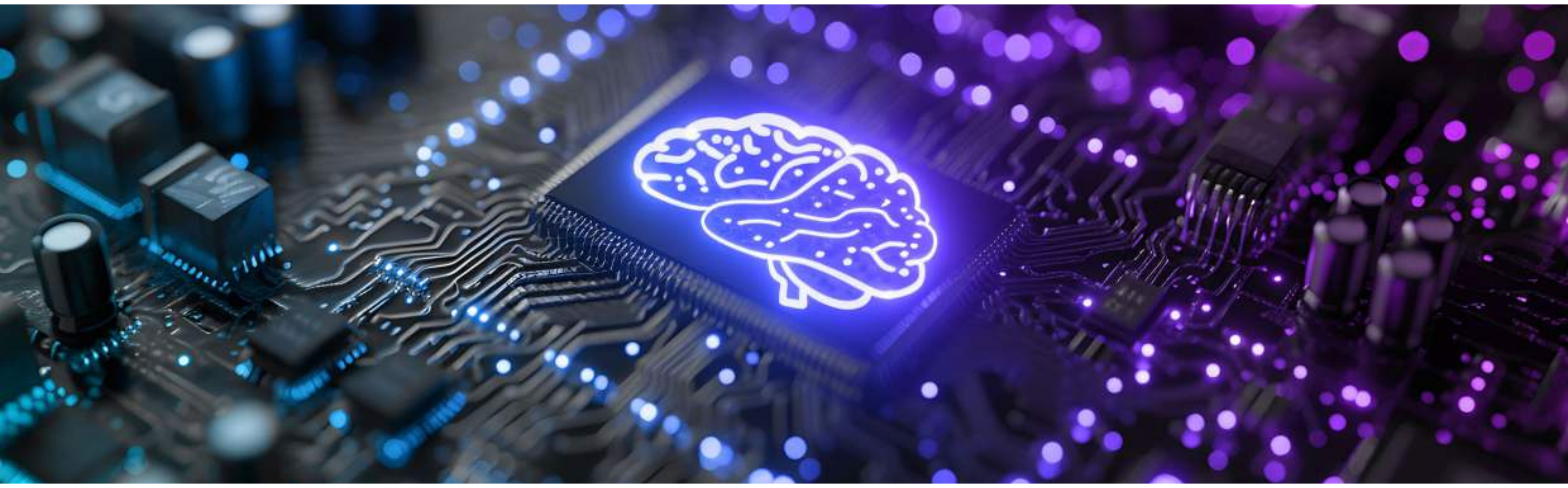
Conclusion

As operator-satellite partnerships continue to gain momentum, the Non-Terrestrial Network (NTN) landscape is poised for rapid expansion. While many initiatives remain in the planning phase, the steady rise in broadband satellite deployments over recent months signals a shift toward broader adoption and commercial readiness.

This growth is fueled by increasing demand for broadband, voice, and data services, particularly in underserved rural areas, as well as the need for resilient connectivity during natural disasters. Advances in satellite-to-cellphone technology are enabling operators to expand their coverage footprints and deliver critical services in scenarios where traditional terrestrial infrastructure is insufficient. Consequently, satellite-enabled offerings are expected to proliferate across a growing number of markets worldwide.

To support this evolving connectivity ecosystem, intelligent assurance solutions with integrated AIOps capabilities are essential. These solutions enable telecom operators to transition from reactive to proactive operations by providing real-time service monitoring, advanced KPI analytics, and actionable insights. This empowers operators to detect anomalies early, resolve issues more quickly, and make informed decisions that enhance service quality and operational efficiency.

Looking ahead, the integration of intelligent assurance into hybrid NTN architectures lays the foundation for closed-loop automation and autonomous service delivery. Whether on land, in the air, or space, this approach ensures consistent, high-quality connectivity, anytime, anywhere, by harnessing the power of intelligence across both terrestrial and non-terrestrial networks.



[1] GSA Snapshot: Non-Terrestrial 5G Networks and Satellite Connectivity https://www.youtube.com/watch?v=7OtOfA3twvE&t=174s

[2] Lynk has an agreement with global satellite operator, SES, for funding and services using SES's fleet of GEO and MEO satellites https://www.ses.com/press-release/ses-and-lynk-global-announce-strategic-partnership-direct-device-d2d-services

[3] Vodafone and AST SpaceMobile Sign Agreement to Create European Direct-To-Device Satellite Service Provider https://www.vodafone.com/news/corporate-and-financial/vodafone-and-ast-space-mobile-sign-agreement-to-create-european-direct-to-device-satellite-service-provider