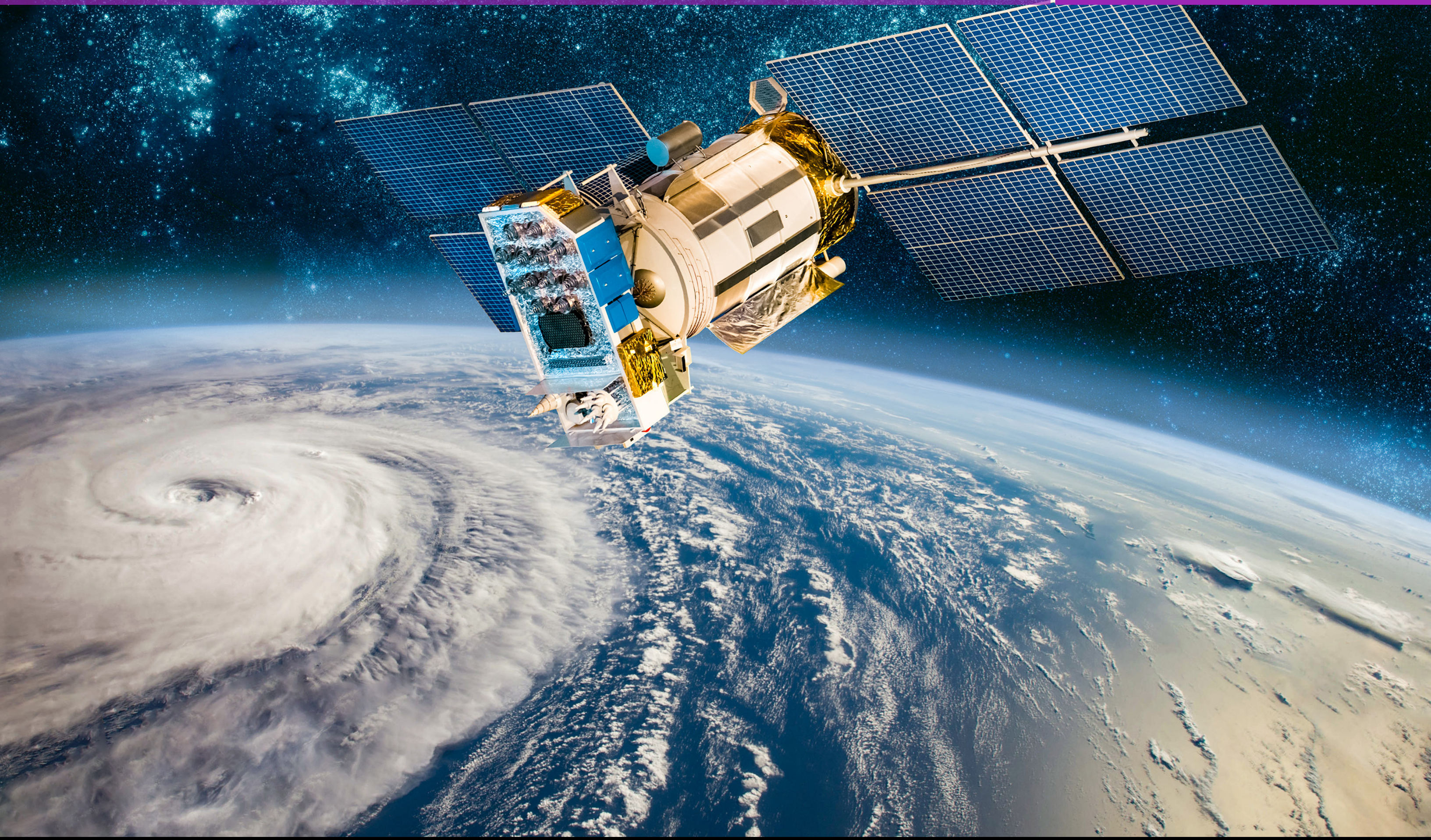
WHITE PAPER



Satellites Bolster 5G Through Non-Terrestrial Networks

KEYSIGHT

Overview

5G presents an inflection point in the evolution of wireless communications technology. It offers massive improvements over 4G in terms of speed, latency, capacity, flexibility, and reliability that will enable new use models. However, the technology carries with it corresponding uptime and coverage demands on networks that have necessitated the creation and utilization of new enabling technologies.

Unlike previous cellular network technologies, which are based exclusively on terrestrial network infrastructure, the 3rd Generation Partnership Project (3GPP) is planning to make 5G into a network that incorporates satellites to augment terrestrial 5G networks. These non-terrestrial networks (NTNs) will extend the reach of 5G to regions lacking terrestrial infrastructure. NTNs can also augment service continuity for machine-to-machine (M2M) and Internet of Things (IoT) devices and bolster the reliability of mission-critical communications. They will also reinforce 5G coverage stability for passengers on moving platforms like planes and trains.

5G NTNs will play a key role across many industries, including transportation, public safety, medicine, energy, agriculture, finance, and automotive

This white paper provides an overview of the:

- origins of non-terrestrial networks (NTNs) in the 5G standard
- advantages of NTNs
- use cases for 5G NTNs
- requirements for testing NTNs

Why Use Non-Terrestrial Networks

3GPP's definition of Release 17 contains enhancements to 5G New Radio (NR) to support NTNs. The 5G NTN marks the first time that a cellular network will use satellite communications.

There are several reasons to introduce satellite links into the 5G standards. The primary motivation is that satellite links enable communications independent of the terrestrial infrastructure. By utilizing satellite communications, mobile network operators (MNOs) can deliver 5G service to areas that do not have infrastructure in place. Satellite communications also enable MNOs to provide service in situations where terrestrial networks become unavailable, such as a natural disaster.

Satellite communications also extenda the availability of 5G service to a broader array of moving platforms. For example, satellite communications can deliver service to moving aircraft, ships, and trains in remote areas where it is not possible to build terrestrial network infrastructure.

Another advantage of the 5G NTN is that satellite links enable scaling or "filling in" of existing terrestrial networks. For example, M2M and IoT applications located at the edge of coverage areas or in difficult-to-reach locations can access 5G through satellite broadband links.

Figure 1 shows several different NTN deployment scenarios that use both satellites and high-altitude platforms — balloons, airships, or pilotless aerial systems in the stratosphere.

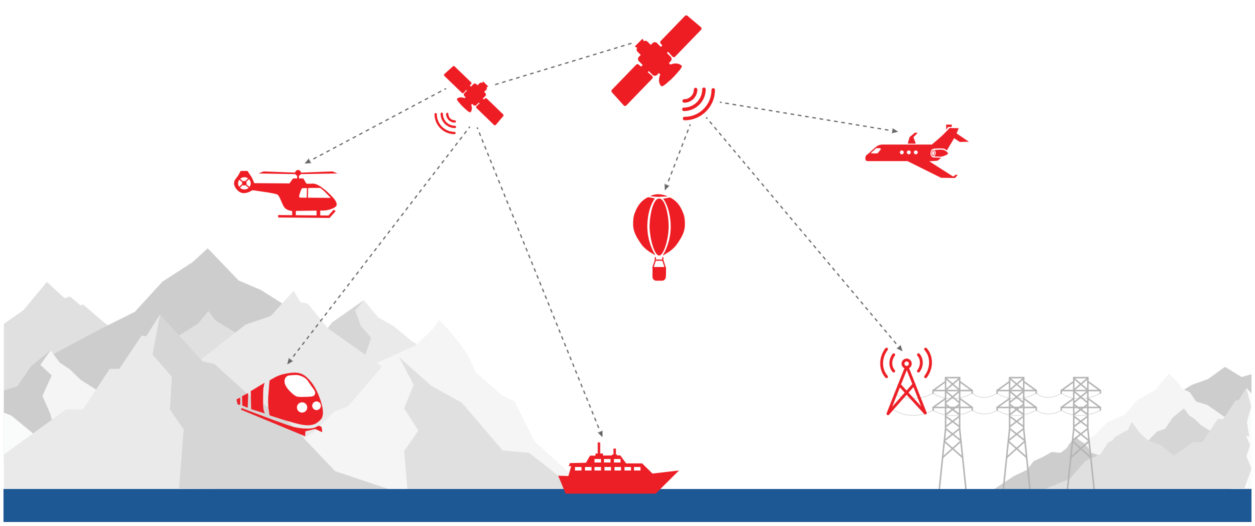


Figure 1. Satellite links bring 5G connectivity to moving and isolated platforms

Use Cases

5G enables some links with much stricter latency requirements compared to past generations. Because of the signal transit time to and from even low Earth orbit distances, 5G NTN satellite communications links should support terrestrial networks for special-purpose applications where latency is less critical. The latency requirement is one crucial factor to consider in determining which applications NTNs can support.

3GPP has defined several 5G NTN uses cases, some of which are described below:

- Multi-connectivity — One of the primary use cases for 5G NTNs, multi-connectivity enables user equipment (UE) to attach to the terrestrial and satellite links simultaneously. Under this use case, time-sensitive low-latency traffic routs through the terrestrial links, while less mission-critical traffic goes through satellite links.
- Fixed cell connectivity — enables users in remote areas or industry premises such as offshore oil platforms to access 5G services.
- Mobile cell connectivity — facilitates seamless 5G mobile cell coverage to aircraft and high-speed rail passengers. This process uses terrestrial networks where available and satellite links in remote areas where terrestrial cell networks are not available.

Other use cases

Terrestrial networks that have gaps in coverage can join through satellite links to enable seamless coverage. Access points can determine when and how to forward traffic from terrestrial networks to the satellite networks. Similarly, 5G NTNs can bolster network resiliency, enabling critical networks to achieve high availability through the aggregation of multiple network connections in parallel to prevent complete network connection outage.

The technology can also facilitate the wide-area IoT satellite links that augment terrestrial networks to enable IoT services over a wide area for relatively high-latency applications. For example, energy networks, transportation, and agriculture. The direct satellite links can also enable emergency communications between public safety agencies, police, fire departments, and hospitals.

5G NTNs can also facilitate direct to node broadcast or direct to mobile broadcast for delivering TV, multimedia, or broadcasting emergency service messages.

Testing Requirements for 5G NTNs

For a satellite communications system, uncovering errors prior to deployment is critical. Errors discovered in operational satellite communications systems can cost as much as 1,000 times more than finding the same error when specifying the system's characteristics. For this reason, it is crucial to emulate as accurately as possible all the various phenomena that may impact the communications links and devices.

A useful test platform for modern satellite systems should address the challenges of simulating the relevant orbital parameters. The platform also requires the capability to handle high-velocity satellite and high-altitude platform testing of long-distance links with satellite interlinking. The traditional method of simulating link distance is by adding buffering for the delayed signal path. The change in the delay then simulates the movement of the satellites and the moving platforms where the satellite link terminates.

Testing of single-link satellite communications systems has long used channel emulators. However, modern systems have evolved significantly in complexity to include technologies such as satellite mesh networks and multiple transponders within a single satellite. Testing of systems involving multiple satellites is much more complicated than performing traditional single satellite link simulations.

Nevertheless, a channel emulator provides a platform that mimics the radio channel that maintains the satellite link to test and simulate a whole network of devices at once. Network-level testing exposes more than a single node for testing and reveals underlying problems that come from subsystem integrations.

Tracking the iterations of hardware and software during development is essential. Objective comparison between variants requires standardizing the operational environment. For full control of the environment, channel emulators can provide an unbiased platform for evaluating performance and comparing different devices, hardware variants, and software iterations; see Figure 2.

Figure 2. A channel emulator between a satellite communications system and a terrestrial network

A channel emulator forms a baseline for building an optimal satellite test bed for 5G NTNs. However, it is only one necessary component. A full test bed requires several other test and measurement instruments to complement the channel emulator. Among the additional equipment required are signal generation, signal analysis, network analysis, and software simulation tools.

Conclusion

Unlike previous cellular technologies, 5G includes provisions for incorporating satellites and high-altitude platforms to augment terrestrial 5G networks. 5G NTNs will expand their reach while increasing reliability and enabling service to remote regions.

The primary uses for 5G NTNs include:

- multi-connectivity in underserved areas
- fixed cell connectivity in remote areas
- mobile cell connectivity on vessels or aircraft
- critical network resilience
- service deployment to remote regions or areas impacted by a natural disaster
- radio access network (RAN) equipment delivery for offloading and storage at the network's edge

Rigorous testing of satellite systems is critical to the successful deployment and maintenance of 5G NTNs. A channel emulator provides a useful test platform for modern satellite systems, which often feature sophisticated technologies such as mesh networks and multiple transponders within a single satellite. Channel emulation offers the capability to test and simulate complex systems, including orbital parameters, high-velocity satellite, and high-altitude platform links with satellite interlinking.

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