Non-Terrestrial Networks (NTN)

Testing and Challenges

WHITEPAPER

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Executive Summary

Non-Terrestrial Networks (NTNs) represent a transformative advancement in the evolution of communication networks, leveraging satellite, high-altitude platform systems (HAPS), and other non-ground-based infrastructures to offer global connectivity. These networks are poised to play a key role in providing broadband internet access to underserved and remote areas, as well as enabling critical applications in aviation maritime, and defense sectors.

However, the deployment of NTN networks comes with significant testing and validation challenges, particularly when it comes to ensuring reliable, high-quality service across varying environmental conditions, altitudes, and geographic regions. This whitepaper explores NTN technologies, testing methodologies in the lab, and the challenges that arise in validating these complex systems before deployment.

01 Introduction to Non-Terrestrial Networks (NTN)

1.1 What Are Non-Terrestrial Networks?

Non-Terrestrial Networks refer to communication infrastructures that operate above the Earth's surface. They can include satellites in Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Geostationary Orbit (GEO), as well as High-Altitude Platform Systems (HAPS) like balloons and drones. These networks are typically used to provide global coverage and are crucial for reaching areas where traditional terrestrial infrastructure is either impossible or uneconomical to deploy.

NTNs can be deployed to augment terrestrial 5G and beyond networks, offering connectivity in regions with poor coverage, and supporting specific applications like remote sensing, IoT, and edge computing.

1.2 Key Applications of NTNs

- **Remote Connectivity:** Providing broadband access in remote and rural regions.
- **Aerospace and Maritime:** Enabling communication for aircraft, drones, and ships in regions outside of terrestrial network coverage
- **Disaster Recovery:** Rapid deployment of communication infrastructure in disaster-stricken areas.
- **Global IoT:** Connecting devices in remote or hard-to-reach locations like the deep ocean, deserts, or polar regions.

Non-Terrestrial Networks (NTN): Testing and Challenges

02 Testing NTN Networks in the Lab

Testing NTNs in a lab environment is essential for ensuring that these systems are reliable, perform well under a variety of conditions, and can meet user expectations. However, testing these systems involves several unique challenges.

2.1 Types of NTN Testing

2.1.1 Satellite Communication Testing

Satellite communication systems in NTNs require testing for signal propagation, interference, latency, bandwidth, and system reliability. This is typically done using simulation-based tools and hardware-in-the-loop (HIL) setups to emulate satellite-to-ground links, multiple orbital paths, and signal behaviors in various conditions.

2.1.2 HAPS Testing

HAPS technologies, such as high-altitude balloons and drones, are often tested for flight stability, signal strength, and interference. Lab tests typically simulate different flight conditions (e.g., altitude variations, wind speed, atmospheric pressure) and communication distances to ensure they can deliver stable service.

2.1.3 Network Protocols & Interoperability

Testing the integration of NTNs with terrestrial networks (e.g., 5G, Wi-Fi, LTE) requires comprehensive network protocol testing. This ensures that devices connected to NTN systems can seamlessly switch between satellite and terrestrial infrastructure without compromising performance or reliability.

Non-Terrestrial Networks (NTN): Testing and Challenges

2.1.4 Latency & Throughput Testing

Given the significant distance between non-terrestrial systems and ground users, NTN networks may experience higher latency and variable throughput. Lab testing focuses on modeling these conditions to assess how these parameters affect user experience in real-world scenarios.

2.2 Lab Testbeds and Simulations

Testing NTNs typically involves creating specialized testbeds that simulate satellite or HAPS communication conditions. Some of the commonly used methods include:

Hardware-in-the-loop (HIL) Testing: This is a crucial technique used to simulate the performance of real-world satellite systems within a controlled environment. HIL setups can emulate the effects of orbital dynamics, signal degradation, and link reliability.

Anechoic Chambers: To simulate the effects of signal propagation in NTN environments, anechoic chambers are often used to isolate the system under test from external interference and evaluate the radio frequency (RF) performance of satellite systems.

Network Emulation: Tools like GNS3 and NS3 are used to simulate NTN environments where satellites, drones, or HAPS are represented as virtual nodes within the network. This helps engineers test network behavior and traffic management without requiring real hardware.

03 Key Challenges in Testing NTN Networks

While lab-based testing can provide valuable insights into NTN performance, there are several challenges in accurately replicating real-world conditions and validating the system's full functionality.

3.1 Propagation and Signal Integrity

3.1.1 Atmosphere and Environmental Variability

The ionosphere and other atmospheric layers can significantly affect signal strength and integrity. In satellite systems, for instance, the presence of moisture, ionospheric irregularities, and atmospheric turbulence can cause signal degradation, leading to bit errors or even system failures. There is a need to replicate these factors within the lab effectively.

3.1.2 Long Path Loss

Due to the significant distances involved, satellite communication often suffers from higher path loss, particularly in LEO and MEO systems. Accurately modeling this path loss in a laboratory environment requires simulation of satellite orbits and signal attenuation.

3.2 Mobility and Link Handover

One of the significant challenges in NTN networks is mobility, where devices move in and out of the coverage area of non-terrestrial systems. Testing seamless handovers between satellites or HAPS and terrestrial networks requires extensive simulation tools that can model these transitions without introducing significant disruptions.

For instance, in a satellite handover scenario, a user's device may be handed over from one satellite to another as it moves across the globe. In a lab, real-time simulations of mobility need to be created.

3.3 Satellite Constellation Testing

Many NTN architectures, particularly LEO satellite constellations, rely on large numbers of satellites working in concert to maintain coverage. Testing the coordination between these satellites, as well as the handoffs between them, involves not only complex software but also robust hardware systems.

Simulating the real-time relative movement and coordination between thousands of satellites in a lab environment needs to be performed.

3.4 Latency and Time Synchronization

One of the defining characteristics of NTNs is their potential to introduce higher latency compared to terrestrial networks. Testing the impacts of this latency, especially in time-sensitive applications such as remote surgery, autonomous vehicles, or real-time video streaming, is crucial. Achieving accurate time synchronization between ground stations and satellites, especially in a dynamic environment, is another item that needs to be addressed.

04 Conclusion

Non-Terrestrial Networks hold the potential to revolutionize global communication, particularly in underserved regions. However, effective testing of NTN systems presents a series of unique challenges. While lab testing can provide valuable insights into system performance, simulating the complex, dynamic nature of satellite or HAPS-based communication networks remains a significant item of value.

As NTNs continue to evolve, testing tool vendors will need to focus on embedding mechanisms to simulate complex mobility scenarios involving Doppler shifts and high latency. Such simulations will need data related satellite positioning vis-à-vis devices. At Amantya, we understand that the drive towards NTN is paramount for achieving ubiquitous connectivity and realizing the promise of 5G. Consequently Amantya is enhancing the AutoRAN solution for enabling testing of NTN scenarios involving relative mobility and high latency within the lab.

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