NTN–TN Integration Through Geostationary Satellite in Cloud-Native 5G Networks

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***Abstract*—Integrating non-terrestrial and terrestrial networks (NTN-TN) is essential to provide ubiquitous coverage in beyond-5G systems. This demo showcases a cloud-native testbed where an NTN UE and a TN UE communicate through a unified 5G core over an emulated geostationary satellite. The setup combines SDR hardware, realistic channel emulation, and automated lifecycle management of mobile network functions using ETSI NFV MANO and open-source platforms.**

***Index Terms*—NTN/TN, B5G/6G, GEO, Management and Orchestration, Cloud-Native, Open5GS, srsRAN**

I. Introduction

The 3^{rd} Generation Partnership Project (3GPP) considers the integration of non-terrestrial networks (NTNs) and terrestrial networks (TN) as an essential feature for 6G mobile networks in order to provide ubiquitous coverage. This integration involves not only adapting the current 5G-New Radio (NR) physical (PHY) and medium access control (MAC) layers to the characteristics of satellite communications in geostationary (GEO) and low Earth orbits (LEO), but also considering emerging trends in the softwarization and disaggregation of mobile network functions (NFs) across the core and Radio Access Network (RAN) segments. This will allow more flexible deployments with automated lifecycle operations overcoming manual management procedures in earth and space segments coping with the dynamicity introduced by such environments, thus fostering the development of stronger business relations between satellite and mobile network operators.

Recent works [1], [2] take into account these aspects in addition to the need of having prototyping and testing platforms to demonstrate the readiness and interworking of 5G NTN-TN. More specifically, the authors of [1] present their user equipment (UE) adaptations based on OpenAirInterface (OAI) and evaluate the performance of their 5G-NTN considering a transparent GEO satellite and employing software defined radio (SDR) hardware. In [2], the authors consider the lifecycle management of 5G NFs based also on OAI software through the use of containers in a single Kubernetes cluster setup using a purely software emulation environment lacking SDR capabilities and protocol adaptations at the UE level for NTN communications.

Our demonstration advances prior work by introducing an innovative testbed integrating all previously mentioned aspects: (i) adaptations at UE side to allow NTN communications on top of the open-source srsRAN [3] software, (ii) a channel emulator enabling realistic 5G NTN communication over a transparent GEO satellite via SDR equipment, and (iii) the automated lifecycle management of open-source mobile NFs, both core and RAN, based on ETSI NFV Management and Orchestration (MANO) principles. This setup enables cloud-native deployment of a 5G network with both real NTN and TN gNBs, supporting UE communication across these nodes, while enhancing automation, flexibility, and portability in distributed environments.

The proposed testbed represents a valuable asset for accurately replicating the NTN environment, thus enabling practical validation of NTN–TN integration prior to real field trials, as demonstrated in our previous work [4]. Moreover, it lays the foundation for future enhancements, including the evaluation of challenging LEO-based satellite scenarios and the development of AI-driven resource management and optimization strategies. Its cloud-based architecture also contributes to reducing hardware costs and facilitates faster, automated deployment and maintenance.

II. System Architecture

Fig. 1 illustrates the experimental setup combining CTTC's CASTLE® testbed for NTN activities and the xG EXTREME® testbed for TN experimentation. On the NTN side, the setup consists of two general-purpose x64 servers with Linux Ubuntu 24.04 LTS operating system, two SDR Ettus X310 devices and a PROPSIM FS16 channel emulator. One of the servers hosts our 5G NR-NTN UE software. This NTN UE is aligned with Release 17 and contains all our modifications and enhancements done on-top of the PHY and MAC layers of the srsRAN UE software to fit the 5G-NR signal into a GEO-based non-regenerative satellite type of communication. Among these enhancements, we consider: updating UE random access procedures, pre-compensation of Doppler frequency shift and large round trip delay, and processing of system information broadcast 19 (SIB19) to support timing advance estimation among others. The other computer, named *Cluster C* in Fig. 1, represents a ground

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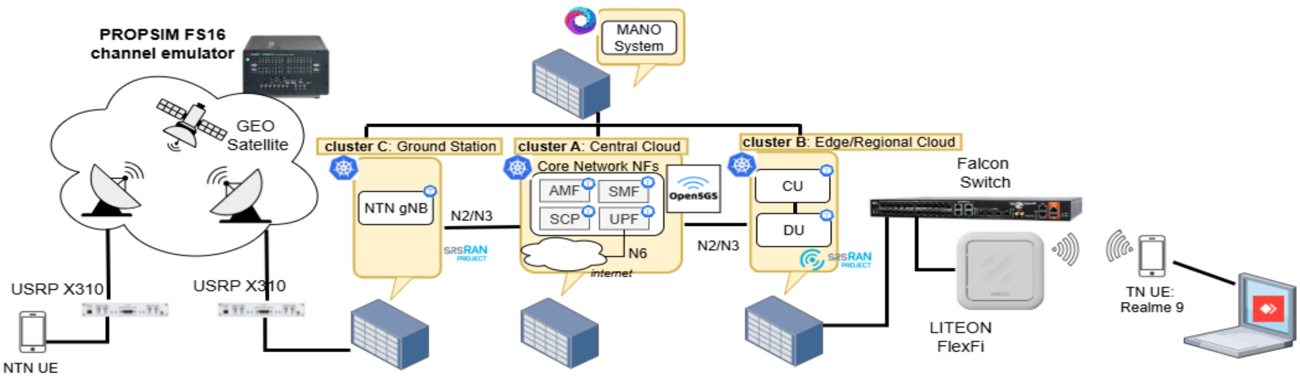

Fig. 1. System Architecture under demonstration. The mobile core is deployed in Cluster A, where NTN gNB (left) and TN gNB (right) are connected.

Station facility, which hosts a single-node Kubernetes cluster where our NTN gNB network service (NS) instance can be deployed upon demand. The channel emulator emulates the time-varying satellite channel using a two line element, power delay profile and transparent architecture to relay the NR-Uu interface between the NTN UE and the NTN gNB. Finally, the SDRs devices act as radio frontends (RF) connected to the channel emulator.

On the TN side, the setup consists of three general-purpose x64 servers. One server executes our MANO system powered by an instance of ETSI Open Source MANO (OSM). The other two servers, named *Cluster A and B* in Fig. 1, act as Points of Presence (PoPs), each running a single-node Kubernetes cluster to host the TN mobile network entities (either core and RAN). In the RAN part, the TN side is completed with a Falcon RX/G O-RAN switch and Precision Time Protocol (PTP) grandmaster, providing the synchronization between the edge/regional PoP and the O-Radio Unit (O-RU), which is a LITEON FlexFi FF-RFI078I41, and a Realme 9 smartphone interfaced via a remote desktop tool (e.g., AnyDesk). The mobile network entities consist of the NS artefacts developed in [5], which allows the distributed and disaggregated deployment of a mobile core based on Open5GS [6] and a disaggregated gNB consisting of a Central Unit (CU) and a Distributed Unit (DU). Remarkably, these artefacts are based on Helm Charts integrated into OSM packages, which enable parametrized deployments, making the system highly flexible and portable for different test scenarios. Indeed, for this work, a new artefact following the same approach as for the TN entities has been generated for the NTN gNB, and the MANO system also manages the Kubernetes cluster in the NTN domain, thus promoting automation in the NTN segment.

III. Demonstration

This demonstration showcases the automated deployment and orchestration of a cloud-native 5G mobile network integrating both NTN and TN segments. It enables end-to-end communication between UEs connected to the different access networks via a unified 5G mobile core instance. The steps of the demonstration are as follows:

1) We request our MANO system to deploy the Open5GS NSs in the central Cloud. Once deployed, we register two UEs, namely one TN UE and one NTN UE in the Unified Data Repository database of Open5GS.

2) Then, we proceed to deploy the TN gNB in ClusterB. The TN gNB consists of two disaggregated NSs, the CU and DU. The PTP artefact is also instantiated to provide the required synchronization between the DU and RU.

3) Now, we proceed to attach the TN UE to the network. After leaving flight mode, the TN UE receives an IP address from the configured data network name (DNN), named *internet*.

4) Next, we deploy the NTN gNB in ClusterC, which uses the USRP X310 as RF connected to the channel emulator. This gNB is configured with the appropriate parameters for a GEO non-regenerative satellite (e.g., radio resource control timers) and to reach the AMF placed in ClusterA.

5) We start the GEO channel emulation considering a *GARUDA* satellite located at 35880 km, where the one-way delay on the service and feeder links are 132 ms and 130 ms, respectively.

6) Now, we proceed to start the NTN UE software and register it in the mobile network. It also receives an IP address in the range of the configured *internet* DNN.

7) Once both UEs are attached to the mobile network, we show there is communication between them through ping and establishing Iperf sessions.

Each step of the demonstration is visualized through our MANO system's GUI and a remote desktop session to the TN UE showing the interaction with the NTN UE (e.g., ping over the emulated GEO link exceeding 500 ms).

References

[1] F. Völk, et al., "5G Non-Terrestrial Networks With OpenAirInterface: An Experimental Study Over GEO Satellites", in IEEE Access, pp. 155098 - 155109, 2024.

[2] F. Muro, et al. "A 5G NTN Emulation Platform for VNF Orchestration: Design, Development, and Evaluation", in IEEE Open Journal of the Communications Society, pp. 5364 - 5376, 2024.

[3] srsRAN Project - Open Source RAN, Available at: https://www.srsran.com/5g [Accessed: 31/10/25].

[4] A. Giuliani, et al., "Evaluating 5G Non-Terrestrial Networks: Laboratory and Field Trials with Geostationary Satellites", in IEEE EuCNC/6G Summit, Poznan, Poland, 2025.

[5] J. Baranda, et al., "End-to-End Slice Orchestration in a 5G cloud-native Mobile Network with O-RAN Split 7.2", in IEEE INFOCOM, London, UK, 2025.

[6] Open5GS 5G Core, Available at: https://open5gs.org/open5gs/docs/guide/01-quickstart/ [Accessed: 31/10/25].