Towards Efficient End-to-End Connectivity in B5G-NTN: in orbit UPF and Dual Connectivity

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***Abstract*—The growing integration of Non-Terrestrial Networks (NTNs) into beyond-5G (B5G) infrastructures opens up new opportunities for enhancing global mobile connectivity, particularly for customers and IoT devices in remote or underserved areas. However, the inherent latency and variability of satellite links and the topology dynamicity of low-orbit constellations introduce significant challenges in maintaining low-latency, high-throughput, and reliable end-to-end connections.**

This work investigates a distributed and hybrid B5G-NTN architecture built upon Dual Connectivity (DC) principle, where user equipments (UEs) can establish simultaneous connections via two satellite paths (e.g., LEO/GEO constellations or multi-LEOs) toward the 5G core (5GC).

DC B5G-NTN Testbed

The proposed architecture in Figure1 logically decouples the Distributed Unit (DU) and Centralized Unit (CU) of the orbital Radio Access Network (RAN) in the space segment through the paradigm of network functions as a service (NFaaS), and allows for dynamic association of UEs with a in orbit external User Plane Function (eUPF) co-located with the RAN [1], [2]. The control-plane entities, including the Access and Mobility Management Function (AMF) and Session Management Function (SMF), remain centralized in the ground segment. Our demonstration emulates variable-bandwidth/delay intra-satellite links and 5G RAN/Core starting from the testbed developed in [3].

In addition, a lightweight proxy-based redirection mechanism (via Squid) is used on the UE to dynamically schedule the HTTP traffic through the selected TUN interfaces toward the selected UPF, based on key performance indicators (KPIs) monitoring at regular intervals.

Differently from [3], the UPF is here experimented in the space segment, by disaggregating the 5GC network functions.

The KPIs are now provided by the Network Data Analytics Function (NWDAF), including link congestion, throughput, and delay.

The novelty of this approach lies in two key aspects:

- A dynamic eUPF is adopted instead of a fixed one in the 5GC, where the UE is directed to connect to the eUPF between the orbital edge RAN and the satellite ground station connected to the 5GC. This reduces backhaul latency and improves service continuity, particularly in constellations with frequent handovers.
- Optimized path selection to the Data Network (DN): After the traffic reaches the UPF, it must traverse a path to the DN. We propose to select this path based on real-time performance metrics provided by NWDAF. This ensures that traffic is routed through the most efficient available DN gateway.

The preliminary results show that adaptive eUPF placement, coupled with intelligent path selection driven by NWDAF feedbacks, improves end-to-end Quality of Service (QoS). This is especially crucial for future NTN scenarios where mobile terminals frequently switch between beams, satellites, or ground gateways.

This architecture can be seen as a practical enabler for resilient, low-latency NTN-ground integrated B5G systems, supporting autonomous services, emergency connectivity, and industrial IoT in dynamic environments.

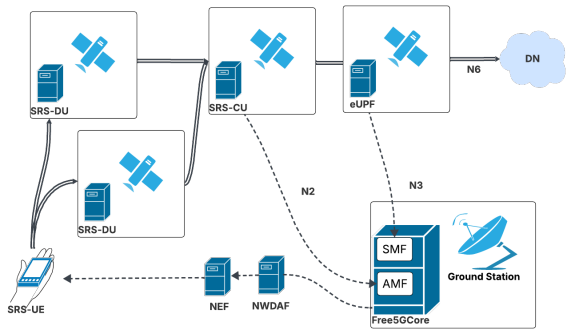

Fig. 1. B5G-NTN architecture compliant to 3GPP Release 17.

References

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