A Multi-connectivity Scheme for Service Continuity Between Terrestrial and Non-Terrestrial Networks

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***Abstract*— This paper proposes a dual steering framework that enables user equipment (UE) to maintain seamless service continuity across integrated terrestrial (TN) and non-terrestrial networks (NTN). The proposed approach introduces control-plane procedures for parallel registration, unified PDU session establishment, and dynamic multi-path management between TN and NTN domains. These procedures significantly reduce signaling overhead and enable efficient dual-access connectivity, allowing uninterrupted service delivery even under fluctuating radio conditions and mobility events. This work presents the conceptual framework and procedural design as a foundation for future implementation and performance evaluation.**

Keywords—5G, 6G, NTN, TN, LEO and Satelite

I. Introduction

The evolution of 5G and the progression toward beyond-5G (B5G) networks has positioned the integration of terrestrial networks (TN) and non-terrestrial networks (NTN) as a fundamental architectural direction for enhancing global coverage and service reliability. Low Earth orbit (LEO) satellites, in particular, provide resilient and scalable connectivity solutions for high-mobility and remote scenarios, effectively addressing the inherent limitations of terrestrial infrastructure.

To facilitate this integration, 3GPP has established comprehensive technical frameworks for NTN across Releases 17 through 19, encompassing both transparent and regenerative satellite architectures. However, while conventional handover mechanisms have been defined, they frequently incur significant signaling delays and session interruptions, particularly during transitions between TN and NTN domains under variable radio conditions.

A critical challenge emerges in ensuring seamless session continuity while minimizing control-plane overhead during such transitions. Existing methodologies lack standardized procedures for maintaining simultaneous connectivity across heterogeneous access networks and for dynamically redirecting traffic during network degradation events.

This paper proposes a multi-connectivity scheme that enables user equipment (UE) to concurrently register with both TN and NTN while establishing PDU (Packet Data Unit) sessions that span both domains. The proposed framework introduces comprehensive control-plane procedures for dual registration, unified PDU session setup, and adaptive traffic steering. Our methodology maintains full compatibility with 3GPP standardization trends and is specifically designed to support uninterrupted service delivery in integrated TN-NTN environments.

II. Related Work

Recent 3GPP releases have substantially advanced the integration of NTNs into the 5G system architecture. TR 22.841 delineates service continuity scenarios where user equipment (UE) maintains simultaneous connections to both TN and NTN, enabling dynamic traffic steering based on link quality or policy decisions. This specification emphasizes the necessity for coordinated registration, multi-access PDU sessions, and core-assisted path switching to support uninterrupted service delivery.

Complementary technical reports, including TR 38.811 and TR 38.821, address the radio aspects of NTN implementation, encompassing support for both transparent and regenerative satellite architectures and necessary modifications to the NR-Uu interface. TR 23.700-95 and TS 23.501/502 extend these efforts at the system level, introducing architectural enhancements for dual connectivity and dynamic routing across TN and NTN domains.

While these specifications define the requisite architectural components, they do not provide detailed signaling procedures for dual registration, session establishment, or traffic steering under simultaneous TN-NTN access conditions. To address this gap, we propose a protocol-level dual steering framework that enables synchronized session control and dynamic path switching, aligned with ongoing 3GPP standardization efforts.

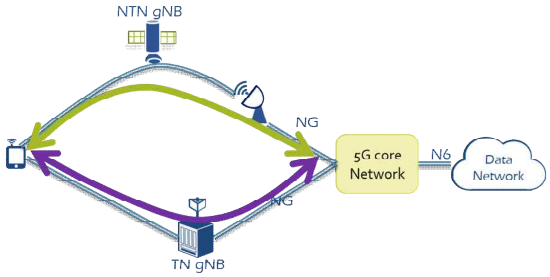

Fig.1. Multi-connectivity in NTN-TN Network

III. Proposed Method

We propose a multi-connectivity mechanism wherein the UE maintains RRC-connected states with both TN and NTN

simultaneously. Depending on deployment scenarios, a single PDU session may span both access networks, or separate sessions may be maintained per domain.

A. Registration Procedure

The UE initiates registration procedures with both terrestrial and non-terrestrial base stations concurrently. While this approach differs from traditional dual registration, it prepares the network infrastructure to support simultaneous connectivity under a dual steering framework. The UE transmits separate Registration Request messages to each base station, explicitly indicating its dual steering capability. This enables each network node to perform authentication and context setup while informing the 5G core network of the UE's capability to maintain connections with both networks.

Unlike conventional approaches where registration occurs sequentially, the proposed method enables parallel attachment from the initial connection phase. This early coordination establishes the foundation for dual connectivity at the radio access level and enables seamless traffic steering across different coverage scenarios.

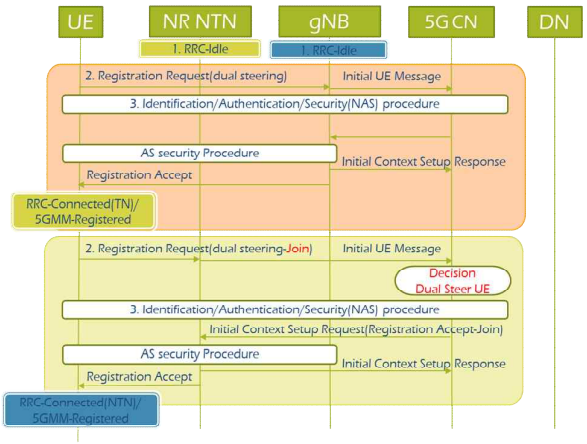

Fig.2. UE Registration Procedure in NTN-TN

B. PDU Session Setup

Once the initial registration phase is successfully completed, the UE initiates the PDU session establishment process. Rather than dispatching separate requests to the TN and NTN access networks, the UE transmits a single PDU Session Establishment Request via the more stable or preferred link. This request explicitly signals the UE's dual steering capability, prompting the 5G core network to configure the PDU session for concurrent operation across both TN and NTN.

Upon detecting the UE's support for simultaneous connectivity, the core network initiates appropriate control-plane procedures to allocate radio access network (RAN)-specific resources on each access leg. Although this approach resembles the multi-access PDU session concept, it is fundamentally distinct in that both TN and NTN operate under a common NR-based radio access technology. This commonality enables centralized session anchoring and unified management through the 5G core network.

Consequently, the UE can transmit and receive data through both TN and NTN interfaces using a single, integrated session context. This design eliminates the need for redundant signaling or parallel session setups, thereby reducing overhead and improving efficiency in dual-connectivity environments.

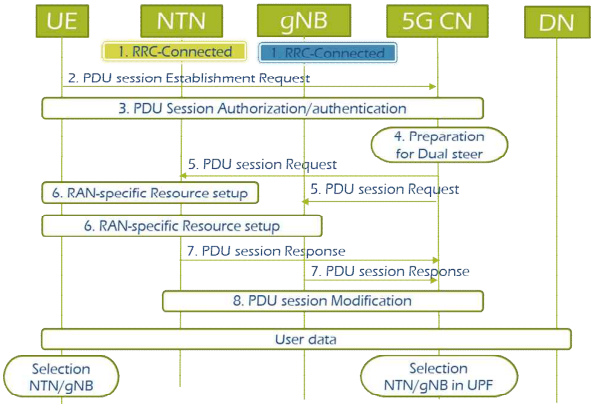

Fig.3. PDU session setup Procedure in NTN-TN

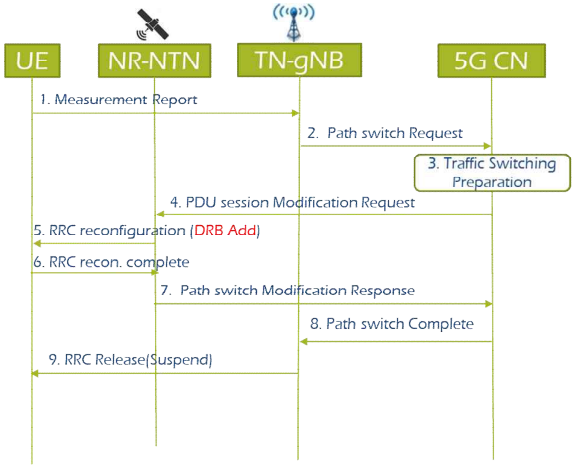

Fig.4. TN-to-NTN Traffic Steering Procedure

C. TN-to-NTN Traffic Steering

With the unified PDU session established across both TN and NTN, the proposed framework supports dynamic traffic steering to maintain service continuity during fluctuating radio conditions. When the TN link experiences performance degradation due to interference, congestion, or mobility, the UE initiates a measurement reporting procedure to reflect the deteriorated link state.

Based on the measurement report, the TN base station transmits a path switch request to the 5G core network. Upon evaluating current connectivity conditions, the core network initiates a session modification procedure to reroute the active session toward the NTN access. This process includes reallocating data radio bearers (DRBs) and provisioning necessary resources on the satellite link.

Subsequently, the UE receives an RRC reconfiguration message that updates its radio configuration to support communication over the NTN link. Upon successful reconfiguration and acknowledgment, the session seamlessly transitions to the NTN path. This mechanism enables uninterrupted service delivery with minimal signaling overhead, enhancing the robustness of TN-NTN integrated networks under diverse operational scenarios.

D. Resume Procedures

In addition to traffic steering from TN to NTN, the proposed framework supports bidirectional resume procedures that enable seamless re-establishment of connectivity when a previously unavailable access path becomes available. This functionality is critical in dynamic environments where either TN or NTN links may temporarily degrade or become unreachable.

When the TN link is restored after being inactive, the UE initiates an RRC Resume Request toward the TN base station. The base station responds with an RRC Resume Response, triggering the core network to reassess the active session's routing path. If necessary, a session modification procedure is initiated to reassign DRBs to the TN link. Simultaneously, the core network may instruct the NTN side to release or retain its DRBs based on operator policy or link conditions.

The framework supports two distinct resume modes:

- With DRB Deletion: The DRBs on the previously active access (e.g., NTN) are released, and the session continues exclusively via the resumed link (e.g., TN).
- Without DRB Deletion: The DRBs on both TN and NTN are retained, enabling the UE to resume multi-path communication without reconfiguration.

These procedures ensure that service continuity is maintained with minimal signaling overhead and flexible session routing. The ability to dynamically resume suspended links contributes to robust performance in scenarios involving intermittent NTN coverage or UE mobility across heterogeneous access zones.

IV. Conclusion

This paper presents a dual steering framework designed to enhance service continuity across integrated TN and NTN environments. The proposed conceptual approach enables UE to initiate parallel registration procedures and establish a unified PDU session spanning both TN and NTN without duplicating signaling efforts. Through coordinated control-plane mechanisms, the framework supports dynamic traffic steering and robust resume procedures, allowing the network to adapt seamlessly to varying link conditions.

The key contributions of this work include: (1) a comprehensive dual steering architecture that maintains compatibility with 3GPP standards, (2) detailed procedural designs for parallel registration and unified session management, and (3) adaptive traffic steering mechanisms that preserve session integrity during network transitions.

Unlike conventional approaches that rely on sequential registration or independent session management, this solution provides a foundation for synchronized connectivity management and flexible session routing. The proposed dual steering capability has the potential to reduce signaling overhead while preserving session integrity, which is critical in hybrid access environments with intermittent coverage or user mobility.

Future work will focus on detailed performance evaluation through simulation models, mathematical analysis of signaling overhead reduction, and the development of a prototype testbed to validate the proposed mechanisms in realistic TN-NTN deployment scenarios. Additionally, further investigation into optimization strategies for different mobility patterns and network conditions will be pursued.

Acknowledgment

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