

High-Reliability and Low-Latency Mobility Based on Integrated Operation of CHO/CPCA and LTM

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Abstract—This paper proposes a new operational framework supporting MR-MC (Multi-Radio Multi-Connectivity) environments, based on the emerging mobility management techniques discussed in 3GPP. While the MR-MC architecture enhances service continuity and resilience, it also introduces far more complex mobility management issues compared to single-cell connections. To address these challenges, this paper proposes an integrated framework that combines LTM (Lower Layer Triggered Mobility), CHO (Conditional Handover), and CPCA (Conditional PSCell Change and Addition). By unifying policy-driven preparation with lower-layer immediate execution, the proposed method ensures both reliability and responsiveness in mobility management. Whereas CHO suffers from limited responsiveness to rapid channel variations and LTM is prone to excessive handover triggers, their integration compensates for these drawbacks by balancing reliability and immediacy. The proposed framework improves transmission efficiency, reduces handover delay, and mitigates signaling overhead, thereby supporting ultra-low latency and high-reliability mobility in next-generation systems.

Keywords—5G, 6G, multi-radio multi-connectivity, CHO, CPC/CPA, LTM, 3GPP standardization, Handover

I. INTRODUCTION

With the evolution toward 5G-Advanced and 6G, mobility support for user equipment (UE) has become a critical enabler to meet the stringent requirements of ultra-low latency and high reliability. In particular, the propagation characteristics of high-frequency bands (mmWave and sub-THz) cause rapid channel fluctuations and frequent link failures, making it difficult to provide stable services with conventional handover procedures alone. To overcome this, the MR-MC (Multi-Radio Multi-Connectivity) architecture has been introduced. MR-MC allows a UE to simultaneously connect to multiple Radio Access Technologies (RATs) and multiple cells, thereby enhancing resilience against link failures and ensuring service continuity during mobility. However, it also introduces much greater complexity in mobility management compared to single-cell connections, thus requiring new procedural support for efficient operation.

In parallel, 3GPP has successively introduced several mobility management techniques such as CHO (Conditional Handover), CPCA (Conditional PSCell Change and Addition), and LTM (Lower Layer Triggered Mobility). CHO provides conditional handovers, CPCA enables conditional PSCell changes and additions, and LTM realizes lower-layer triggered mobility. While these methods complement mobility performance in different ways, their individual operation is insufficient to simultaneously achieve both policy consistency and immediate execution in MR-MC environments.

This paper proposes a novel operational framework that integrates CHO and CPCA with the extended LTM procedure for inter-gNB environments. The proposed approach is designed to operate efficiently in MR-MC scenarios and aims to guarantee high-reliability and low-latency mobility through collaborative network-UE operation.

II. RELATED WORKS

3GPP has introduced MR-MC architectures together with CHO, CPCA, and LTM as independent mobility management techniques for next-generation mobile systems. MR-MC strengthens service continuity by enabling simultaneous connections to multiple RATs and cells, yet also complicates mobility procedures. Accordingly, various schemes have evolved within the standardization process.

A. CHO (Conditional Handover)

CHO is a mobility procedure in which a UE executes handover immediately once predefined conditions (e.g., event triggers) are met. It improves reliability and reduces unnecessary latency. Initially specified in Rel-16 TS 38.300 [1], CHO was extended in Rel-17 with support for multiple candidate cells, explicit behaviors for condition expiry, and enhanced recovery mechanisms, thereby expanding its scope and robustness. However, its L3 (RRC)-based condition evaluation limits responsiveness to rapid channel variations, and candidate invalidation upon condition expiry may result in resource wastage.

B. Integrated Operation of CHO and CPCA

In Rel-17/18, CPCA was introduced for flexible PSCell management. In Rel-19, 3GPP TS 37.340 [2] specifies integrated operation of CHO and CPCA, coordinating MCG and SCG mobility under a unified candidate and policy framework. The standard allows CHO and CPCA to run in parallel for reduced interruption, to follow sequentially with CHO first for stability, or to activate selectively depending on policy, while also enabling both to share a unified candidate list. This integration improves efficiency but raises challenges in consistency, timing, signaling, and rollback.

C. LTM (Lower Layer Triggered Mobility)

LTM, introduced in Rel-18 [1], enables mobility triggered by L1/L2 events, providing ultra-low-latency handovers. By bypassing RRC intervention, LTM achieves faster execution and improved reliability under rapid channel dynamics. However, it is highly sensitive to channel variations, which can cause frequent unnecessary handovers. Continuous candidate preparation also increases signaling overhead and resource inefficiency. Moreover, its reliance on lower-layer

signaling paths (e.g., MAC CE) may expose security vulnerabilities [7][9].

D. Evolution of LTM

- Rel-18: Defined intra-gNB L1/L2 triggers and minimized higher-layer involvement.
- Rel-19: Extended applicability to inter-gNB environments.

In Rel-19 TS 38.300 [1] officially recognizes that LTM can be applied to both intra-gNB and inter-gNB cases using the same procedure [6][7]. Consequently, LTM after Rel-19 provides a foundation to integrate with CHO and CPCA, enabling policy-driven candidate preparation alongside ultra-low-latency execution.

III. A PROPOSED METHOD

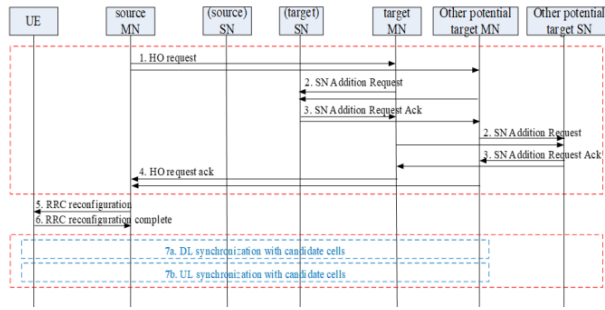


Fig. 1. Handover Pre-preparation and early synchronization procedures

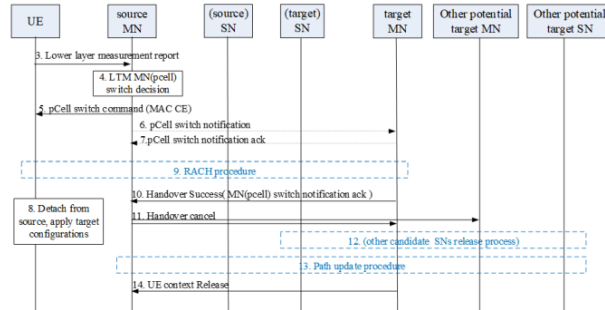


Fig. 2. Integrated procedure for CHO/CPCA/LTM operation

This paper proposes a new operational framework that integrates CHO and CPCA with the extended inter-gNB LTM procedure. The key design elements are as follows:

- Enhanced Early Synchronization: Candidate PCells and PSCells are pre-configured and synchronized in advance, maintaining DL/UL alignment to enable immediate handover execution.
- Efficient Candidate Management: The UE performs L1/L2 measurements of neighboring cells, and the network selects candidates with high execution probability. Unsynchronized cells are automatically removed from the candidate list to minimize resource waste.
- Support of LTM: Once conditions are met, the LTM procedure is triggered and executed via MAC CE and other lower-layer signaling [5]. Handover completion

is coordinated by control message exchanges between the source and target gNBs.

- Simultaneous Transitions: MCG handovers (CHO) and SCG changes (CPCA) can be executed in parallel, thereby minimizing N2/Xn latency.

By combining the reliability of CHO/CPCA, which provides stable handovers through predefined conditions, with the immediacy of LTM, which enables low-latency execution via lower-layer triggers, the proposed framework achieves robust and responsive mobility management.

IV. CONCLUSIONS

The proposed scheme eliminates RRC reconfiguration delays, enabling significantly faster transitions compared to CHO/CPCA alone [6]. Moreover, integrated candidate management enhances service continuity and reliability [9][10]. While signaling overhead may increase, this drawback can be mitigated through unified candidate control and lightweight LTM execution. In summary, the proposed approach combines policy-driven preparation with lower-layer immediate execution, achieving a balance between reliability and responsiveness that individual techniques cannot provide. It can serve as a valuable reference model for mobility management in 5G-Advanced and 6G standardization [1][2][8]. This study analyzed the extended inter-gNB LTM procedure with CHO/CPCA operations, and proposed a novel integrated mobility management framework. Future works include validating the proposed framework in testbeds to complement simulations, and exploring AI/ML-based policy integration for optimized candidate management and mobility decisions. These efforts will enhance the adaptability and robustness of integrated CHO/CPCA/LTM mobility management in next-generation systems.

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