Velocity-Aware Handover Optimization Based on O-RAN Architecture

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***Abstract*— Mobility Robustness Optimization (MRO) is a key feature in cellular networks that aims to reduce unnecessary or failed handovers. Traditional SON-based MRO methods apply uniform handover parameters (e.g., CIO, TTT, Hysteresis) to all UEs within a cell, which can degrade the performance of slow-moving or stationary UEs. This paper proposes a framework leveraging the O-RAN architecture to dynamically control handover parameters for each UE based on its velocity. The proposed method improves network efficiency by applying optimized parameters to high-speed UEs while avoiding unnecessary control for stationary ones.**

Keywords*— *O-RAN, MRO, Handover Optimization, RIC, xApp, rApp, UE Velocity

I. Introduction

Mobility management is a critical function in 5G and beyond networks. Conventional Mobility Robustness Optimization (MRO), introduced in 3GPP Releases 9 and 10, aims to minimize handover failures, ping-pong handovers, and incorrect cell selections by tuning parameters such as Cell Individual Offset (CIO), Time-to-Trigger (TTT), and Hysteresis. However, SON-based MRO typically applies the same handover settings to all UEs in a cell, regardless of their velocity or behavior. This can degrade the handover performance, especially for stationary or slow-moving UEs, by triggering unnecessary handovers or missing timely handover opportunities for fast-moving UEs.

The Open RAN (O-RAN) architecture introduces a disaggregated and intelligent control plane through the use of Near-Real-Time RAN Intelligent Controller (Near-RT RIC) and Non-Real-Time RIC (Non-RT RIC). According to the O-RAN Alliance specifications, the rApp in Non-RT RIC is responsible for network-wide analytics and policy generation, while xApps in Near-RT RIC perform localized, near-real-time control actions. This separation of roles makes it feasible to implement velocity-based per-UE handover optimization.

This paper proposes an O-RAN-based handover optimization framework that uses UE velocity information to apply tailored parameters to each UE. The velocity information is collected via the O1 interface and analyzed by the rApp to determine a reference velocity threshold. Based on this, the rApp generates a handover policy, which is transferred via the A1 interface to the xApp. The xApp, in turn, monitors UE velocity in near-real-time and applies the parameters only to UEs exceeding the reference threshold, ensuring faster and more accurate handovers for mobile users while maintaining stability for stationary ones.

II. O-RAN Based System Architecture

The proposed solution reinterprets traditional SON-based MRO within the O-RAN architecture as follows:

A. rApp (Non-RT RIC)

It aggregates statistical data from the network via the O1 interface, including UE velocity, handover success rates, and MRO failure logs. It analyzes this data to determine a velocity threshold that represents the boundary below which MRO problems are rare. It then generates optimized handover parameters such as CIO, TTT, and Hysteresis for high-velocity UEs. The rApp supports long-term, system-wide optimization and allows segmentation by geographic area, time slot, and UE category. These policies are delivered to xApp via the A1 interface.

B. xApp (Near-RT RIC)

The xApp continuously monitors UE velocity using real-time data from the gNB. When a UE's velocity exceeds the reference threshold provided by the rApp, it applies the handover parameters to that specific UE. The xApp ensures policy compliance and avoids conflicting actions using priority-based resolution mechanisms in cases where multiple policies apply simultaneously.

C. O1 Interface

This interface facilitates the flow of telemetry data, such as UE mobility metrics and cell-level KPIs, from gNB to SMO and further to rApp. It enables holistic network visibility and supports offline or batch processing for policy derivation.

D. A1 Interface

Policies generated by rApp are transferred to xApp through this interface. It supports not only one-time policy delivery but also lifecycle management, including updates and expiration handling.

E. E2 Interface

Through this path, xApp communicates directly with gNB to enforce control decisions. Handover-related RRC parameters are conveyed to the UE based on xApp logic.

This distributed yet cooperative architecture enables the rApp to provide network-wide, strategic intelligence while allowing the xApp to execute fast, fine-grained control actions. Its modularity also allows future enhancements such as machine-learning-based policy generation and cross-domain collaboration.

Fig. 1. illustrates the proposed O-RAN-based architecture for velocity-aware handover optimization.

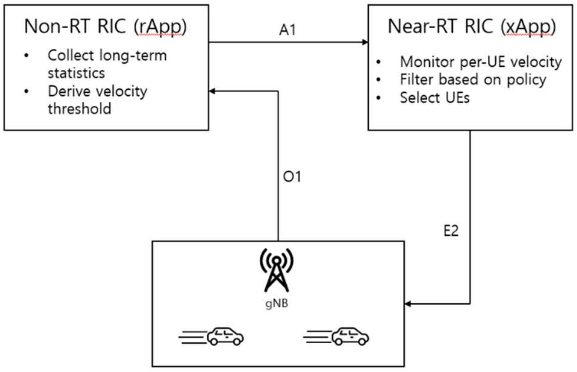

Fig. 1. O-RAN-based architecture for velocity-aware handover optimization.

III. Proposed Method

This study proposes a two-stage optimization framework, with separate roles for policy generation (rApp) and parameter enforcement (xApp):

A. *Policy Generation (rApp)*

The rApp uses data collected via the O1 interface to estimate UE velocity profiles and identify velocity ranges associated with successful handovers. By isolating UEs that do not encounter MRO issues, the rApp defines a reference velocity threshold. This threshold is dynamically adjusted to account for network variations such as congestion, interference levels, and load distribution.

Using regression models or simple ML algorithms (e.g., decision trees or k-means clustering), the rApp derives optimal handover parameter combinations for UEs exceeding the threshold. These include adjustments to CIO, TTT, and Hysteresis tailored to specific velocity bands. The rApp also tags policies with contextual metadata such as applicable time-of-day, cell ID, or UE category (e.g., vehicular, pedestrian). Generated A1 policies are then transmitted to the xApp.

Policy prioritization and conflict resolution mechanisms are incorporated to manage overlapping policy scopes. The architecture supports future enhancements such as hierarchical policy inheritance across neighboring cells or regions.

B. *Parameter Enforcement (xApp)*

The xApp receives A1 policies and tracks individual UE velocity in near-real-time via gNB reports or RAN exposure APIs. When a UE exceeds the predefined threshold, the xApp applies the corresponding handover parameter set by communicating with the gNB through the E2 interface. This results in real-time adaptation of Event A3 thresholds, enabling more responsive handover triggering.

To prevent instability, hysteresis regions are established around the velocity threshold to reduce frequent parameter toggling. If the UE slows down below the reference velocity, default parameters are restored after a configurable delay. Additional enhancements such as considering heading direction, predicted movement trajectory, and contextual awareness can further improve robustness.

The xApp also supports anomaly detection; if a UE demonstrates abnormal handover behavior despite policy compliance, alerts can be sent to the rApp for policy revision. This feedback loop enables semi-autonomous and adaptive control.

IV. Expected Benefits and Future Work

The proposed approach delivers the following benefits:

- Reduced handover failures in high-speed scenarios (e.g., highways, railways)
- Minimized unnecessary handovers for low-speed or static users
- Enhanced spectral and signaling efficiency through selective parameter application
- Improved Quality of Experience (QoE) by tailoring control to each UE
- Scalability and automation through policy-driven orchestration

As future work, we plan to implement the framework on NS-3-based O-RAN simulators to quantitatively validate performance gains. The model will be extended to include directional and sensor-based information (e.g., inertial data) for more accurate mobility prediction. We also aim to apply reinforcement learning techniques to allow autonomous policy refinement based on observed outcomes.

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