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Handover xApp

Technical Specifications

Overview

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The Intelligent Handover xApp is an advanced application designed for deployment in Open RAN networks, aimed at optimizing mobility management and ensuring seamless connectivity in dynamic, high-mobility environments. It is specifically developed to address the growing complexity of modern networks, where users frequently traverse multiple cells, frequency bands, and Radio Access Technologies (RATs). Operating within the Near-Real-Time RAN Intelligent Controller (Near-RT RIC), the xApp performs continuous analysis and management of handover operations using real-time data and advanced AI techniques. Central to its functionality is the integration of Deep Reinforcement Learning (DRL), a powerful machine learning methodology that enables the xApp to dynamically adapt handover decisions based on evolving network conditions.

By leveraging DRL, the xApp predicts optimal target cells, ensures efficient spectrum utilization, and reduces unnecessary handovers, which can degrade the overall user experience and strain network resources. Unlike traditional handover mechanisms based on fixed thresholds or simplistic algorithms, the Intelligent Handover xApp learns and evolves, making context-aware decisions that optimize key performance indicators (KPIs) such as signal strength, throughput, and latency. The xApp's architecture is inherently modular and scalable, aligning with the principles of the O-RAN Alliance. It interacts with the RAN through the E2 interface, providing direct control over handover-related parameters while monitoring critical metrics like SS-RSRP distribution, user throughput, and resource block utilization. This real-time data feedback loop allows the xApp to respond swiftly to network dynamics, ensuring consistent service quality even in high-density environments such as urban areas, transit hubs, and highways.

An important feature of the xApp is its support for multiple handover scenarios, including intra-frequency, inter-frequency, and inter-RAT transitions. This flexibility is vital for heterogeneous network deployments where various RATs coexist, such as 5G-NR, LTE, and Wi-Fi.

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The Intelligent Handover xApp enables dynamic and efficient user handovers across cells, frequency bands, and Radio Access Technologies (RATs) within the Open RAN ecosystem. It empowers mobile network operators (MNOs) to meet stringent Quality of Service (QoS) requirements while enhancing overall network efficiency. This xApp utilizes Deep Reinforcement Learning (DRL) to make real-time, intelligent decisions about handover operations [1]. By continuously analyzing network metrics, such as signal quality, user throughput, and resource utilization, the xApp dynamically adjusts handover parameters to optimize user experience and maintain network stability.

Its ability to support multiple handover types, including intra-frequency, inter-frequency, and inter-RAT transitions, makes it highly adaptable to diverse network environments. In addition to its adaptability, the Intelligent Handover xApp incorporates customizable policy frameworks, enabling operators to implement user-centric, QoS Flow-oriented, and slice-specific policies. This flexibility ensures precise handover management tailored to the specific needs of users and services.

The xApp's integration with the Near-Real-Time RAN Intelligent Controller (Near-RT RIC) ensures seamless operation within the O-RAN architecture, allowing for real-time optimization of network performance. The xApp prioritizes reliable handovers to low-latency cells for vehicles, ensuring uninterrupted connectivity. Simultaneously, it facilitates load balancing by redirecting mobile broadband users to less congested cells, thereby improving overall resource allocation and service quality.

Parameters Monitored Through E2 Interface – Inputs to Handover xApp

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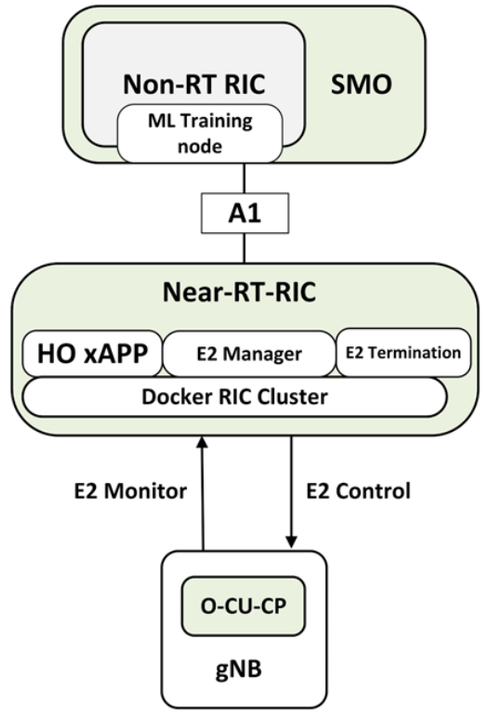
The xApp utilizes the E2 interface to collect real-time network data for decision-making. Key monitored parameters include:

- **SS-RSRP Distribution:** Provides information about signal strength from serving and neighbouring cells.
- **User Equipment Identity (UE ID):** Identifies users for monitoring and control actions.
- **Cell Global Identity (CGI):** Identifies serving and target cells.
- **5G QoS Identifier (5QI):** Defines QoS requirements, such as packet error rate and latency.
- **Mean Number of RRC Connections:** Tracks the average number of active UEs in each cell.

Optional Parameters:

- **DL/UL Throughput Distribution:** Monitors user throughput in downlink and uplink.
- **Radio Resource Utilization:** Tracks PRB usage and availability.
- **Handover Statistics:** Includes inter-gNB, intra-gNB, and inter/intra-frequency handovers.



Parameters Controlled Through E2 Interface – Outputs from Handover xApp

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- The xApp uses the E2 interface to execute optimized handover decisions. Key controlled parameters include:
- **Mandatory Parameters:**
  - **UE ID:** Identifies the user subject to handover.
  - **Primary Cell ID:** CGI of the current serving cell.
  - **Target Primary Cell ID:** CGI of the target cell for handover.
  - **List of PDU Sessions:** Specifies PDU sessions subject to the handover procedure.
  - **List of DRBs:** Identifies DRBs involved in the handover.
- **Optional Parameters:**
  - **List of Secondary Cells to Be Setup:** Configures secondary cells for dual connectivity post-handover.

Handovers	HO Triggered	Cancelled by the RIC	Delay to handover start (ns)	Started	Finalized	Failed	Handover duration (ns)	Connections (Re)Established
Initiated by eNB	0+-0	0+-0	0+-0	30+-0	30+-0	0+-0	4213124+-0	6+-0
Initiated by eNB and decided by O-RAN	30+-0	0+-0	10000161+-0	30+-0	30+-0	0+-0	4213124+-0	6+-0
Initiated by eNB and decided by O-RAN+HO xApp	1783+-93	1766+-93	17793826+-4409160	16+-1	16+-1	0+-0	4268541+-62713	30+-1
Initiated by O-RAN+HO xApp	28+-1	0+-0	161+-0	18+-1	18+-1	0+-0	3949941+-25942	25+-1
	3GPP/eNB	O-RAN/RIC+HO xApp						

Machine Learning-Driven Handover Optimization

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The Intelligent Handover xApp leverages Machine Learning (ML) to enhance its decision-making capabilities, enabling dynamic and intelligent handover management. At the core of its operation are pre-trained models provided by the Non-RT RIC, which act as the initial foundation for policy enforcement. These models allow the xApp to make informed handover decisions even at the start of deployment.

A key feature of the xApp is its integration of a Reinforcement Learning Cycle, where it continuously refines policies based on real-time network feedback. This involves the collection of data on network states, the actions taken by the xApp, and the resulting outcomes or rewards [1]. Through this iterative process, the xApp improves its understanding of the network environment, enabling more effective and context-aware handover strategies. Dynamic adaptation is another hallmark of the xApp, allowing it to modify its handover strategies in response to changing conditions such as network congestion, user mobility patterns, or shifts in traffic demand.

This ensures optimal performance across a wide range of scenarios, making the xApp particularly valuable in heterogeneous and dynamic networks. By combining pre-trained models, reinforcement learning, and real-time adaptation, the Intelligent Handover xApp represents a cutting-edge solution for mobility management in modern Open RAN systems.

Prerequisites for Installing the HO xApp

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- **System Requirements**

- **Software Requirements**:
  - **Open-Source RIC Platform**: Installed and configured (e.g., O-RAN Software Community RIC).
  - **Kubernetes**: For container orchestration (v1.20 or higher recommended).
  - **Docker**: For HO xApp deployment (v20.10 or higher).
  - **Helm**: For managing the xApp deployment (v3).
- **Other Tools**:
  - Git for downloading xApp source code or images.
  - E2 Termination in the RIC for handling E2 messages.

- **Preparation Steps**

1. **Set Up RIC**:
   1. Install and configure the RIC platform on the host machine using O-RAN Software Community documentation.
   2. Verify RIC services are active (e.g., RIC Manager, E2 Termination).
2. **Configure RAN Components**:
   1. Ensure the open-source RAN (e.g., srsRAN) is operational and connected to the RIC.
   2. Configure the RAN for E2 interface communication with proper Service Models (SMs) like RC and RSM.

Installation Instructions for HO xApp

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- **Download HO xApp:**
  - Clone the repository or download the HO xApp docker image.
- **Prepare Kubernetes Cluster:**
  - Deploy the RIC platform on Kubernetes.
- **Deploy HO xApp:**
  - Using Helm.
- **Connect to RIC Platform:**
  - Ensure the HO xApp connects to the RIC E2 termination by configuring the config.json file of the xApp with proper E2 SMs and endpoints.
- **Validate Deployment:**
  - Confirm logs to ensure successful deployment.
- **Testing and Integration:**
  - Ensure the HO xApp exchanges E2 messages with the RAN nodes.
  - Test functionality by simulating low and high traffic loads.

Key features

- AI-Driven Decision-Making: Integrates DRL algorithms to enhance real-time handover decisions.
- Seamless Integration with Near-RT RIC: Fully compliant with O-RAN architecture, enabling near-instantaneous adaptation to network conditions.

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- Multi-Type Handover Support: Handles intra-frequency, inter-frequency, and inter-RAT (Radio Access Technology) handovers.
- Policy-Driven Optimization: Implements user-centric, QoS Flow-oriented, and slice-specific policies via A1 interface inputs.
- Load Balancing: Ensures efficient resource utilization by redistributing traffic to less congested cells.
- Dynamic Adaptation: Adjusts strategies based on evolving metrics such as signal quality, user throughput, and congestion levels.

Bibliography

[1] R. M. Sohaib, O. Onireti, Y. Sambo, R. Swash and M. Imran, "Energy Efficient Resource Allocation Framework Based on Dynamic Meta-Transfer Learning for V2X Communications," in IEEE Transactions on Network and Service Management, vol. 21, no. 4, pp. 4343-4356, Aug. 2024. https://ieeexplore.ieee.org/document/10530188

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About us

VelinkX Ltd. specializes in creating xApps leveraging Open RAN technology, focusing on enhancing connectivity for autonomous and urban mobility. Our solutions are designed to bring efficiency, reliability, and real-time performance in dynamic wireless environments.

Our Services in the Open-RAN area include:

- xApp and rApp development for the RAN Intelligent Controller.
- Dedicated simulations and algorithm design.
- Consultancy services.
- Whitepapers and technical articles deliver.

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