Design and implementation of an xApp integrating FlexRIC with the ns-O-RAN Framework

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***Abstract*—This paper presents the design and implementation of a traffic anomaly detection xApp based on per-UE Key Performance Metric (KPM) monitoring, within an O-RAN-compliant simulation framework. The framework integrates the near-real-time RIC platform FlexRIC from OpenAirInterface (OAI) with the ns-3 simulator, resulting in a unified ns-O-RAN environment. The proposed xApp leverages real-time KPM data to identify abnormal traffic patterns at the UE level, enabling intelligent and fine-grained RAN control. This work demonstrates the feasibility of anomaly detection in simulated O-RAN environments and provides a foundation for evaluating AI-driven RAN control strategies.**

***Index Terms*—O-RAN, Near-RT RIC, xApp, FlexRIC,ns-O-RAN**

I. INTRODUCTION

O-RAN is a next-generation Radio Access Network (RAN) architecture focused on intelligent control through the introduction of the RAN Intelligent Controller (RIC), characterized by open interfaces, functional disaggregation, and virtualization. Within the O-RAN framework, the RIC is classified based on the required response latency for control objectives into Non-Real Time (Non-RT) and Near-Real Time (Near-RT) controllers. Among these, the Near-RT RIC manages radio network control functions within stringent latency constraints of approximately 0.5-1 ms. The Near-RT RIC achieves this through xApps, specialized applications deployed on its platform, to determine real-time radio network control policies [1].

In this study, we utilize the FlexRIC platform as a Near-RT RIC solution, characterized by a monolithic architecture that simplifies use case development and implementation compared to the ORAN-SC RIC. Owing to its ultra-lightweight design, FlexRIC offers significantly reduced latency, making it particularly suitable for specialized 5G private networks that require highly reliable services for a limited number of clients [2].

Thus, this paper proposes an integrated architecture, termed ns-O-RAN, combining FlexRIC and the ns-3 simulator via the O-RAN E2 interface, alongside software-defined networking-based real networks. Furthermore, we demonstrate the feasibility of developing xApps that leverage Key Performance Metric (KPM) data within the proposed FlexRIC-based simulation environment.

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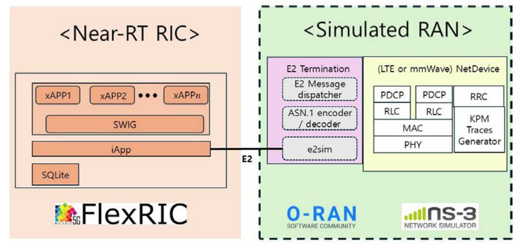

Fig. 1. Integration Architecture of FlexRIC with the ns-O-RAN Framework

II. SYSTEM MODEL

Previously, ns-3 simulations were capable of generating cell- and UE-level data but did not support O-RAN structures. To address this limitation, we developed the ns-O-RAN framework by integrating the E2 interface and expanding it into a software-defined network architecture [3]. The ns-3 mmWave module was designed to conduct end-to-end simulations of 3GPP-based 5G cellular networks. Within this module, the physical (PHY) and MAC layer classes support 3GPP New Radio (NR) frame structures and numerology, ensuring compatibility with the latest mobile communication technologies. Additionally, the mmWave module's MAC layer supports carrier aggregation and various scheduling policies, as well as connections to LTE base stations, facilitating fast secondary cell handover and channel tracking functions [4].

The ns-O-RAN framework transmits RAN data generated by the ns-3 mmWave module to the E2 interface using SCTP (Stream Control Transmission Protocol)-based packets via the e2sim E2 simulator. Consequently, each gNB and eNB within the scenario establishes a connection to the Near-RT RIC through an E2 Termination entity, enabling real-time KPM collection and control message delivery with the FlexRIC platform.

FlexRIC, as a Near-RT RIC platform from OpenAirInterface (OAI), adopts a Software Development Kit (SDK) approach instead of a traditional network API model. For low-latency communications, FlexRIC xApps directly interface with RAN functions using controller-internal applications (iApps) and the E42 protocol, while employing SWIG as an interface compiler to facilitate xApp development in various programming languages.

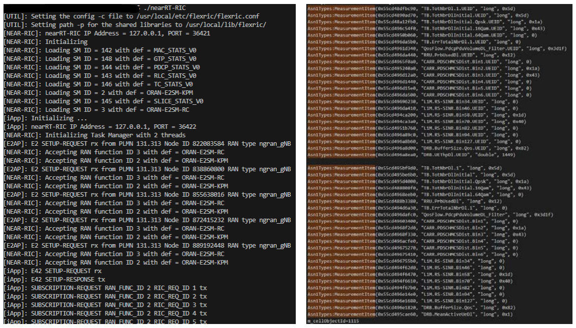

Fig. 2. near-RT RIC log / ns3log

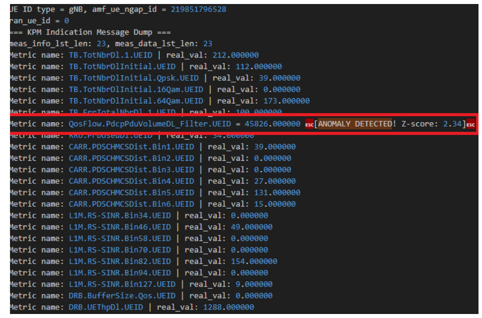

Fig. 3. Integration Architecture of FlexRIC with the ns-O-RAN Framework

Although the SDK is implemented in C, it can be extended to languages such as Python, C++, and Java using SWIG [2]. The architecture of FlexRIC primarily comprises two essential modules. The agent library deploys E2-compatible agents within base stations, operating independently of various Radio Access Technologies (RATs) and vendor implementations. The server library manages connections to these agents, stores network information in the Radio Network Information Base (RNIB), and processes E2SM subscriptions. These subscriptions are configured through iApps, which can either perform their own control logic or serve as interfaces for external controllers running xApps [5].

III. Design and Developement xAPP

In the initial stage of xApp design, we construct simulation scenarios based on ns-3 to create environments for generating Key Performance Metric (KPM) data. Users can customize realistic radio access networks by configuring parameters such as Stand Alone (SA)/Non Stand Alone (NSA) structures, cell and UE counts, mobility models, channel models, traffic patterns, and handover algorithms. During xApp development, the xApp generates KPM Subscription messages transmitted to E2 nodes and subsequently extracts relevant information from the received KPM Indication messages.

IV. Results and Evaluation

We implemented a KPM callback function to automatically process incoming messages. This function decodes ASN.1 formatted KPM messages, extracting UE-specific metrics, logging them, or saving the data for further analysis.

In this study, we implemented a traffic anomaly detection algorithm based on the z-score method. The z-score is defined as , where is the current observed UE-specific PdcpPdu data volume, is the mean, and is the standard deviation within a defined window. The xApp considers a z-score of 2 or higher as indicative of anomalies, corresponding to the top 2.3% of the distribution. This method effectively detects sudden increases in downlink traffic for specific UEs. The customizable design and implementation of xApps in the ns-3 simulation environment allow for extensive data collection and analysis under various conditions, highlighting the potential for integrating KPM, RC, and Machine Learning Operations (MLOps) in diverse use cases.

V. Conclusion

This paper proposes an architecture utilizing the ns-3 based ns-O-RAN framework to generate cell- and UE-level RAN data and integrate it with FlexRIC via the E2 interface. We demonstrate the feasibility of designing and operating customized xApps in a simulated environment. Due to its lightweight monolithic structure, FlexRIC enables rapid development and deployment, making it particularly suitable for low-latency scenarios such as specialized 5G private networks [2]. We anticipate extending this proposed architecture to industrial-specific network use cases, facilitating advanced real-time control research and development of relevant xApps.

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