Development on Open-RAN Simulator with 5G-LENA

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***Abstract*—Open radio access network (O-RAN) has gained great attention owing to openness and intelligent management. To orchestrate and optimize mobile access networks with artificial intelligence (AI) and machine learning (ML) techniques, the O-RAN community standardized the RAN intelligent controllers (RICs). Owing to RICs, the mobile network operator can obtain more optimization solutions for classical use cases (e.g., on-demand traffic steering, anomaly detection, Quality-of-Service (QoS) management, and base station on-off policy). To intelligently control the network, RICs need to collect the data to make and verify the intelligent application. Thus, the O-RAN simulator is necessary for obtaining RAN data collection and testing intelligent applications in RICs. In this work, we develop a network simulation-3 (ns-3)-based novel O-RAN simulator by benchmarking the ns-O-RAN project. A real-world near-real-time RIC and ns3-simulated 5G NR gNBs are integrated through the E2 interface by exchanging E2 messages, RAN key performance measurements (KPMs), and RIC Control Messages. We implement the novel O-RAN simulator with ns-3 and present the experimental validation results.**

***Keywords*—Open radio access network, network simulator-3, 5G-LENA project**

I. Introduction

Nowadays, the open radio access network (O-RAN) paradigm has dramatically gained wide attention from industry to academia owing to its flexibility, openness, and intelligence [1]. It facilitates flexible mobile network architectures that can efficiently support the various 5G services while improving network performance. The O-RAN standardization community defines the RAN Intelligent Controller (RIC) to intelligently control the mobile network by leveraging machine learning (ML) and artificial intelligence (AI) techniques. In particular, the intelligent applications (i.e., xApps and rApps) collect the data (e.g., measurement at RAN, user performance) from the base stations and analyze the collected data to provide the control action to the based stations. Intelligent applications in the near-real-time RIC and the non-real-time RIC are defined as xApp and rApp, respectively. xApps provide intelligent network control service between 10 msec and 1 sec, whereas rApps operate above 1 sec [2]. For instance, xApp can provide the Radio Resource Management (RRM) service with data-driven approaches based on live telemetry in a real-time manner (within 1 sec) [3].

A fundamental challenge in establishing intelligent control in O-RAN is to obtain the radio access network that provides datasets for training intelligent applications and testbeds for verifying intelligent applications. One simple approach is to exploit real-world radio access networks straightforwardly, but this might entail suboptimal AI/ML models with unsatisfactory performance. Also, this approach is not suitable for examining large-scale networks and various application scenarios. To address this difficulty, it is necessary to develop efficient network simulators dedicated to the O-RAN. Lacava *et. al.* [4] presented the ns-o-RAN project that combines the functions of a mobile network in network simulation-3 (ns-3) with an E2 interface to communicate an E2 message between the simulated environment and a near-real-time RIC. This platform makes the 4G/5G mobile access network by extending the mmWave project [5]. Although the mmWave project-based mobile access network was designed as a 5G mobile access network, it provides a limited 5G NR feature and it may be hard to represent the practical 5G access network. Therefore, to make a more practical 5G access network, we introduce a novel ns-3-based O-RAN simulator by benchmarking the ns-O-RAN project with a 5G-LENA project that developed a 3GPP-compliant NR module [6]. The proposed simulator integrates real-world near-real-time RIC and 5G-LENA-based 5G access network with the E2 interface to exchange E2 messages, RAN key performance measurements (KPMs), and RIC Control Messages. Our O-RAN simulator is implemented with ns-3 and its validity is examined through experimental results.

II. 5G-LENA based O-RAN simulator

As in [4], a real-world near-real-time RIC and mobile network in ns-3 are integrated with the E2 interface in our simulator. We extend the 5G-LENA based-mobile network modules [6] that are a 3GPP-compliant NR module to provide ns-3 simulation capabilities. Thus, 5G-LENA based-mobile network modules provide more various 5G NR features (e.g., flexible frame structure utilizing multiple numerologies support, bandwidth parts, LowDensity Parity Check coding for data channels, modulation and coding schemes with up to 256-QAM, Frequency Division Multiplexing of numerologies, Orthogonal Frequency-Division Multiple Access, flexible time- and frequency-resource allocation and scheduling, and dynamic TDD) than existing mmWave modules [4]. Figure 1 illustrates the architecture of the proposed O-RAN simulator

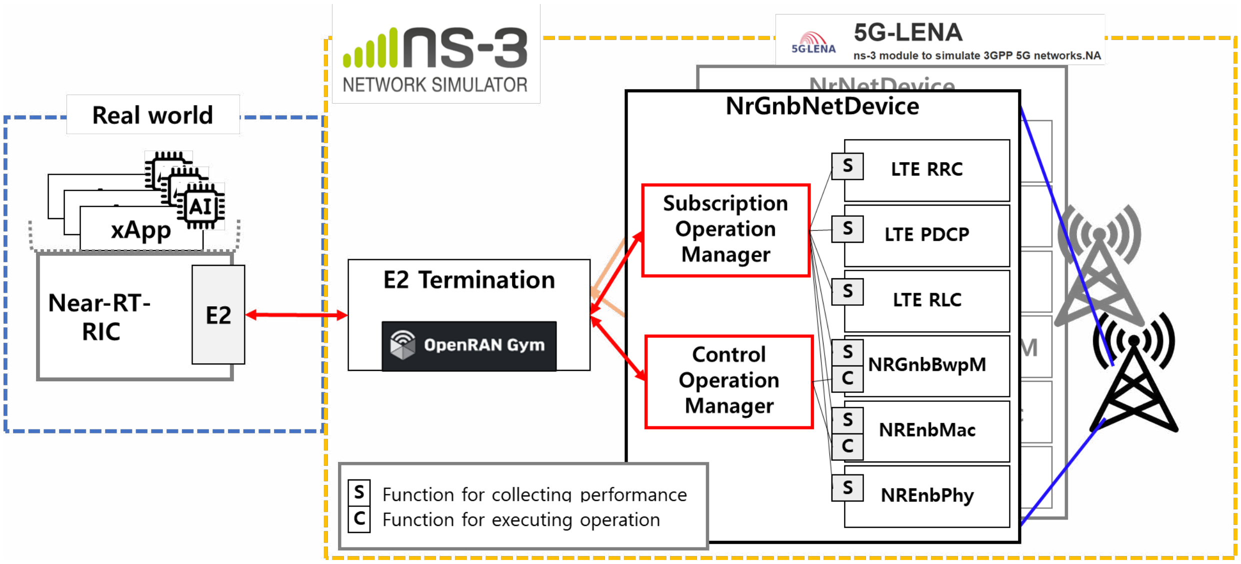

Fig. 1. Simulator Architecture.

which consists of two types of worlds: real world and virtual world. In the real world, the near-RT-RIC collects the mobile network data from the virtual world and processes xApp to analyze the collected mobile data and find the optimal network control action. Note that any near-RT-RIC having a compliant-E2 interface can be used in this simulator. On the other hand, in the virtual world, ns-3 is integrated into the Near-RT-RIC via E2 Termination. To combine ns-3 and Near-RT-RIC via E2 Termination, we modify the E2 modules in ns-o-ran project [4] to fit the newly ns-3 version.

Therefore, all modules in ns-3 can interact with near-RT-RIC via E2 Termination when the modules can encode and decode the exchanged message by the E2 message format. To make the E2 messages (e.g., E2SM RIC Indication Message) and send messages to Near-RT-RIC via E2 Termination, we extend the gNB module in 5G-LENA (i.e., NrGnbNetDevice). In this module, we define two functions (i.e., Subscription Operation Manager and Control Operation Manager). The Subscription Operation Manager is responsible for collecting the mobile network performance (e.g., the transmit downlink volume per the mobile device or the total downlink volume by the gNB) from the predefined layers in gNBs (i.e., LTE RRC layer, LTE PDCP layer, LTE RLC layer, NRGnbBwpM function, NREnbMac layer and NREnbPhy layer) and reporting the collected mobile network performances to near-RT-RIC. Note that these layers were defined and implemented by the 5G-LENA project team and we will develop the collect functionality at each layer (e.g., the functionality is described as s box in Figure 1). In this work, the NrGnbNetDevice only generates the meaningless performance parameter by the Subscription Operation Manager to verify the integration between near-RT-RIC and NrGnbNetDevice. On the other hand, the Control Operation Manager is responsible for decoding the control message from xApp and triggering the network operation (e.g., handover procedure) according to the control message. To this end, we define the executing operation function at each layer, and the Control Operation Manager can trigger network operation to the appropriate layer. For instance, when xApp controls the radio resource management by itself, the Control Operation Manager triggers the radio resource procedure to the NREnbMac layer.

III. Simulation Results

To verify the implementation that integrates a real-world near-real-time RIC and 5G-LENA project-based mobile network in ns-3 with the E2 interface, we conduct a simple simulation where one gNB is located and exchange the dummy message with simple xApp in near-real-time RIC. We use the OpenRAN Gym RIC [4] and the simple xApp that only decodes the received message from the gNB.

In the simulations, we can observe the several message types that are exchanged between the gNB and the xApp. Figure 2 shows the E2SM RIC Indication Message from gNB to the xApp. Note that the Indication Message can be exchanged between gNB and xApp after setting up the connection between E2 termination in NS3 and RIC and finishing the E2 Subscription Request/Response step. The exchange messages related to the above procedures can also be observed when conducting our simulation. After the Subscription Request/Response step, the gNB makes an RIC Indication Message with the measured performance parameters as shown in the below box. [1] Then, gNB transmits the RIC Indication Message via the E2 Termination module to Near-RT RIC. When receiving the RIC Indiction Message, the Near RT RIC forwards it to the appropriate xApp. In Figure 2, the right and left above boxes represent the sending RIC Indication Message from gNB and the receiving RIC Indication Message to xApp.

[1] In this simulation, the measurement function to collect the performances is not implemented and thus gNB generates the fixed performance value to make RIC Indication Message.

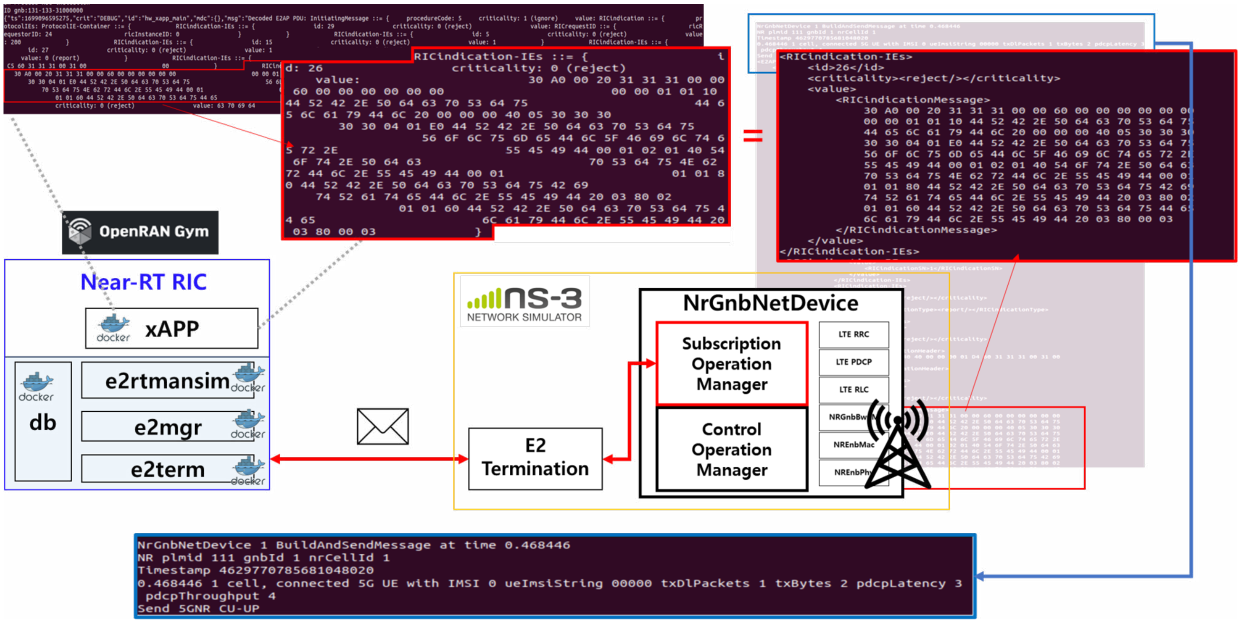

Fig. 2. Simulation Result.

We can find that these messages show the same Indication messages. From this result, we verify the gNB and xApp in our implemented simulator can exchange the messages defined by the O-RAN standardization group via the E2 interface.

IV. Conclusion

This work has proposed a novel O-RAN simulator. Following the ns-O-RAN project, we implement the E2 termination modules in the recent version of ns-3 and the integration modules in the 5G-LENA modules. For future works, gNB modules and layer modules can be extended to collect the network performance parameter and conduct various decisions by xAPP at an ns-3-based mobile network.

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