ns-O-RAN: Simulating O-RAN 5G Systems in ns-3

A. Lacava, M. Bordin, M. Polese, R. Sivaraj, T. Zugno,
F. Cuomo and T. Melodia

Institute for the Wireless Internet of Things
Northeastern University, Boston, MA | Sapienza, University of Rome
lacava.a@northeastern.edu | andrea.lacava@uniroma1.it

This work was partially supported by Mavenir, by Sapienza, University of Rome under Grant "Progetti per Avvio alla Ricerca - Tipo 1", year 2022 (ARI21816B3DC365), and by the U.S. National Science Foundation under Grants CNS-1923789 and CNS-2112471.
From monolithic to Open RAN

Traditional “black-box”

Open, programmable and virtualized
New game changing entity: RAN Intelligent controller (RIC)

- Centralized abstraction of the network;
- Open interfaces enabling full control for the operators;
- AI agents implemented over RAN;

Base stations functionalities of classical RAN are:

- Virtualized as network functions (programmability and modularity);
- Divided across multiple nodes (disaggregation toward scalability);
- Enable interoperability with different wireless networks;
Open Challenges toward Intelligent Open RAN

- Datasets, platforms, development and testing
- AI/ML that generalizes to different deployments and scenarios
- Agile spectrum, infrastructure, and AI management
ns-O-RAN: Simulating O-RAN 5G Systems in ns-3

- Integration of a real-world RIC with a simulated RAN in ns-3
  - Enabling large scale simulations for O-RAN
  - KPI and Control messages exchange supported
  - Realistic dataset generation

- No infrastructure expenses
  - Highly customizable
  - Implement custom use cases

- O-RAN compliant
  - Create the xApp on ns-3 and use it on a real RAN with no software changes
• 3 different repositories

RAN functional simulator, fork of https://github.com/nyuwireless-unipd/ns3-mmwave (aligned to latest updates)

Fork of https://github.com/o-ran-sc/sim-e2-interface in Dec. 2020 – commit a8f2a

ns3-mmWave

ns-O-RAN

Provides RAN simulation with E2AP and E2SM APIs

Contributed to OSC (Oct 2022) https://github.com/o-ran-sc/sim-ns3-o-ran-e2

e2sim

Uses e2sim as a library
Fork of OSC E2sim

- [https://github.com/o-ran-sc/sim-e2-interface](https://github.com/o-ran-sc/sim-e2-interface)

Originally a framework to develop xApp with no RAN side

- Connection to the near-RT RIC was the only one supported
- Only support replay of messages and reading control actions
• Update of latest ASN.1c definitions
• Enables multiple E2 connections on the same process
• Implements parsing and callback system for control messages
ns-O-RAN

• Wrapper on e2sim library for ns-3
  • Agnostic from RAN module
  • Uses code from ns-3 (Ptr, Object, Simulator)
• Enables O-RAN E2AP and E2SM:
  • Anybody can implement their own scenario using O-RAN
ns-3 mmWave module for O-RAN

- Customized fork of the ns-3 mmWave module [1]
  - Each NetDevice (eNB or gNB) has its own E2 Interface connected to the RIC;
  - NetDevices can send reports about their status;
  - The RIC can control dynamically the NetDevices;
- Our contribution:
  - Adapted to develop oran-e2sim and use cases
  - Implemented subset of standard KPMs
  - Helper classes that can be extended to support newer ASN.1c definitions
- It will be upstreamed to the original project

---

Building xApps with ns-O-RAN and Simulated Control Loops

- Complete framework for xApps
  - Design of E2SM
  - Study of the TS use case from the scenario to the solution
- Quality of datasets
  - Scalable scenarios
  - 3GPP-based channel conditions
- Enabling AI
  - Offline dataset collection
  - Online simulated inference

- Definition of the scenario
- Definition of Service Models
- Creation of Indication Message
- Creation of Control Message
- AI design
- Training / Testing
- Onboarding on a real RAN

AI Agent
Near RT RIC
E2 Interface
NS-3 Environment
ns-O-RAN
E2sim

State $S(t)$
Reward $R(t)$
Action $A(t)$

$S(t+1)$ $R(t+1)$ $S(t+1)$
Programmable and Customized Intelligence for Traffic Steering in 5G Networks Using Open RAN Architectures

- Optimization of Handover Management using a data-driven approach
- Control over hundreds of UEs and dozens of BSs
- Issues on implementation:
  - Deploy cost
  - No standard framework to support the use case;
  - Need of a LOT of datasets with different policies implemented to train the AI agent;

Hands on ns-O-RAN with Scenario Zero

• Integration of ns-O-RAN with the OpenRAN Gym near-RT RIC

• Tutorial on OpenRAN Gym website:
  • https://openrangym.com/tutorials/ns-o-ran
Scenario Zero Results

ns-O-RAN

RIC E2 Termination

xApp

<table>
<thead>
<tr>
<th>Measurement</th>
<th>All</th>
<th>Single eNB</th>
<th>Single gNB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wireshark Filter</td>
<td>e2ap</td>
<td>e2ap and sctp.port == 38471</td>
<td>e2ap and sctp.port == 38472</td>
</tr>
<tr>
<td>Number of Packets</td>
<td>157</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Time span (s)</td>
<td>439.220</td>
<td>429.324</td>
<td>439.211</td>
</tr>
<tr>
<td>Average pps</td>
<td>0.4</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Average size (B)</td>
<td>396</td>
<td>259</td>
<td>661</td>
</tr>
<tr>
<td>Bytes exchanged</td>
<td>62148</td>
<td>10352</td>
<td>26456</td>
</tr>
<tr>
<td>Average Data Rate (Bps)</td>
<td>141</td>
<td>24</td>
<td>60</td>
</tr>
<tr>
<td>Average Data Rate (bps)</td>
<td>1.131</td>
<td>192</td>
<td>481</td>
</tr>
</tbody>
</table>
Next steps

- Upgrade of the ASN definitions for E2AP and E2SM to version 3.0
- Support to new use cases
- Better support for O-RAN and DRL
Next release

- Upgrade to ns-3 3.38
  - New building system
  - New channel model
- Release of the custom xApps
- Open Issues for contribution

- September 2023
Thanks for the attention!
Questions?