Institute for the Wireless Internet of Things

at Northeastern University



UNIVERSITÀ

DEGLI STUDI

DI BERGAMO

2nd RESTART Tech Camp on 5G and Open RAN

AI in O-RAN: Use cases, good practices and hands-on

Salvatore D'Oro Institute for the Wireless Internet of Things Northeastern University s.doro@northeastern.edu

Andrea Pimpinella University of Bergamo andrea.pimpinella@unibg.it

9-12 September 2024, Milan, Italy

An extremely brief intro to O-RAN





Traditional "black-box"



Open, programmable and virtualized



• Open Interfaces

+

- RAN Intelligent Controllers (RICs): Non and near real-time network control
 - Abstract the network
 - Allow telecom operators to implement *custom control logic*
 - xApps, rApps, dApps



L. Bonati, M. Polese, S. D'Oro, S. Basagni, and T. Melodia, "Open, Programmable, and Virtualized 5G Networks: State-of-the-Art and the Road Ahead," Computer Networks, vol. 182, Dec 2020.

Al in O-RAN





Open RAN as an Enabler for AI-based Cellular

Why do we need AI/ML in O-RAN?

Institute for the Wireless Internet of Things at Northeastern

| | Control and le | Control and learning objective | | Input data | Timescale | Architecture | Challenges and limitations | |
|---------|--|---|-------------------|--|------------------------------|-------------------|--|--|
| rApps { | Policies, models, slicing | | > 1000 devices | Infrastructure-level KPMs | Non-real-time > 1 s | Non-real-time RIC | Orchestration of large scale deployments with multiple near-RT RICs, RAN nodes | |
| xApps { | User Session Management e.g., load balancing, handover | | > 100 devices | CU-level KPMs e.g., number of sessions, PDCP traffic | Near-real-time 10-1000 ms | A1 gNB CU | Process streams from multiple CUs and sessions | |
| | Medium Access Management e.g., scheduling policy, RAN slicing | | > 100 devices | MAC-level KPMs e.g., PRB utilization, buffering | Near-real-time 10-1000 ms | RIC F1 | Operate at small time scales, make decisions involving several DUs/UEs | |
| dApps - | Radio Ma e.g., resourc beam | Radio Management e.g., resource scheduling, beamforming | | MAC/PHY-level KPMs e.g., PRB utilization, channel estimation | Real-time < 10 ms | DU Open FH | Deployment of AI/ML models at the DU is not supported | |
| | Device DL/UI e.g., modulatio blockage | L Management on, interference, e detection | 1 device | I/Q samples | Real-time < 1 ms | RU | Require device- and/or RU-level standardization | |

- Adapt to changing network conditions
 - Hard to model otherwise
- Innovate in areas dominated by heuristics
- **M**odel-free optimization
- Leverage data generated in real time

S. D'Oro, M. Polese, L. Bonati, H. Cheng and T. Melodia, "dApps: Distributed Applications for Real-Time Inference and Control in O-RAN," in *IEEE Communications Magazine*, vol. 60, no. 11, pp. 52-58, November 2022.

Lifecycle of AI/ML in O-RAN



Institute for the Wireless Internet of Things

at Northeastern



- From data collection to online fine-tuning and inference
- Covers all aspects of **AIOps**:
 - Monitor
 - Engage
 - Act

Use Cases



Developing Open, Programmable, and Intelligent Networks

Institute for the Wireless Internet of Things at Northeastern



•

dApps - closing the real-time loop in Open RAN



- Programmable elements in DUs and CUs
 - Spectrum sharing, beam management, inference on user plane
- Now considered in O-RANALLIANCE nGRG

Assignment Overview



Assignment – Traffic/Slice classification



- Scenario:
 - Static dataset
 - 3 Slices:
 - eMBB
 - URLLC
 - mMTC

• Objective:

- Process KPMs from UEs
- Provide a label for each entry
- Correctly classify the slice
- Input:
 - Single KPM entry
- Output:
 - Slice ID



How? Dataset description

- Available at https://github.com/wineslab/colosseum-oran-coloran-dataset:
 - CSV formatted
 - 7 LTE base stations
 - 42 UEs
 - 10 MHz (50 Physical Resource Blocks (PRBs))
 - 3 Slice profiles:
 - **eMBB:** Constant bitrate traffic (4 Mbps per UE)
 - MTC: Poisson traffic (30 pkt/s of 125 bytes per UE)
 - URLLC: Poisson traffic (10 pkt/s of 125 bytes per UE)
 - Scheduling policies available to each slice:
 - Policy 0: Round-robin (RR)
 - Policy I:Waterfilling (WF)
 - Policy 2: Proportionally fair (PF)

OpenRAN Gym



First publicly-available research platform for data-driven O-RAN experimentation at scale

- Open-source
- End-to-end Open RAN network
- Near-RT RIC
- E2 Interface
- xApp dev kit
- Data collection
- Network Slicing
- Integration with Colosseum





Website: openrangym.com

Dataset format





• An example

| 1 | Timestamp | num_ues | IMSI | RNTI | slicing_enabled | slice_id | slice_prb | power_multiplier | scheduling_policy | dl_mcs | dl_n_samples | dl_buffer [bytes] | tx_brate downlink [Mbps] |
|---|---------------|---------|---------------|------|-----------------|----------|-----------|------------------|-------------------|--------|--------------|-------------------|--------------------------|
| 2 | 1617070530226 | 7 | 1010123456003 | 77 | 1 | 0 | 6 | 1 | 0 | 4 | 12 | 0 | 0.00543256 |
| 3 | 1617070530476 | 6 | 1010123456003 | 77 | 1 | 0 | 6 | 1 | 0 | 0 | 3 | 0 | 0.001824 |
| 4 | 1617070530725 | 6 | 1010123456003 | 77 | 1 | 0 | 6 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5 | 1617070530975 | 5 | 1010123456003 | 77 | 1 | 0 | 6 | 1 | 0 | 0 | 0 | 0 | 0 |

- We provide:
 - Sanitized pickle files (train/test)
 - Dataset as DataFrame
 - Baseline scripts to load/process/test data and algorithms
 - Colab notebook



KPMs over time



Correlation





- Logs start once UE attach
 - No traffic at that time
 - Hard to detect which slice is active as traffic is ~0
 - We sanitized the dataset to remove those entries
 - Some *might* still be in there occasionally

- We will not have time to create xApps
 - Visit openrangym.com if you are interested in going forward with the conversion and test them on Colosseum

Institute for the Wireless Internet of Things

at Northeastern University

2nd RESTART Tech Camp on 5G and Open RAN

AI in O-RAN: Use cases, good practices and hands-on

Salvatore D'Oro Institute for the Wireless Internet of Things Northeastern University s.doro@northeastern.edu

9-12 September 2024, Milan, Italy