EUCNC | 6G Summit
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Towards Closed-loop Automation in 5G Open RAN: Coupling an Open-Source Simulator with xApps

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Objectives & Contributions

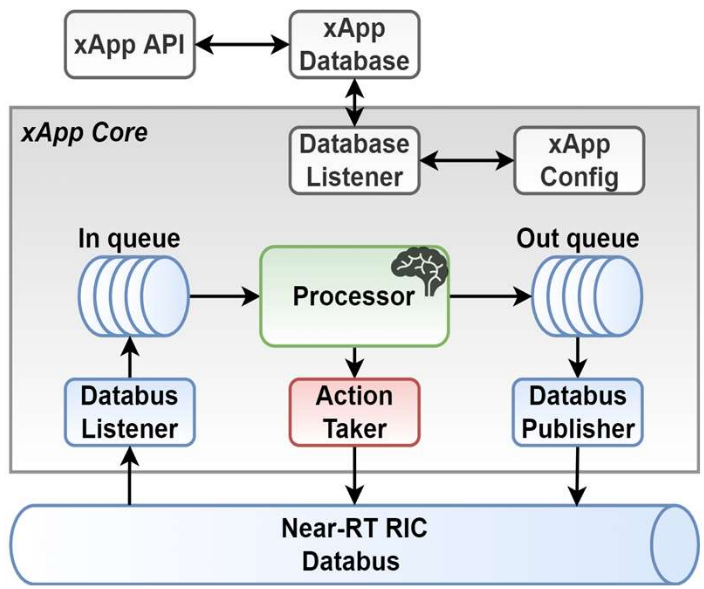
- Technological solutions for optimization of 5G network resources and services in an **automated** and **self-configured** manner.
- Practical implementation of **intelligence loops** in disaggregated **Open Radio Access Network (O-RAN)**.
- Open source and general-purpose **5G simulator**, compliant with 3GPP specifications, to generate physical-layer measurement reports.
- Demonstration of training/testing of **Machine Learning (ML)** within O-RAN architecture.
- Use case: **closed-loop** power adjustment of the Radio Units via **Deep Reinforcement Learning (DRL)** for optimizing the network-wide throughput.
- Simulation results outline the **interaction loop** between the developed 5G simulator and the deployed ML model in a virtualized server of a real testbed.

System Model & Parameters

- Urban 5G network area
- K macro (UMa) and/or micro UMi cells. Each cell has one Radio Unit (RU) with a total bandwidth B.
- N Physical Resource Blocks (PRBs) for transmissions with bandwidth W.
- OFDM modulation scheme.
- U UEs are located inside the network area.
- Each UE can connect to a single PRB of an RU.
- Sum-power constraint over all transmitting PRBs: $\sum_{n=1}^{N} P_{n,k} < P^{max}$
- Minimum power constraint for each PRB: $P_{n,k} > P^{min}$
- SINR of each connected UE: $SINR_u^{n,k} = \frac{P_{n,k} \cdot G_{k,u}}{(\sum_{k' \neq k}^{K} P_{n,k'} \cdot G_{k',u}) + N_0}$
- Throughput of each connected UE: $R_u^{n,k} = W \cdot log_2(1 + SINR_u^{n,k})$

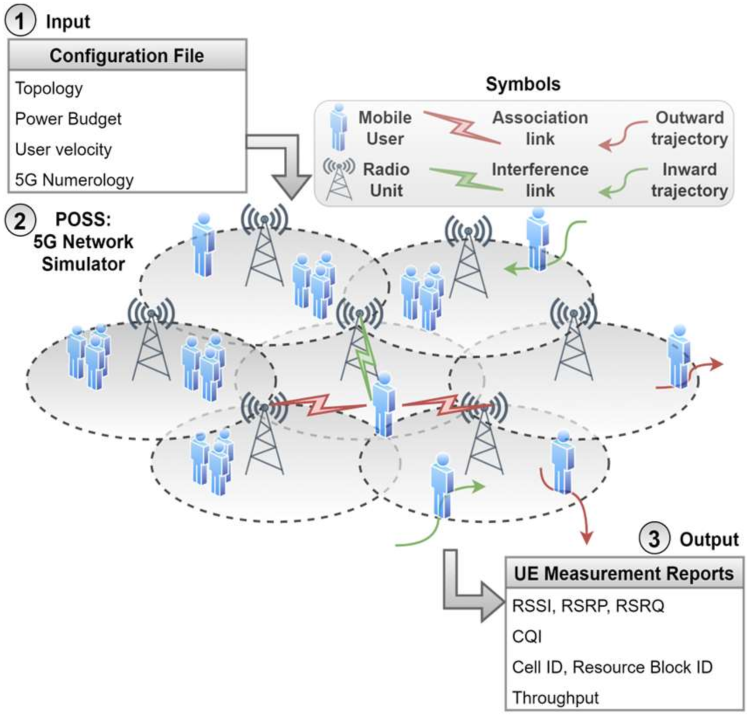
Supporting xApps: Near-RT RIC Architecture

- O-RAN is controlled by a centralized controller (near-RT RIC), capable of regulating the power levels to maximize the network-wide throughput.
- The intelligent module of the xApp core is the Processor (code for ML).



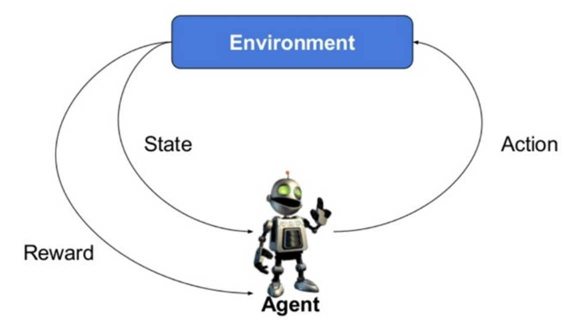
POSS: a Python Open-Source Simulator for 5G systems

- A general-purpose flexible 5G simulator is built in the form of xApp.
- Flexible topology, power budget, user characteristics, 5G numerology.
- Respects the maximum/minimum power budget limitations.
- Interference, channel and bit-rate calculations based on 3GPP/5G specifications of UMa/UMi.
- Association based on maximum throughput criterion.
- Random Walk and Handover calculations.
- Outputs 7 metrics:
  - Receive Strength Signal Indicator (**RSSI**), Reference Signal Received Power (**RSRP**), Reference Signal Received Quality (**RSRQ**), Channel Quality Indicator (**CQI**), associated **RU ID**, associated **PRB ID** and UE experienced **throughput**.



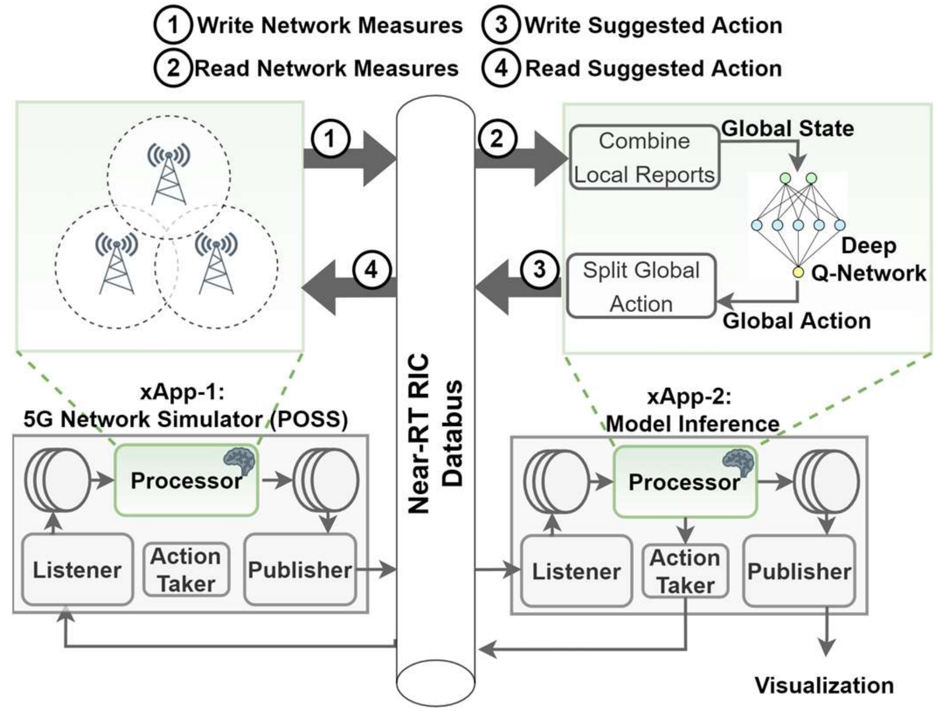
Throughput Optimization algorithm

- Network-wide throughput maximization through power regulation.
- Proper adjustment of power levels, while simultaneously mitigating the co-channel interferences.
- Objective function: $\max_{p \epsilon P} \sum_{k \in K} \sum_{n \epsilon N} W \cdot log_2\left(1 + SINR_u^{n,k}\right)$
- DRL terminology: The centralized **agent** (the near-RT RIC) interacting with a telecom **environment** (cellular areas) aims to maximize the **objective function** (the network throughput) by observing the **state space** (the measurement reports) and taking **actions** (power level adjustments).
- Following a **trial-and-error** approach, the agent gradually converges in power control policy that ensures increased network utility.



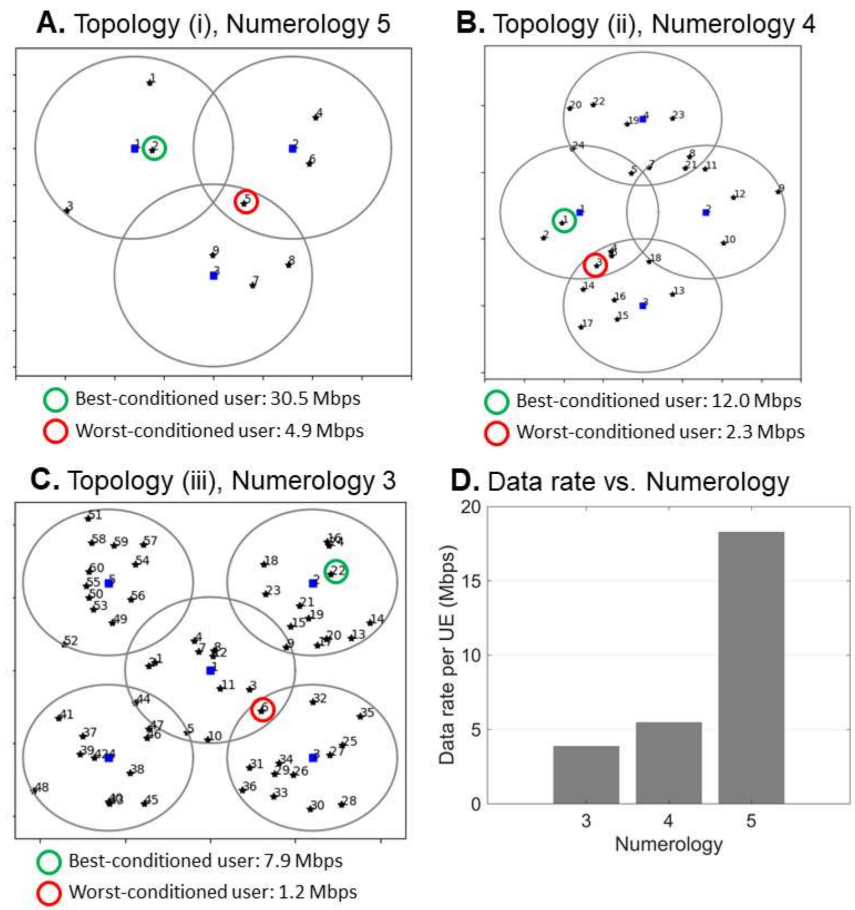
Network Automation through xApps

- Practical implementation and interaction of the POSS and the DRL agent was deployed in the form of xApps in the near-RT RIC.
- **xApp1**: generates **5G-compliant measurement reports** of UEs in a configured network topology.
- **xApp2**: pre-trained DRL agent. It reads the **measurement reports** from the Databus and infers the DRL model to get the **corrective power levels**.
- This process is **continuously repeated** to visualize the time-course of the model inference performance.
- Diverse objective-specific AI/ML models can be deployed, dockerized and stored in a dedicated ML catalogue for potential future inference.



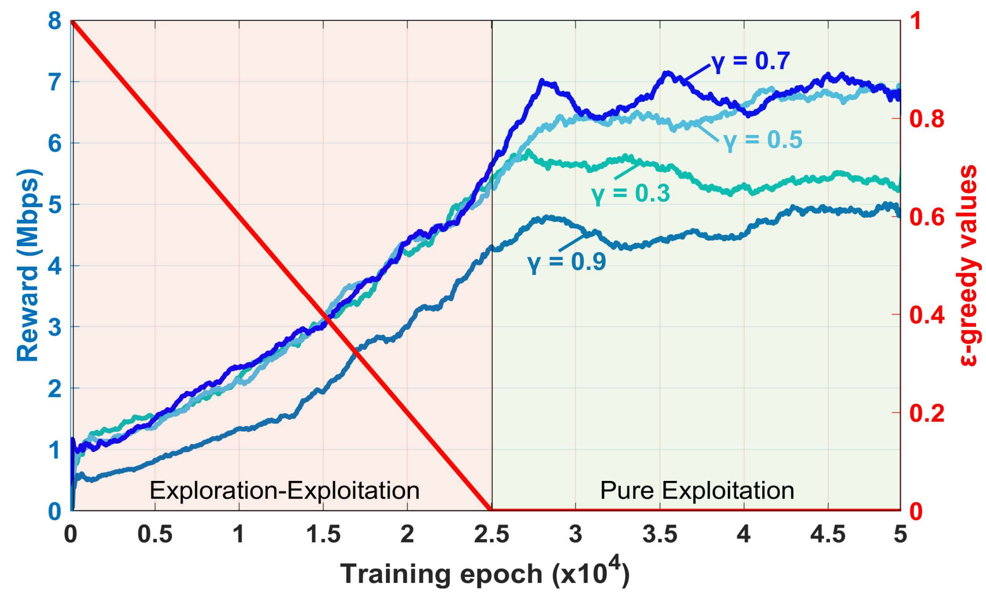
xApp1: Simulator Functionalities

- 3 configuration scenarios of the simulator are considered, parameterized as full-capacity scenarios:
  - (i) with a **3-cell** topology and **numerology 5** (**3 PRBs** per RU, each one with bandwidth **5.76 MHz**)
  - (ii) with a **4-cell** topology and **numerology 4** (**6 PRBs** per RU, each one with bandwidth **2.88 MHz**)
  - (iii) with a **5-cell** topology and **numerology 3** (**12 PRBs** per RU, each one with bandwidth **1.44 MHz**).
- Heterogeneous demand points: fixed reception points/PCs (0m/s), pedestrians (1m/s) and vehicles (10–20m/s).
- Average UE data rate is positively correlated with the numerology.
- UE capacity decreases with the numerology

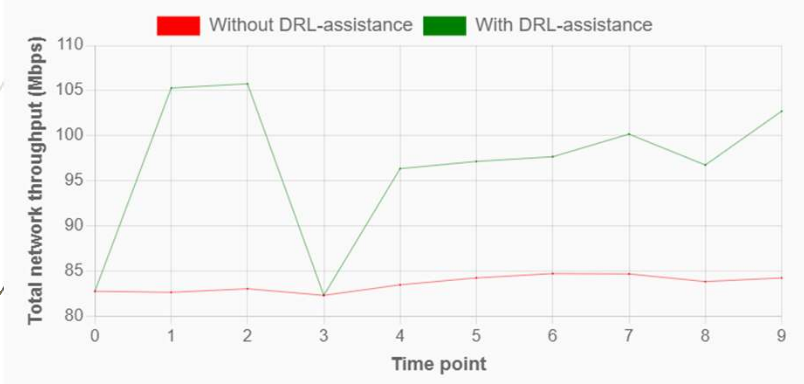


xApp2: Training &Evaluating the DRL agents

- Offline training prior deployment as xApp.
- Training process was performed with simulated measurements by the POSS simulator.
- In each training episode, the initial power levels are set to the average power level.
- Discount factor (γ) is associated with the extent to which the agent prefers immediate ($\gamma = 0$) or future ($\gamma = 1$) rewards.
- Learning curve of the training with ε-decaying.



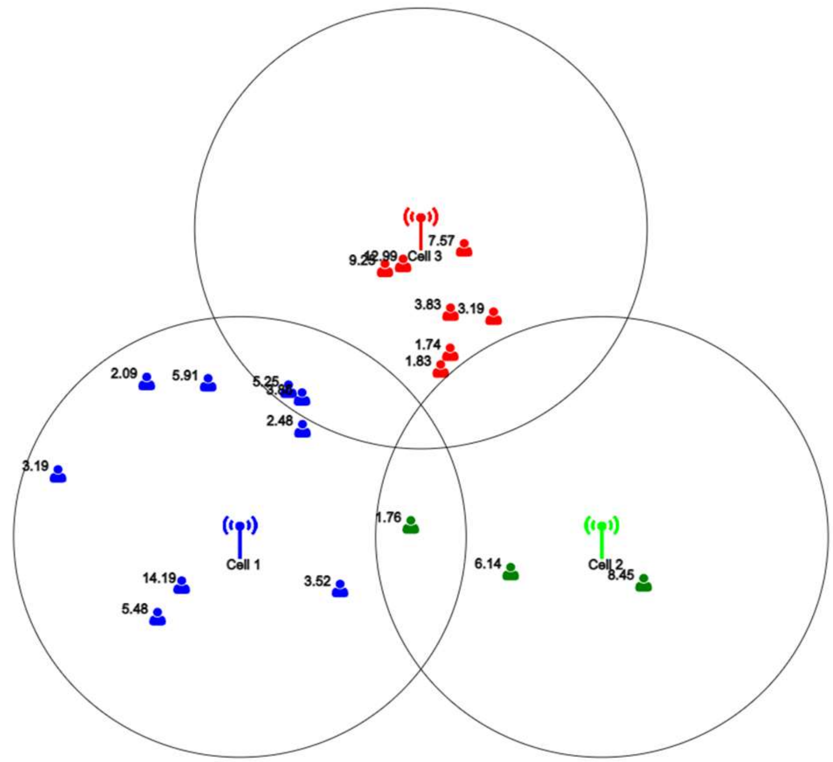
Overall Assessment: Integrating xApp1/xApp2



Instantaneous Power Levels

0 Watt — 25 Watt

	Rb1	Rb2	Rb3	Rb4	Rb5	Rb6	Rb7	Rb8	Rb9	Rb10	Rb11	Rb12
Ru1	1.27	2.34	0.78	2.06	34.33	5.88	5.57	4.32	1.98	4.36	5.87	6.48
Ru2	5.69	6.51	0.10	4.09	0.10	3.86	6.21	3.48	3.14	5.59	0.10	2.60
Ru3	2.38	4.35	2.01	1.53	4.83	5.59	5.43	0.10	35.82	5.73	0.10	0.10



Conclusions & Take-aways

- **Open RAN** can effectively leverage **AI/ML** capabilities.
- **xApps** enable network **automation** and **optimization**.
- Provision of an **open-source Python 5G simulator**.
- Presentation of **DRL** coupled and trained on simulated **5G-compliant metrics**.
- General development framework to support **multiple xApps**.
- Demonstration of the **Internal Architecture of Near-RT Controller**.

Thank you for your attention!

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