Institute for the Wireless Internet of Things
at Northeastern University

Colosseum Evolutions: O-RAN, AI, NRDZ

Colosseum Team

Institute for the Wireless Internet of Things

Northeastern University

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Let's hear your thoughts

What capabilities do you think are missing from Colosseum?

What would you like to use for your research?

Outline

- ~~Discussion~~
- OpenRAN Gym
- AI JumpStart
- NRDZs
  - Idea
  - Colosseum for NRDZs

Open Challenges

Need testing of closed-loop control without compromising network performance

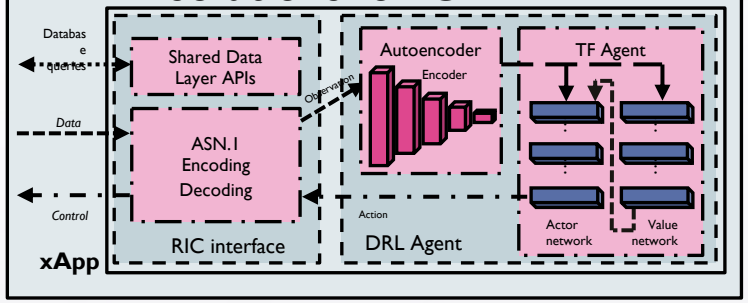
OpenRAN Gym

A toolbox for Intelligent O-RAN

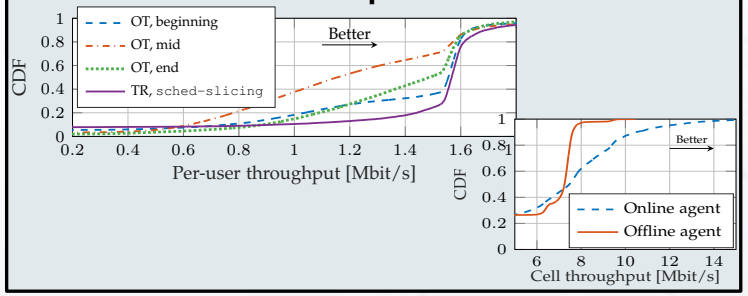
www.openrangym.com

Collect datasets at scale on virtual RF scenarios

Design, train, and package ML solutions for O-RAN



Test and refine on experimental wireless platforms

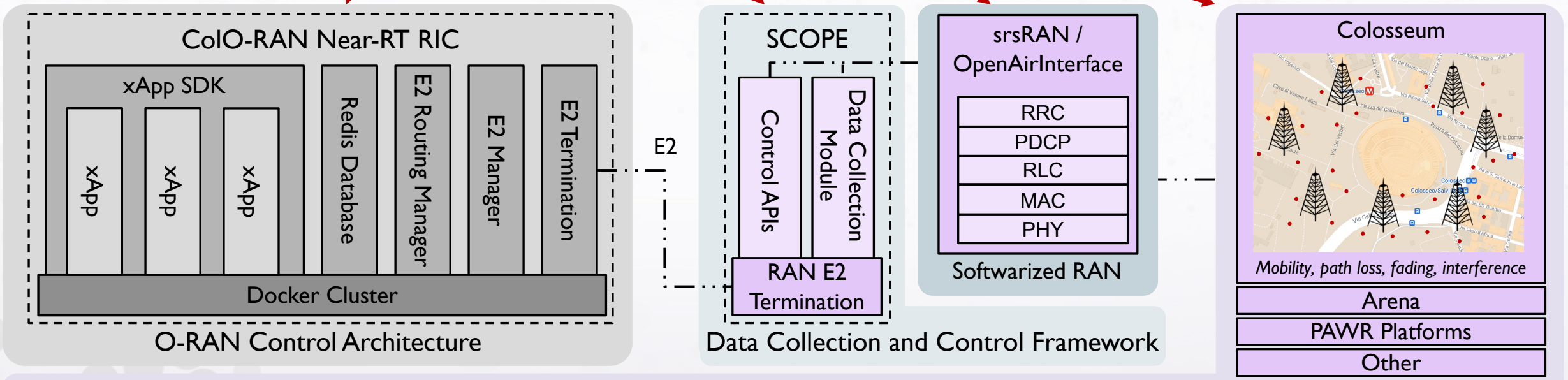


OpenRAN Gym is supported by RFDataFactory and the AI Edge Institute

L. Bonati, M. Polese, S. D'Oro, S. Basagni, and T. Melodia, *"OpenRAN Gym: An Open Toolbox for Data Collection and Experimentation with AI in O-RAN,"* in Proc. IEEE WCNC Workshops, 2022

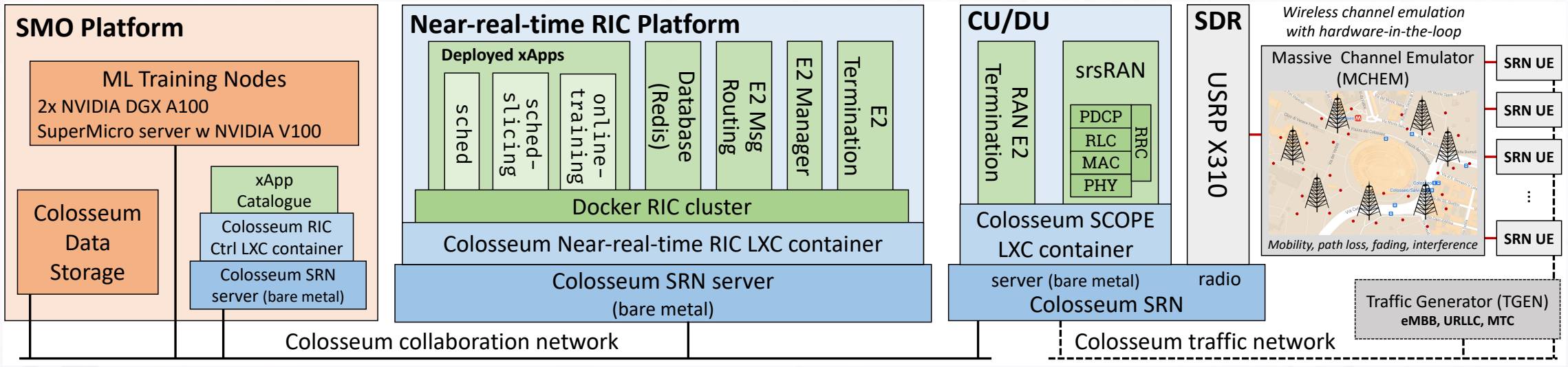
OpenRAN Gym – A Toolbox for Intelligent O-RAN

- O-RAN-compliant **near-real-time RIC** running on Colosseum (ColO-RAN)
- RAN framework for **data-collection and control** of the base stations (SCOPE)
- **Programmable** protocol stacks (based on srsRAN at this time)
- Publicly-accessible **experimental platforms** (e.g., Colosseum, Arena, PAWR platforms)



O-RAN Near-real-time RIC: ColO-RAN

- O-RAN-compliant implementation of OSC near-real-time RIC, adapted to work on Colosseum
- Runs custom xApps w/ control loops for network control and performance optimization
- Connects to the softwarized RAN through the O-RAN E2 interface



M. Polese, L. Bonati, S. D'Oro, S. Basagni, T. Melodia, "*ColO-RAN: Developing Machine Learning-based xApps for Open RAN Closed-loop Control on Programmable Experimental Platforms*", arXiv:2112.09559 [cs.NI]

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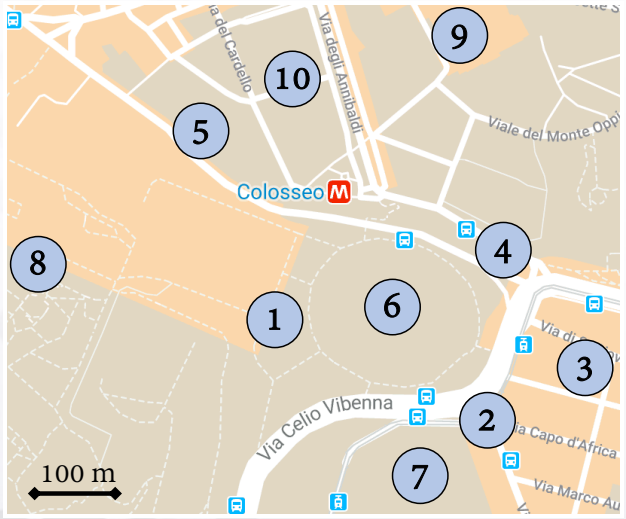
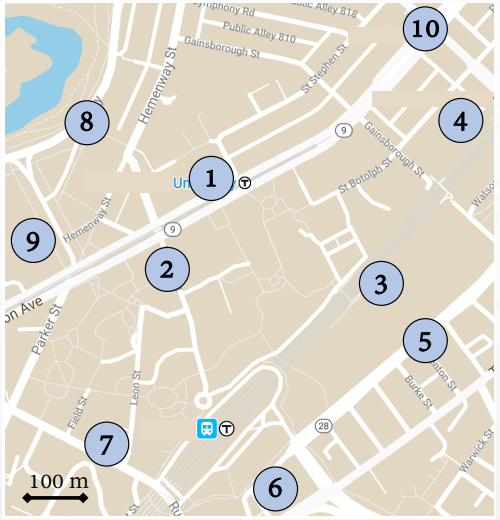
Softwarized RAN & Data Collection Framework: SCOPE

L. Bonati, S. D'Oro, S. Basagni, and T. Melodia, "*SCOPE: An Open and Softwarized Prototyping Platform for NextG Systems,*" in Proceedings of ACM MobiSys, Virtual Conference, June 2021

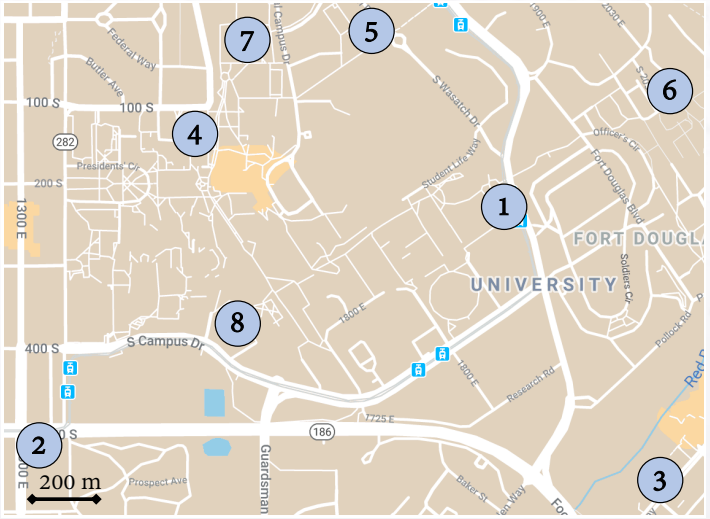
- Data collection and control framework (currently based on srsRAN)
- Paired w/ Colosseum allows to collect data in:
  - Different RF scenarios (specify effects such as path loss, position/distance of BSs/UEs, mobility/speed)
  - Traffic flows and types among nodes
- Exemplary scenarios representative of cellular deployments in:



Rome, Italy



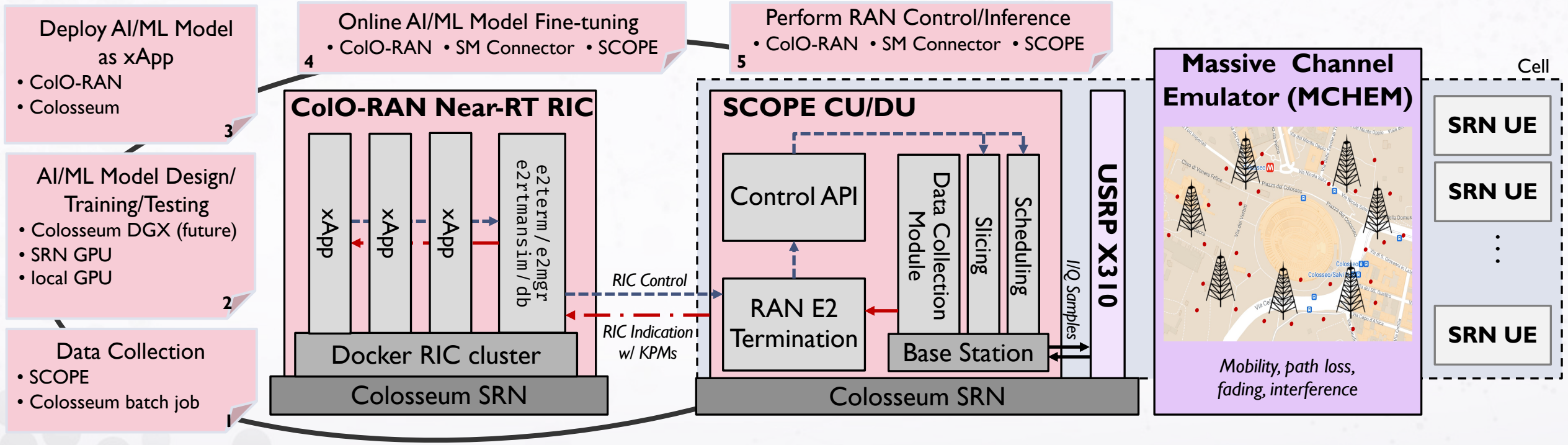
Boston, MA



Salt Lake City, UT (POWDER)

OpenRAN Gym workflow

End-to-end flow for Open RAN AI/ML development



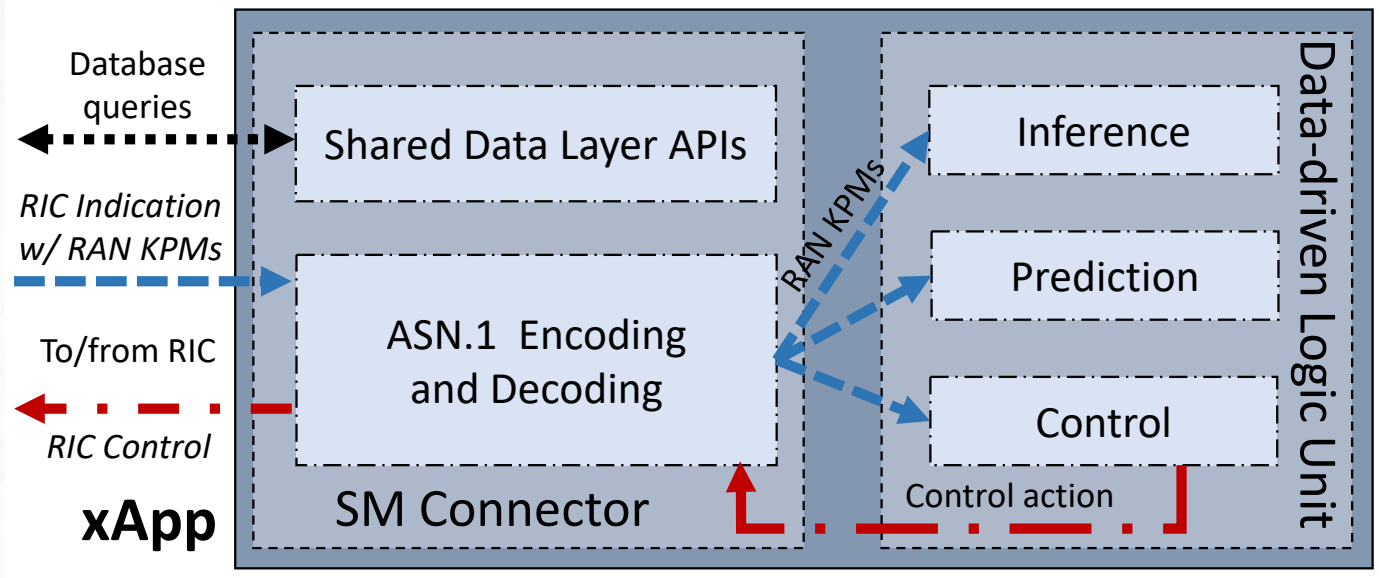
xApp Structure

Data-driven logic unit:

- Process RAN data and compute control action

SM Connector:

- Interface w/ the RIC and get data from the RAN
- Forward RAN data to data-driven logic unit
- Send computed control actions to RAN through RIC and E2 termination



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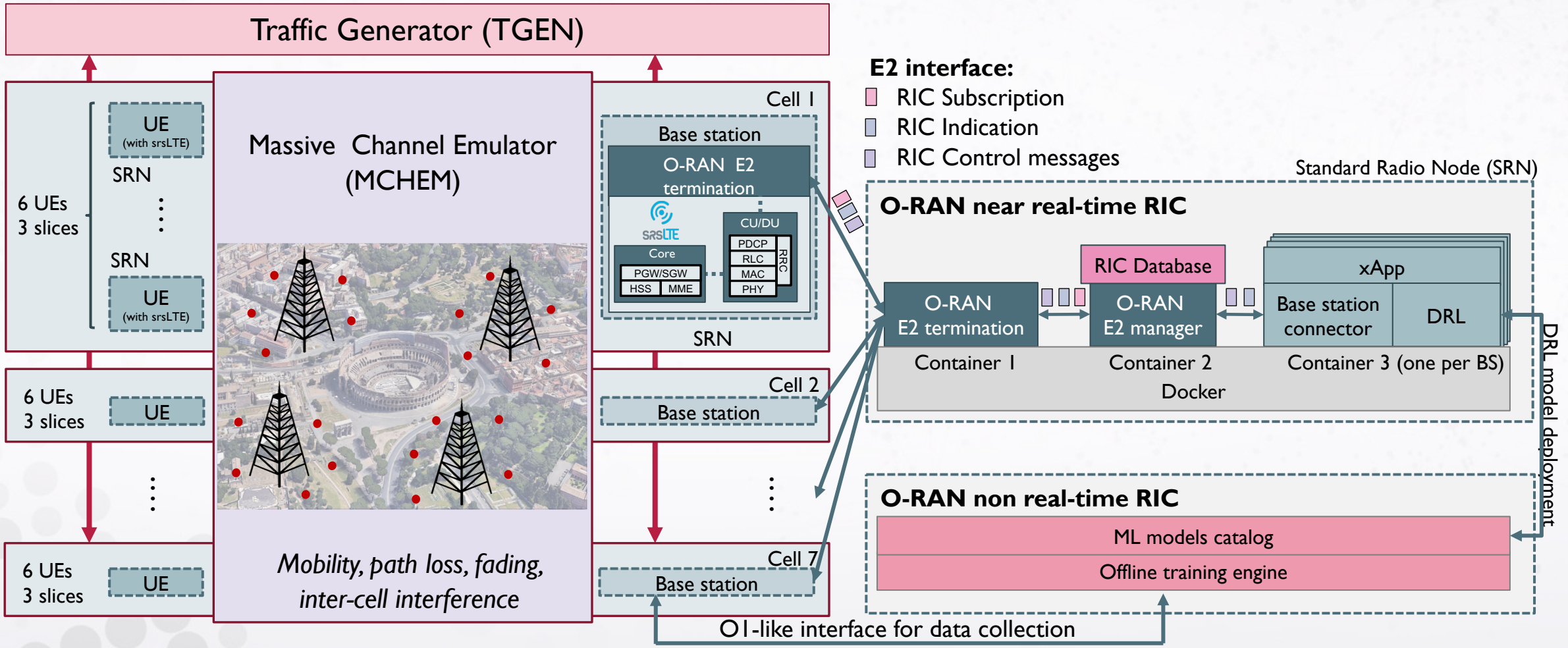
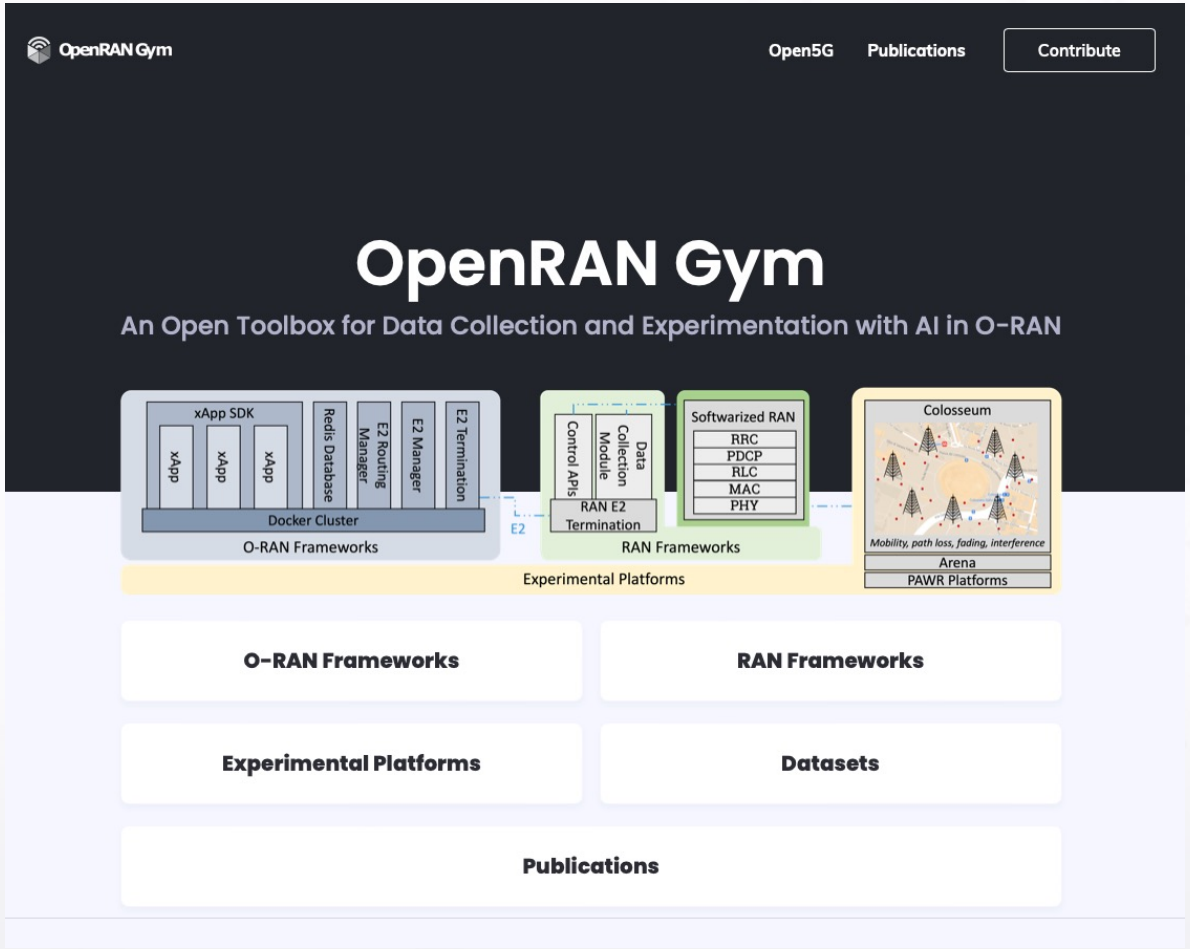
CoIO-RAN Testing Deployment – 42 users and 7 base stations

OpenRAN Gym on a large-scale Colosseum deployment – 7 base stations, 42 UEs, 3 slices



OpenRAN Gym – where do you start?

www.openrangym.com



OpenRAN Gym – where do you start?

- SCOPE repo: https://github.com/wineslab/colosseum-scope
- ColO-RAN RIC repo: https://github.com/wineslab/colosseum-near-rt-ric
- E2 termination for SCOPE: https://github.com/wineslab/colosseum-scope-e2

Tutorials

- SCOPE: https://www.youtube.com/watch?v=cqC_IC0uCHg

- O-RAN in Colosseum: https://www.youtube.com/watch?v=PdzxIda8CWU

Let's take a look

AI Jumpstart for Colosseum

Goal: *extend* ***AI*** *capabilities of* ***Colosseum*** *and provide researchers access to unique* ***AI+wireless*** *experimental facilities*

Possible use cases:

- Efficient training of large-scale wireless datasets collected on Colosseum
- Real-time, AI-driven 5G signal processing on for PHY layer & above
- Model-free adaptation to current network conditions and requirements

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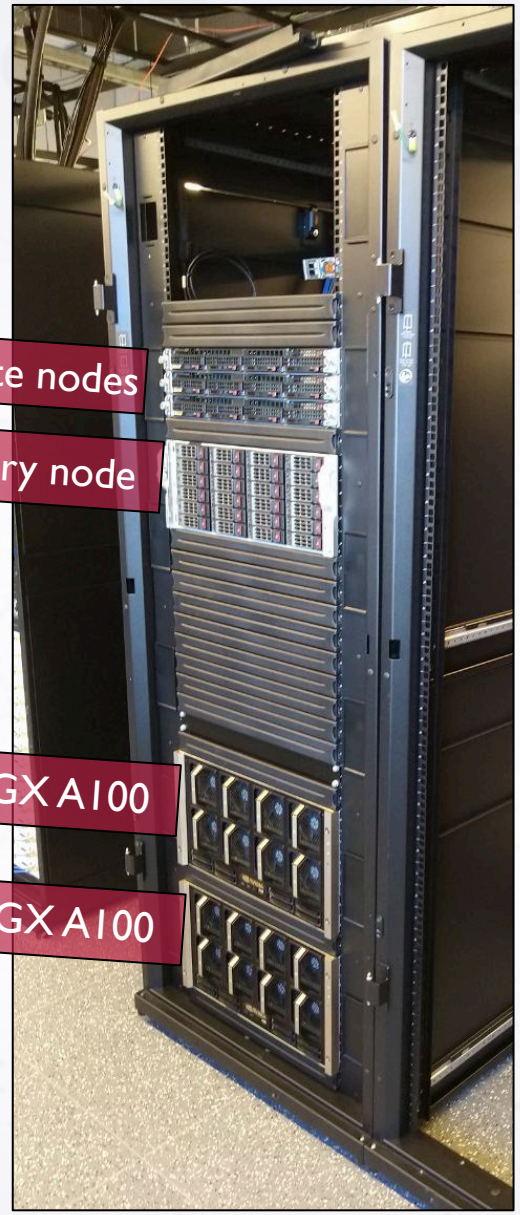
AI Jumpstart rack

- 2x NVIDIA DGX A100
  – 8 GPUs each, 10 petaFLOPS compute power.
- 1x large memory node
  – 6 GPUs, 3TB of RAM.
- 3x compute nodes.
- 1x Mellanox Infiniband switch – Tbps dedicated.

8 NVIDIA A100 GPU 40 GB

Mellanox Infiniband switch



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AI Jumpstart Integration in Colosseum

The system is fully integrated with Colosseum:

- Users can reserve SRNs and GPU resources
- Container orchestration based on Nomad
  - Test pilot on AI Jumpstart system to evaluate future applications to the whole Colosseum

GPUs are integrated in the reservation system

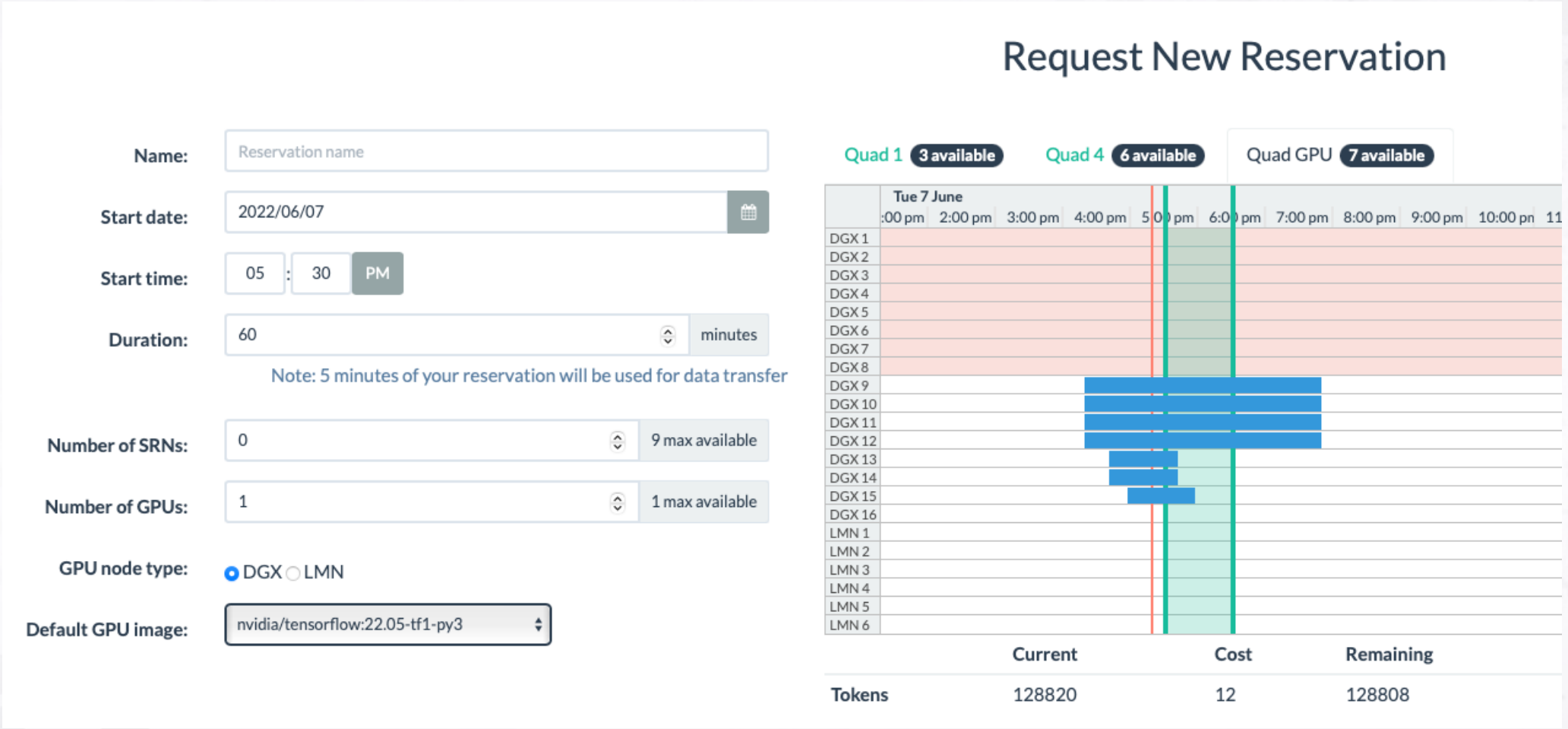

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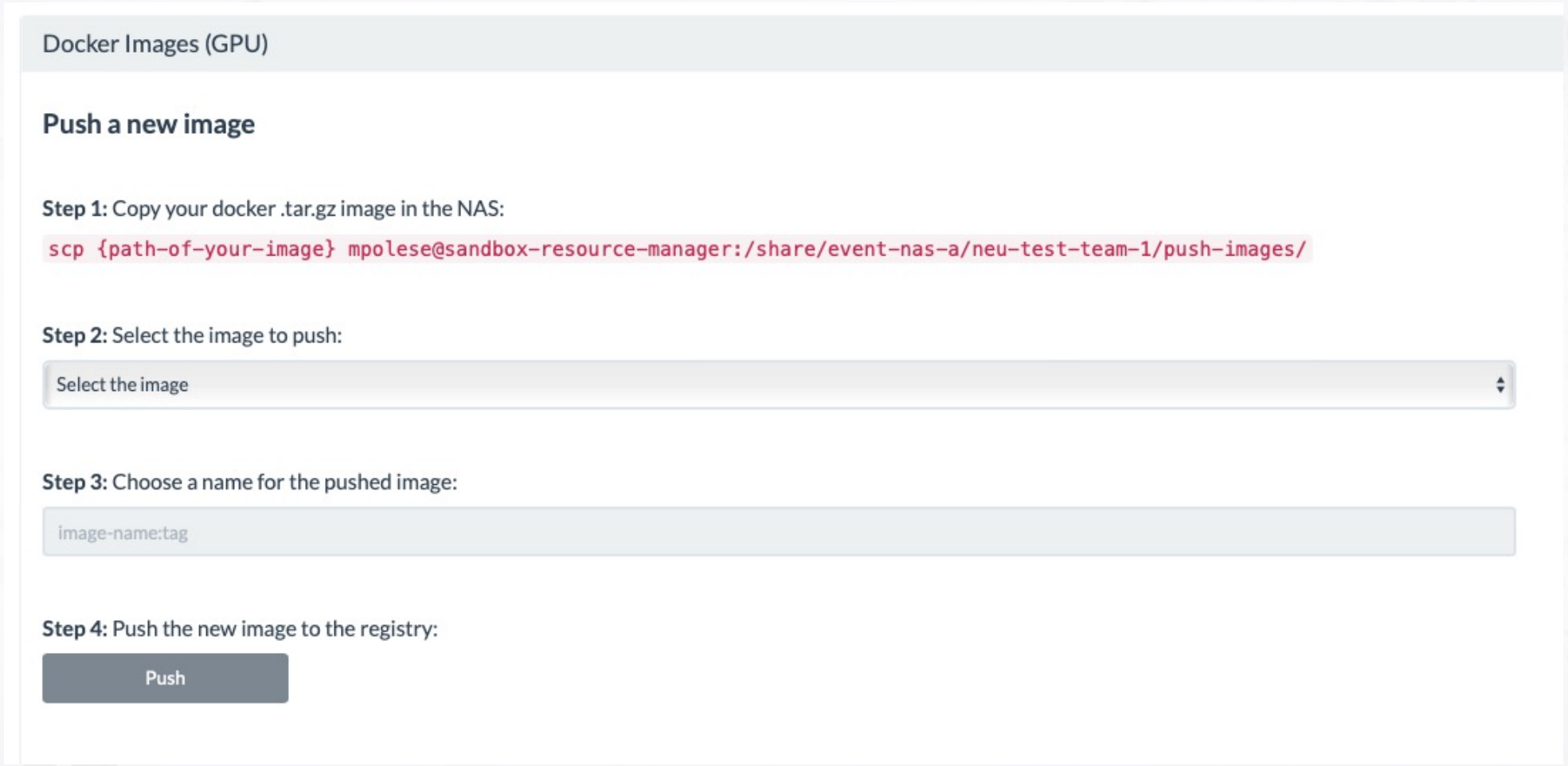
Image management system

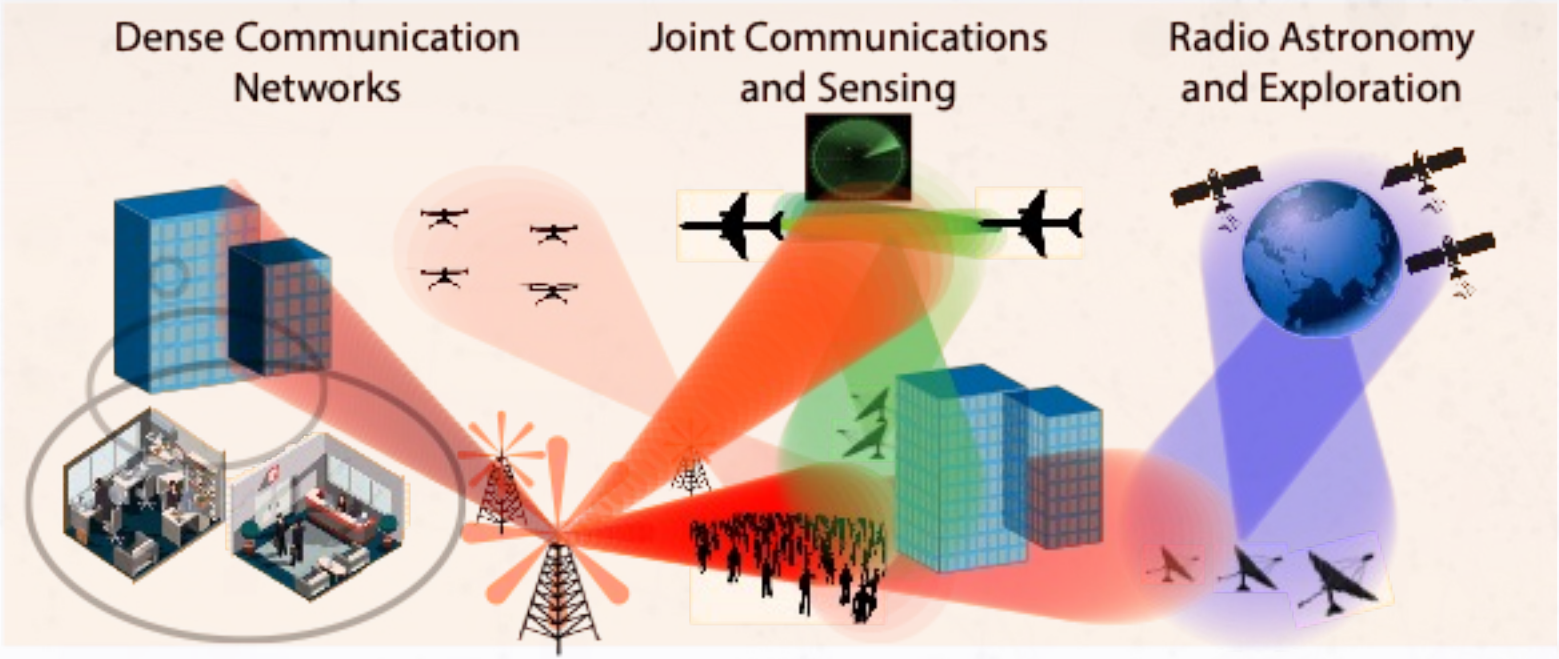


Onboarding users for testing

- The AI Jumpstart rack is available to test users
- If you are interested, email villa.d@northeastern.edu and m.polese@northeastern.edu with subject [Colosseum AI] Test account request

- General availability later in the summer

National Radio Dynamic Zones



Spectrum is a

- **limited** resource with
- many **different** uses and stakeholders

How can we improve the coexistence of different services?

M. Polese et al., Coexistence and Spectrum Sharing Above 100 GHz, https://arxiv.org/abs/2110.15187

NRDZ Goal

NRDZ is an NSF program that wants to:

- Create safe playgrounds for spectrum experiments that are not allowed under current regulations

- Bring together passive and active users to explore new uses of spectrum and spectrum sharing

NRDZ and Colosseum

How can we enable controlled, repeatable experiments for NRDZs?

- Controlled environment
- No risk of harming actual active/passive users
- Multiple RF scenarios

- Hardware-in-the-loop
- Software-based protocol stacks

Emulate NRDZs in Colosseum

1. Open RF experimental environment available to the NSF community
2. Large scale
3. Integrated with other over-the-air testbeds (PAWR)

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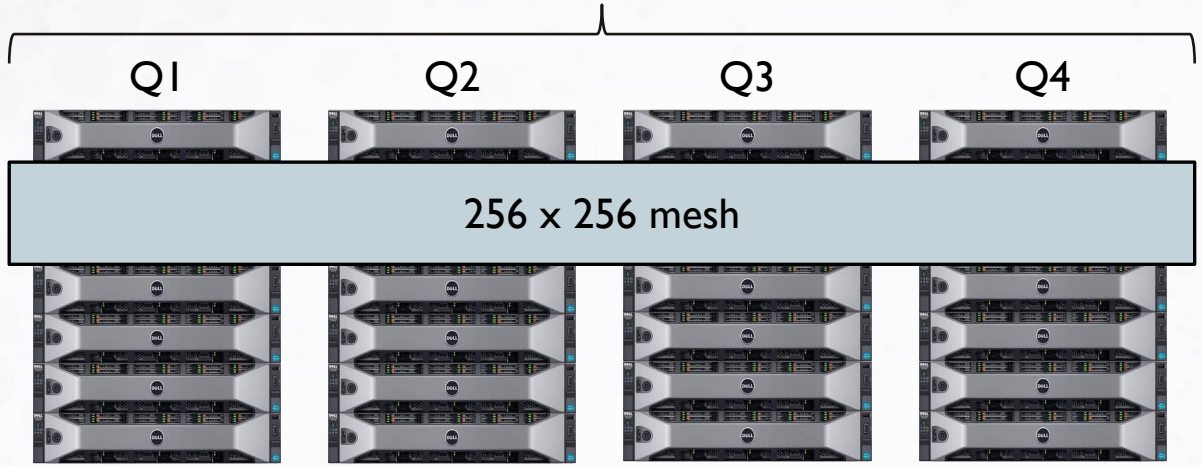
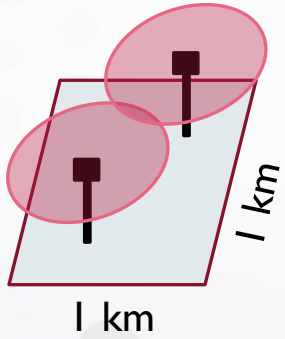
Current Colosseum and planned extensions

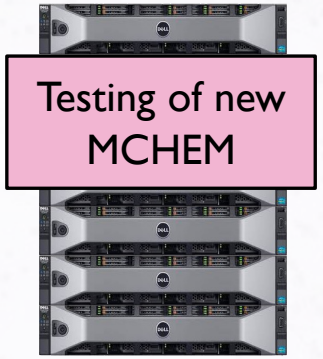
Existing Colosseum



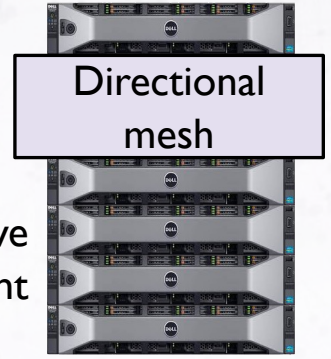


Sub-6 GHz – Omnidirectional

NRDZ extensions

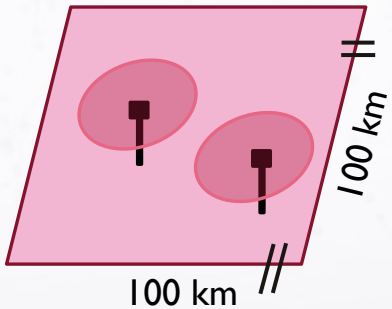


Development quadrant

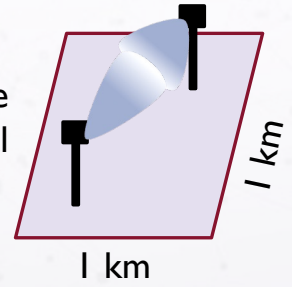


mmWave quadrant

New Wireless Emulation Capabilities



mmWave Directional



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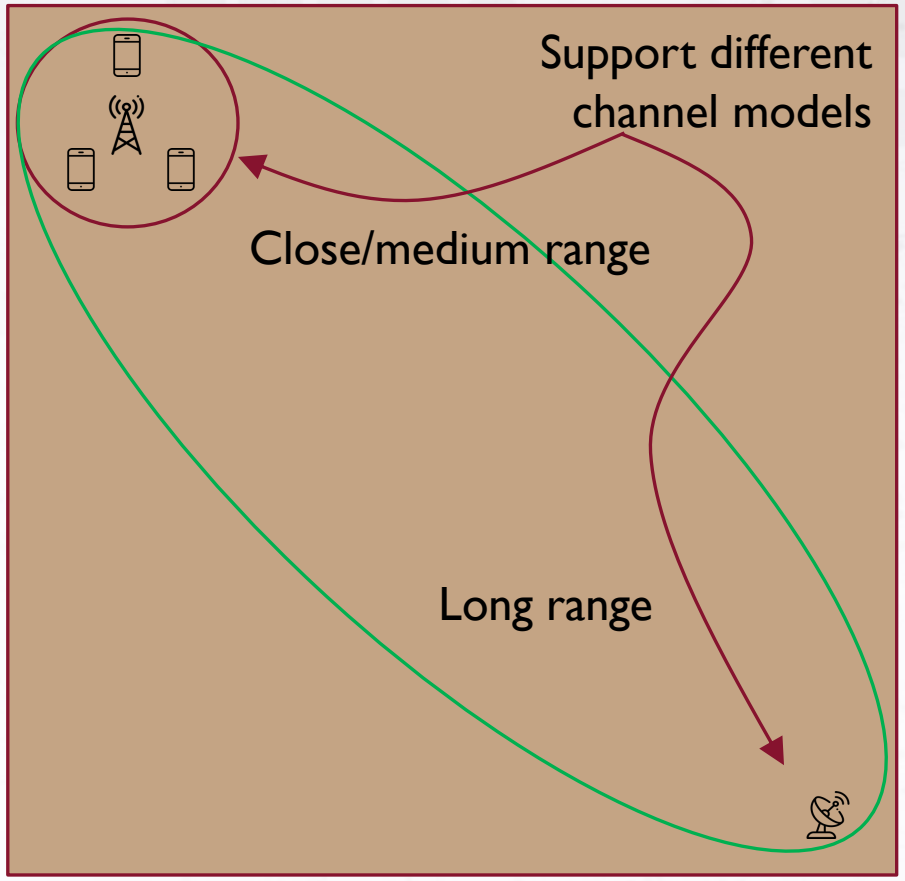
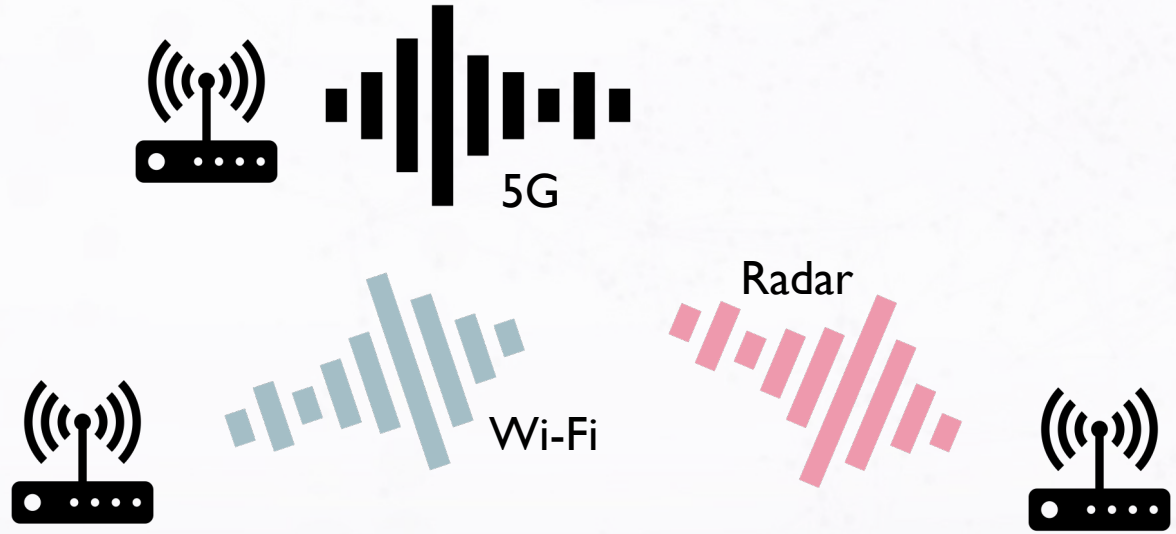
NRDZ and Colosseum



- Understand coexistence with different waveforms and receivers
- Study near-far interference issues
- Develop spectrum sharing solutions in heterogeneous environments
  - Example: CBRS radar coexistence – primary detection and secondary adaptation in a large geographical area

Coexistence issues with generic waveforms

- Colosseum is based on software-defined radios
- Generate custom waveform – or standard compliant waveforms



Study interference in different RF scenarios

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Near-far interference issues

- Out-of-band emissions from powerful close-by signals in adjacent bands may disrupt weak signals from distant transmitters

Assess out-of-band interference in multiple RF scenarios

Spectrum sharing

- Develop spectrum sharing solutions in heterogeneous environments
  - Example: CBRS radar coexistence – primary detection and secondary adaptation in a large geographical area

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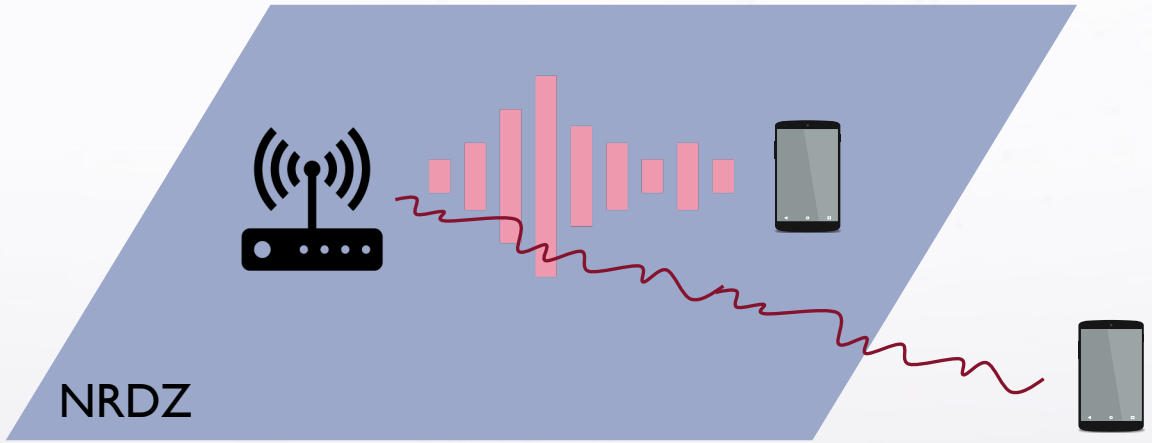
Colosseum experiments to shape NRDZ rules

Develop repeatable pipelines to evaluate different configurations for NRDZs:

- Spectrum utilization
- Spill over and impact on legitimate receivers



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Long-range Extension

Goals

Increase emulation range to 100 km x 100 km

Enable meaningful scenarios for long-range communications with SDRs

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NRDZ and Colosseum – next steps

- NRDZ long range implementation is ongoing
- Release for testing soon
  - Dedicated experiment portal
  - Dedicated scenarios
  - **Looking for input** from the NRDZ community on what you would like to study and model in Colosseum

NRDZ and Colosseum – next steps

- mmWave scenario modeling
  - Colosseum is based on pre-generated, inflexible scenarios
  - Extend its capabilities to support dynamic beamforming for directional scenarios
- mmWave MCHEM architecture
  - Identify FPGA design (number of channels, bandwidth) and RF frontends that fit bandwidth needs

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