Automating and Testing End-to-End O-RAN Systems

Michele Polese, Open6G OTIC

m.polese@northeastern.edu

Joint work with Stefano Maxenti, Leonardo Bonati, Davide Villa, Hai Cheng, Salvatore D'Oro, Gabriele Gemmi, Hithesh Shekar, Florian Kaltenberger, Sakthivel Velumani, Pedram Johari, Tommaso Melodia

Open6G OTIC PlugFest Themes

Joint North American PlugFest

- **O-RAN System Testing with Layer 1 Acceleration**
  - End-to-end performance testing
  - Integration of additional fronthaul components
  - Interoperability with additional RUs

- **O-RAN E2E Deployment Templates, DevOps, and Test Automation**
  - Automated deployment of DUT on OpenShift
  - End-to-end blueprint for automated deployment

- **Demonstrate consistent and repeatable open fronthaul testing in multiple labs**
  - Conformance testing for Synergy DU with Asia & Pacific OTIC in Singapore
  - Executed an overlapping set of tests with KeySight RuSIM/CoreSIM

PF Spring 2024 hosted by Asia & Pacific OTIC in Singapore and North American OTIC in the Boston Area

Testing and Integration with NVIDIA

Supporting NVIDIA in the Spring 2024 O-RAN PlugFest - themes:

- O-RAN E2E Deployment Templates, DevOps, and Test Automation
- O-RAN System Testing with Layer 1 Acceleration

RU and Fronthaul Integration and Testing

- Integration and testing of commercial RUs with NVIDIA ARC
- Testing and validation of Dell switches as fronthaul with NVIDIA ARC

Automation and Integration with OpenShift

- Integrated NVIDIA ARC on OpenShift platform
- Developed CI/CD/CT pipelines for automated DU testing
- End-to-end performance profiling with multiple TDD configs
- Integration with Open5Gs core network
- Proof of Concept with OAI SoftUE and NVIDIA ARC

Proof-of-Concept: NVIDIA ARC with OAI Soft-UE

X5G

CN OPEN AIR INTERFACE
- Dell PowerEdge R750
- 5G OAI CN (2024-w10)

CU-DU NVIDIA
- Gigabyte E251-U70
  - A100 GPU + Mellanox NIC
- OAI L2 v2.2.2
- NVIDIA Aerial L1 cuBB 23-4

RU FOXCONN
- Foxconn RPQN7801
- Cf 3.75 GHz – BW 100 MHz

Soft-UE OPEN AIR INTERFACE

+

- Dell PowerEdge R340
  - 6 CPUs, 32 GB RAM
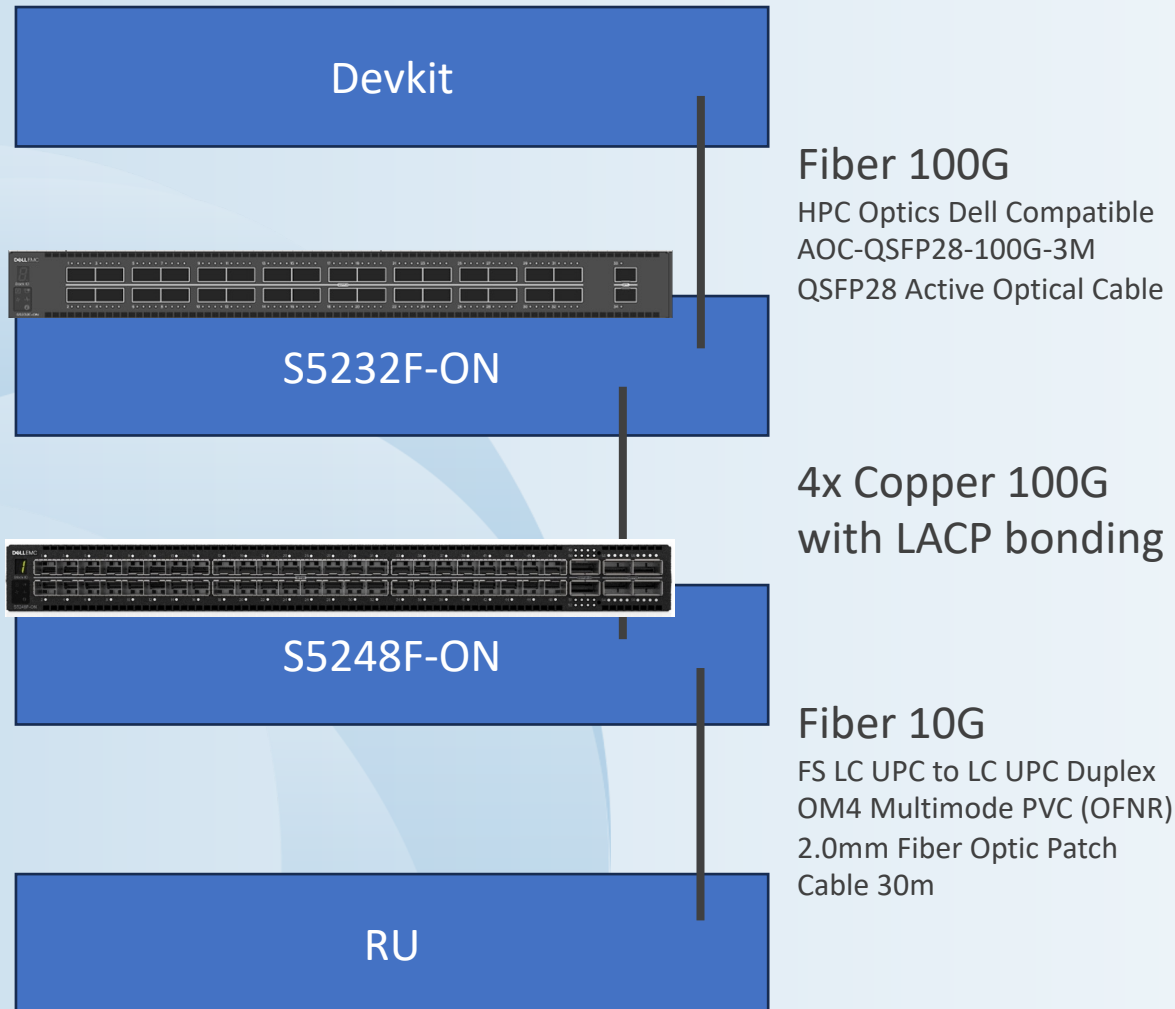- NI USRP x410
- OAI Soft-UE (2024-w12)

Lab RF Environment

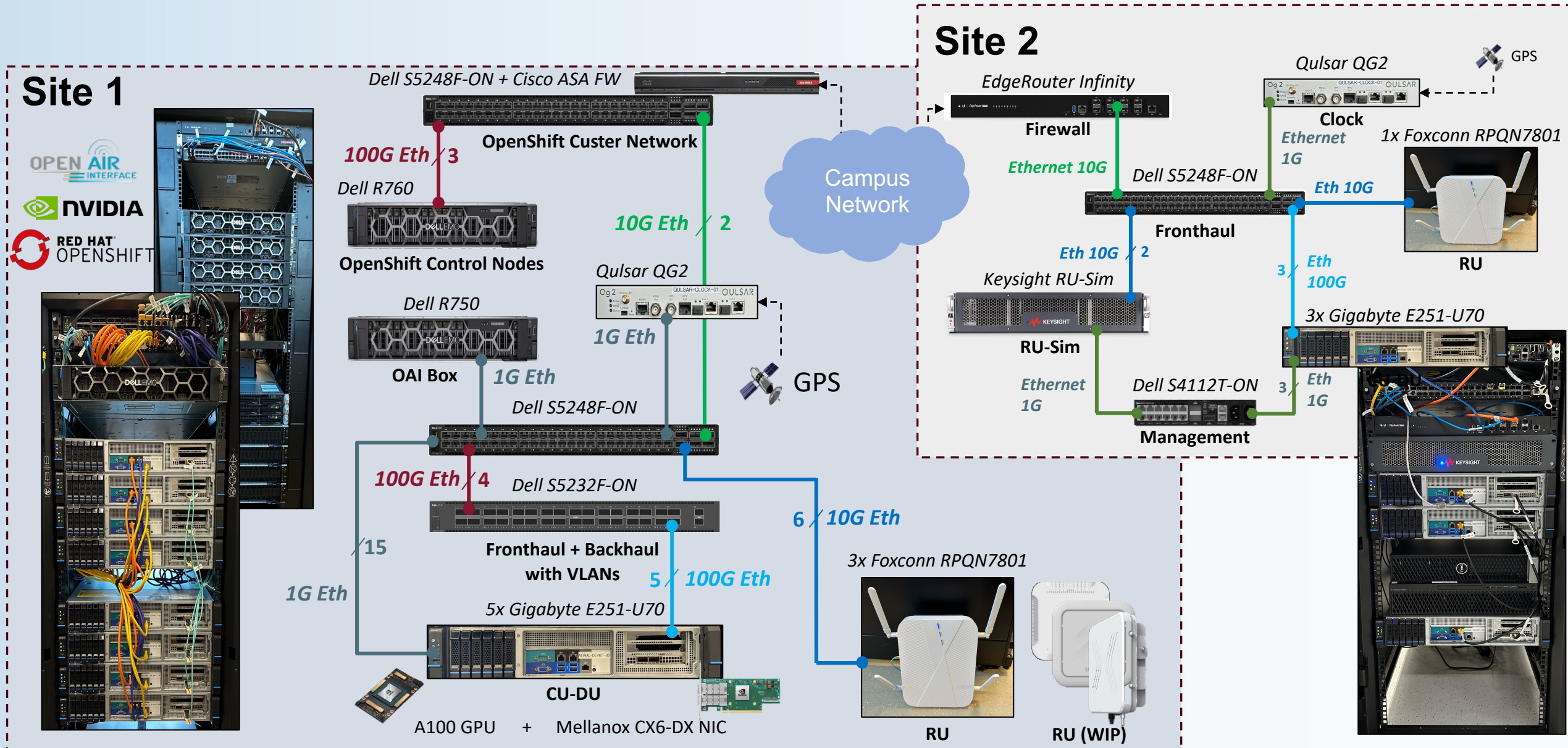First test of Software-Defined UE with commercial NVIDIA ARC stack

- Research on next-gen UE algorithms
- Test alternative modulation and coding schemes
- Debug and expose OTA messages

Tested and validated Dell S5232F-ON switch for ARC FH

Devkit

Fiber 100G
HPC Optics Dell Compatible
AOC-QSFP28-100G-3M
QSFP28 Active Optical Cable

S5232F-ON

**4x Copper 100G
with LACP bonding**

S5248F-ON

Fiber 10G
FS LC UPC to LC UPC Duplex
OM4 Multimode PVC (OFNR)
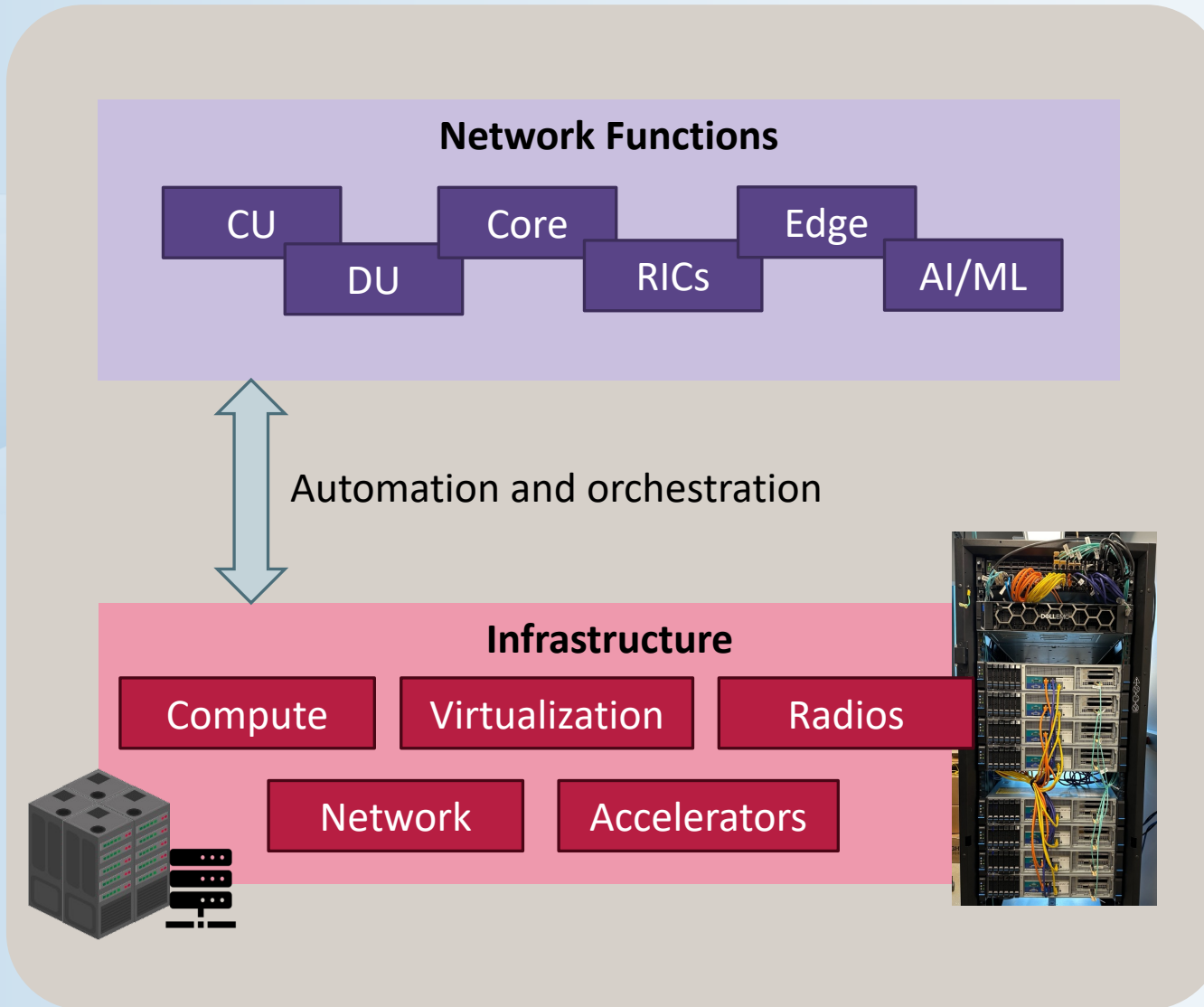2.0mm Fiber Optic Patch
Cable 30m

RU

- Integrated and tested new Dell S5232F-ON switch for the ARC fronthaul interface, including PTP and SyncE setup

- Dell S5232F-ON has high QSFP port density required for Northeastern University 8-node deployment

- RUs are connected to S5248F-ON (two hops)

- Reproduced KPIs of the setup with only the S5248F-ON

Open RAN and Automation

Network Functions

CU · DU · Core · RICs · Edge · AI/ML

↕ Automation and orchestration

Infrastructure

Compute · Virtualization · Radios · Network · Accelerators

Deploy an end-to-end 5G network

Host multiple tenants on the same RAN

Provide custom applications at the edge

Deploy AI/ML models for and on the RAN

Test multi-vendor end-to-end networks
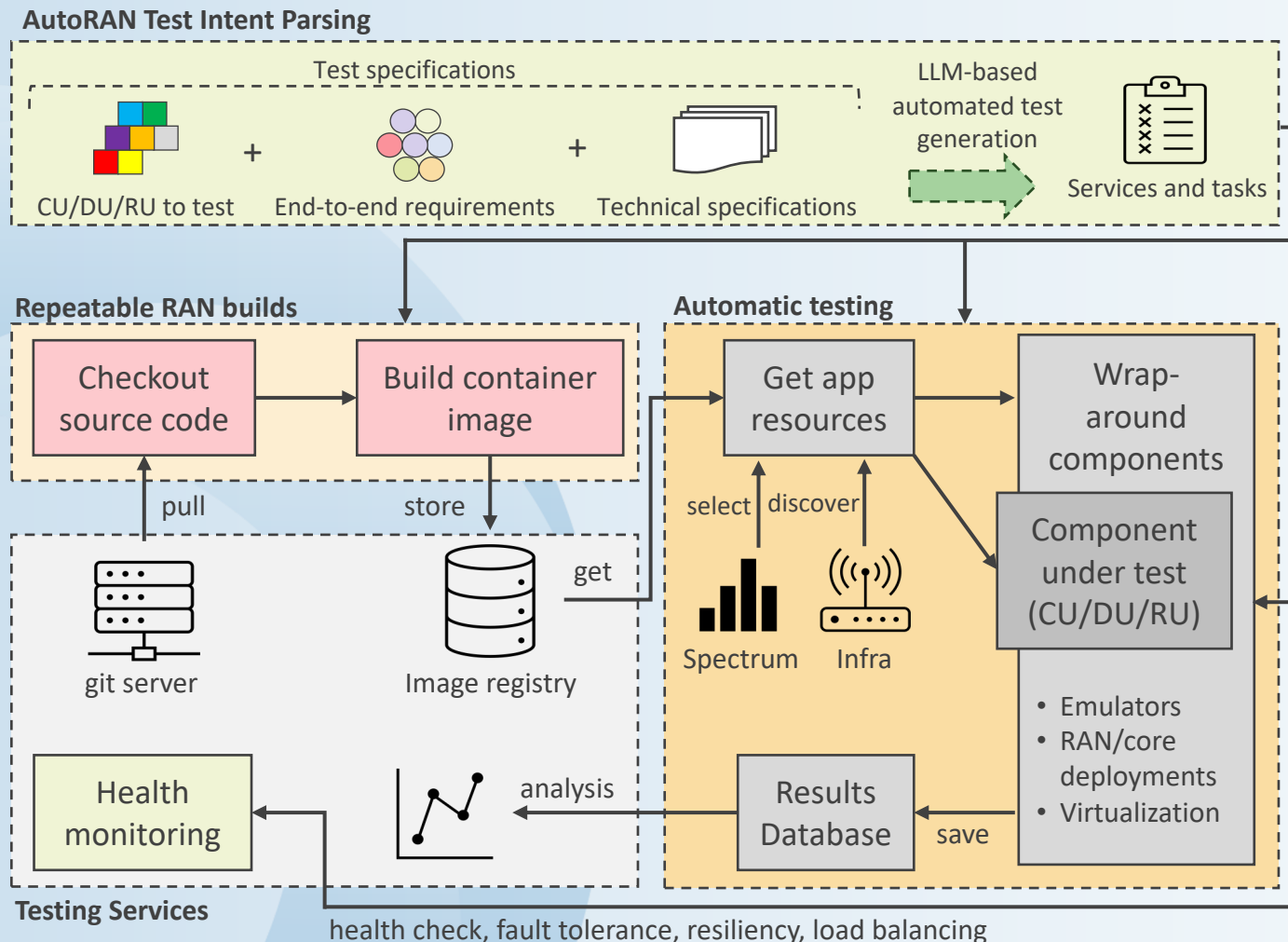
Test interoperability across systems

AutoRAN – CI/CD/CT for Open RAN

Public Wireless Supply Chain INNOVATION FUND

O-RAN ALLIANCE

Goal: Develop CI/CD/CT techniques for automated Open RAN testing

AutoRAN Test Intent Parsing

Test specifications

CU/DU/RU to test + End-to-end requirements + Technical specifications

LLM-based automated test generation

Services and tasks

Repeatable RAN builds

Checkout source code → Build container image

Automatic testing

Get app resources → Wrap-around components

Component under test (CU/DU/RU)

- Emulators
- RAN/core deployments
- Virtualization

select / discover

Spectrum / Infra

pull / store

get

git server / Image registry

Testing Services

Health monitoring ← analysis ← Results Database ← save

health check, fault tolerance, resiliency, load balancing

- **Thrust 1: Pipelines and Automation for CT**
  - Repeatable RAN builds
  - End-to-end test orchestration
  - Automated interface code generation

- **Thrust 2: LLM-based Test Generation**
  - CT intent language definition
  - LLM-driven translation
  - Automated test analysis and reporting

- **Thrust 3: Deployment in Open6G OTIC**
  - Integrate with OTIC offering
  - Web-based interface

- **Thrust 4: Outreach and Standardization**

zTOUCH

NVIDIA AT&T

Institute for the Wireless Internet of Things at Northeastern
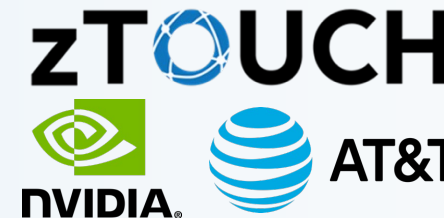
Open RAN and Automation for Testing

- CI/CD of RAN software as part of an Open RAN (O-Cloud)

- Integration with real-world platforms, radio devices, user devices
  - Testing against heterogeneous (but automated) endpoints – smartphones, 5G modems, RU/UE emulators

- Automatic and continuous testing of RAN functionalities over the air and in emulated environments

- Evaluation of how updated software affects RAN KPIs
  - Beyond unit testing

- Simplification of development and testing of Open RAN software
  - Toward an automated OTIC

RitiRAN Workshop - co-located with VTC Fall 2024   Call for Papers   TPC

Welcome to the RitiRAN Workshop website! ✕

The First Workshop on Research and Innovation in Testing and Integration for Open Radio Access Networks (RitiRAN), co-located with VTC Fall 2024 in Washington, DC, will bring together researchers from academia, industry, and government with the goal of advancing the state of the art on testing and integration for Open Radio Access Network (Open RAN) systems.

RitiRAN Workshop - co-located with VTC Fall 2024

First Workshop on Research and Innovation in Testing and Integration for Open Radio Access Networks (RitiRAN) - co-located with VTC Fall 2024

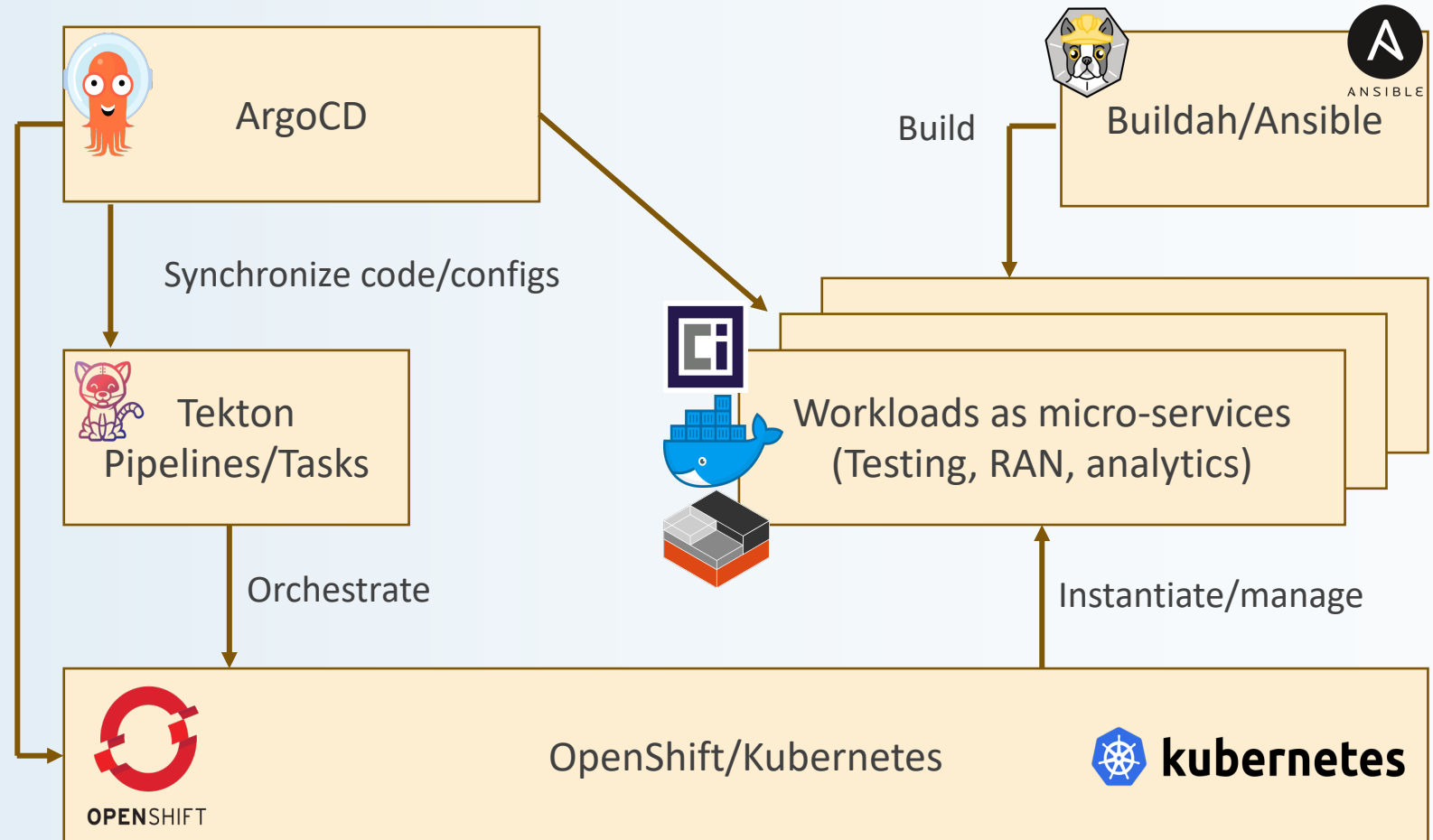# Automation for End-to-End Deployments
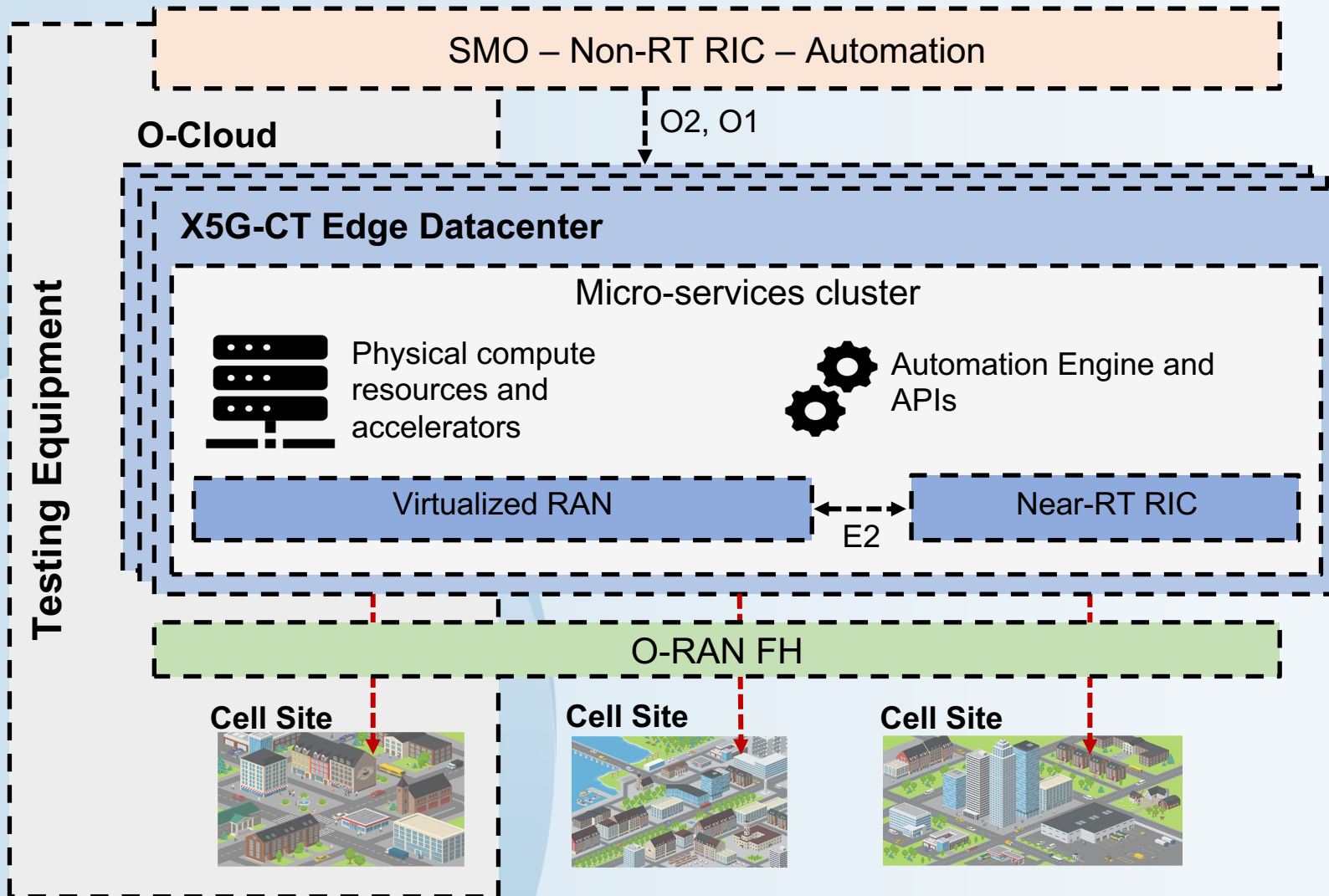
End-to-end Automated Solution:

- OpenShift cluster with control and workers nodes

- Manage NICs and accelerators (GPUs)

- Virtualized RAN workloads with OAI and NVIDIA ARC

- OSC Near-RT RIC on OpenShift

- Automation pipelines to deploy the end-to-end infrastructure

- Multiple RUs and testing equipment connected to fronthaul/backhaul infrastructure
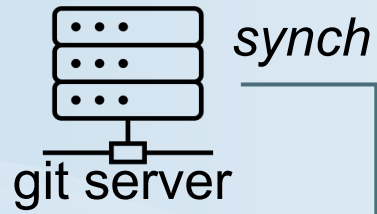
Automation Stack

- **CI/CD for stack deployment and reconfigurability**

- **Infrastructure-as-code**

- **Resiliency and redundancy**

- **Automated and repeatable builds**

ArgoCD

Build — Buildah/Ansible

Synchronize code/configs

Tekton Pipelines/Tasks

Workloads as micro-services (Testing, RAN, analytics)

Orchestrate

Instantiate/manage

OpenShift/Kubernetes

L. Bonati, M. Polese, S. D'Oro, P. Brach del Prever, T. Melodia, *"5G-CT: Automated Deployment and Over-the-Air Testing of End-to-End Open Radio Access Networks,"* **IEEE ComMag, 2024**

Automation Architecture

Automating NVIDIA ARC as DUT

X5G-CT Worker Node

ARC Pod

- OAI L2/L3 Container
- IPC
- CUBB PHY Container
- E2 RAN Termination Container

PTP | Network | GPU

Gigabyte E251-U70
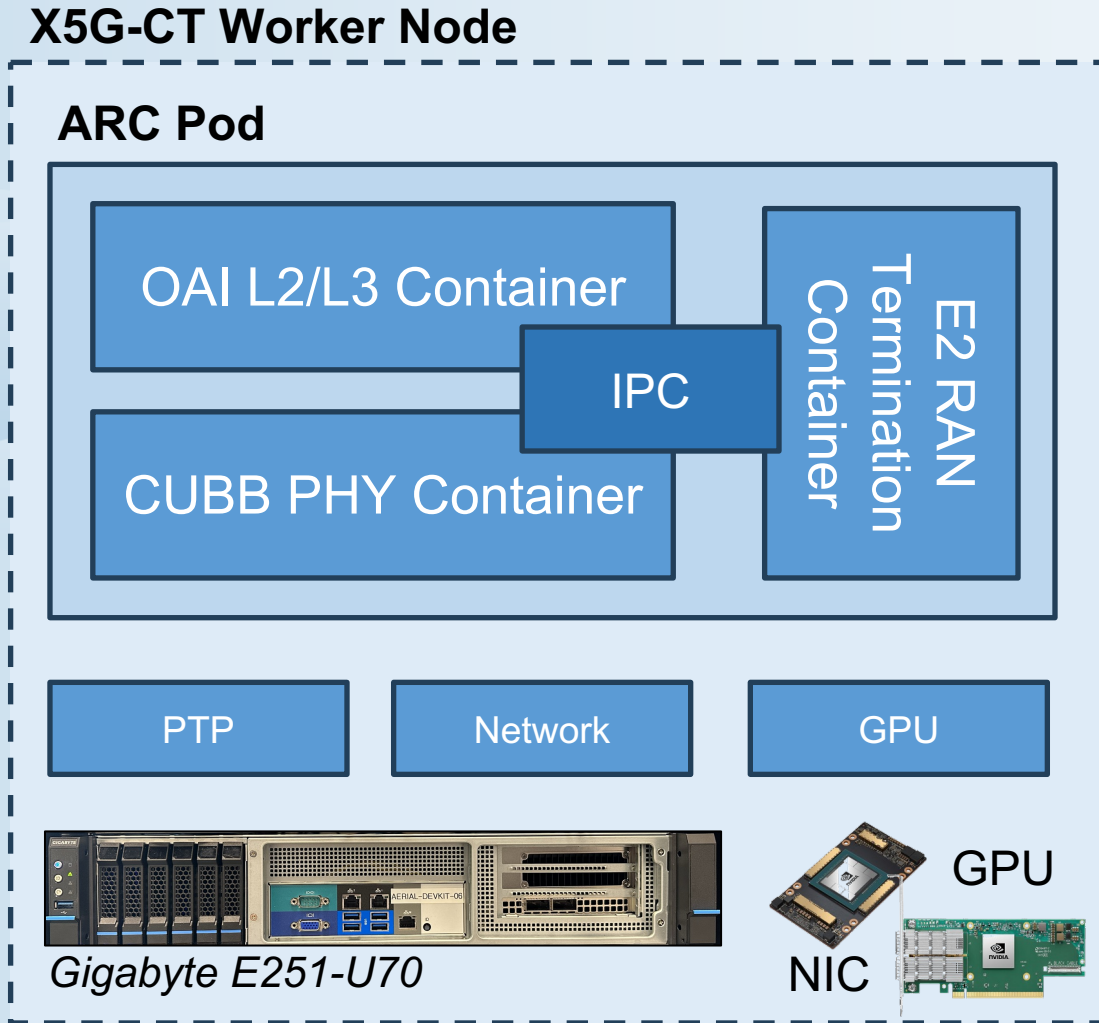
GPU

NIC

- Manage L1 and L2/L3 on a single **pod**
  - Multiple containers to isolate workloads
  - Dedicated CPU cores for guaranteed performance

- Direct **IPC on shared pod memory**

- OpenShift operators for Infrastructure-as-Code:
  - PTP operator (from OpenShift itself)
  - NVIDIA GPU Operator (to install CUDA, the OpenKernel modules, the RDMA driver)
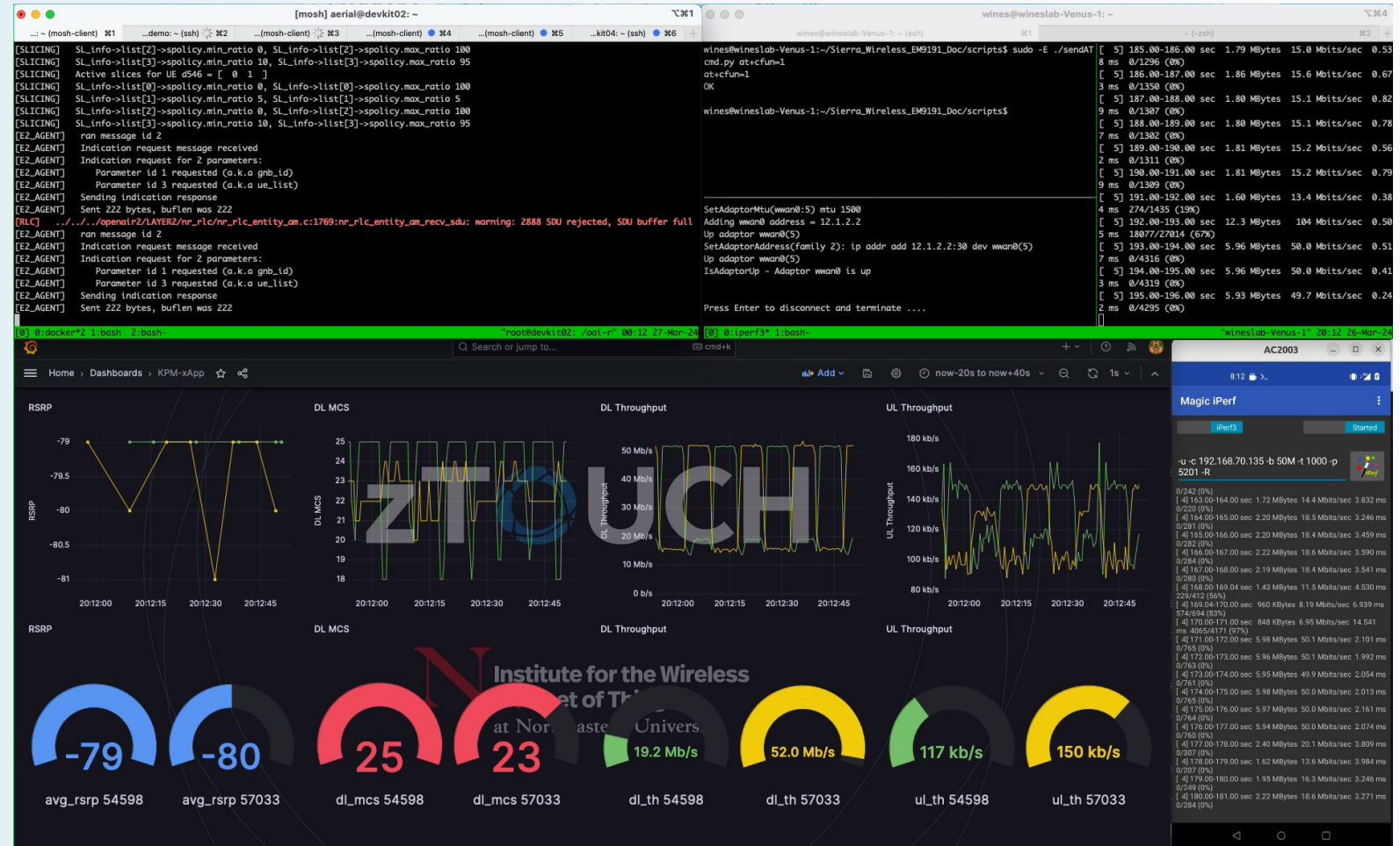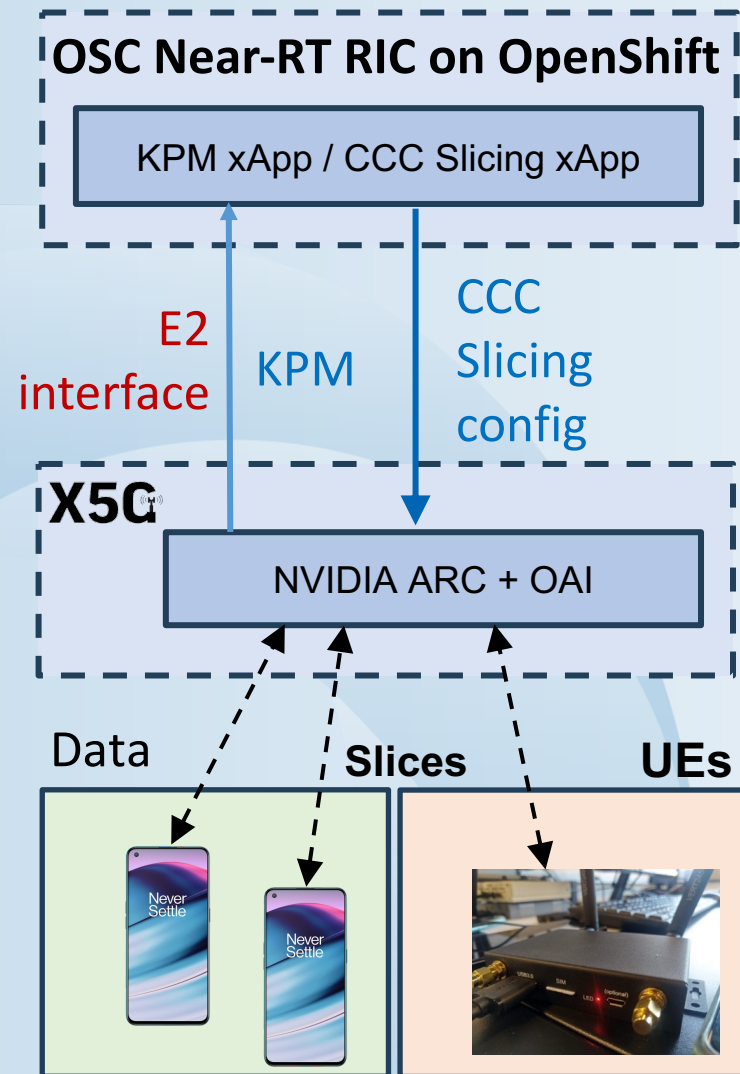 - NVIDIA Network Operator

- Start the gNB in ~~40 s~~ 16 s

Integration with the OSC Near-RT RIC
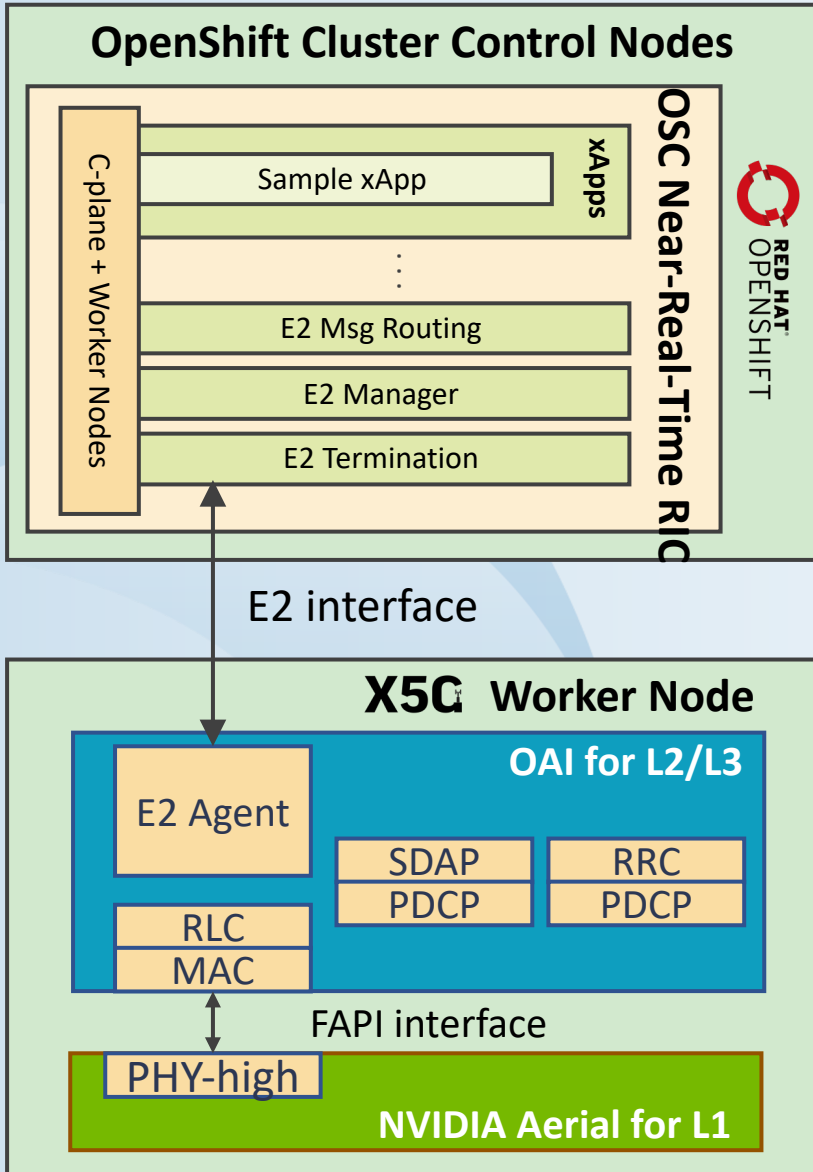
KPM xApp with InfluxDb and Grafana

RAN Slicing with OSC RIC and NVIDIA ARC

Demo Time!

With Stefano Maxenti