

From Open RAN to Open AI-RAN: The Future Connectivity Fabric That Learns and Senses

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Outreach Director, AERPAW

**OAI Foundation Hands-on Workshop
at NC State University, Raleigh, NC
Oct. 13-14, 2026**

NC STATE



Welcome to Raleigh: NC State at a glance

Land-grant R1 university, founded 1887

An anchor of the Research Triangle with Duke and UNC, Chapel Hill



40,500+

students: the largest university
in North Carolina

>\$765M

record research expenditures in
FY2025 ([link](#))
#6 in public universities (without a
medical school)

#2

for research commercialization
among U.S. public universities

70+

industry, government and
nonprofit partners on
Centennial Campus

Think and Do: 250+ startups from NC State research, with more than \$1.7B in venture capital raised

NC STATE



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NC State ECE: where wireless, AI and networked systems meet

Department of Electrical and Computer Engineering, Koch Hall, Centennial Campus

#14

public grad **Computer Engineering** program (U.S. News 2026; #27 overall)

#19

undergraduate **Electrical Engineering** program (U.S. News)

\$290M

College of Engineering research spending, 2024-25; 12,500+ students

Research areas

Communications, Controls, Signal Processing & Learning

Machine Learning and AI

Networking

Computer Architecture and Systems

Electronic Circuits and Systems

Power Electronics and Power Systems

Physical Electronics, Photonics & Magnetics

Bioelectronics Engineering

Quantum Information Science & Engineering

Red: the areas closest to today's talk and to OAI

And, Computer Science, ITRE, and College of Engineering

NSF AERPAW Platform · xGI Initiative

(Various wireless labs, such as, NextG Lab and MPACT and resources, such as, RB IV Indoor Wireless Platform (Under construction))

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AERPAW: NSF's aerial wireless testbed in Raleigh



Two sites: Lake Wheeler (rural, $\sim 7 \text{ km}^2$) and Centennial Campus (urban, $\sim 1 \text{ km}^2$)

Note: AERPAW site visit scheduled for **4:30 – 7 PM ET on Day 2, Oct 14, 2026**

Bring your OAI experiment to the sky: open to researchers at aerpaw.org

NSF PAWR platform

Led by NC State with the Wireless Research Center, Mississippi State and RENCI; Cary, Raleigh and NCDOT as partners

Programmable radios that fly

SDRs, Ericsson 5G, Keysight RF sensors and COTS UEs on UAVs, ground vehicles and helikites

Open stacks, OAI included

Sample experiments for OAI 5G SA, srsRAN and GNU Radio; develop in the digital twin, then fly

AORA student challenge on AERPAW

AERPAW Open Research on Autonomy

Registration deadline: Dec 31, 2026
Experiment Submission: April 30, 2027



The Challenge

Open-ended: combine autonomous UAS with 5G/6G wireless. Build on GNU Radio, srsRAN + OCUDU, or **OpenAirInterface**.



Digital Twin → Testbed

Stage 1: develop in AERPAW's digital twin, open to all teams. **Stage 2:** top 6 finalists deploy unmodified on the real aerial testbed.



Review & Evaluation

Five wireless and UAS experts score novelty, stability, reproducibility, report clarity and potential impact.

STUDENT PRIZES (expected to grow as new sponsors join)

1st place

\$5,000

+ USRP B206mini

2nd place

\$3,000

+ USRP B206mini

3rd place

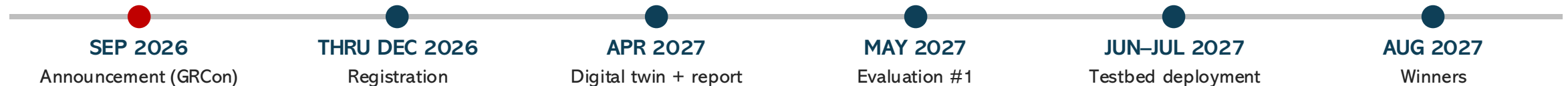
\$2,000

4th–6th place

\$500 each

runner-up awards

TIMELINE



Sponsors

Platinum: ODC Gold: NI Silver: Keysight Technologies, AUVSI North Carolina
Bronze: Vadum, Thurling Consulting
Want to sponsor AORA's student awards? aerpaw-contact@ncsu.edu

Scan to
register



xGI Initiative: the future of intelligent wireless networked systems

Our mission: The xGI Initiative at NC State advances the future of intelligent wireless networked systems through interdisciplinary research spanning communications, networking, AI, sensing, hardware, and autonomous applications. By integrating innovations across the wireless stack — from RF platforms and O-RAN architectures to AI-native networks and large-scale testbeds — xGI develops transformative technologies for next-generation communication, sensing, and connected systems. Through strong partnerships with industry and government, xGI accelerates innovation and real-world impact while positioning NC State as a national leader in next-generation technologies.

xGI Team:

- 22+ faculties from ECE, CSC and MAE.



Vijay K Shah, Director



Suresh Venkatesh, Associate Director



Ismail Guvenc



Jacob Adams



Mihail Sichitu



Ali Gurbuz



Brian Floyd



Huaiyu Dai



Hamid Krim



Wenye Wang



Alexandra
Duel-Hallen



Yuan Liu



Chau-Wai
Wong



Alper Bozkurt



Ruozhou Yu



Yuchen Liu



Xiaorui Liu



Tianfu Wu



Dara Ron



Dongkuan
(DK) Xu



Jaemin Lee



Zhishan Guo

RESEARCH AREAS

Five interconnected thrusts

01 Intelligent Wireless, Networking & Distributed Systems

5G/6G O-RAN AI-RAN Satellite and aerial networking
Spectrum sharing Digital twins Wireless security
Network optimization

[READ MORE →](#)

02 AI Foundations & Learning

Foundation models Agentic AI Explainable AI Federated learning
Graph learning AI optimization

[READ MORE →](#)

03 Sensing, Perception & Integrated Intelligence

ISAC Radar RF sensing Wireless localization and tracking
Human-machine sensing Autonomous perception

[READ MORE →](#)

04 Communication Systems, Hardware & Platforms

Antennas RFICs mmWave/THz Phased arrays MIMO
Wireless PHY Quantum signal processing and communications

[READ MORE →](#)

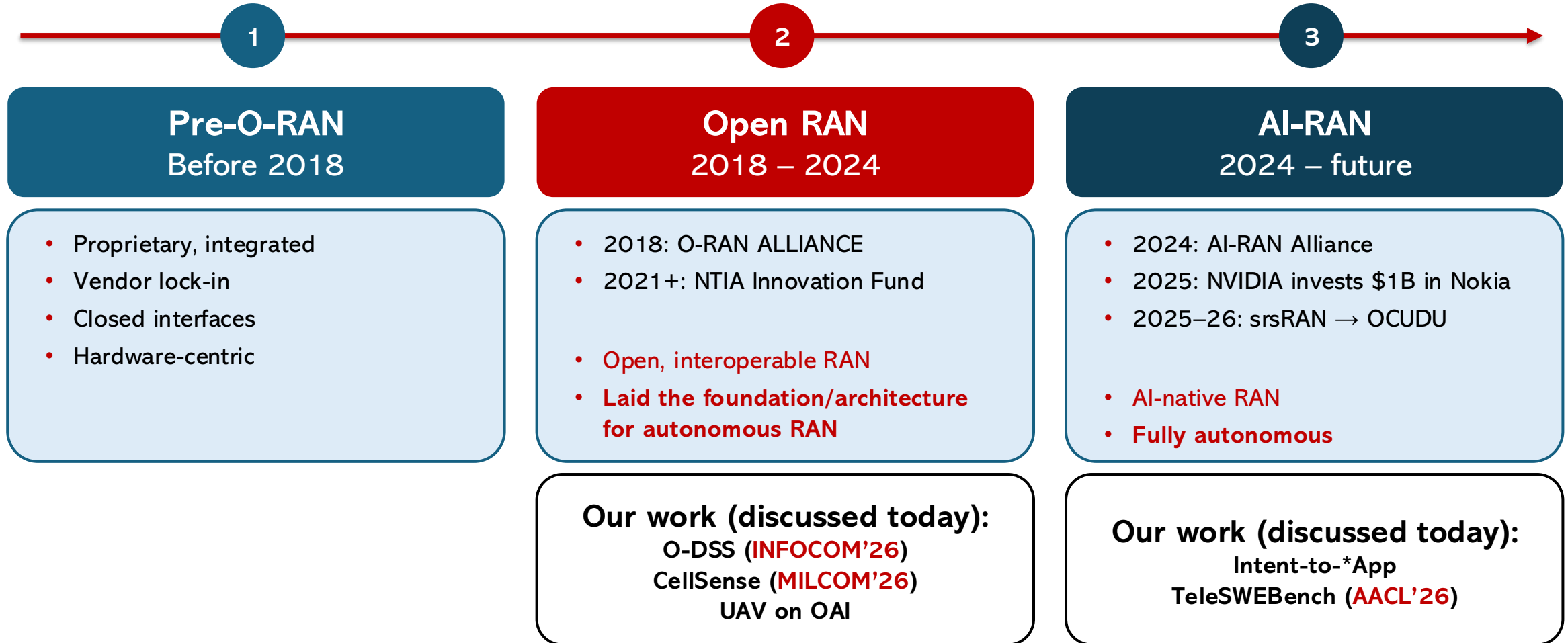
05 Autonomous Systems & Applications

UAVs Robotics IoT Agriculture Smart infrastructure
Healthcare Human-centered systems

[READ MORE →](#)



Outline: from Open RAN to Open AI-RAN



PART I

The Open RAN Era



*Open interfaces, programmable control, and a wave of excitement
(2018–2024)*



(Very Briefly) Open RAN architecture

Founded in 2018 by AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO and Orange – driven by **Network Operators**

Openness and intelligence: standardized open interfaces and APIs

Flexibility by design: 3GPP split 7.2x between O-RU and O-DU

> 1 s

Non-RT RIC · rApps

High-level policy and optimization

10 ms – 1 s

Near-RT RIC · xApps

Near-real-time control over E2

< 10 ms

Real-time RIC* · d/μApps

PHY/MAC-level inference and control

* Not yet standardized; under study in the nGRG RS-02 research item.

* Already adopted by industry though, Nokia/NVIDIA's AI-RAN has dApps.

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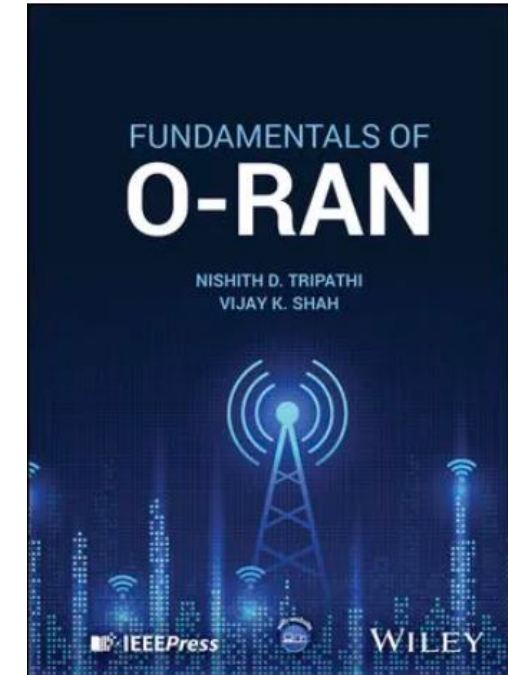


Telecom Equipment · 3 Min Read

Nokia bets on dApps, Nvidia GPUs for 5G open RAN competitiveness: Report

Nokia is adopting a new open RAN interface, E3, for dApps and leveraging Nvidia GPUs to enhance its 5G competitiveness against rivals. This strategy aims to attract telcos with advanced user-plane capabilities, contrasting with Ericsson and Samsung's resistance to dApps.

Vijay K. Shah, PhD



ECE 592 / CSC 591

AI-native Telecom Networks: Open RAN and AI-RAN. Online for non-NCSSU students (Fall semester)

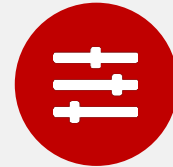


What Open RAN got right



Standardized, open interfaces

O-RAN ALLIANCE specifications for fronthaul, E2, A1 and O1, built alongside 3GPP



A programmable control plane

The RIC turned RAN control into applications: xApps and rApps



Open stacks and testbeds

OpenAirInterface, srsRAN/OCUDU, Colosseum and AERPAW put a real RAN in academic labs



A home for AI

KPM and I/Q data exposure plus closed-loop control points, designed for ML from day one

Plus public investment (e.g., NTIA Innovation Fund)



Our (AI) xApps, rApps and dApps

Open AI Cellular (OAIC)

- 4G and 5G: srsRAN and OAI
- OSC RIC and FlexRIC
- SDRs and COTS UEs
- ZMQ multi-UE support
- AI-driven RAN controllers

www.openaicellular.org

Interference classification xApp

IEEE MILCOM '23 · best demo award

SPARC: IC xApp + RB-scheduling μ App

ACM CoNEXT '24

mmWave beam-switching xApp

IEEE DySPAN '24

O-DSS: radar detection, localization + spectrum control

IEEE INFOCOM '26

Radar detection xApp

IEEE JSAC '24

IMPACT xApp

NTIA RIC Forum 2024 demo

PRISMA: explainable anomaly detection

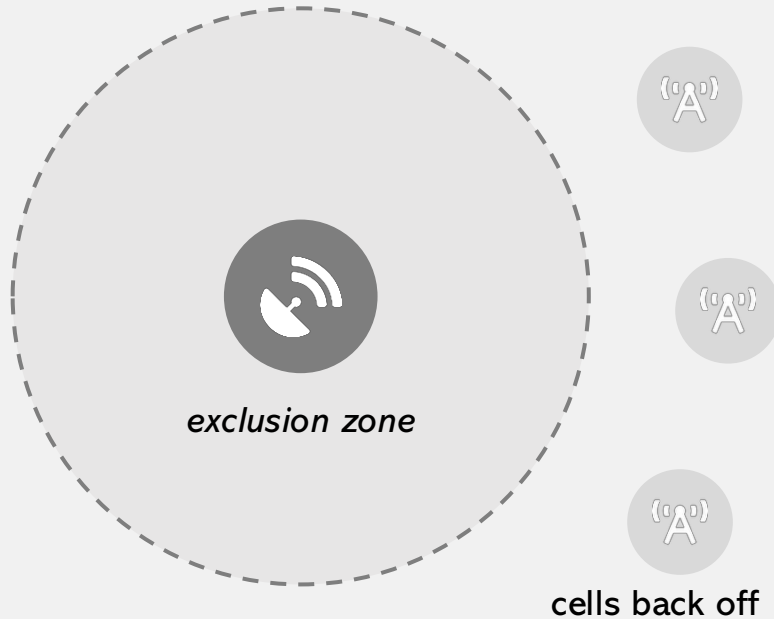
Under review (with Yale)

UE positioning xApp, 5G sensing dApp

ongoing

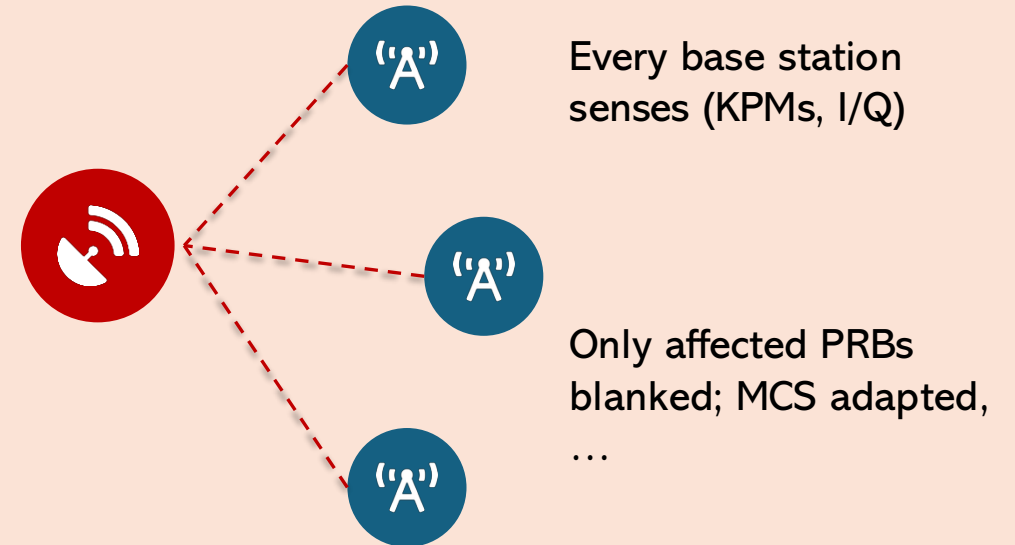
Why O-DSS: from static to dynamic protection

Today: static protection



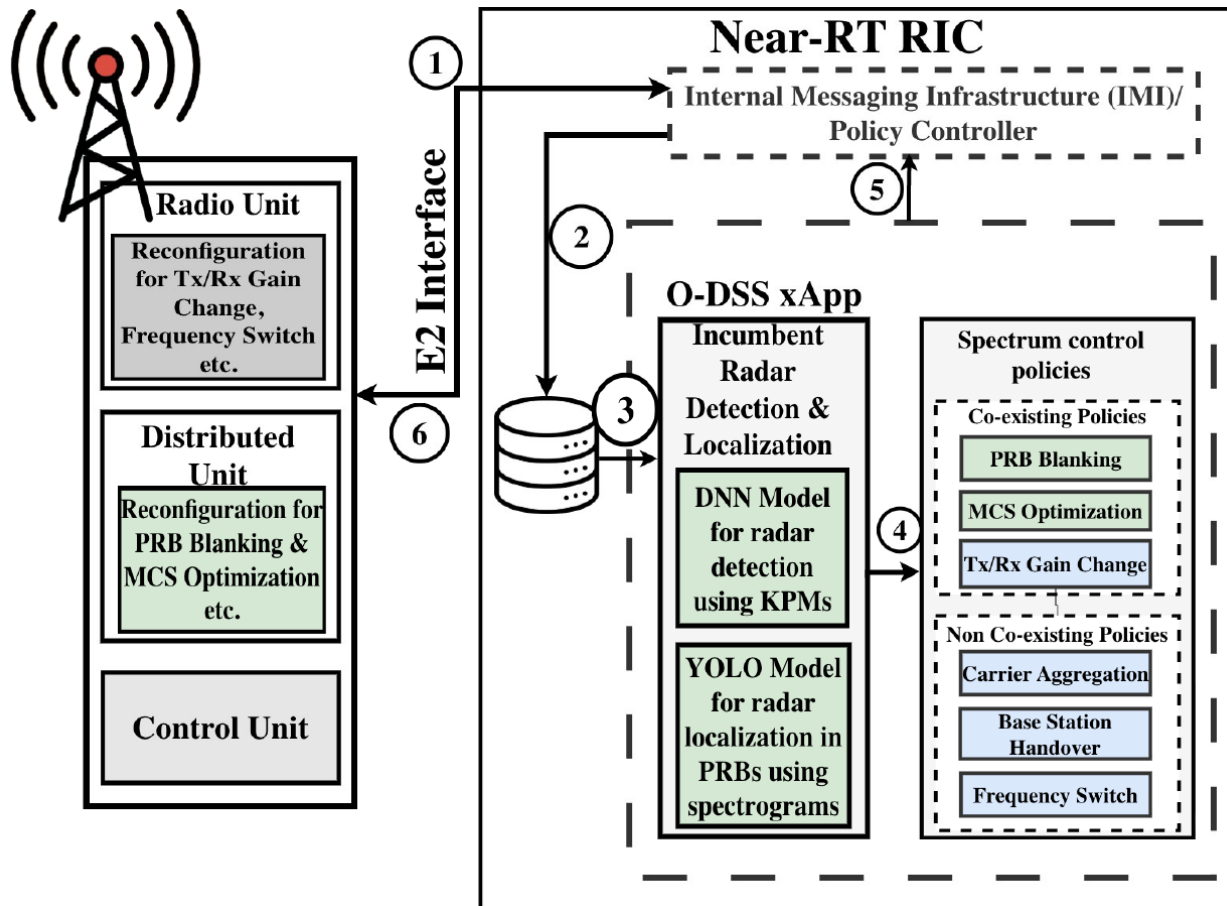
~60 s detection · protection in minutes
static rules

O-DSS: dynamic coexistence



< 60 ms detection · < 700 ms response
O-DSS

O-DSS system: two-mode detection



1

RAN telemetry
KPMs over E2

2

Default detection
lightweight DNN on KPMs (radar activity)

3

Triggered localization
I/Q spectrogram + YOLO (localizes radar-affected RBs)

4

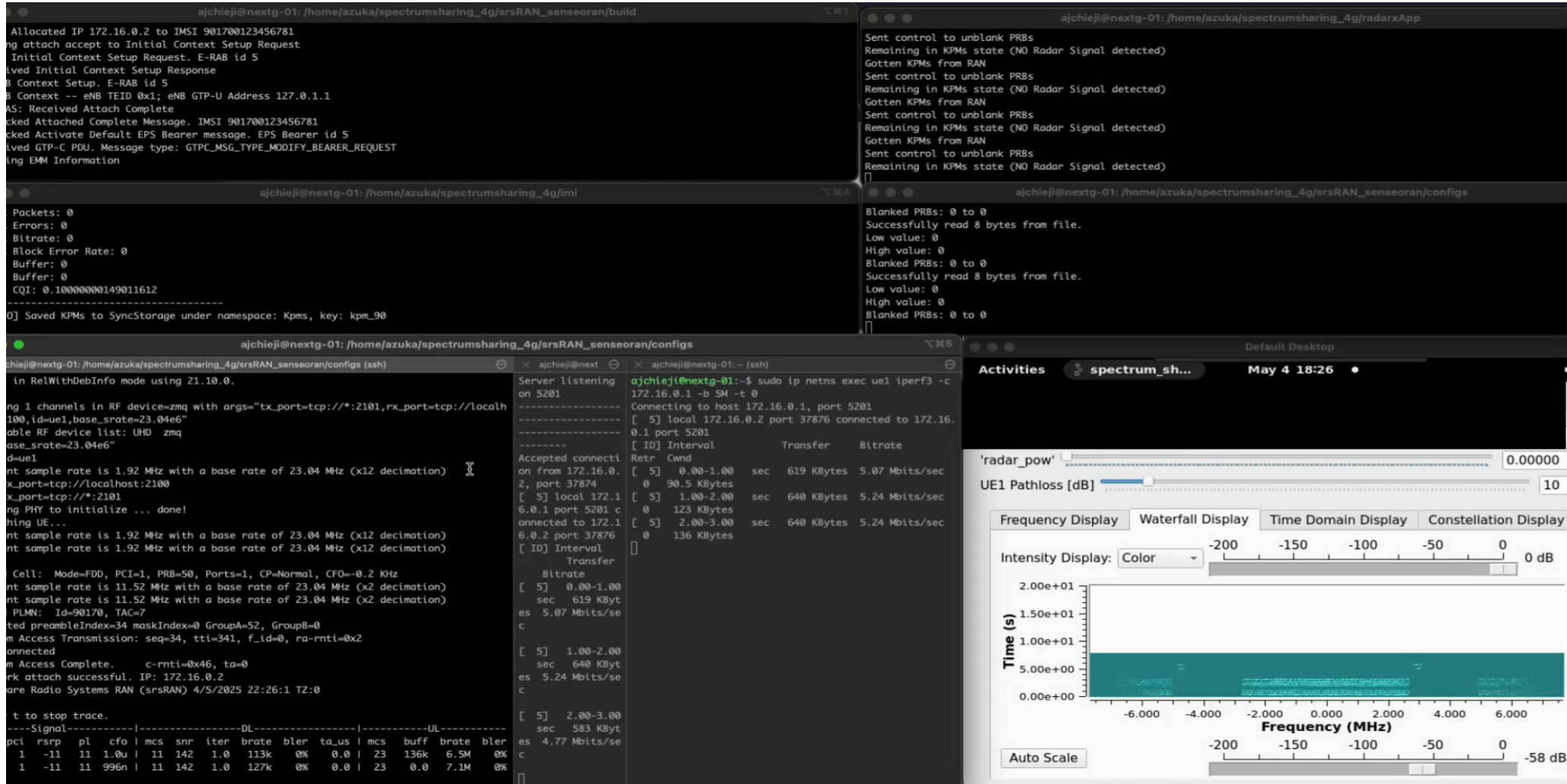
Coexistence action
PRB blanking + Radar-aware MCS adaptation

5

Closed loop
enforced back at the BS (in milliseconds)

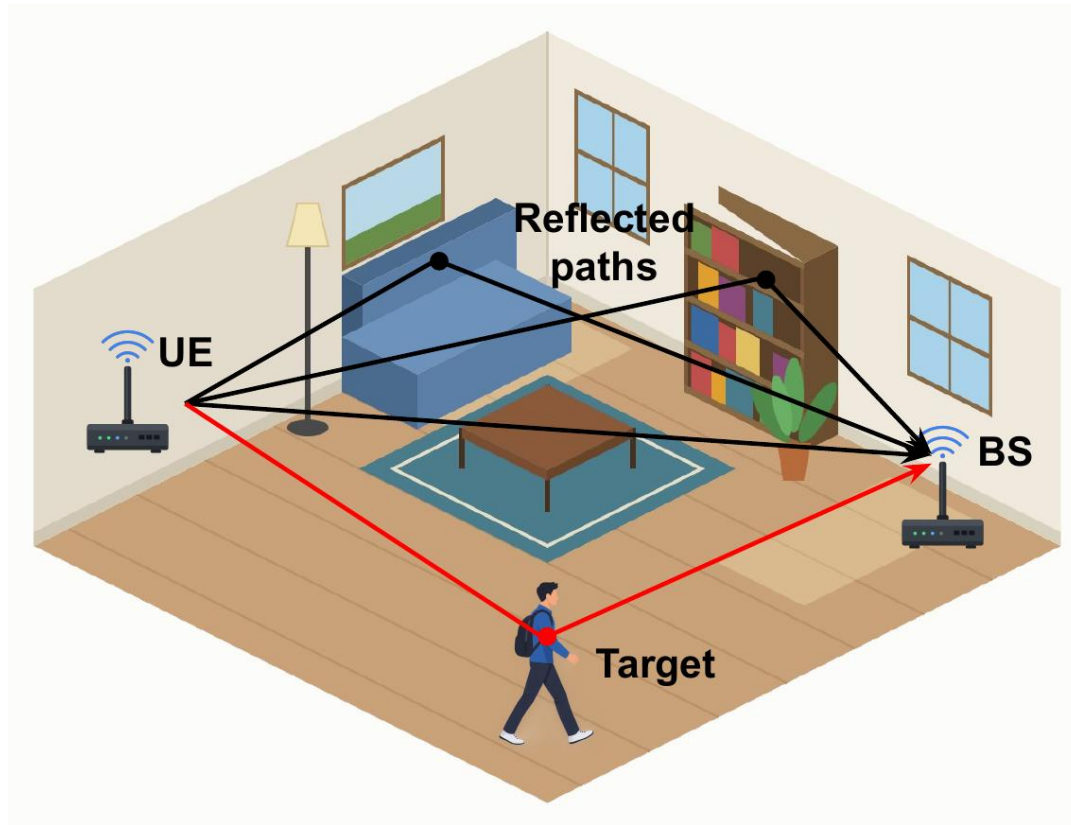
KPMs by default; spectrograms only after radar is detected

O-DSS demo



CellSense: sensing passive objects from uplink SRS

Bistatic sub-6 GHz ISAC on a standard 5G stack · MILCOM 2026, with RPI

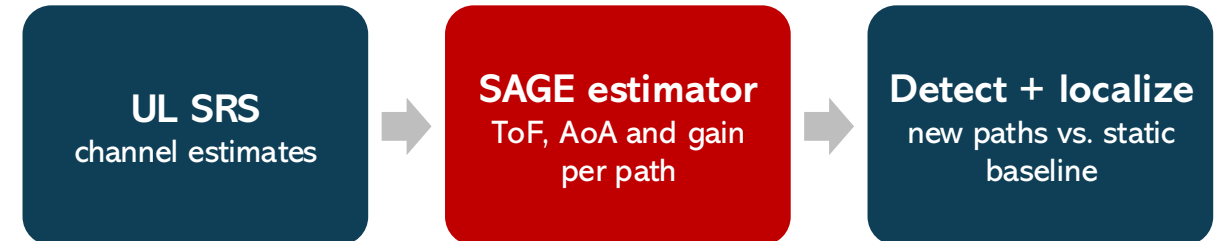


Why sub-6 GHz sensing is hard

Rich multipath: many strong, overlapping paths

Target echoes are much weaker than the dominant paths

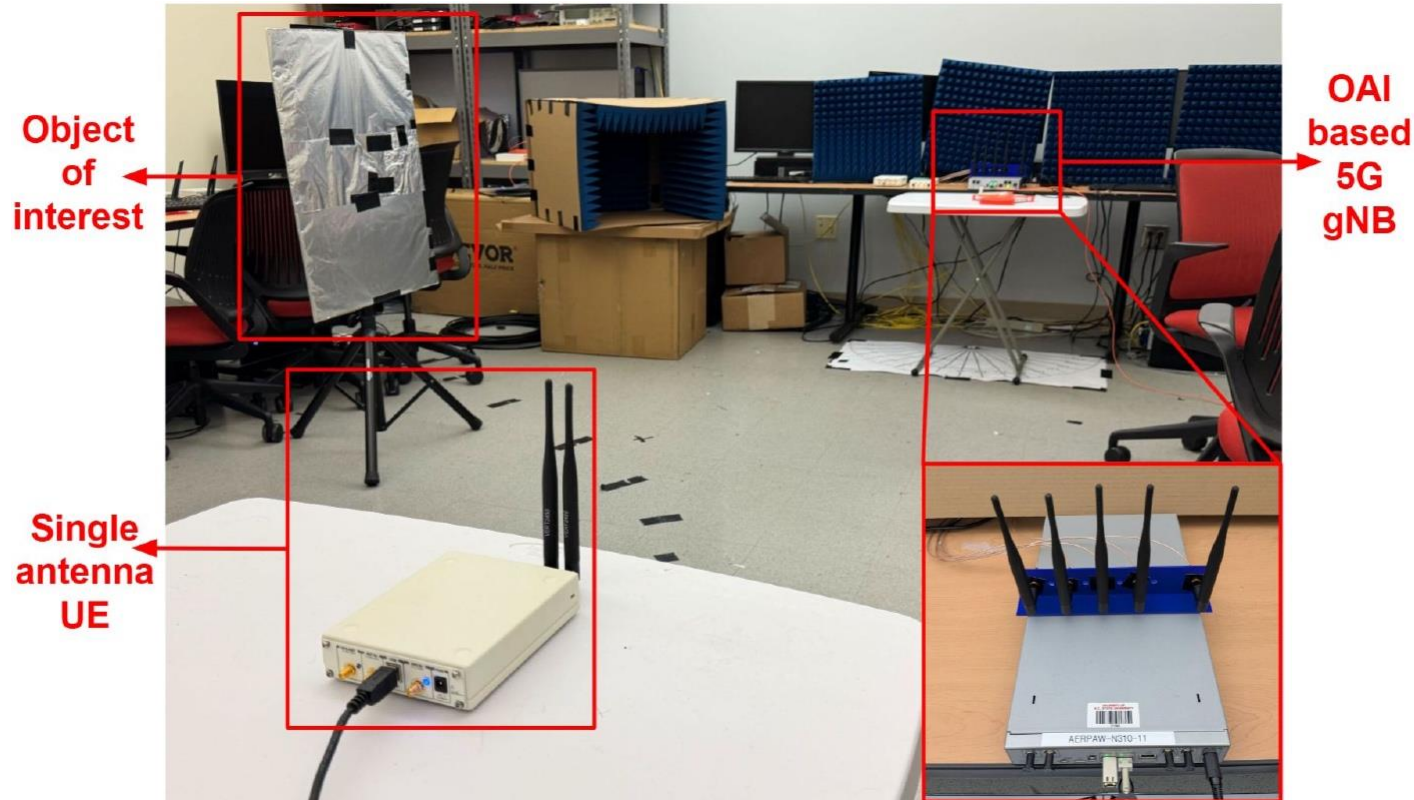
How CellSense works



Static paths form a repository; bipartite matching tracks paths over time, and a target sits where the bistatic ellipse meets its AoA ray

No dedicated sensors: sensing from pilots every 5G base station already receives

CellSense runs on OAI: a 5G SDR prototype



Cluttered lab: reflective target, B210 UE, N310 OAI gNB (inset)

OAI-based 5G gNB

An AERPAW USRP N310 with a 4-element ULA

Single-antenna UE

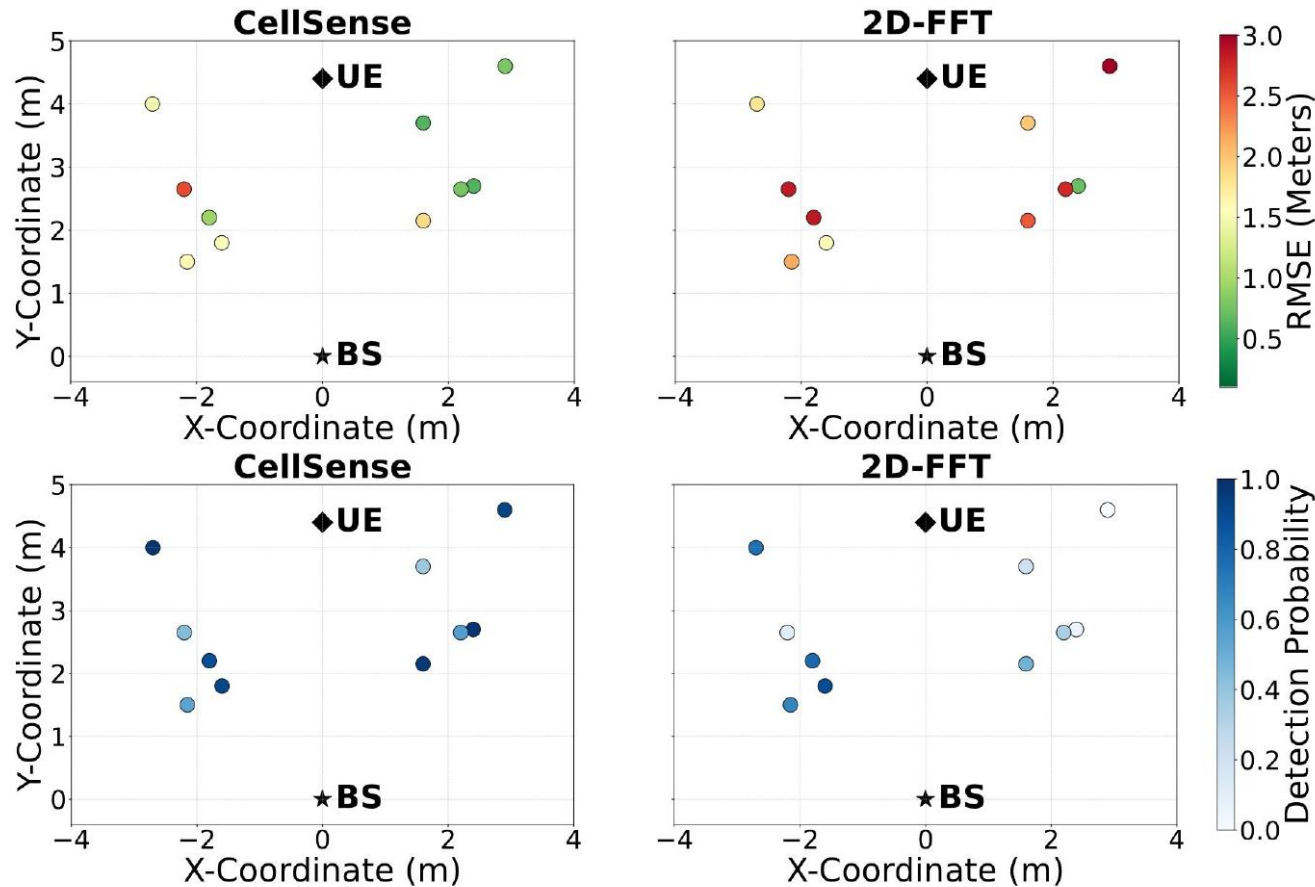
USRP B210 sending standard uplink SRS

Calibrate once

RF-chain phase offsets measured with the UE at boresight; stable across UE sessions

Same OAI stack you use: sensing is a layer on top of channel estimation, not a new radio

CellSense in a real cluttered lab



Top: RMSE per location. Bottom: detection probability.

43% → 76%

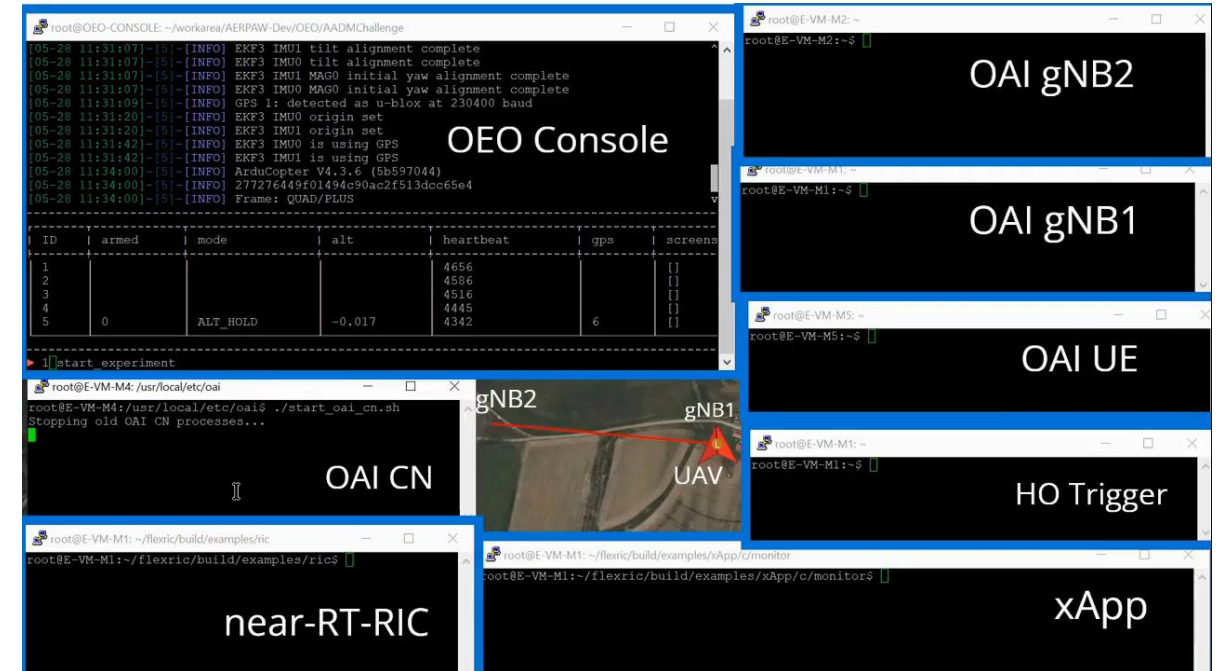
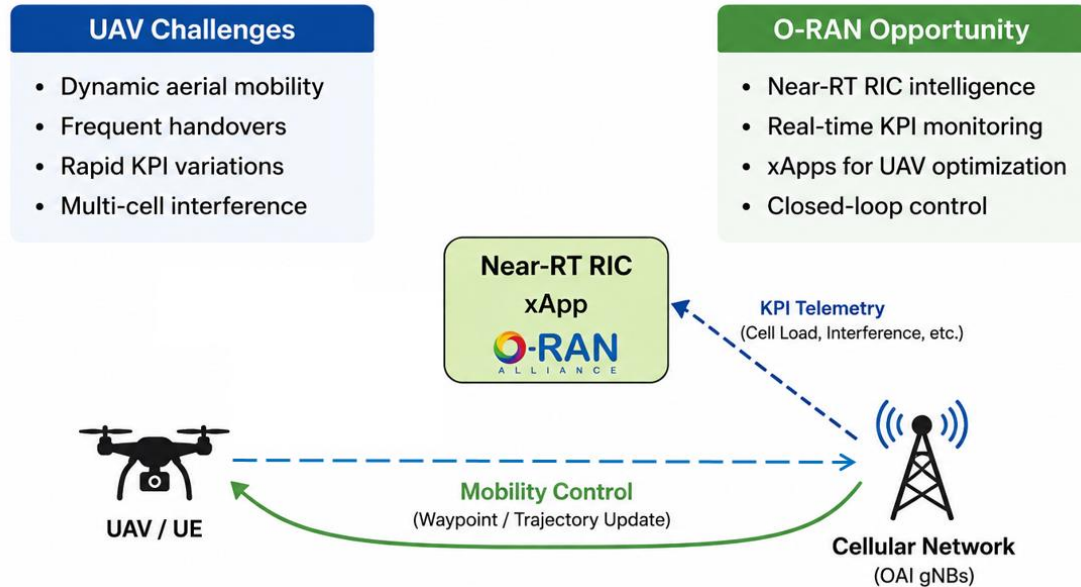
detection probability vs. a 2D-FFT static-subtraction baseline

2.2 → 1.28 m

localization RMSE across the same locations

10 pre-mapped target locations among strong static reflectors. In ray-traced simulation, indoor detection rose from 22% to 74%.

OAI in the air: O-RAN control of UAVs in AERPAAW



Key idea: KPIs in, waypoints out

Running: UAV UE handover between two OAI gNBs (digital twin)

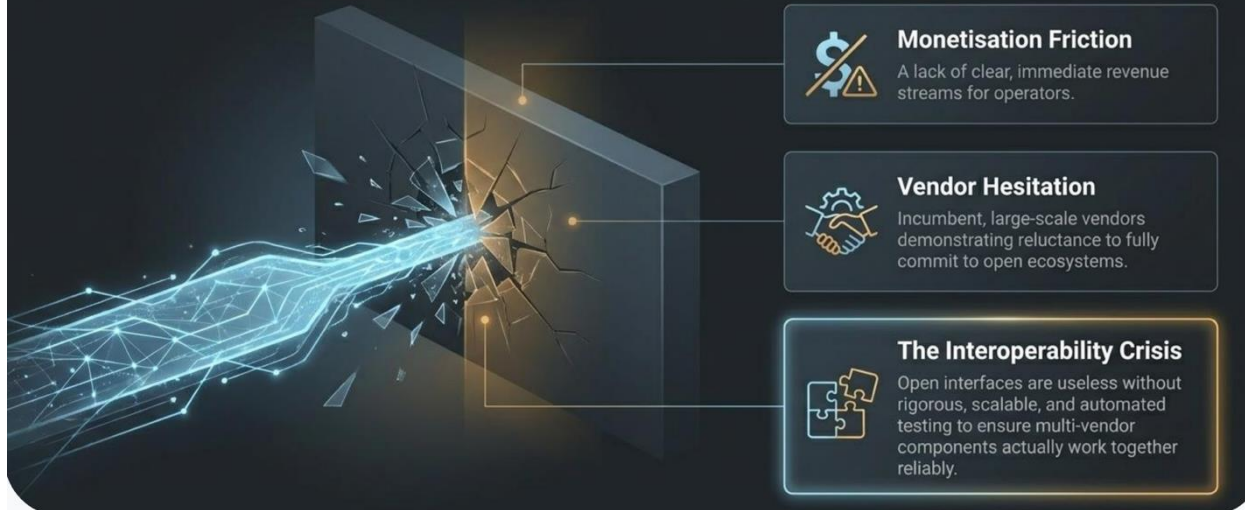


Under testing in AERPAAW; not yet publicly available.

Acknowledgement: S. Hossen (PhD student)

Open RAN: From early excitement to a maturity headwind

By 2024, the promise of Open RAN collided with deployment realities



Early excitement

- Enthusiasm mainly in academia and smaller vendors
- New players: AirHop, Cirrus360, Rimedo Labs; O-RU vendors such as Benetel, Battelle etc.
- Large-scale deployments in Japan and global trials
- Dish Wireless: first O-RAN operator

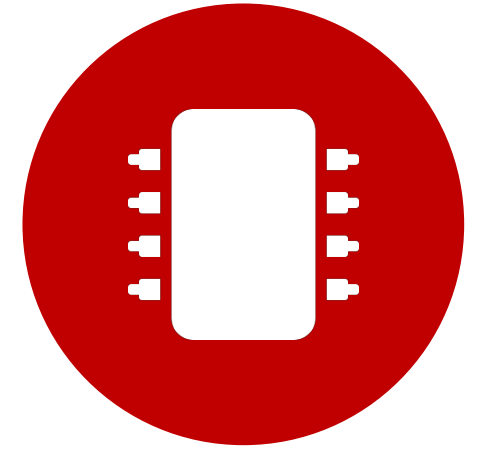
Root Cause

Revenue: No new revenue streams – still rely on subscriptions! No concrete savings either!

Interoperability crisis: Open RAN opened up the RAN, who is going to integrate quickly and reliably?

PART II

The AI-RAN Era



AI moves into the cellular network itself (2024–)



2024: birth of the AI-RAN Alliance

Founded by DeepSig, Ericsson, Nokia, Samsung, Softbank, AWS etc... **driven by Network Vendor (and hyperscaler)**



AI-for-RAN

AI-driven spectral and operational efficiency, resource management, maintenance

O-RAN supports this via xApps / rApps



AI-on-RAN

AI workloads on the RAN power applications at the network edge

Robotics, sensing, object detection



AI-and-RAN

Shared infrastructure for AI and RAN workloads; new monetization

LLM inference alongside RAN

AI-RAN Alliance, ai-ran.org

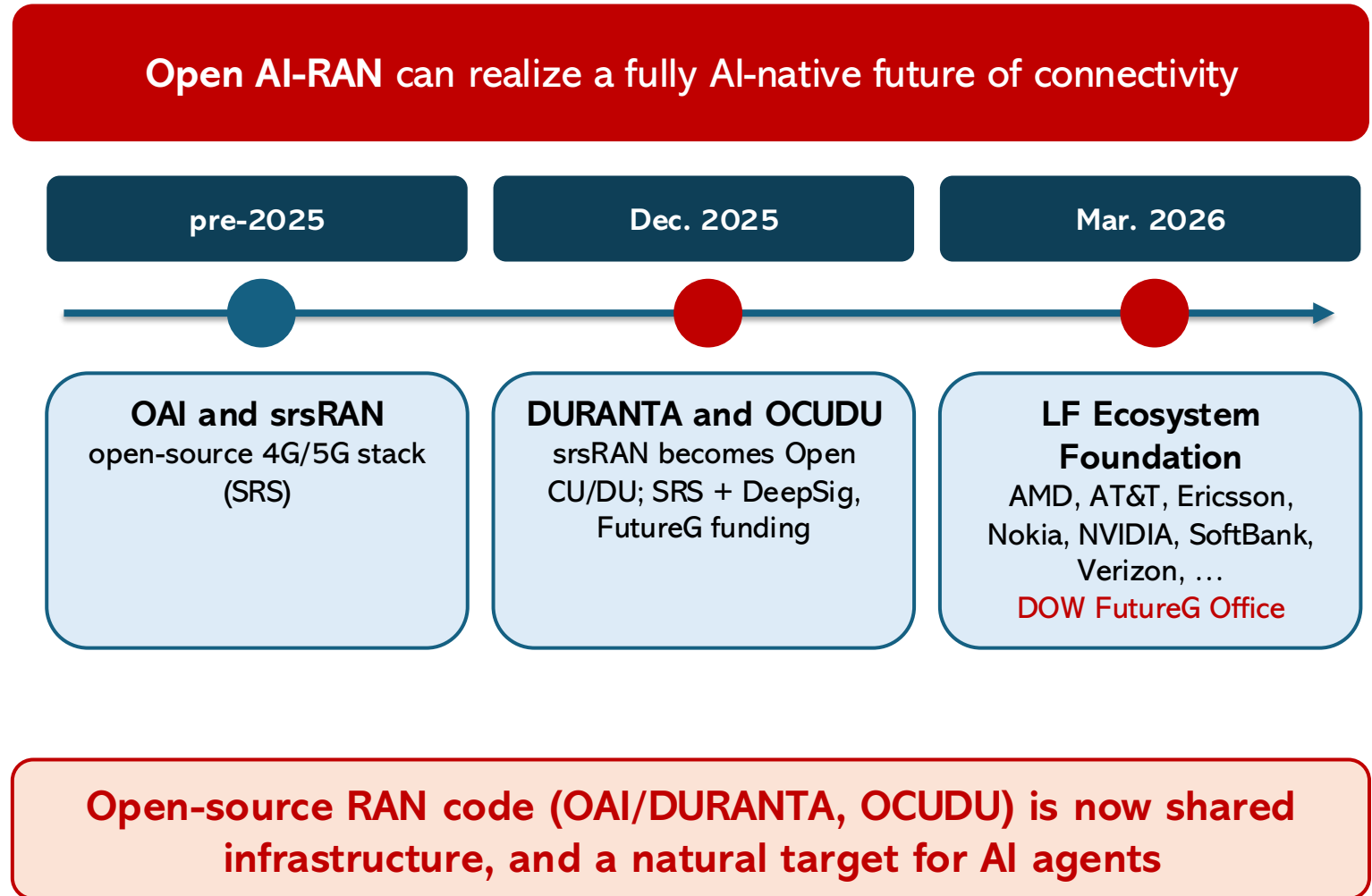


AI-RAN and Open RAN: convergence?

Yes, no, maybe: the answer seems to be all of them

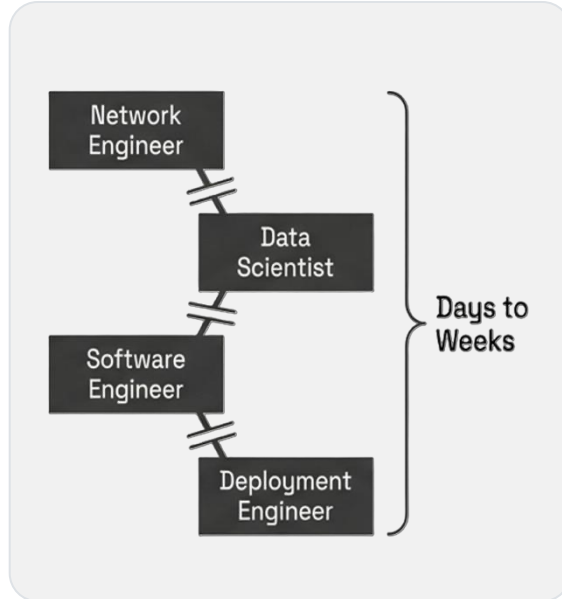


Sources: Linux Foundation press release
(Mar. 1, 2026).



From operator intent to a live xApp, autonomously

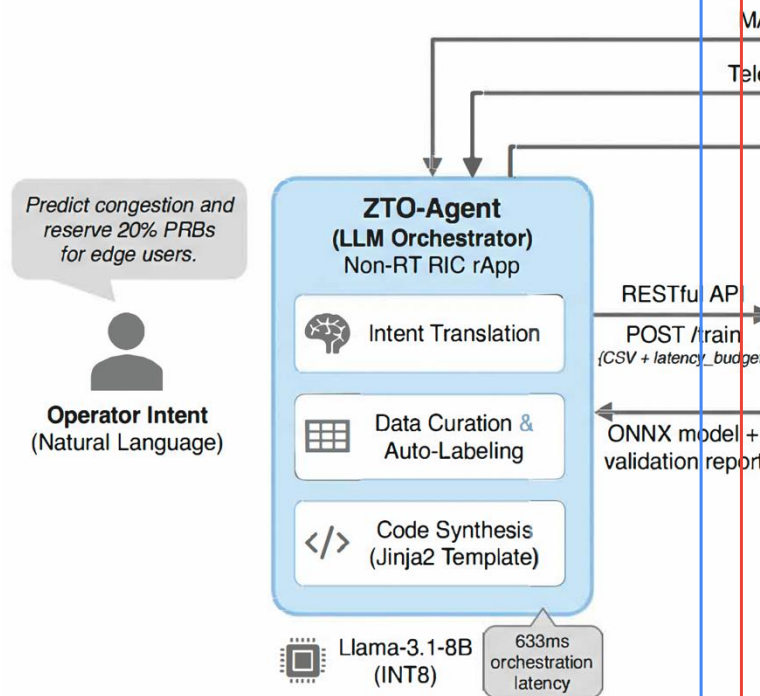
O-RAN AI Provisioning Gap



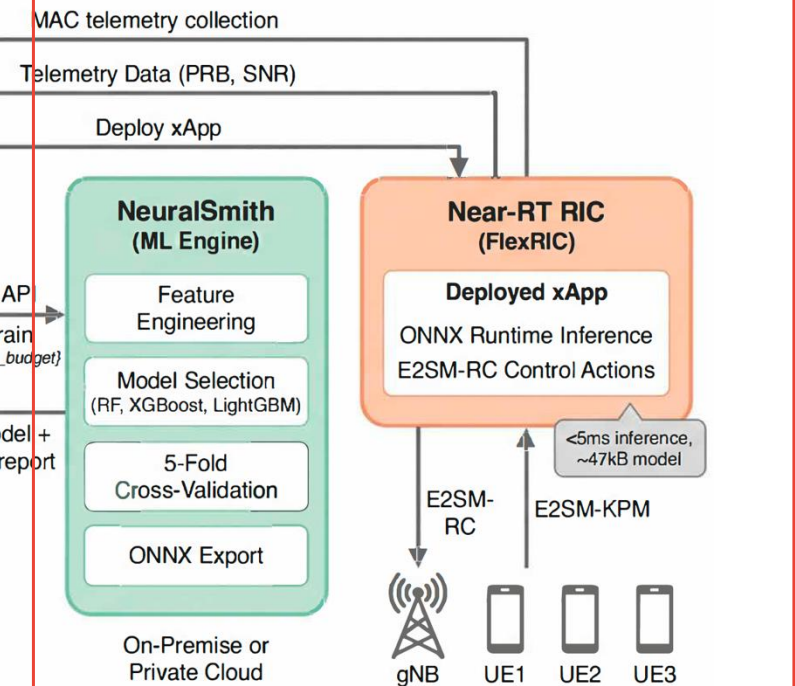
Network conditions change in milliseconds, but manual AI provisioning takes days.

Let the LLM think, let the ML engine compute.

Brain 1: ZTO-Agent The LLM Orchestrator (Non-RT RIC)



Brain 2: NeuralSmith Autonomous ML Engine

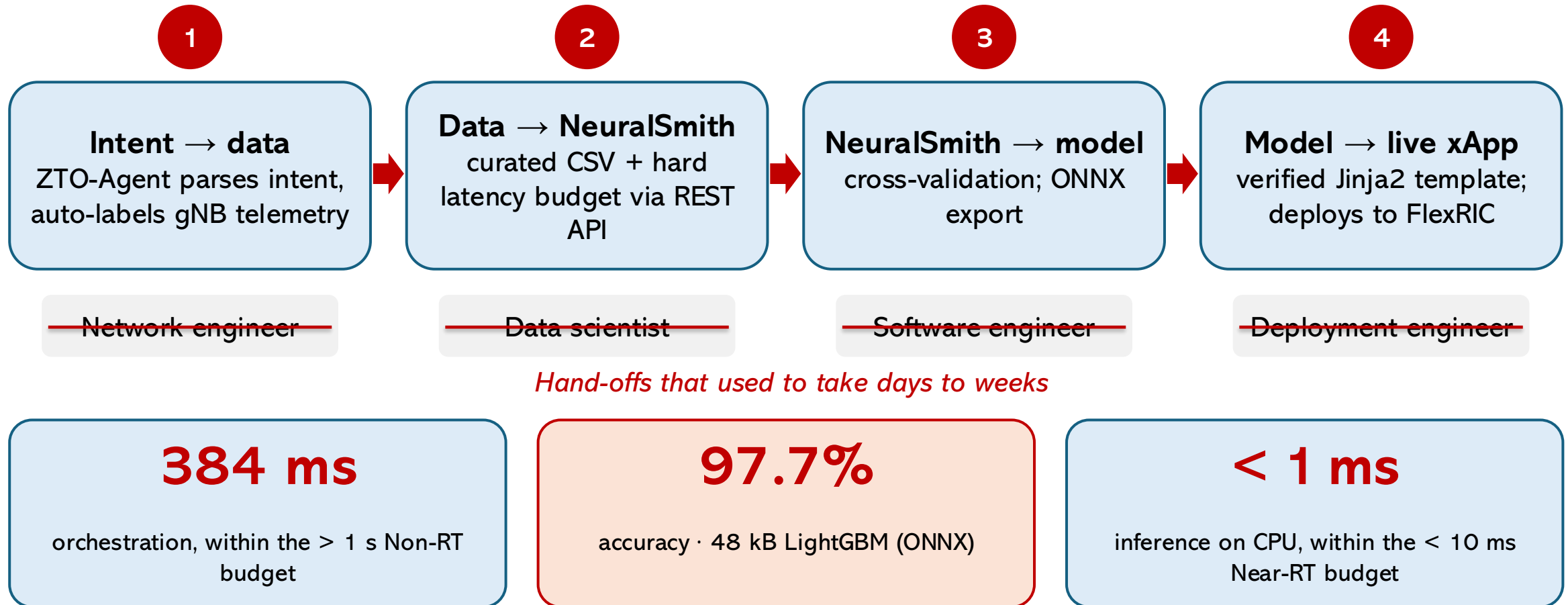


Dual-Brain Architecture

Seyed Bagher Hashemi Natanzi, Pranshav Gajjar, Bo Tang, and Vijay K. Shah, Advanced AI Service Provisioning in O-RAN through LLM Engine Integration, <https://arxiv.org/pdf/2605.23809>

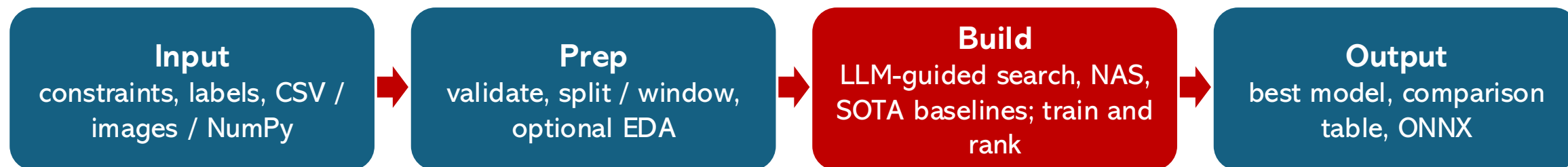
From operator intent to a live xApp, autonomously

“Predict congestion and reserve 20% PRBs for edge users.”



Seyed Bagher Hashemi Natanzi, Pranshav Gajjar, Bo Tang, and Vijay K. Shah, *Advanced AI Service Provisioning in O-RAN through LLM Engine Integration*, <https://arxiv.org/pdf/2605.23809>

NeuralSmith: an AI/ML engineering automation tool



MODALITIES

-  Image
-  Tabular
-  Time-series
-  Auto-labeler

AUTONOMY LEVELS

L3 · Autonomous (--agent-plus)
runs without confirmation

L2 · Assisted (--agent)
proposes runs; human “yes” gate

L1 · Ask (default)
chat guidance only

INTERFACES

VS Code extension

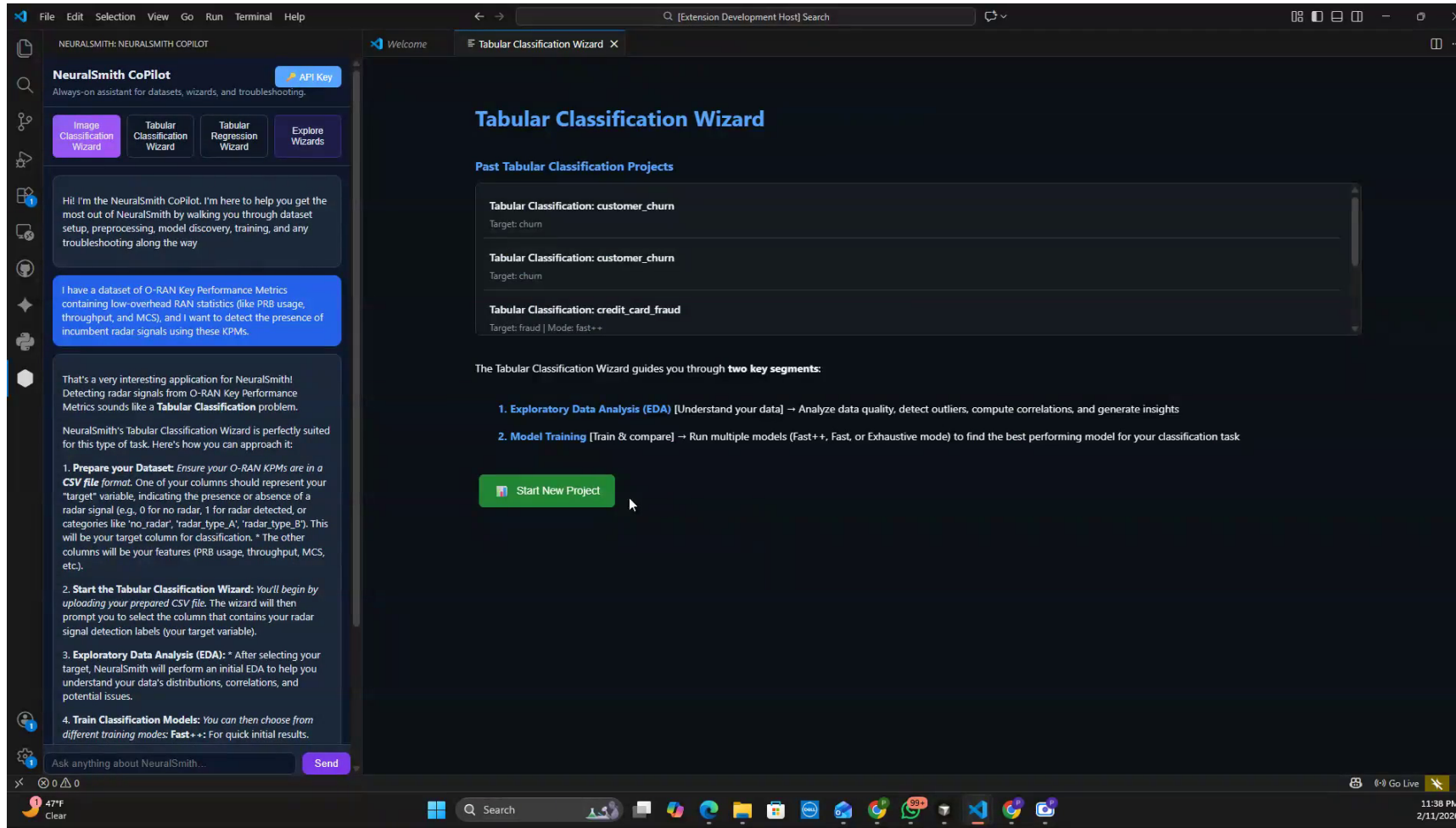
CLI · pip install neuralsmith-cli

Skill for Cursor / Claude Code (MCP)

Bring your own LLM: Google, OpenAI, Anthropic, Ollama

Natural language in, validated edge models out, entirely on user's machine

NeuralSmith demo: VS Code extension



- 1 Prompt the CoPilot sidebar in plain English
- 2 Wizard runs model search/optimization on the dataset
- 3 Best model + comparison table appear in-editor

Also available as :

- CLI agent (plus) mode
- Cursor/Claude Code skill

TeleSWEBench: can agents write telecom code?

Knowing O-RAN is not the same as changing its code

15k+ srsRAN commits
2023–2025, now OCUDU

Cascaded generation
cheapest model first

Validator
clarity, faithfulness, tier (≥ 0.9)

734 tasks
with executable unit tests

313

Difficult

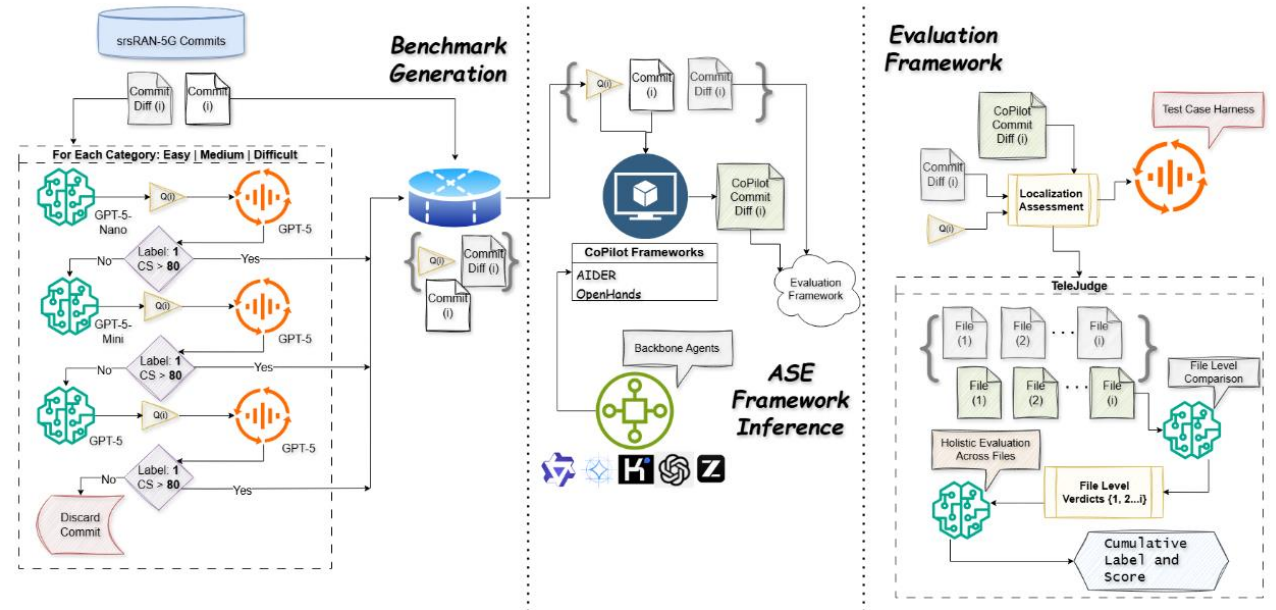
279

Medium

142

Easy

NC STATE

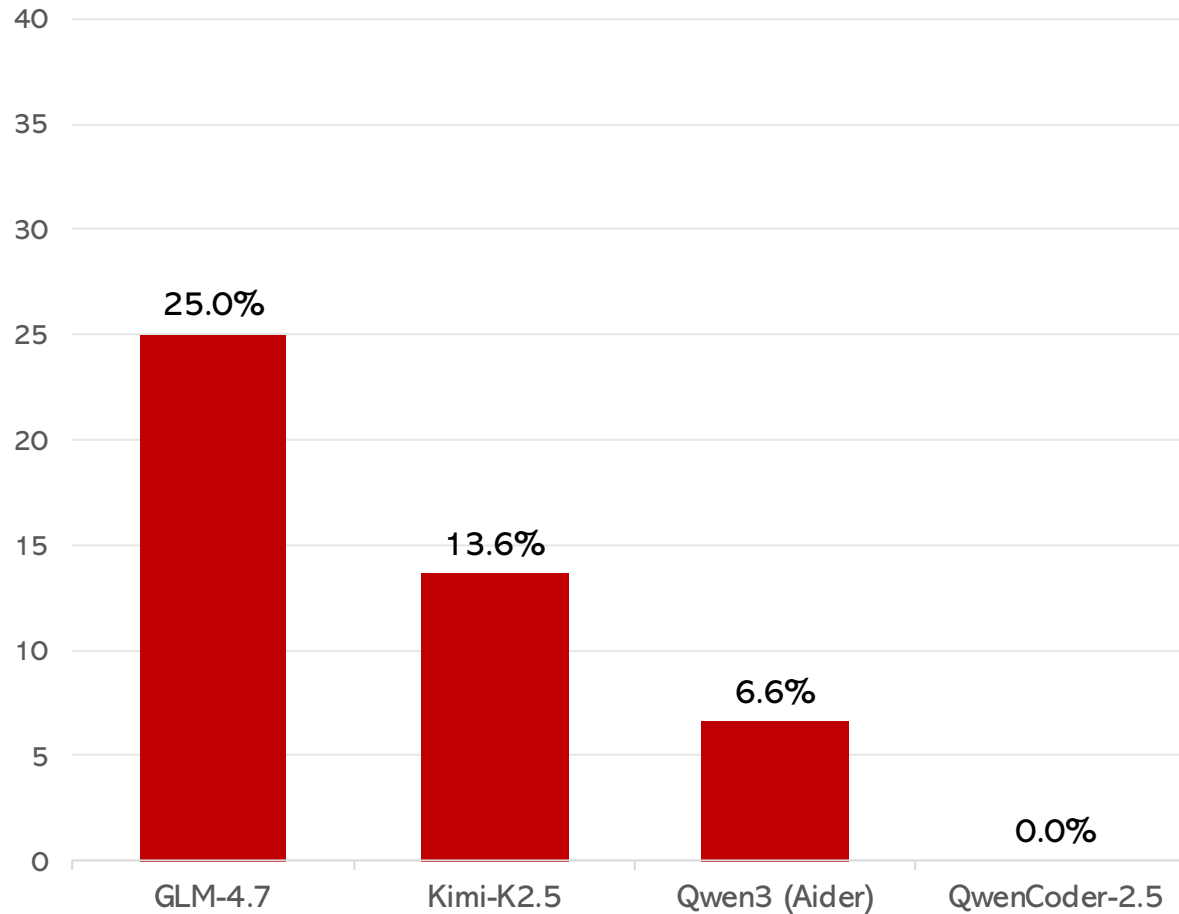


P. Gajjar, A. Mamaghani, D. Bharadia, V. K. Shah, "TeleSWEBench: A Commit-Driven Benchmark for Evaluating LLM-Powered Software Engineering in Telecommunications", AACL 2026. [arXiv:2606.05001](https://arxiv.org/abs/2606.05001), 2026.

Vijay K. Shah, PhD

Stage 2: shippable ~25% of the time, at best

Ship-ready percentage (SRP) on exact-match patches



25%

best ship-ready rate, even when the right files were edited

Passing tests $\neq$ shippable

QwenCoder-2.5: 57.7% pass unit tests, 0% accepted by TeleJudge

SRP counts exact matches only; end-to-end success over all 734 tasks is far lower

Looking Ahead...

Open RAN built the **connectivity fabric**. Open AI-RAN is starting to make it **sense and learn**, and, also importantly, we can now **measure the gap**.



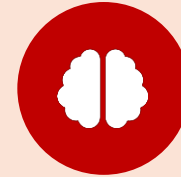
Open: the fabric

O-RAN interfaces, OAI, OCUDU and AERPAW make the RAN programmable



It senses

O-DSS senses spectrum, CellSense senses objects, OAI gNBs steer UAVs



It learns, not yet alone

ORANSight, intent-to-xApp and AI5GTest help; agents ship correct code ~25% of the time

“AI is eating the software, and [telecom] software is eating the world”
Open + AI-native + verified (and economy*) => Open AI-RAN => autonomous NextG networks



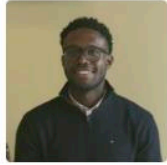
Thanks to my team and collaborators



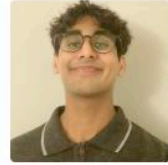
Dara Ron, PhD
(Spring 2024 -)
RESEARCH ASSISTANT
PROFESSOR



Ta-seen Niloy
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PHD STUDENT



Azuka Chiejina
(Summer 2023 -)
PHD STUDENT



Pranshav Gajjar
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PHD STUDENT



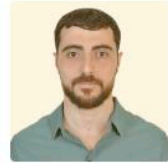
Abiodun Ganiyu
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Farzad Mehri
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Osman Mamudu
(Fall 2024 -)
MS STUDENT



Ali Abbas
(Fall 2024 -)
PHD STUDENT



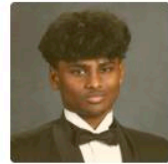
Md. Sharif Hossen
(Fall 2023 -)
PHD STUDENT (CO-ADVISED
WITH DR. ISMAIL OUVENC)



Bibhor Kumar
(Fall 2025 -)
PHD STUDENT



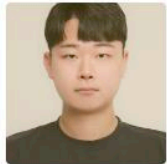
Emmanuel Ojo
(Fall 2025 -)
PHD STUDENT



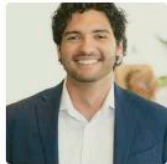
Rohin Arivudainambi
(Spring 2026 -)
UNDERGRADUATE STUDENT



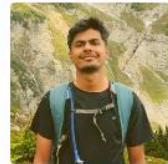
Anton Saenko
(Spring 2026 -)
UNDERGRADUATE STUDENT



Corbin Kim
(Fall 2026 -)
PHD STUDENT



Diego Mejia
(Fall 2026 -)
UNDERGRADUATE STUDENT



Aditya Timalisina
(Fall 2026 -)
PHD STUDENT

O-DSS: A. Chiejina, D. Muruganandham, V. Chaudhary, K. Chowdhury (with UT Austin, MSU)

CellSense: B. Kumar; I. K. Jain (with RPI) · **UAV on OAI / AERPAW:** S. Hossen

ORANSight-2.0; TeleSWEBench · P. Gajjar; Collaborators: A. Mamaghani and D. Bharadia (with UCSD)

AI5GTest: A. Ganiyu, P. Gajjar

Intent-to-xApp: S. B. Hashemi Natanzi, P. Gajjar, B. Tang (with WPI)

Grateful to our sponsors



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Questions?

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vijay.shah@ncsu.edu

