



# SMaRT-5G: 5G Energy Efficiency Metrics, Models, and System Tests

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# What is SMaRT-5G

- Sustainable Mobile and RAN Transformation 5G (SMaRT-5G)
- Started by ONF (Open Networking Foundation)
- Series of PoCs that demonstrate progressively advanced energy savings techniques on both Open-RAN and traditional RAN architectures
  - Create an ecosystem to help push the industry on sustainability
  - Leverage and promote open source
  - Establish an avenue to test and try new technology
- Two PoCs so far
  - Fyuz 2023 – October 2023
  - NTIA RIC Forum – March 2024
- More PoCs under planning
- **R&D Efforts on energy measurements, modeling, and metrics**
  - Funded by the National Telecommunications and Information Administration (NTIA) of the US Department of Commerce through a research grant through their Public Wireless Supply Chain Innovation Fund (PWSCIF)
  - Joint effort with Rutgers WINLAB

# A Note on Recent Organizational Changes

- ONF - US-based, operator-driven, community-led nonprofit consortium
  - Fostered innovation in software-defined programmable networks
  - Accelerated the state-of-the-art in open networking solutions leveraging open source software
    - Built and launched numerous open source projects into the ecosystem in 13 years, including SMaRT-5G
- ONF has now graduated the work into three independent projects hosted by the Linux Foundation
  - LF Broadband, **Aether**, and P4
  - The SMaRT-5G project is now under the Aether umbrella.

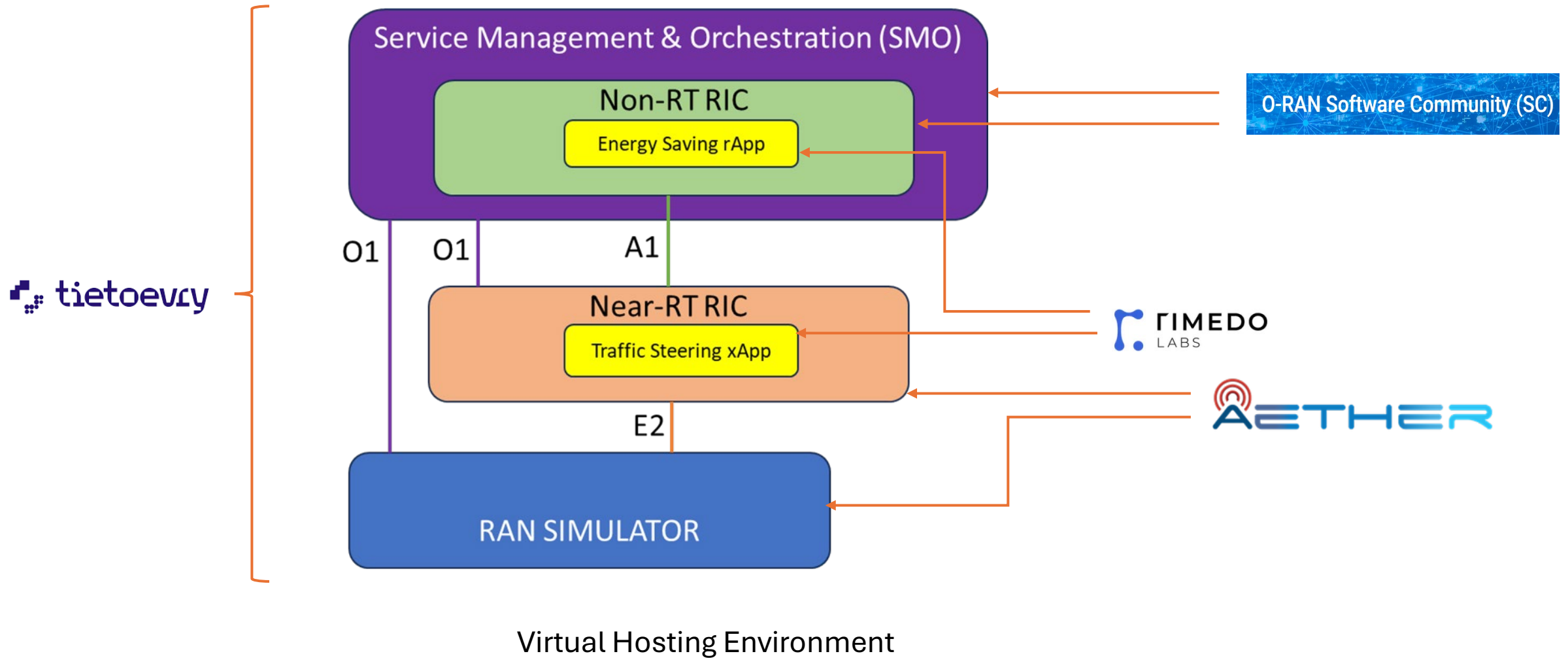


<https://aetherproject.org/>

\*Note: The NTIA grant is yet to be transferred to Aether from ONF

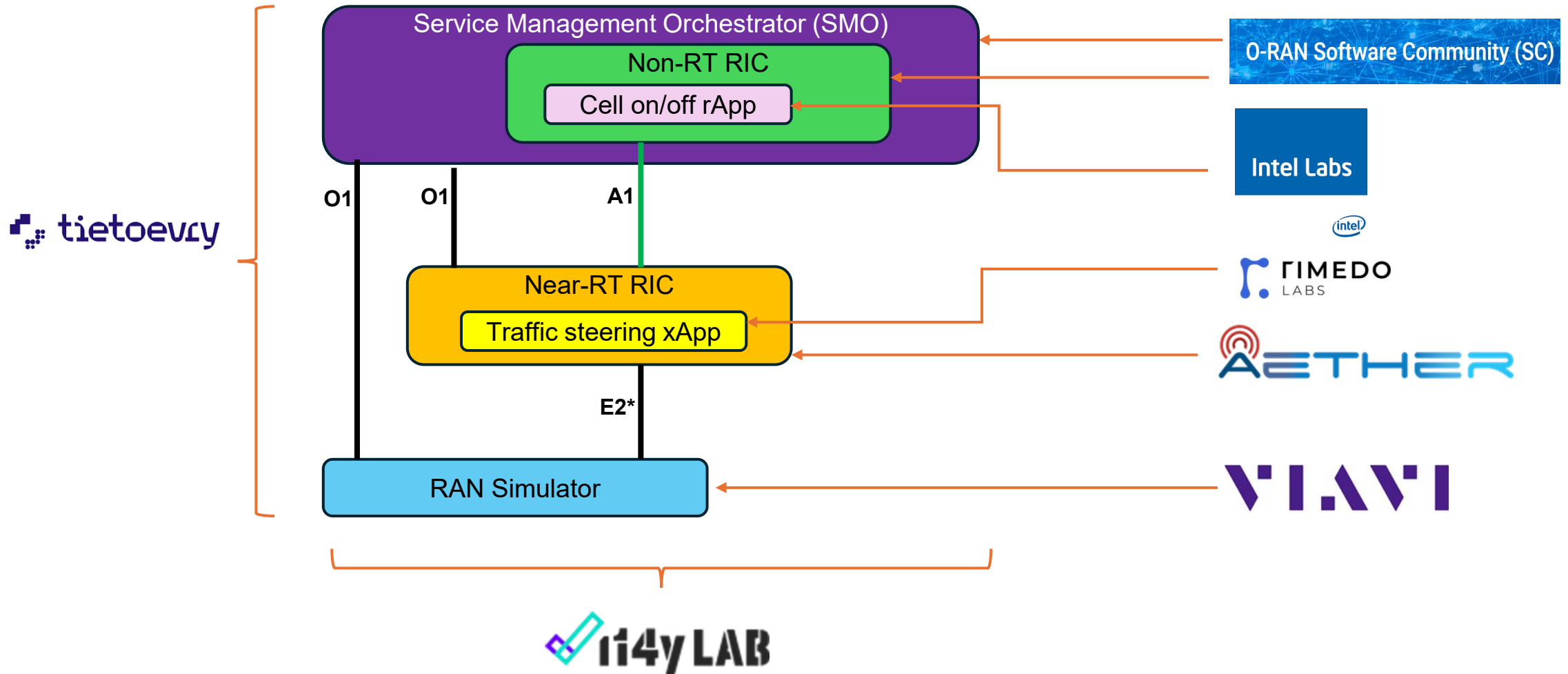
# SMaRT-5G : Fyuz 23

## Energy Saving rApp Working with Traffic Steering xApp



# SMaRT-5G : NTIA RIC Forum

AI/ML Driven Energy Saving rApp Trained Using Real Network Data Working with Traffic Steering xApp



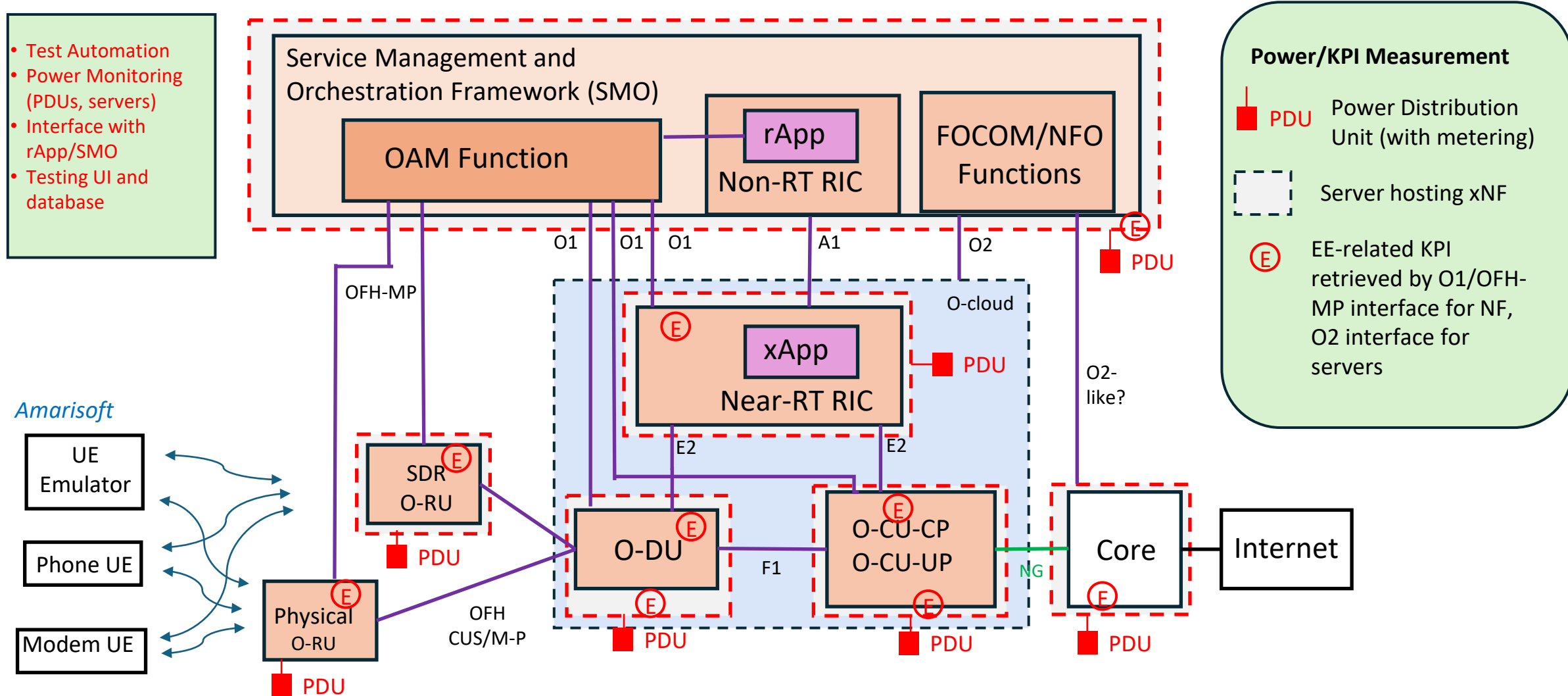
# 5G Energy Efficiency Metrics, Models, and System Tests

## Project Summary

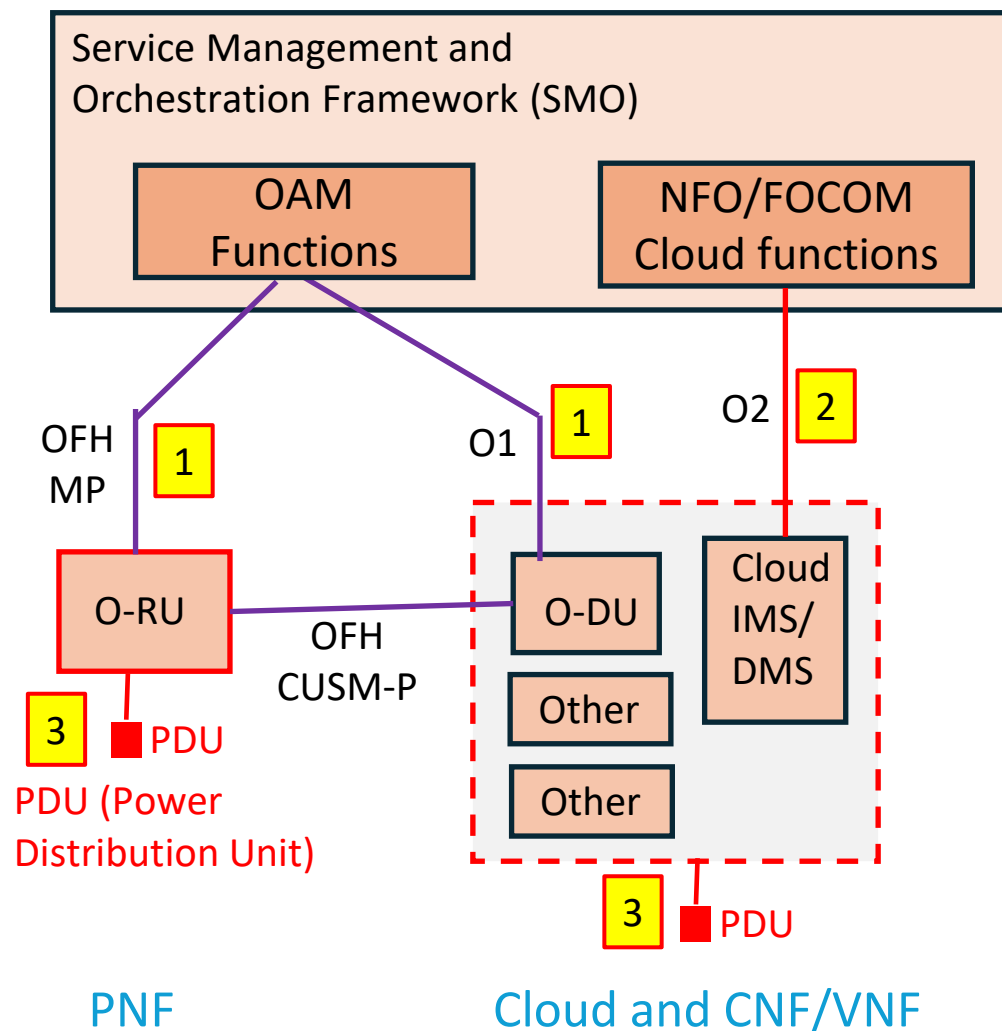
- Research, develop, and validate accurate and effective test methods:
  - To measure the energy efficiency of 5G network components
  - Effectiveness of end-to-end Open RAN energy optimization strategies
  - Joint effort with Rutgers WINLAB
- Find a minimal set of parameters and scenarios need to achieve effective results, in the context of Open RAN networks
- Experimental research conducted in an established test lab leveraging synergy with other multi-vendor Open RAN projects.
- The expected outcome is to develop and validate:
  - Innovative effective measurements for energy consumption of various RAN and core components
  - Energy consumption metrics, KPIs, APIs to be supported by RAN and core equipment
  - Energy consumption models which can be used in simulation and analytics studies, and
  - Methods to assess end-to-end energy efficiency of different algorithms and dedicated applications
- Stretch goal – SMO application/rApp which can be used to monitor and optimize energy consumption

# Test System Architecture

## POET: A Platform for O-RAN Energy Efficiency Testing



# Measurements



- Test System gathers and analyzes metrics from three sources
  - 1** Power/energy and performance metrics reported by NF over northbound interface (e.g., O1, OFH-MP)
    - power/energy for RU and PNF
    - bytes, throughput, latency, mcs, #ue, utilization etc.
  - 2** Power/energy metrics for cloud infrastructure and estimates for CNF/VNF reported over northbound interface (e.g. O2)
    - Server metrics (e.g., ipmitool)
    - Cloud tools (e.g., Kepler, Scaphandre)
  - 3** Metrics for actual power/energy supplied by PDU (power distribution unit)
- Ongoing discussion for standardization of metrics
- Will use proprietary interfaces as needed, and provide input into standards discussion

In a controlled test environment, we will also have end-to-end performance measurements from the UEs and test servers (e.g., iPerf).



# Open-Source for O-RAN Test R&D

- Open-source projects play a key role in O-RAN ecosystem innovation
- Openly accessible, pre-competitive implementation of standard, or pre-standard, reference framework
- Fosters use of software best practices and innovation
  - Especially important for cloud-native and disaggregated systems
- Enabler for research, pre-standards/standards collaboration
- Enabler for university hands-on education, pipeline of talent pool, workforce training
- Enabler for innovation in rApp/xApp ecosystem
- Provides insights and input for standardization
- Only viable option for reference implementation in multiple labs

POET is using/plan to use open source from OAI, Aether, srsRAN, and O-RAN Software Community

# Initial Series of Tests

- Testing under different user traffic and load scenarios
  - Number of UEs, traffic load, types of load, MCS values etc.
- Different radio scenarios
  - Frequency bands, channel bandwidth, path loss, MIMO modes, etc.
  - Physical RUs and SDR-based RUs
- Different types of O-RU (e.g., indoor/outdoor,)
- Different server architectures (e.g., with and without accelerators)
- Automated scenario creation and associated data collection
- Multi-pronged approach for energy/performance data collection
  - Monitored PDUs – collect energy measurements supplied to the equipment
  - Server energy measurements where VNF/CNF (CU, DU etc.) are run
  - Collect energy/performance measurements reported by the NF (over O1, O2 or other NBI etc)
- Once the data is collected:
  - Analyze it, and develop KPIs and energy consumption model(s)
    - Key set of variables affecting energy consumptions
    - How these variables are affecting energy consumption

# Energy Efficiency

*EE* (Energy Efficiency):

$$EE = \frac{\text{Desired network performance}}{\text{Energy consumed in relevant portion of network}}$$

- For the energy consumption (denominator) we plan to measure power consumption and energy consumption using the multi-pronged approach
- The desired network performance is a “loaded term” - depending on the context
- MNOs broadly use throughput, accessibility and retainability to measure performance.
- However, EE metric may be influenced by factors such as
  - Channel efficiency (e.g., MCS distribution)
  - Fairness criteria (e.g., cell-edge performance)
  - Traffic mix (e.g., video versus file transfer) ..... etc.
- We plan to collect various performance measures and explore their correlations to energy efficiency

# Performance Measurements

- For the network performance, collect performance measures:
  - Number of UEs / RRC connections per cell
  - PRB utilization per cell
  - DL and UL throughput (Mbps) per cell and per UE
  - DL and UL data volume (bytes) per cell and per UE
  - Latency: per UE and aggregate across UEs per cell
  - MCS value: per UE and aggregate across cell
  - Characteristics of UE traffic mix
  - System hardware resources
- Explore all correlations with energy consumption to improve measurement and testing strategies

# Community Engagement

- The program details, its scope, relevance and importance have been socialized in various industry forums such as:
  - Aether SMaRT-5G initiative
  - O-RAN Interest groups and its members
    - SuFG – Sustainability Focus Group, esp. Task Group TG2 on Energy Measurements
    - TIFG – Test and Integration Focus Group, esp. Test Task Group
    - Working Groups (WG6, WG4, WG1 etc.)
  - Open Air Interface (OAI)
  - O-RAN Software Community (open source for O-RAN)
- Seeking collaboration and laying groundwork for future adoption
- Current collaborators include BubbleRAN and Cognizant, which more in the pipeline

Please join us !!

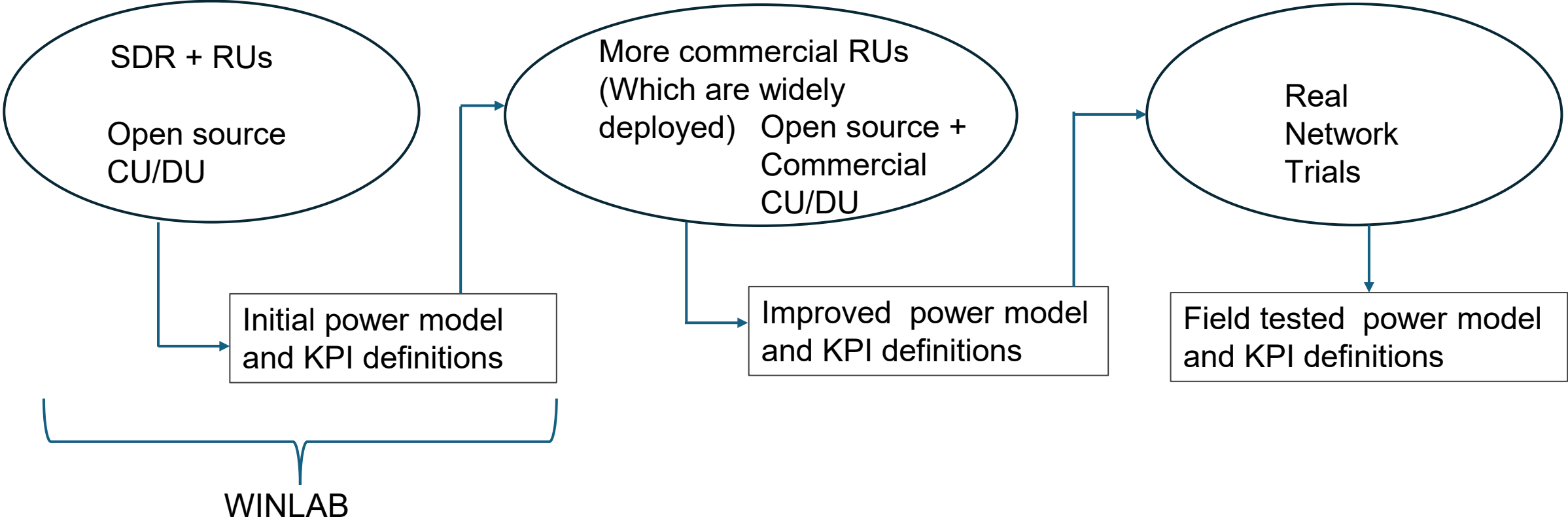
# Current Status

- Initial measurement using SDRs is done
  - Assessment and analysis underway
- In the process of integrating the first physical RU
  - Almost there!
- More RUs are being procured
- Discussions with NTIA funded labs like ORCID to expand measurements

A paper “POET: A Platform for O-RAN Energy Efficiency Testing” is accepted at the RitiRAN Workshop – IEEE VTC Fall 2024 Conference.

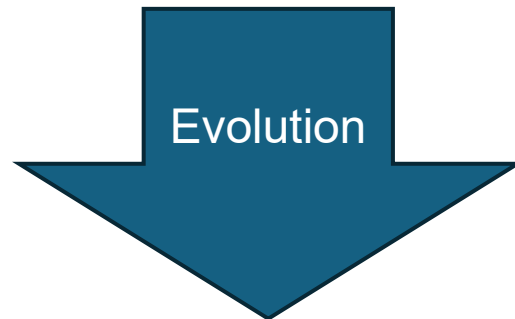
See the article: <https://www.rcrwireless.com/20240828/5g/5g-energy-efficiency-metrics-models-and-system-tests-reader-forum>

# Evolution Path – Validation with Real Network

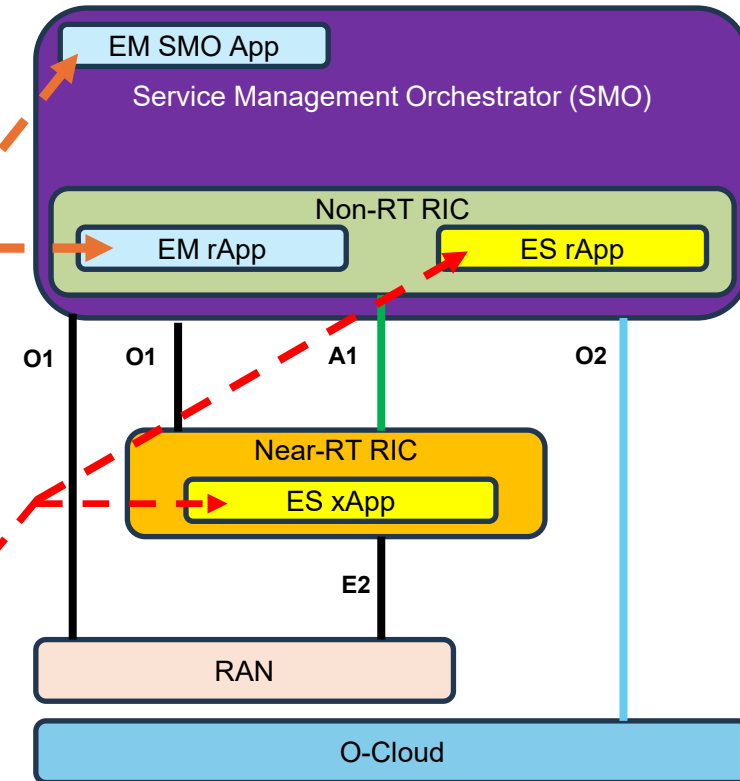


# Evolution Path – Develop Energy Management/Optimization Capabilities Using R&D Results

- Create a power model (scope of the current work):
  - Energy consumption =  $f(\text{parameter-1}, \text{parameter-2}, \dots, \text{parameter-n})$ 
    - May not be a simple function, could be an algorithm



- Use the model and associated results to:
  - Monitor and assess energy efficiency of the network
    - EM rApp or EM “SMO app”
  - Create energy optimization RIC applications (ES x/rApps)



**This will bring the full benefits of the current R&D effort to the industry**



Thank you!