

Towards frictionless reproducibility in the POWDER platform

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https://powderwireless.net

NSF award: # 1827940



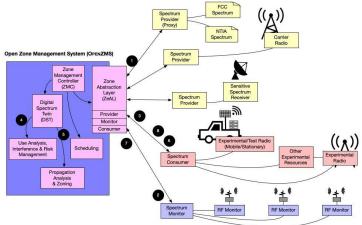




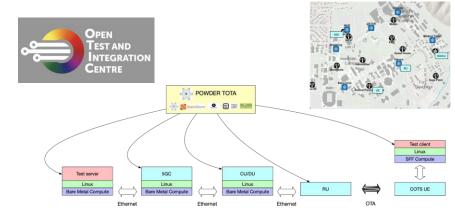


POWDER Ecosystem Overview

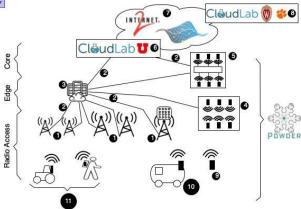




POWDER Radio Dynamic Zone (RDZ)



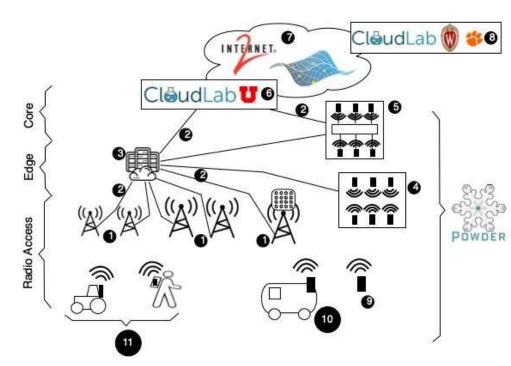
POWDER Open RAN Open Test and Integration Center (OTIC)



POWDER Platform

Basestation (rooftop, mMIMO, dense), (2) Fiber front/backhaul,
 Near Edge Compute, (4) Indoor OTA Lab,
 Controlled RF Lab, (6) Edge/Metro Compute,
 WAN connectivity, (8) Remote cloud, (9) Fixed Endpoint,
 Predictable courier w/ endpoint, (11) Other courier w/endpoint





- Remotely accessible research infrastructure for mobile and wireless research
- Used for fundamental research (academic/non-academic) & testing/development & teaching
- Key features:
 - Variety of hardware building blocks deployed in lab & outdoors
 - Variety of compatible ready-to-run open source software stacks
 - Sophisticated experimental control framework/experimental workflow
 - FCC Innovation Zone
 - BYOD/BYOS capabilities

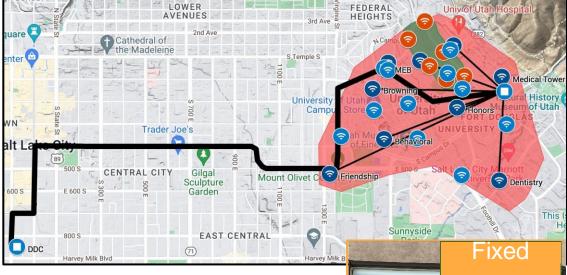
Highly ffexible real-world lab-as-a-service

(1) Basestation (rooftop, mMIMO, dense), (2) Fiber front/backhaul, (2) Near Edge Computer (4) Indeer OTA Lab

- (3) Near Edge Compute, (4) Indoor OTA Lab,
- (5) Controlled RF Lab, (6) Edge/Metro Compute,
- (7) WAN connectivity, (8) Remote cloud, (9) Fixed Endpoint,
- (10) Predictable courier w/ endpoint, (11) Other courier w/endpoint

















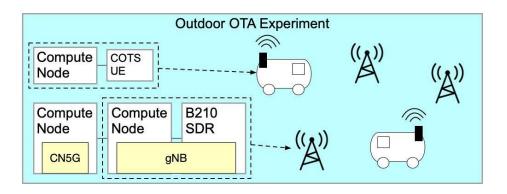


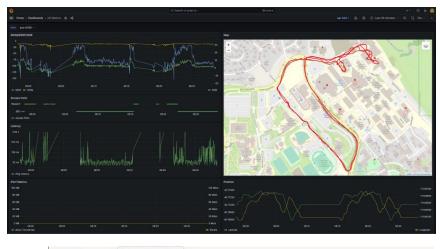


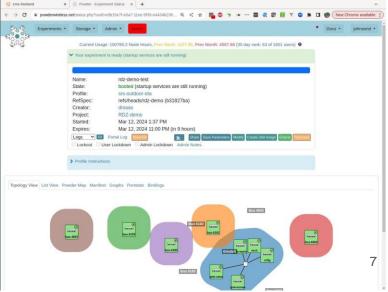
Illustrative example

From "nothing" to operational 5G network in less than 10 minutes

- Operating over-the-air
- With open source building blocks
- Remote access to user equipment on campus shuttle
- Data being collected for analysis







Test Case

Management System

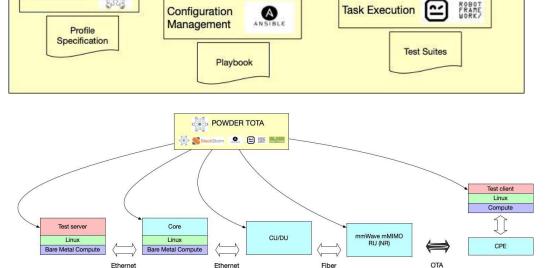
Test Cases

P

Kiwi TCMS

- O-RAN Alliance Open Test and Integration Center (OTIC)
- Open RAN & 5G/NextG related testing
 - E2E and functional testing 0
- Developed Testing Orchestration & Testing Automation (TOTA) framework
 - Integrates with POWDER to "orchestrate" test setup
 - Interact with commercial/open source 0 tools to "automate" testing

Sophisticated 5G/NextG/Open RAN testing environment



Fronthaul

(4)

(3)



Testing Workflow

(2)

Workflow Engine StackStorm StackStorm

Ethernet

POWDER API





Illustrative examples

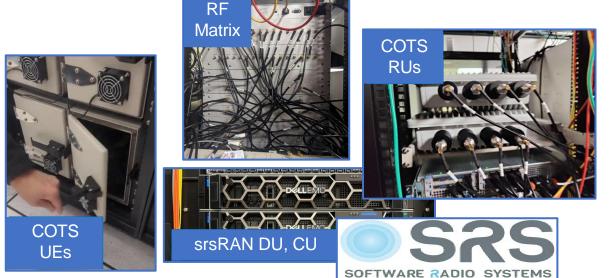
- Private-5G vendor (Celona) using POWDER for handover testing in real world environment
- O-RAN vendor (Mavenir) using POWDER for 5G mMIMO mmWave testing
- Handover testing with COTS RU and open source CU/DU (srsRAN + Benetel)

Mix of BYOD + POWDER equipment

Using POWDER TOTA workflow







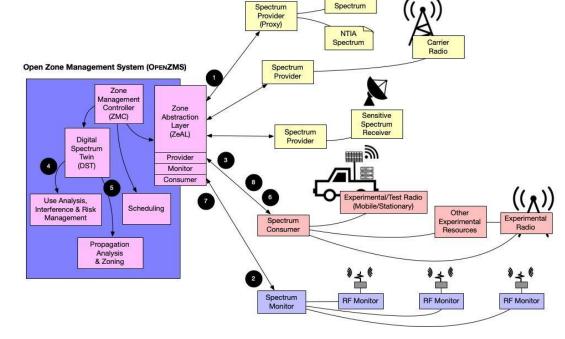




FCC

- Use POWDER to prototype a radio dynamic zone (RDZ)
- Explore use cases and workflows to define software architecture: roles, interfaces, APIs
- Build an open source Zone Management System (*OpenZMS*)
 - Separate from POWDER: well-defined interface to integrate at any facility
- POWDER-RDZ: use OpenZMS to manage spectrum for POWDER

Operational (prototype) RDZ

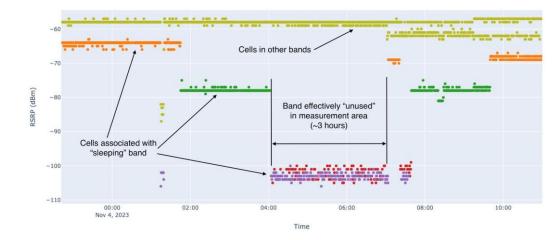


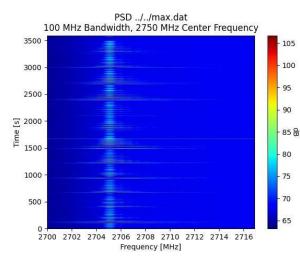




Illustrative examples

- POWDER spectrum access:
 - Program experimental license (PEL)
 - FCC Innovation Zone
 - \circ $\;$ Allowed to use, but not interfere
- OpenZMS:
 - Operational spectral intelligence and management
 - More on PEL coming up
- Other use cases ->
 - Sharing with commercial provider
 - Sharing with federal radar systems



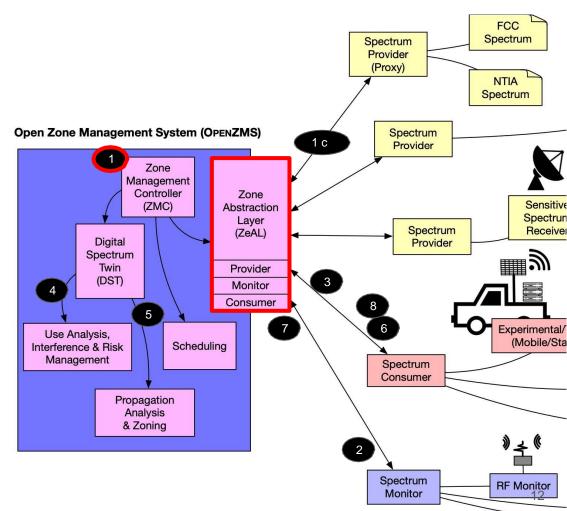






Program Experimental License (PEL)

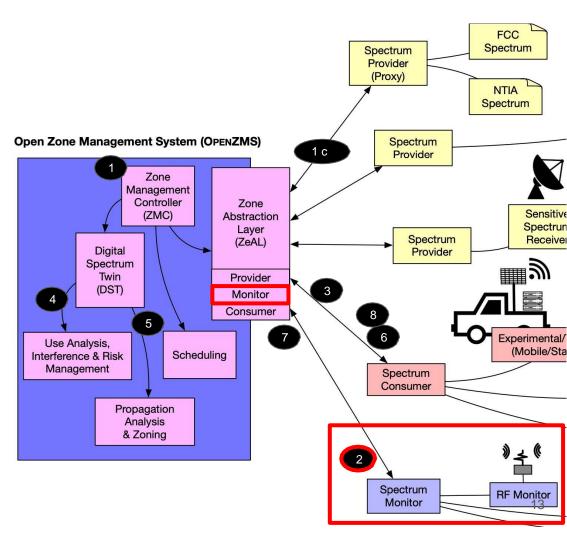
- a. Role/element player registration
- b. Initial RDZ geography, models
- c. Spectrum available through PEL





Program Experimental License (PEL)

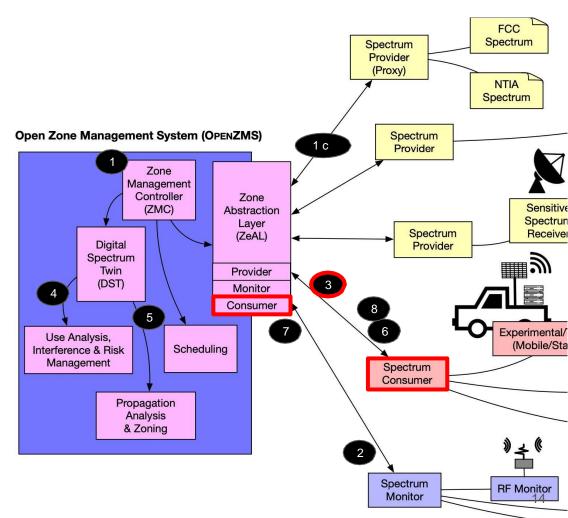
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- 2. ZMS observes PEL spectrum range (monitor), data into DST (in ZMS)





Program Experimental License (PEL)

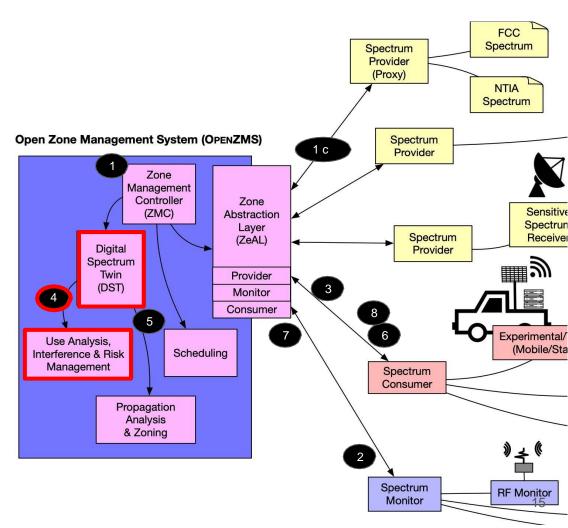
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- 3. Request to use spectrum from platform (consumer) (X MHz in range Y-Z MHz)





Program Experimental License (PEL)

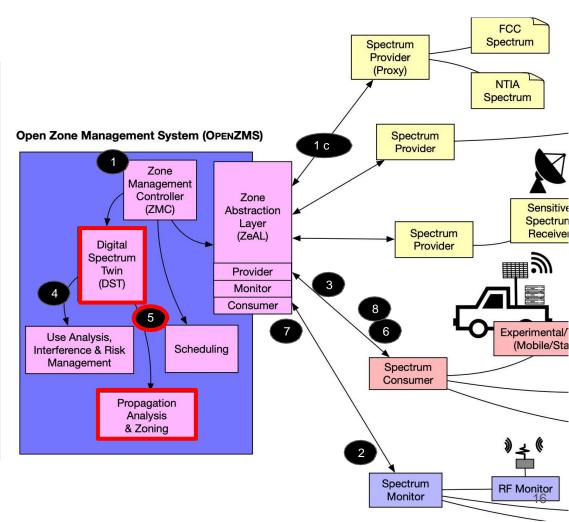
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- 4. Use monitor data to determine if/where request fits (in ZMS)





Program Experimental License (PEL)

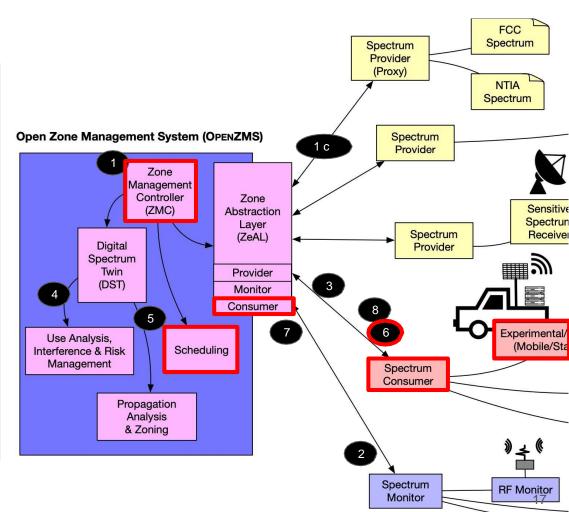
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- 3. Request to use spectrum from platform *(consumer)* (X MHz in range Y-Z MHz)
- 4. Use monitor data to determine if/where request fits (in ZMS)
- 5. Use propagation analysis to ensure test will not interfere outside RDZ (in ZMS)





Program Experimental License (PEL)

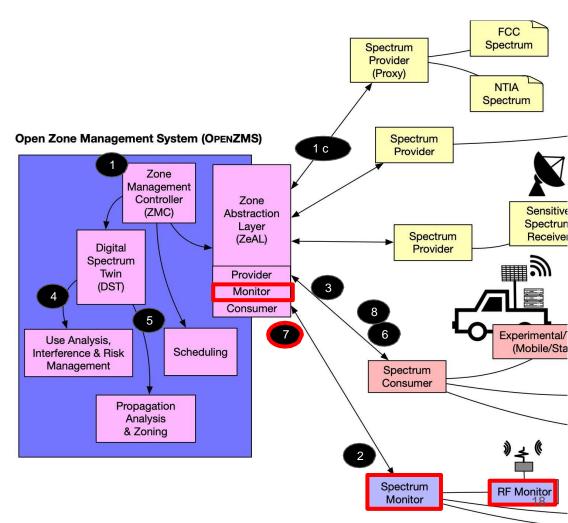
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- 3. Request to use spectrum from platform *(consumer)* (X MHz in range Y-Z MHz)
- 4. Use monitor data to determine if/where request fits (in ZMS)
- 5. Use propagation analysis to ensure test will not interfere outside RDZ *(in ZMS)*
- 6. Notify platform (consumer) to proceed





Program Experimental License (PEL)

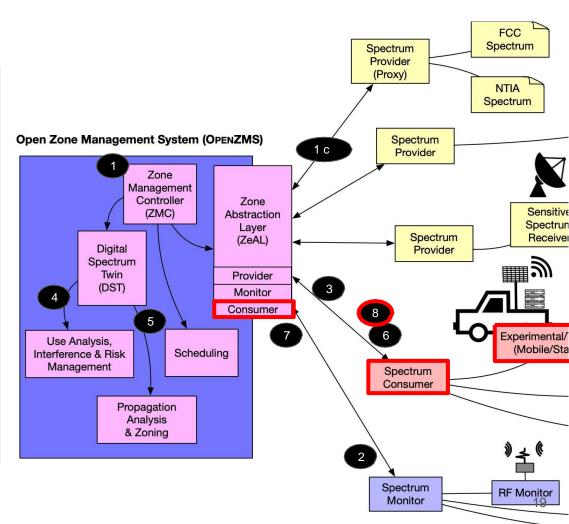
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- 4. Use monitor data to determine if/where request fits (in ZMS)
- 5. Use propagation analysis to ensure test will not interfere outside RDZ *(in ZMS)*
- 6. Notify platform (consumer) to proceed
- 7. If spectrum monitor (monitor) indicates interference...





Program Experimental License (PEL)

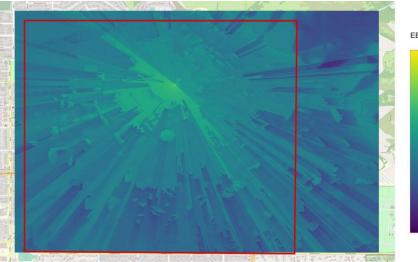
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- 3. Request to use spectrum from platform *(consumer)* (X MHz in range Y-Z MHz)
- 4. Use monitor data to determine if/where request fits (in ZMS)
- 5. Use propagation analysis to ensure test will not interfere outside RDZ *(in ZMS)*
- 6. Notify platform (consumer) to proceed
- 7. If spectrum monitor *(monitor)* indicates interference...
- 8. ...Instruct platform (consumer) to terminate transmission



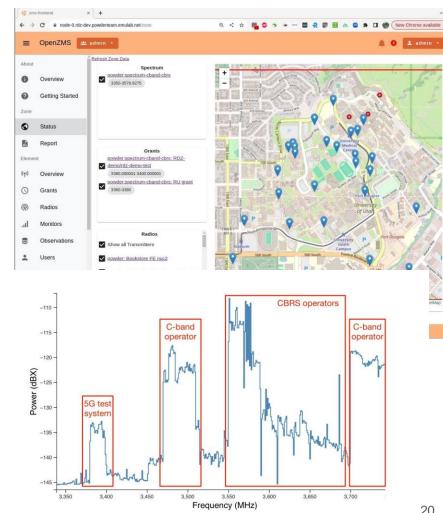


OpenZMS:

- Ensures test transmitter does not interfere outside RDZ
- Uses monitor data to schedule test transmitter grant in unoccupied spectrum







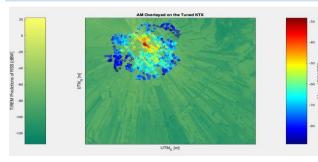
Digital Spectrum Twin Architecture

Georgia POWDER-RDZ: Digital Spectrum Twin

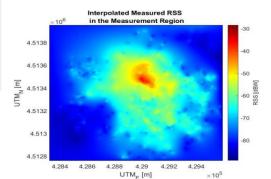
Digital spectrum twin (DST):

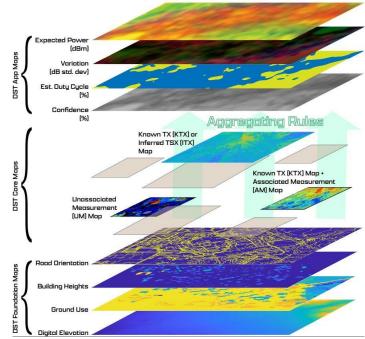
- Based on TIREM plus enhancements:
 - Full DST life cycle
- Detailed topology maps of POWDER environment ("foundation maps")
- Improving prediction accuracy using measurement data ("core maps")
- Developing "application maps"
 - \circ E.g., expected power for different RDZ scenarios

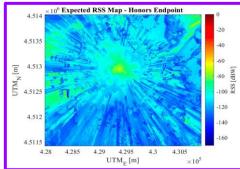
(Also using Altair Feko)



Source: Serhat Tadik and Greg Durgin (Georgia Tech)

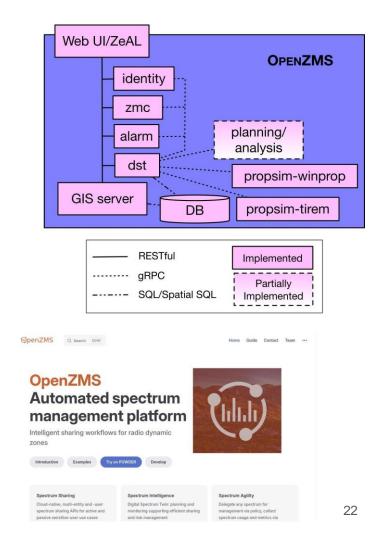








- POWDER-RDZ is available, pre-release: <u>https://powderwireless.net</u>
 - Use via POWDER experiments
- OpenZMS: <u>https://openzms.net</u>
 - Test-drive on POWDER; or manually deploy (pre-release, early adoption)
 - Heavy development: sharing (efficiency, parallelism), monitoring/detection, RFI mitigations
 - Deployed at Hat Creek Radio Observatory (collaboration with CU Boulder) in March 2024

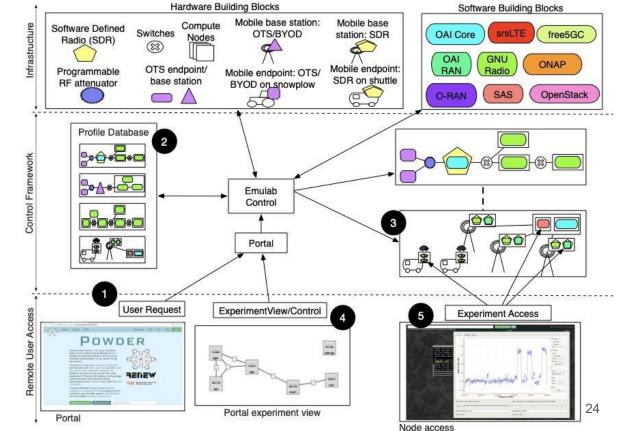




Towards frictionless reproducibility

POWDER concepts and workflow

- Hardware and software "building blocks"
- *Profile* mechanism:
 - "Recipe" to combine building blocks into an E2E experiment
- Basic workflow:
 - Access portal & select profile
 - Select profile parameters
 - POWDER control framework
 "instantiates" profile into running experiment
 - On-demand, or scheduled when resources become available
 - Configures experiment as specified in profile
 - User access experiment resources (remotely)



POWDER concepts and workflow

More on profiles:

- Request required resources (radios, servers, spectrum...)
- Describe experiment configuration (network, software, config scripts...)
- Parameterizable, version controlled; git repo backed;
- Means to create sophisticated E2E experiments
- Instantiate via graphical user interface or through programmatic API POWDER provided:
- - "library" of parameterized Ο ready-to-run profiles (srsRAN, OpenAirInterface, Open RAN, RF measurement)
- User created:
 - from scratch, fork POWDER Ο provided..

All the examples and use cases described earlier are realized through profiles

Primary reproducibility mechanism in POWDER



POWDER experimental workflow



Selected Profile: oai-outdoor-ota (Repo: 05b2fdf1, refs/heads/master)

OAI 5G w/ Open5GS using the POWDER Dense Deployment

This profile deploys a 5G core and radio access network using the following components:

Open5GS core network: All of the core network functions (AMF, SMF, UPF, etc.) are deployed to a single compute node with LAN connections to the gNodeBs in the experiment. The NFs are wrapped in system services and automatically started when you instantiate your experiment.

One or more OpenAirInterface gNodeBs: The gNB soft-modems are deployed to NUC i7 compute nodes paired with NI B210 SDRs. Each SDR is connected to a custom medium-power TDD RF front end capable of operating from 3358-3600 MHz.

An orchestration node (optional): This node is currently used to aggregate time-coherent logs for all of the relevant processes in the 5G network. Promtail is used to push relevant logs from other nodes in this experiment to the Loki instance running on this node, and Grafana is used to present logs/data via a web interface.

It is designed to be used with this Mobile Endpoints profile, which instantiates an experiment with 5G COTS UEs deployed to campus shuttles that operate in and around the Dense Deployment sites.

Note: This profile currently requires the use of the 3410-3450 MHz spectrum range and you need an approved reservation for this spectrum in order to use it. It's also strongly recommended that you include the following necessary resources in your reservation to gaurantee their availability at the time of your experiment:

2x d430 compute nodes to host the core network and orchestrator The set of the Dense Deployment sites you plan to use POWDER mobile endpoints

If you want your experiment to run for more than a single day, you'll need to make separate single-day reservations for the mobile endpoints, since the maximum reservation duration for those is one day.

Finally, the mobility of the campus shuttles that host the COTS UEs and the medium-power RF front ends used in the Dense Deployment mean that some links may be short-lived (< 30 s in duration); others may last a few minutes. Link quality and duration will depend on the shuttle route and Dense Deployment site in question. Some routes will not pass close enough to close links at every dense deployment site.

Show Profile

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Next



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			Please	Optional	s below and then cli	ck Next.				

Check Resource Availability

PowderTeam -

Project:

Advanced Options

Click Node to Select	gnb-ustar gnb-maria orch gnb-guesthouse cn5g
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Ev3.	Experiments *	Storage *				Docs •
Eng		1. Select a Profile	2. Parameterize	3. Finalize	4. Schedule	

You have requested radio spectrum and/or use of specialized Powder resources in your profile. If you do not have a reservation for it, you may want to create one; spectrum and other specialized equipment are scarce resources and may not be immediately available. If you do make a reservation, you will want to be sure to schedule the start of this experiment to coincide with the start of your reservation(s). Please click on *Create New Resource Reservation* to create a new reservation.

You may also set the termination time of your experiment to coincide with the end of your reservation(s), so that you do not have to remember to extend your experiment.

Sta	rt on date/time (optional) 0	
06/24/2024	Time	
End	d on date/time (optional) 9	
MM/DD/YYYY	Time	

Previous

Finish

kobus



View Source View XML

Repository https://gitlab.flux.utah.edu/dmaas/srs-outdoor-ota.git

Description

srsRAN 5G w/ Open5GS CN5G using the POWDER Dense Deployment

This profile deploys a 5G core and radio access network using the following components:

- Open5GS core network: All of the core network functions (AMF, SMF, UPF, etc.) are deployed to a single compute node with LAN connections to the gNodeBs in the experiment. The NFs are wrapped in system services and automatically started when you instantiate your experiment.
- One or more srsRAN gNodeBs: The gNB soft-modems are deployed to NUC i7 compute nodes paired with NI B210 SDRs. Each SDR is connected to a custom medium-power TDD RF front end capable of operating from 3358-3600 MHz.
- An orchestration node (optional): This node is currently used to aggregate time-coherent logs for all of the relevant processes in the 5G network. Promtail is used to push relevant

Topology Visualize View Source View XML

Repository https://gitlab.flux.utah.edu/dmaas/mobile-endpoints.git

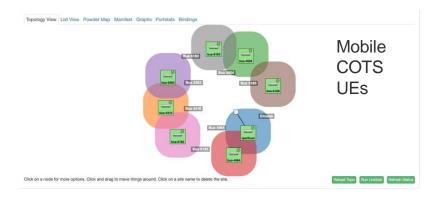
Description Mobile Endpoints for LTE/5G Experiments

POWDER provides a number of mobile endpoints deployed to university campus shuttles. In addition to other tools and SDRs, these mobile endpoints are equipped with LTE/5G modems that are capable of attaching to networks that include gNodeBs running at POWDER Dense Deployment sites.

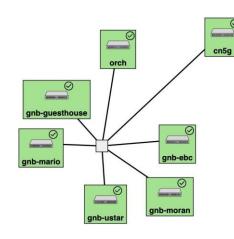
This profile instantiates an exeriment that includes all of the currently available mobile endpoints traversing routes that come near one or more Dense Deployment sites. It is primarily intended to be run in conjunction with one of our outdoor 5G profiles:

- OAl Outdoor 5G
- srsRAN Project Outdoor 5G

You'll need to instantiate one of these, or something similar, before you instantiate this profile if you want the UEs to attach to a 5G network. In fact, in its default configuration, this



5G RAN + Core





Different core + RAN profiles for private 5G vendor + same mobile endpoint profile



Topology Visualize View Source View XML

Repository https://gitlab.flux.utah.edu/dmaas/mobile-endpoints.git

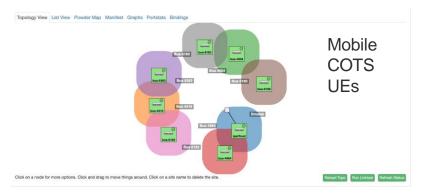
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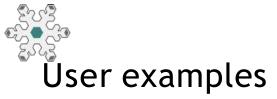
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ACM MobiCom paper: Mahesh Marina and students (University of Edinburgh)

Made available as POWDER profile to community



Home > Conferences > MOBICOM > Proceedings > ACM MobiCom '23 > CoreKube: An Efficient, Autoscaling

and Resilient Mobile Core System



CoreKube: An Efficient, **Autoscaling and Resilient Mobile Core System**

Authors: 🔔 Jon Larrea, 🔔 Andrew E. Ferguson, Mahesh K. Marina Authors Info & Claims

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Artifact Evaluation of Corekube

In order to evaluate CoreKube as a core, we need an environment to emulate UEs and RANs that connect to it. We will use the Nervion RAN emulator (Larrea, 2021). The official Nervion Powder Profile, available as a deployment profile within the Powder Platform, will deploy both Nervion and CoreKube on Powder.

Creating an Experiment

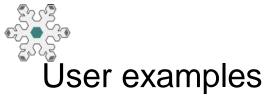
P Evaluation.md

README.md

A single-ue-ck.ison

Users need to set up a new CoreKube deployment on the Powder Platform. We assume that you have an account on the Powder Platform with your SSH public key attached.

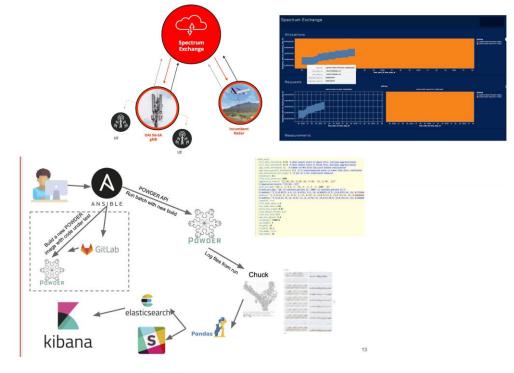




LINUX FOUNDATIO	At	out Community	Newsroom Q		
	Communi	ty (SC)			
D-RAN LIANCE	Wiki	Mailing List	Seed Code	Charter	Overview Presentation

O-RAN Software Community (OSC) (Community lab offline) Using POWDER for testing Use POWDER APIs:

- Quick setup of OSC SW components
- Run complex test scenarios



Zylinium Research

DoD funded Spectrum Sharing research Used POWDER for over-the-air (OTA) testing Use POWDER APIs:

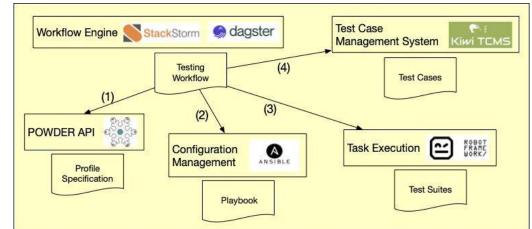
• Spinning up OTA resources as part of development/testing workflow

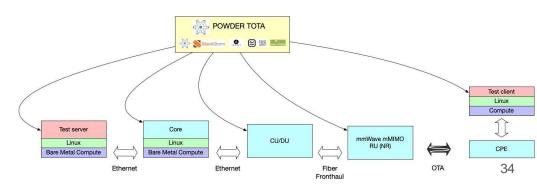


Testing example

Testing Orchestration and Testing Automation (TOTA)

- Testing Orchestration: using profile mechanism
- Testing Automation: framework of open source tools
- Workflow engine:
 - Interacts with POWDER platform (1) to orchestrate test setup (profile
 - mechanism) Uses Ansible to configure (2)components in the test setup
 - Uses Robot to execute the (3)
 - required test suite Stores results in Kiwi Test Case (4) Management System

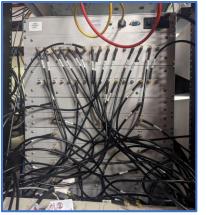




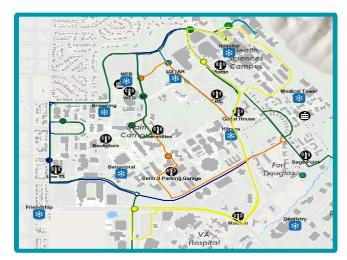


Repeatable mobility?

- Programmable conducted RF attenuator matrix
 - Repeatable, but lacks realism Ο
- Mobile endpoints on campus shuttles
 - (Sort of) repeatable, real world Ο
- Often: start conducted, then outdoor





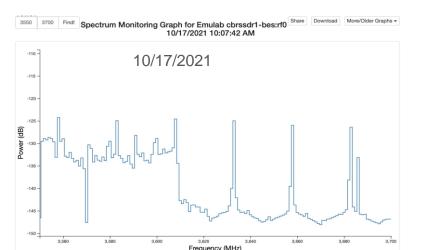


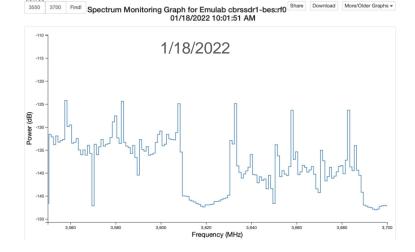


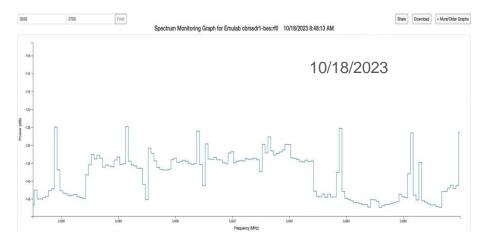


What about spectrum/RF conditions?

- Maybe:
 - Point of outdoor wireless testbed is repeatable experiments in the context of changing 0 spectrum/RF conditions?
- Still:
 - We need better "spectral intelligence"... 0
 - Can we capture the "spectral conditions" at play during an experiment?
 Can we programmatically "capture changes" in the spectral environment?
 Maybe... OpenZMS DST is a starting point
 - 0







Lessons?

What makes wireless frictionless repeatability hard?

- Changing wireless environment
- "Real world labs" are difficult to operate!
- Complex "ecosystem"
 - And testbeds are difficult to use
- "Domain science" is rapidly evolving
- Open source is great, but not necessarily mature
- Inherently cross-disciplinary
- "Stakeholders" have different interests, needs and skill levels



Thank you!



Powder (the Platform for Open Wireless Data-driven Experimental Research) is flexible infrastructure enabling a wide range of software-defined experiments on the future of wireless networks.

Powder supports software-programmable experimentation on 5G and beyond, massive MIMO, ORAN, spectrum sharing and CBRS, RF monitoring, and anything else that can be supported on software-defined radios.

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Platforms for Advanced Wireless Research





