Zone Management Systems: OpenZMS, POWDER-RDZ, HCRO-RDZ

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David DeBoer[¥], Jacobus Van der Merwe*
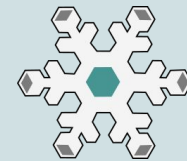
*Kahlert School of Computing, University of Utah
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[¥]University of California Berkeley, Hat Creek Radio Observatory

https://powderwireless.net   https://openzms.net   https://www.colorado.edu/lab/wirg/

Radio Dynamic Zone (RDZ)

Zone for experimental radio transmission ("opposite" of NRQZ)

- Developed by Thomas Kidd (Navy CHIPS 2018)
- A specific geographic area
- Coexisting with other spectrum users inside zone
- No spill over, protect receivers outside from special transmitters inside zone
- Allow experimental systems pushing boundaries of radio technology
- RDZ operations: tools, intelligence, hardware

NRQZ
Passive Radio Astronomy

Cellular Deployments

RDZ

CBRS
SAS
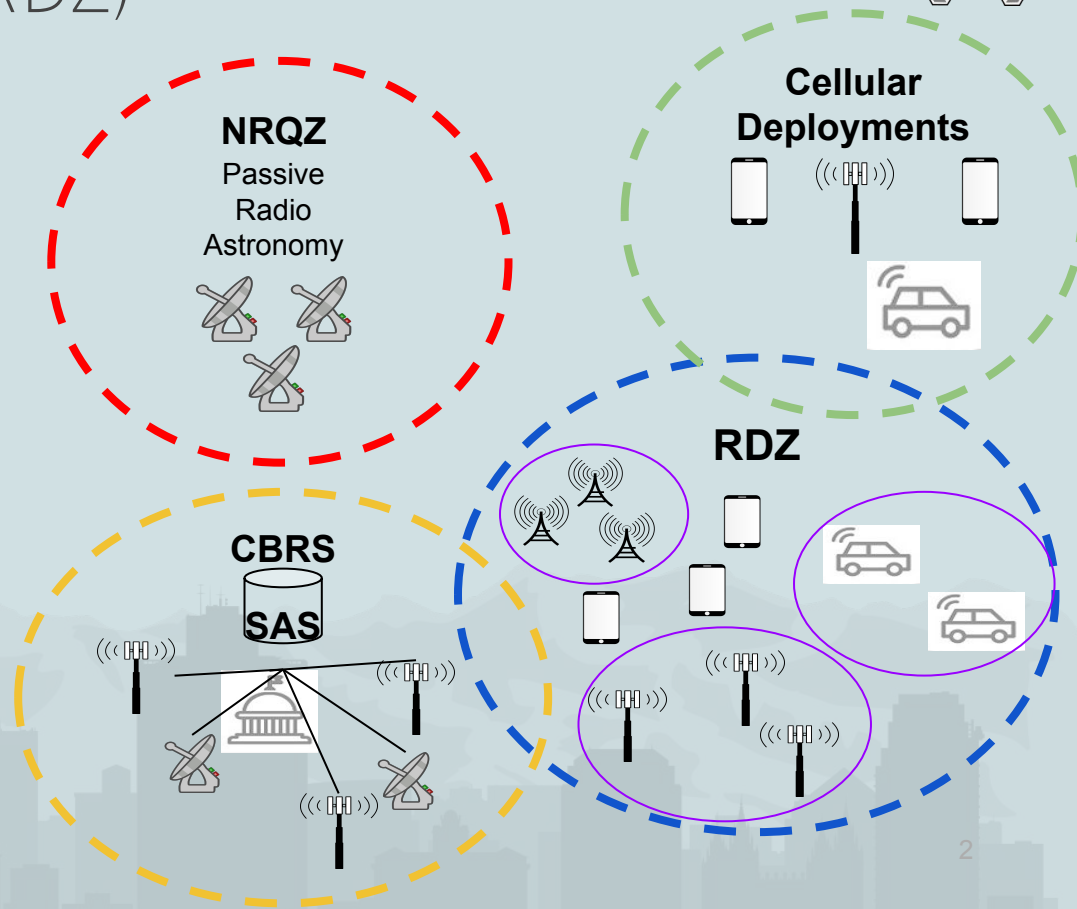
OpenZMS

- A prototype *Zone Management System*
  - Automatic, dynamic spectrum management for RDZes
  - "Spectrum robot": predict, model, allocate, monitor, protect
- Open source, modular *framework*
  - Multi-party, multi-spectrum grant scheduling
  - Digital spectrum twin-based prediction, data analysis
  - Modular monitor API, developing analysis framework
  - Interference analysis, mitigation
  - Active and passive sharing use cases
  - Manage many kinds of radios, certified and experimental
- Manages POWDER-RDZ, HCRO-RDZ


Open Zone Management System (OPENZMS)
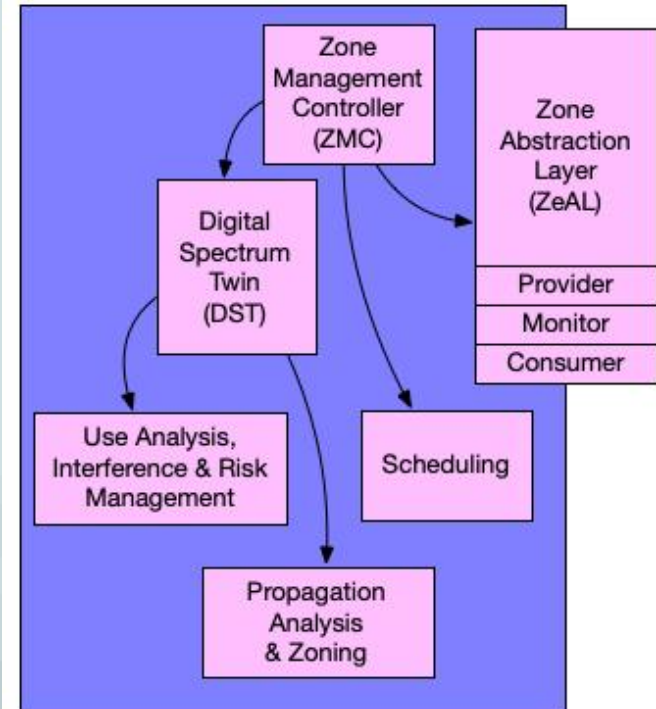
OpenZMS

- Why not use, extend CBRS/SAS, AFC/SDI?
- RDZ concept has different requirements:
  - Many kinds of spectrum sharing and testing
  - Spectrum and policy agility, interference mitigation
  - Visibility into competing use (privacy)
  - Municipal/regional deployment (more data, local policy)
 - Manage radios that do not implement a particular spectrum-sharing protocol


Open Zone Management System (OpenZMS)
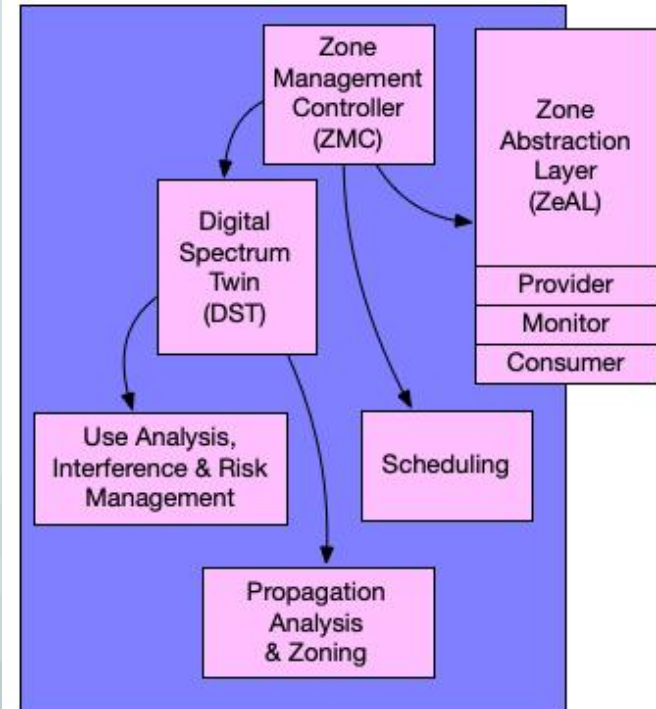
OpenZMS Implementation

- Cloud-native: loosely-coupled services, event-based flows
- Modular: new bands, analyses, mitigations
- Centralized management
  - Grants: explicit, dynamic delegations of tx/rx authority
  - Authoritative in zone: prediction, policy, enforcement, risk mitigation
- Municipal-scale deployments
  - Anticipate hierarchy and federation
  - Delegated spectrum authority, observability
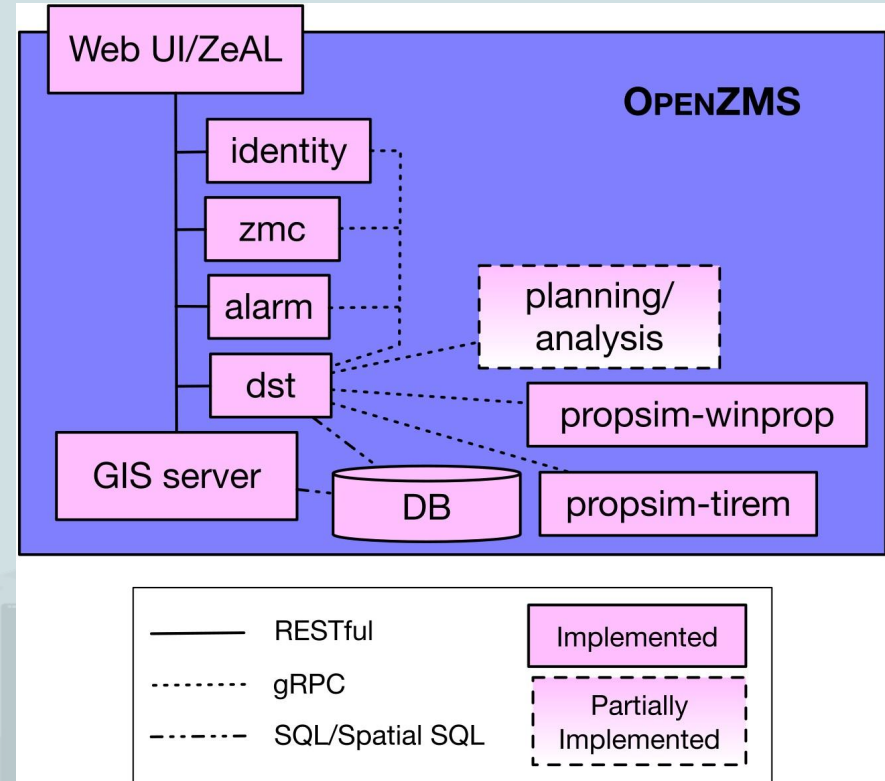
POWDER-RDZ Concept
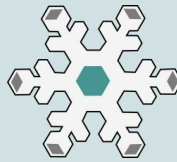
- Use POWDER to prototype a radio dynamic zone (RDZ)
- Explore use cases and workflows to define software architecture: roles, interfaces, APIs
- Deploy OpenZMS to manage spectrum for POWDER-RDZ
  - Separate from POWDER: well-defined interface to integrate at any facility
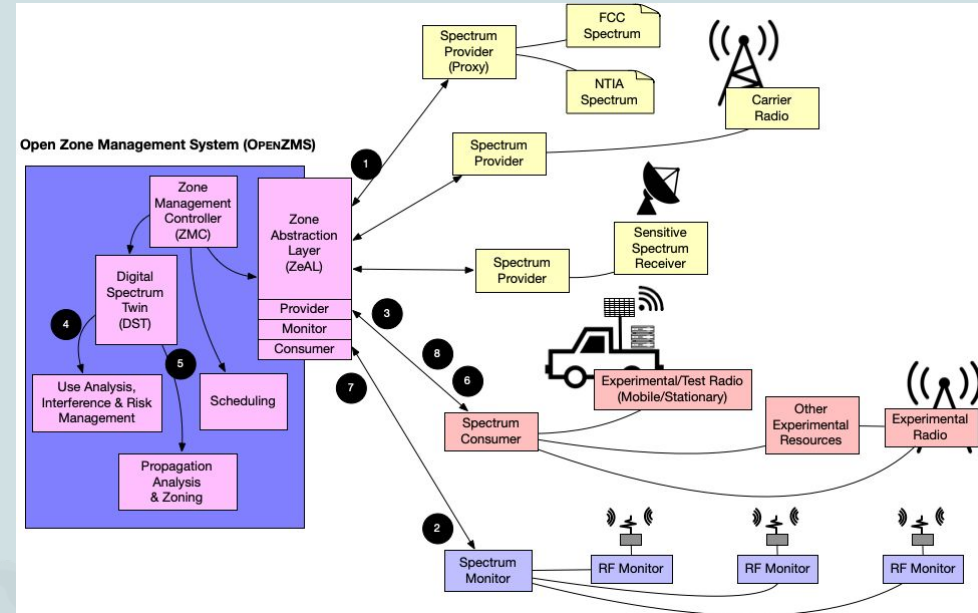
Kobus Van der Merwe
Sneha Kasera

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Neal Patwari
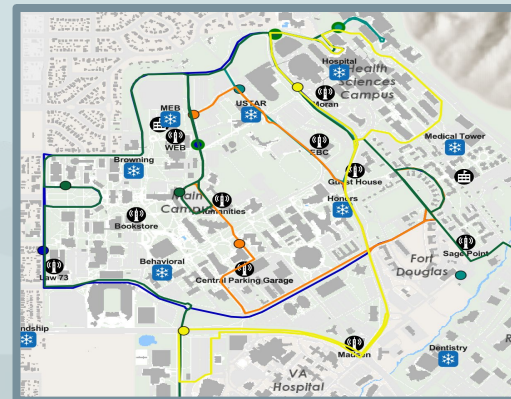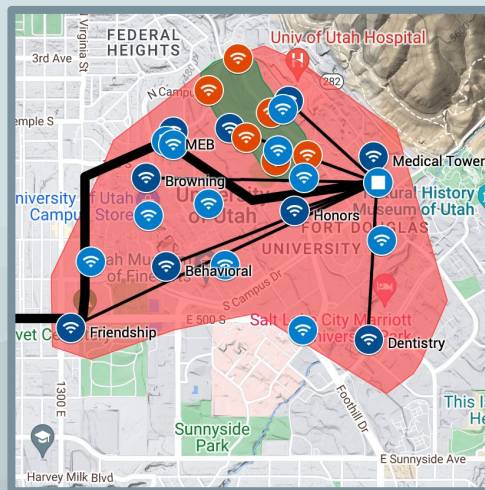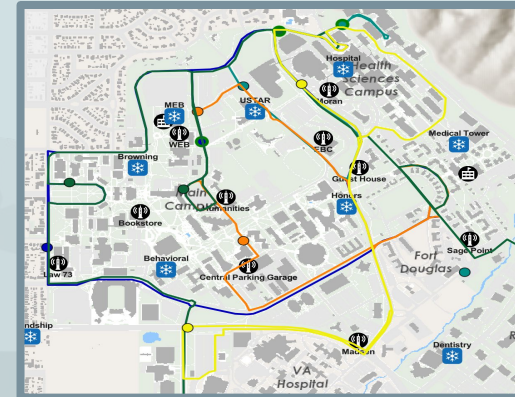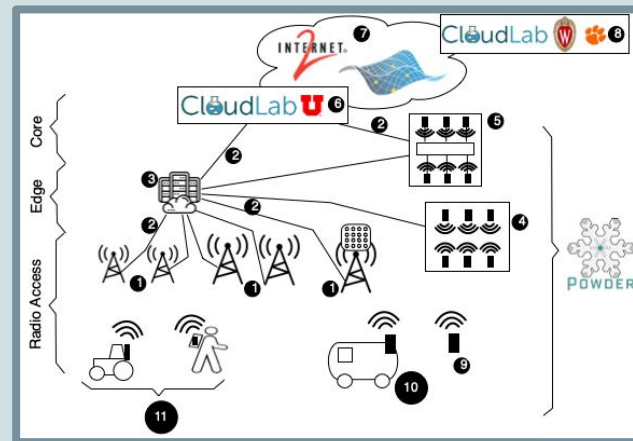
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Greg Durgin
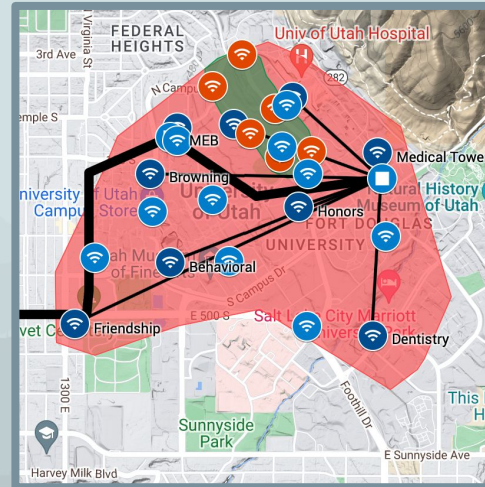
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Vijay Gopalakrishnan

POWDER-RDZ Context

- POWDER: platform, infrastructure for mobile and wireless research
  - Radio (SDR, COTS), compute, software building blocks
  - Indoor, outdoor, mobile
  - Sophisticated experiment control framework, experiment workflow

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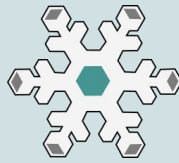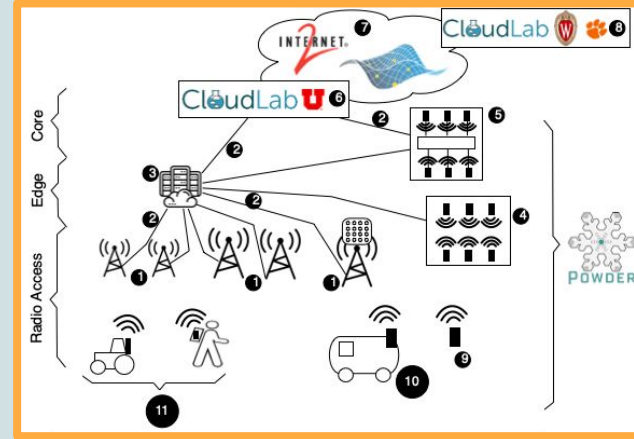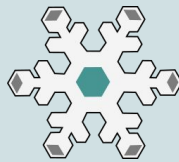
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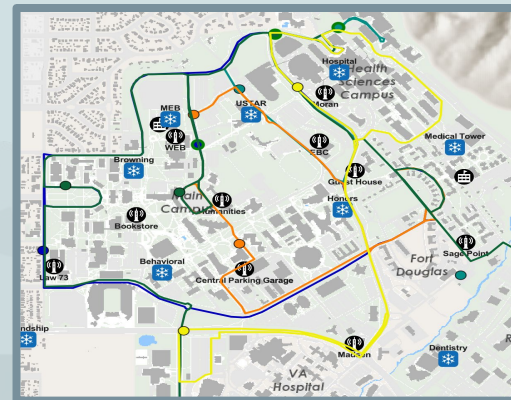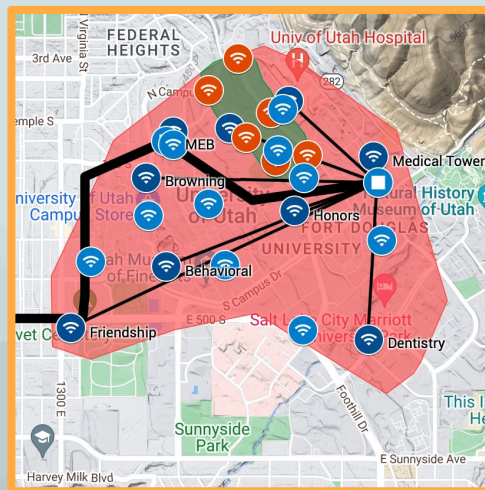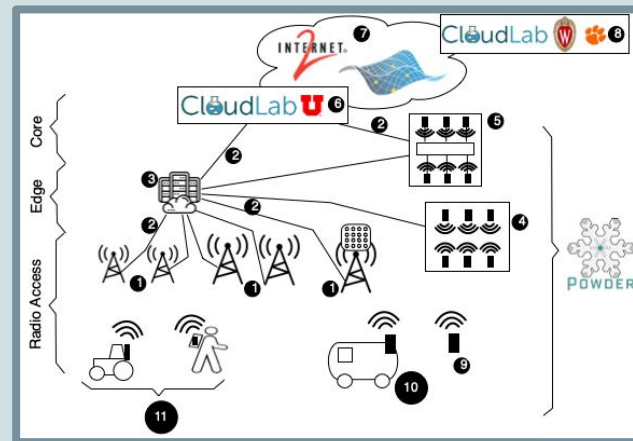
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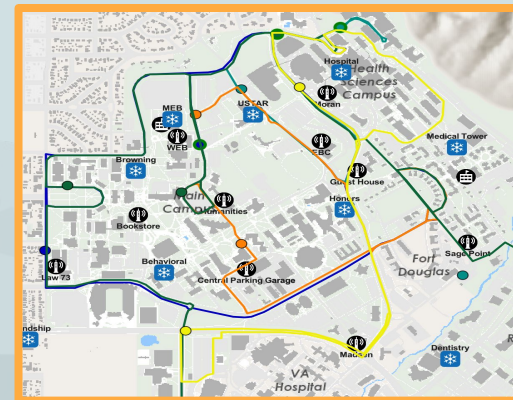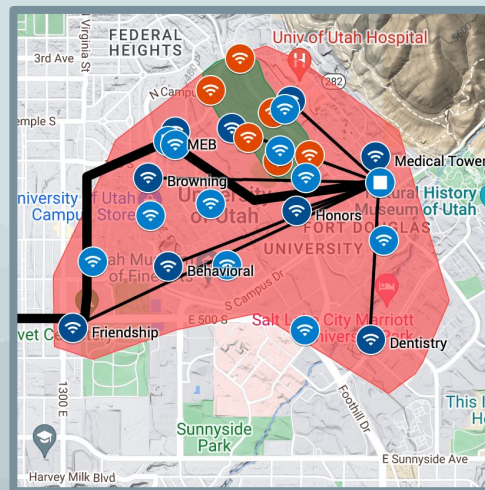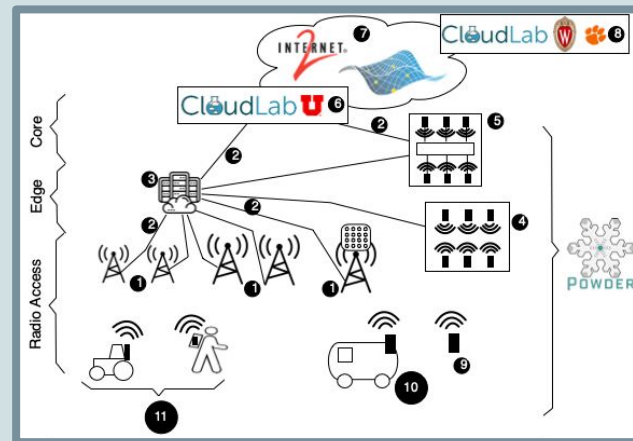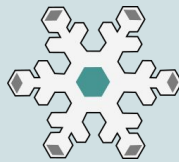
- POWDER: platform, infrastructure for mobile and wireless research
  - Radio (SDR, COTS), compute, software building blocks
  - Indoor, outdoor, mobile
  - Sophisticated experiment control framework, experiment workflow
- *Challenges:*
  - Spectrum access
    - Maintain: agility
  - Use spectrum intelligently
    - Occupancy, prediction

RDZ Architecture with OpenZMS

RDZ Role Players:
1. Zone management system: Interacts with zone participants via *Zone Abstraction Layer (ZeAL)*
2. *Spectrum Provider*: makes spectrum available to RDZ
3. *Spectrum Consumer*: uses spectrum to perform tests
4. *Spectrum Monitor*: provides ability to monitor spectrum use
   a. Spectrum Observer: stakeholder subscribing to observation reports (from monitors)

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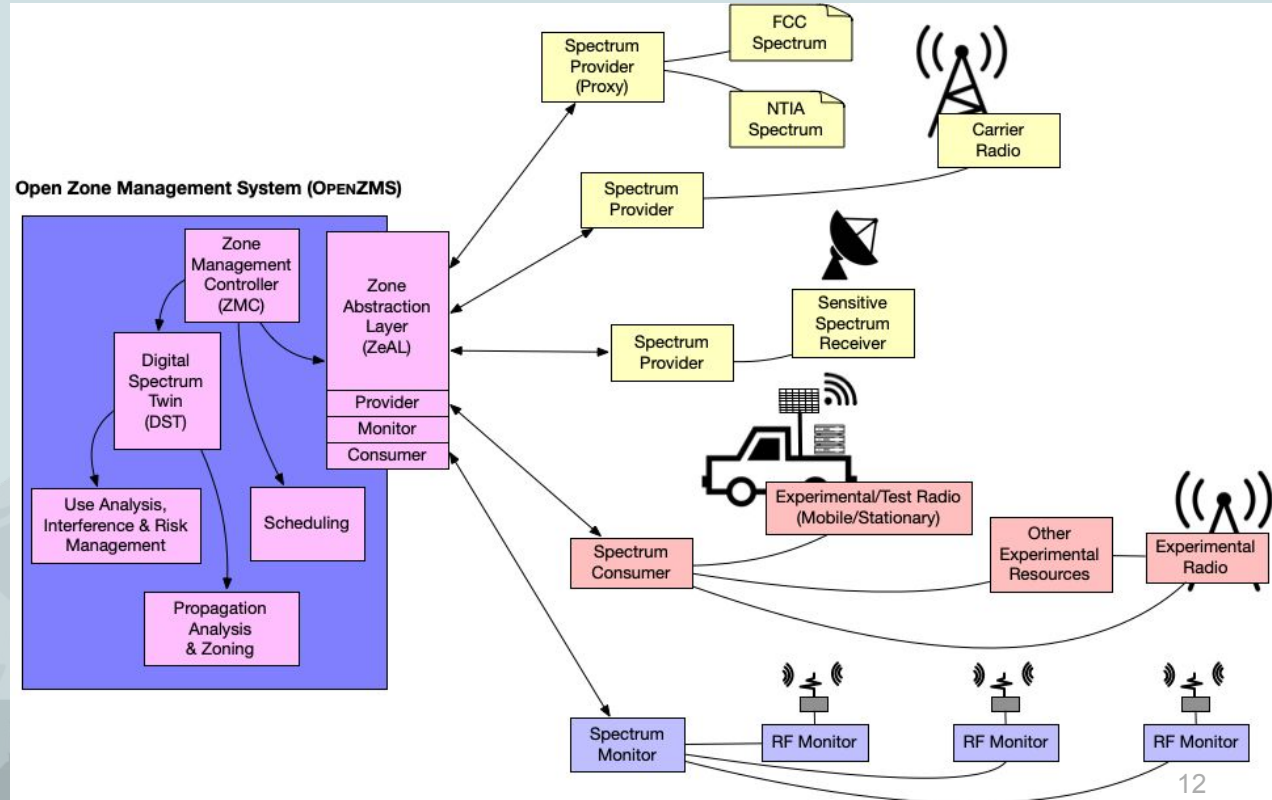   a. Spectrum Observer: stakeholder subscribing to observation reports (from monitors)

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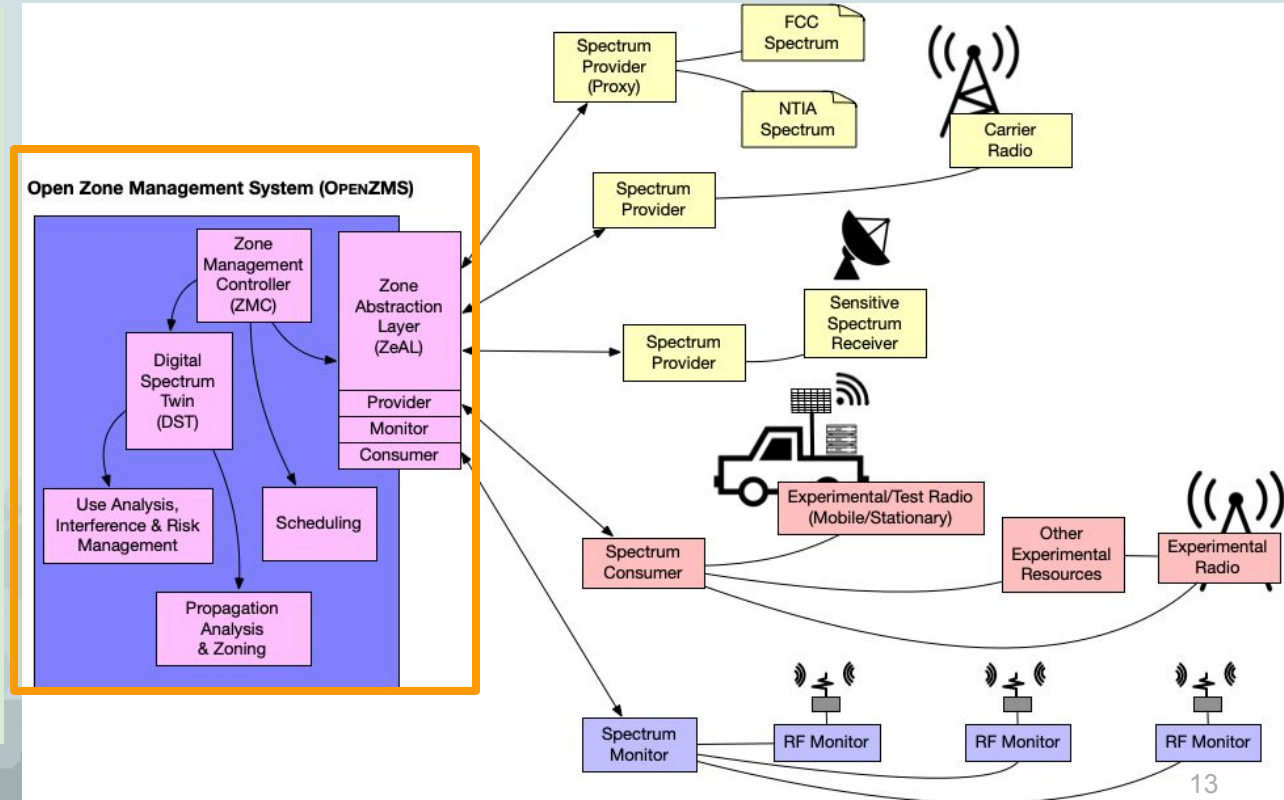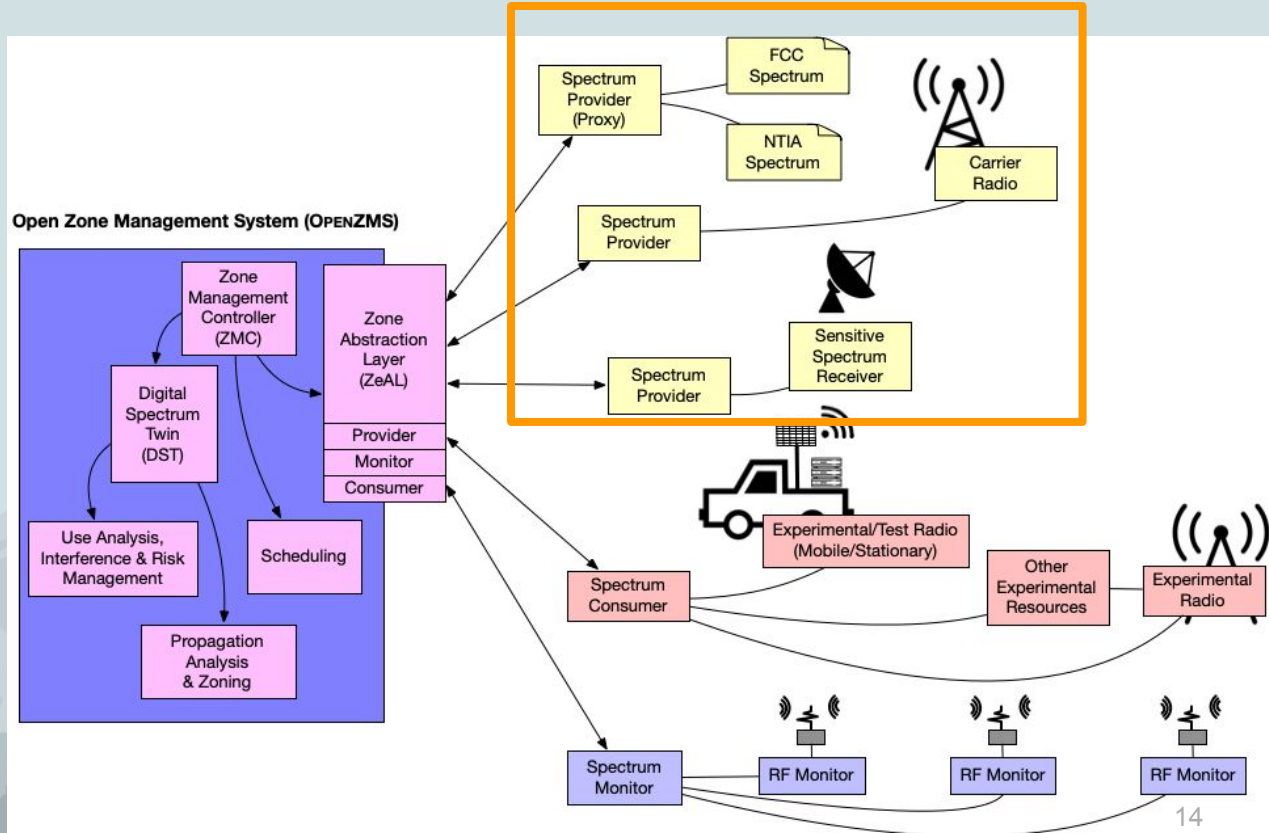   a. Spectrum Observer: stakeholder subscribing to observation reports (from monitors)

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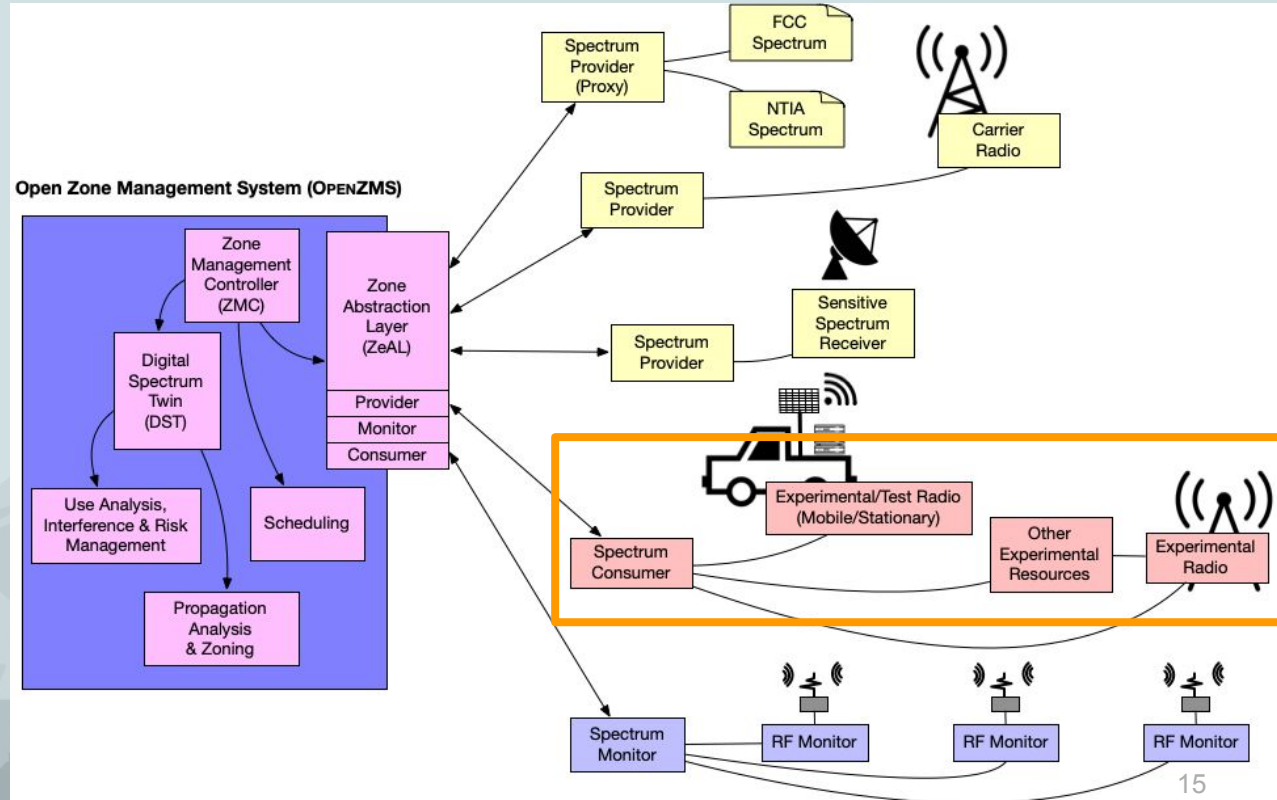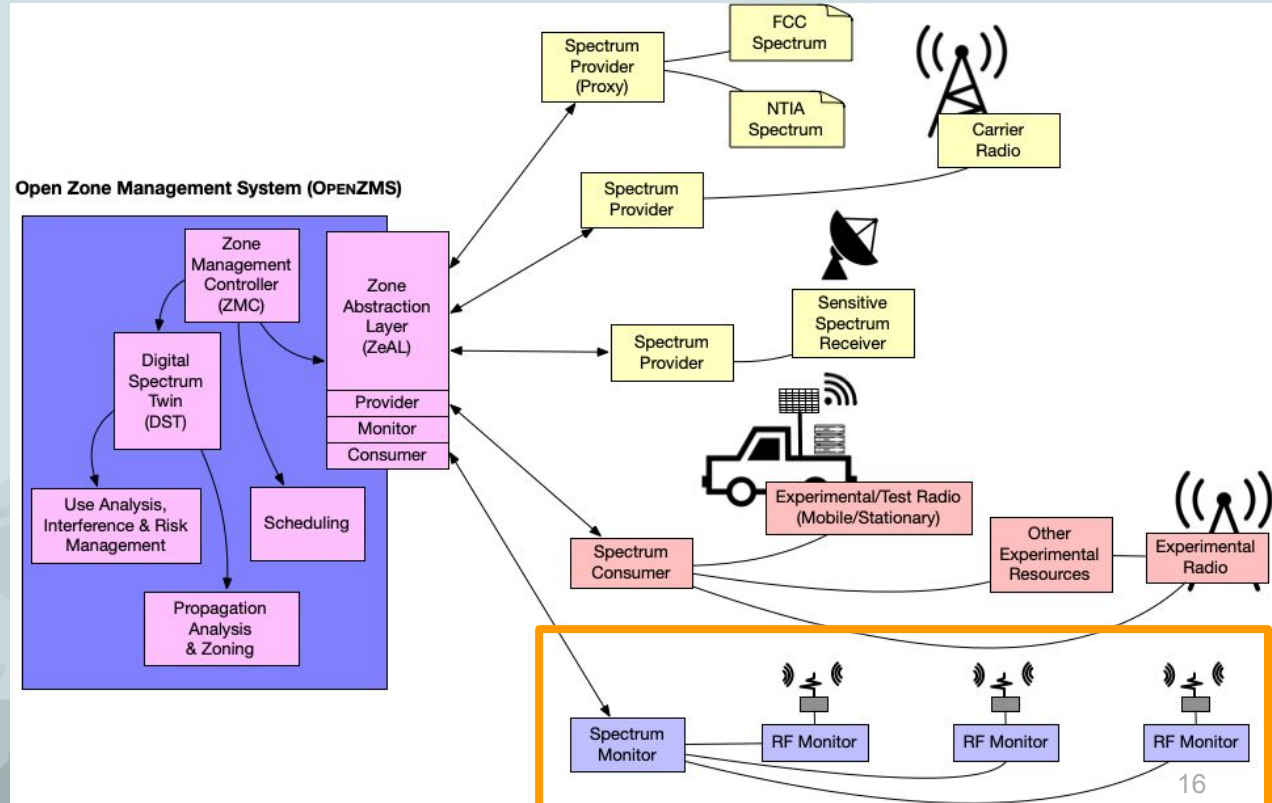   a. Spectrum Observer: stakeholder subscribing to observation reports (from monitors)

OpenZMS Element Integration

- **OpenZMS and POWDER are separate systems**
  - POWDER implements and uses OpenZMS APIs
  - POWDER provides resources and building blocks
    - Inline TX monitoring, RF kill switch, experiment automation
- **POWDER is an OpenZMS *Element***
  - Registers its Radio metadata with OpenZMS
  - Delegates Spectrum to be managed
  - Consumes Spectrum by requesting Grants for user experiments
  - Provides Monitors to report Observations
  - Handles Grant pause/revocation notifications from OpenZMS on violations
- **Other organizations, facilities as Elements:**
  - In POWDER-RDZ: campus providers, commercial providers, other incumbents

HCRO-RDZ

- Build an RDZ at Hat Creek Radio Observatory (HCRO)
  - Deploy OpenZMS at HCRO
- Extend/integrate OpenZMS:
  - Integrate CU RFS sensors with OpenZMS monitor APIs
  - Add several grant priority mechanisms (primary/secondary, etc)
  - Add RA protection criteria abstractions (ITU-R RA 769.2)
  - Add RFI mitigation (alarm service)
- HCRO RDZ Key takeaways: RFI, DPA concept (e.g., CBRS, AFC), SAS/AFC/ZMS concept, TARDyS4/ODS concept (StarLink collaboration basis)
- S.O.P.P.: Satellite Orbit Prediction Processor
  - RFI mitigation for RA; RFI mitigation for EOS
- CU-Boulder RF Sensor (RFS) daily liveness check

HCRO-RDZ

- Use HCRO to prototype a radio dynamic zone (RDZ)
- Spectrum sharing with terrestrial commercial wireless providers
  - PG&E 900 MHz Smart Utility meters
  - StarLink internet satellite constellations
  - CBRS in northern California
  - 3GPP LTE
- Manage spectrum sharing in HCRO-RDZ with grant mechanisms and publicize RA observing schedule (ala IIC) to commercial test partners

Home > Dashboards > Analyst's Dashboards > Signal Strength Data

Last 1 hour | 5s

DB Type | average_db | Frequency (MHz) | 915 | Bandwidth (MHz) | 26 | Temperature | rpi_cpu_temp

HCRO

Power Level over Time (PT)

Name	Mean	Max
E 450	-74.1 dBm	-74.1 dBm
NNE 60	-44.3 dBm	-42.7 dBm
NbE 540	-54.7 dBm	-35.3 dBm
W 230	-60.6 dBm	-47.8 dBm

-35 dBm
-40 dBm
-45 dBm
-50 dBm
-55 dBm
-60 dBm
-65 dBm
-70 dBm
-75 dBm

06:50 06:55 07:00 07:05 07:10 07:15 07:20 07:25 07:30 07:35 07:40 07:4

RF Sensor Map

N 1000
N 830
NbE 540
NNE 60
W 230
E 450
500 m

Temperature over Time (PT)

Name	Mean	Max
NNE 60	43.7 °C	45.3 °C
E 450	46.1 °C	48.7 °C
NbE 540	48.1 °C	51.6 °C
W 230	61.1 °C	62.8 °C

65 °C
60 °C
55 °C
50 °C
45 °C
40 °C

06:50 06:55 07:00 07:05 07:10 07:15 07:20 07:25 07:30 07:35 07:40 07:4

Data Points (Per Frequency) Last 10 minutes

Sensor	Count
NbE 540	385
E 450	392
W 230	396
NNE 60	402

RFI over Time (PT)

Name	Mean	Max
E 450	1.00	1.00
NNE 60	1.14	11.4
NbE 540	21.4	178
W 230	127	317

350
300
250
200
150
100
50
0

06:50 06:55 07:00 07:05 07:10 07:15 07:20 07:25 07:30 07:35 07:40 07:4

Data Points (All) Last 24 Hours

Sensor	Count
NNE 60	8679
E 450	8529
W 230	8489
NbE 540	8451

Could DPAs and IIC be Used for Satellite Protections?

- RA observatories are particularly vulnerable to satellite-based interference
  - Alert RA telescope of upcoming satellite passes to avoid acquiring data during noisy (or <u>potentially dangerous</u>!) overpasses
- Passive EESS satellites see large swaths of ground as they pass over
- Could IIC be used to synchronize satellite and ground-based passive and active spectrum use?
  - Turn off ground-based emitters in satellite field of view during brief overpasses

- **Satellite ephemerides could be used to implement DPA protections by way of an IIC portal**

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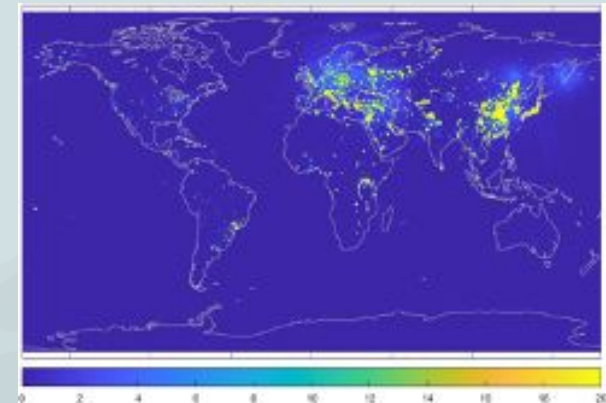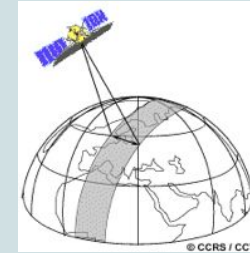
Percent of time that the 1.413 GHz passive microwave sensor on NASA's SMAP mission detects RFI level of > 5 K between April 2015 and March 2016. ITU recommended interference limit is 0.05 K.

(Mohammed et al., IEEE Trans. Geosci. Remote Sens., 2016, cited in CORF publications).

Example: POWDER-RDZ

Instantiate POWDER profile: operational 5G network, mobile UEs

Outdoor OTA Experiment

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

Example: POWDER-RDZ

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- Operating over-the-air
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Example: POWDER-RDZ

OpenZMS ensures that tx does not interfere outside the RDZ
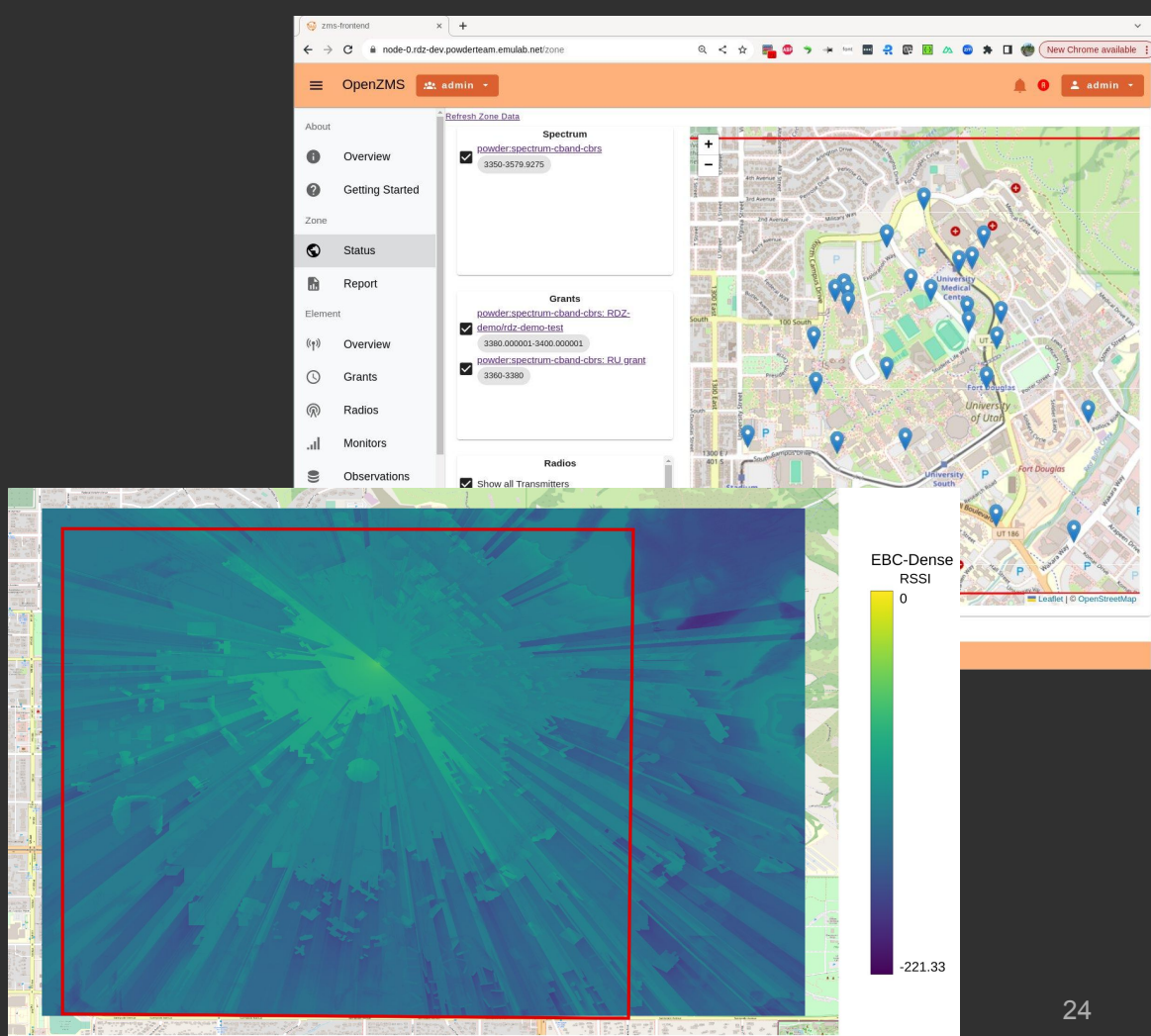
Example: POWDER-RDZ

OpenZMS uses monitor data to schedule grants in unoccupied spectrum
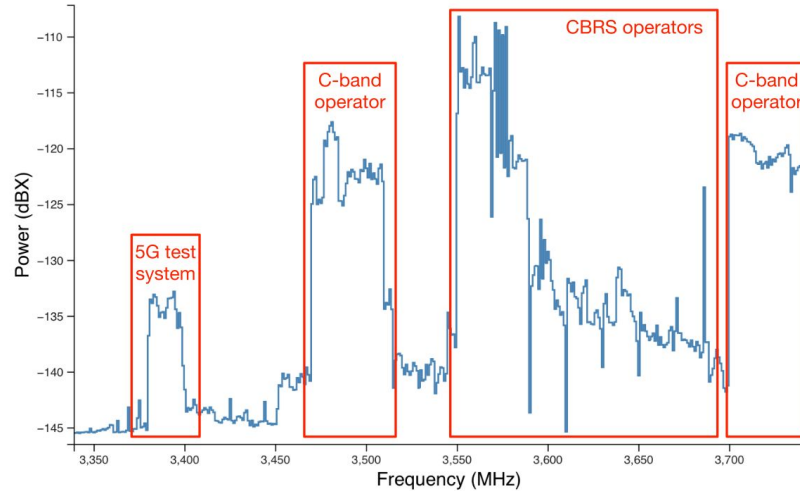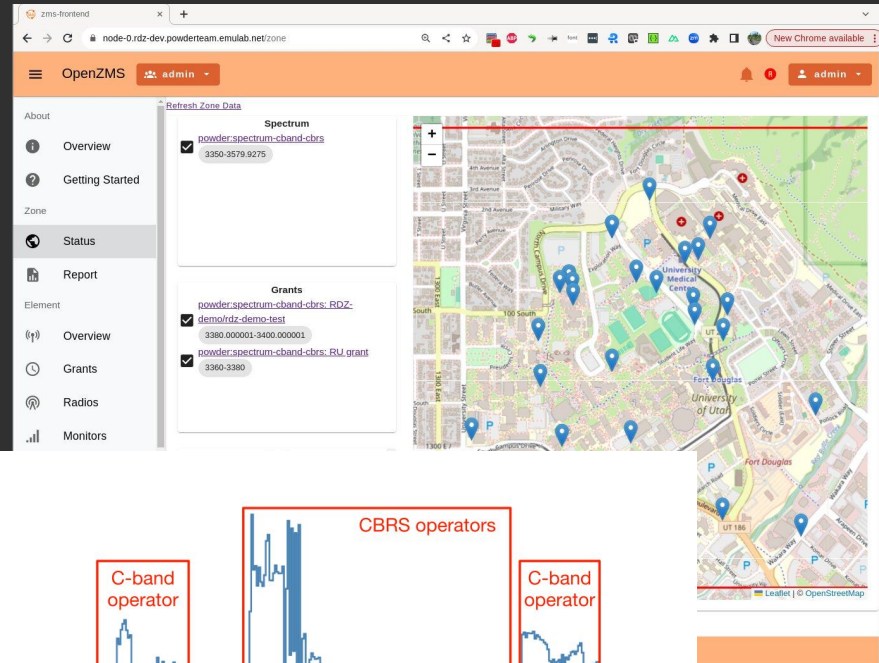
Example: HCRO-RDZ

OpenZMS uses CU RFS monitor data to protect RA from test TX based on protection criteria

Example: HCRO-RDZ

OpenZMS uses CU RFS monitor data to protect RA from test TX based on protection criteria

27
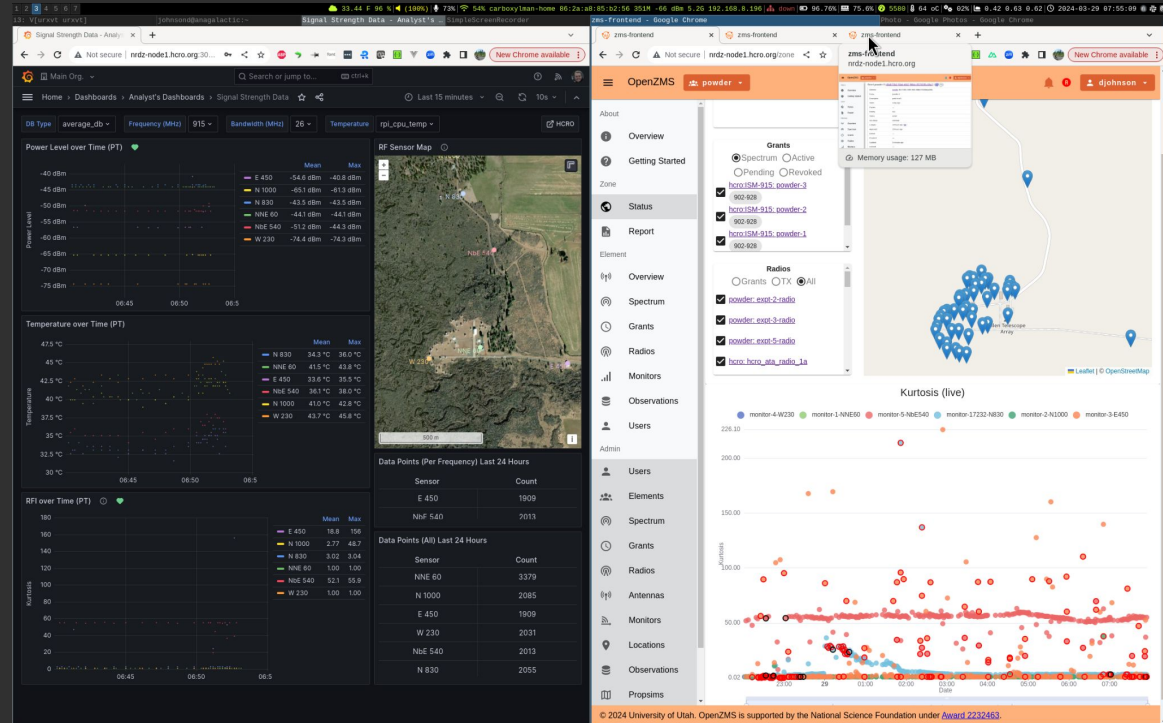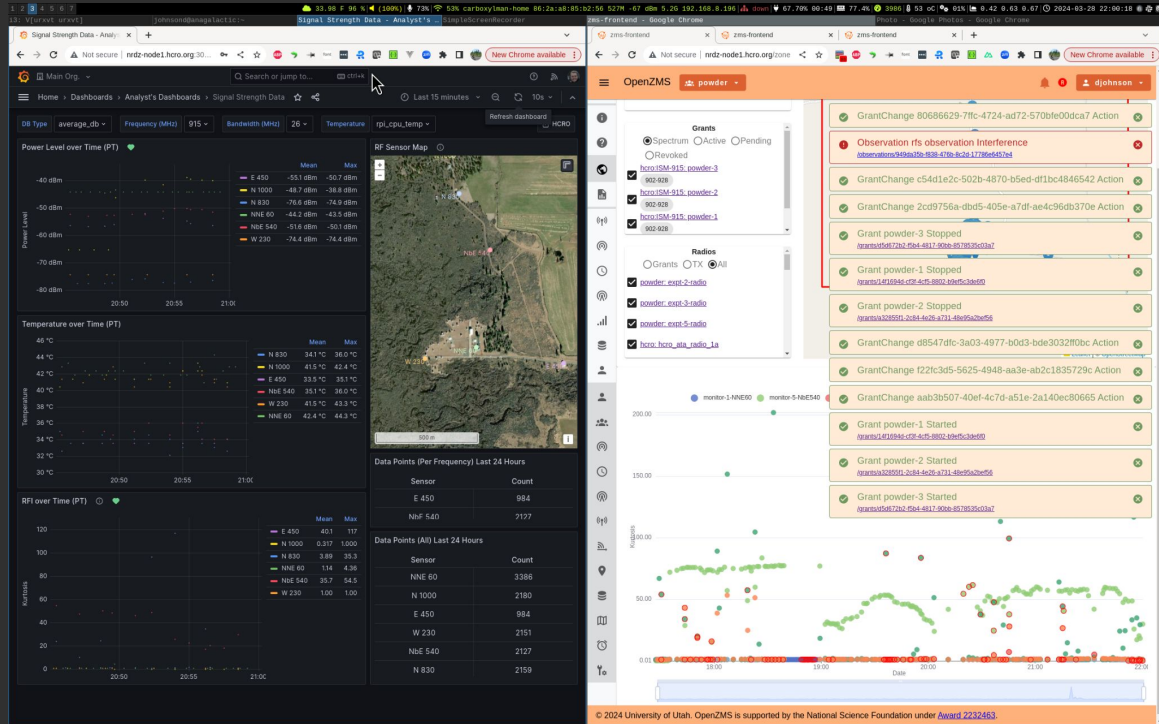
Conclusion: Community, Resources

- POWDER-RDZ is available, pre-release: https://powderwireless.net
  - Use via POWDER experiments
- OpenZMS: https://openzms.net
  - Test-drive on POWDER; or manually deploy (pre-release, early adoption)
  - Developing: sharing efficiency/parallelism, monitoring/detection, RFI mitigation
  - ***Deployed at Hat Creek Radio Observatory*** in March 2024
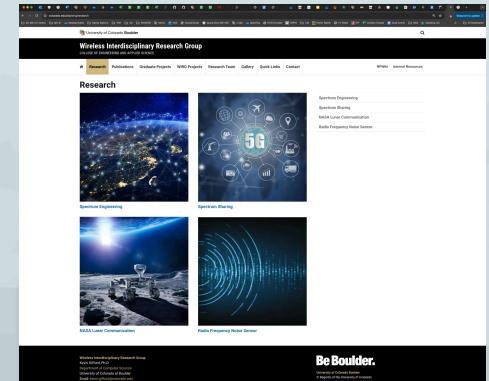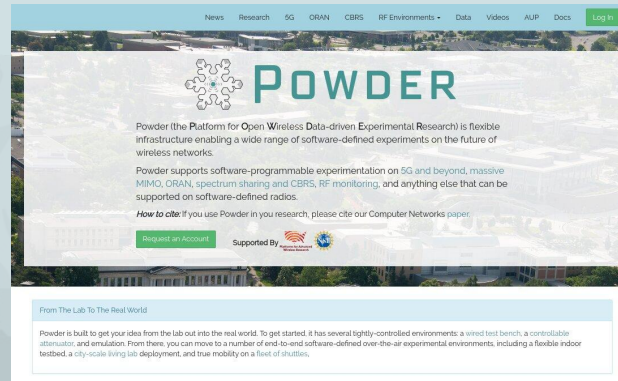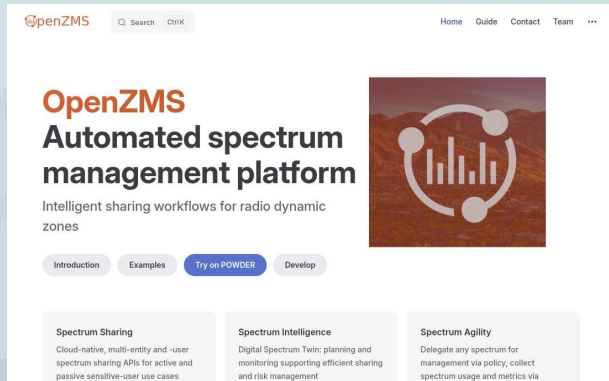
Backup

Sharing Use Cases

Spectrum Sharing Use cases

- Radio astronomy facility
- Federal radar
- Commercial provider
- Example spectrum sharing workflow
  - POWDER Program Experimental License
  - Use spectrum in certain bands when unoccupied by incumbents

- Concept:
    - ASR-9, NEXRAD radar systems: 2.7-2.9 GHz
    - Primary and secondary channels
    - *Sharing:*
        i. Using "band" in between
        ii. *Using secondary when radar is using primary; vice versa*
- Challenges:
    - *Do with no impact on radar operation*
    - Regulatory process: getting permission from NTIA, radar operators
- Approach:
    - Slow progression...
    - Eventually: detect primary/secondary; use alternative

PSD ../../max.dat
100 MHz Bandwidth, 2750 MHz Center Frequency

KMTX	ASR SLC	Buffer	Free

* Current understanding

2705	2715	2725	2735	2745	2755	2765	2775	2785	2795	2805	2815	2825	2835	2845	2855	2865	2875	2885	2895

Source: Jacob Bills (University of Utah)
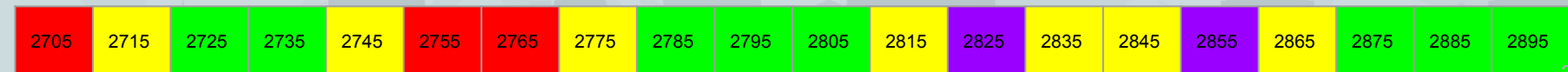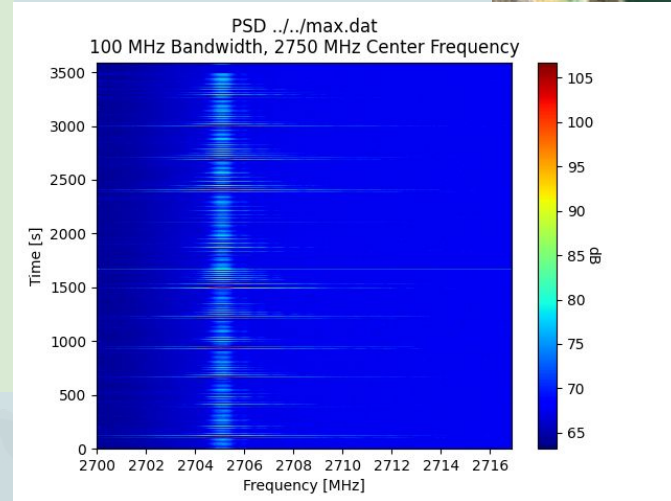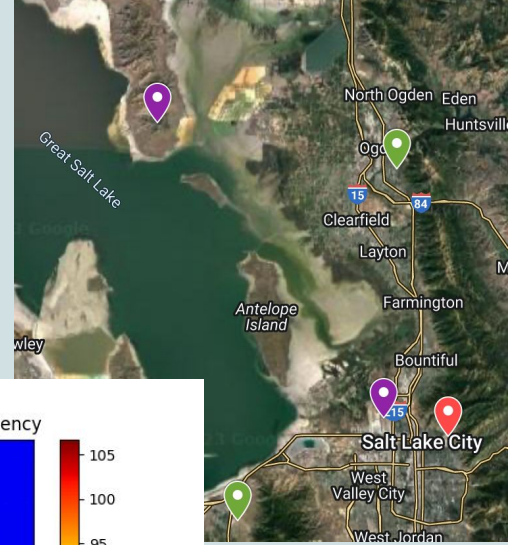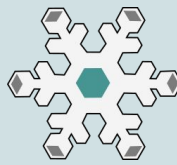
- Concept: when provider idles cells (energy efficiency), make use of "unoccupied" spectrum
- Challenges:
  - Cell idling is a dynamic (in-network) decision
  - Ensure there is no provider impact from sharing
  - Operator permission
- Proposed solution:
  - Cell idle/active detection mechanism
  - RF propagation analysis to determine "safe operating area"
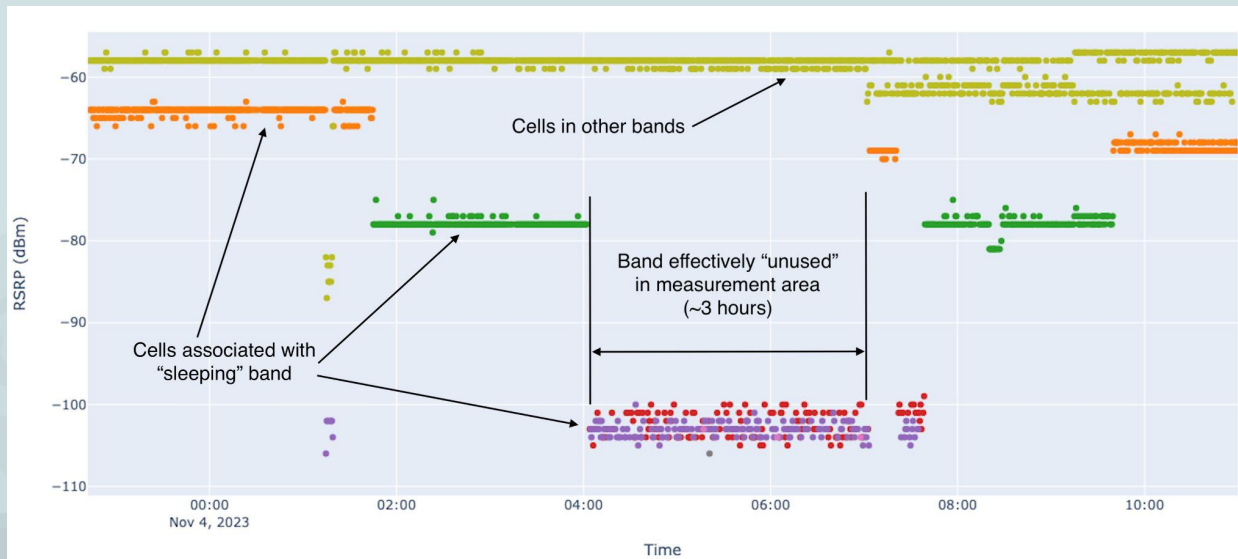
Source: Basit Awan
(University of Utah)

RDZ Workflow

Program Experimental License (PEL)
1. **Initialization**
   a. Role/element player registration
   b. Initial RDZ geography, models
   c. Spectrum available through PEL

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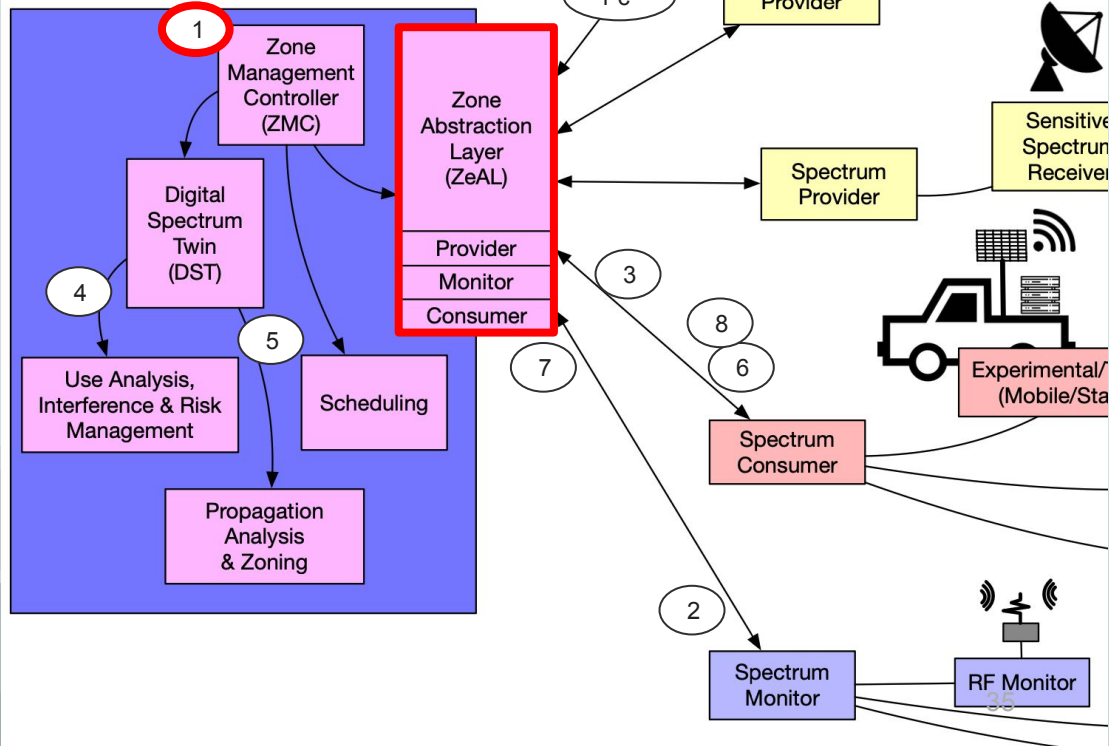
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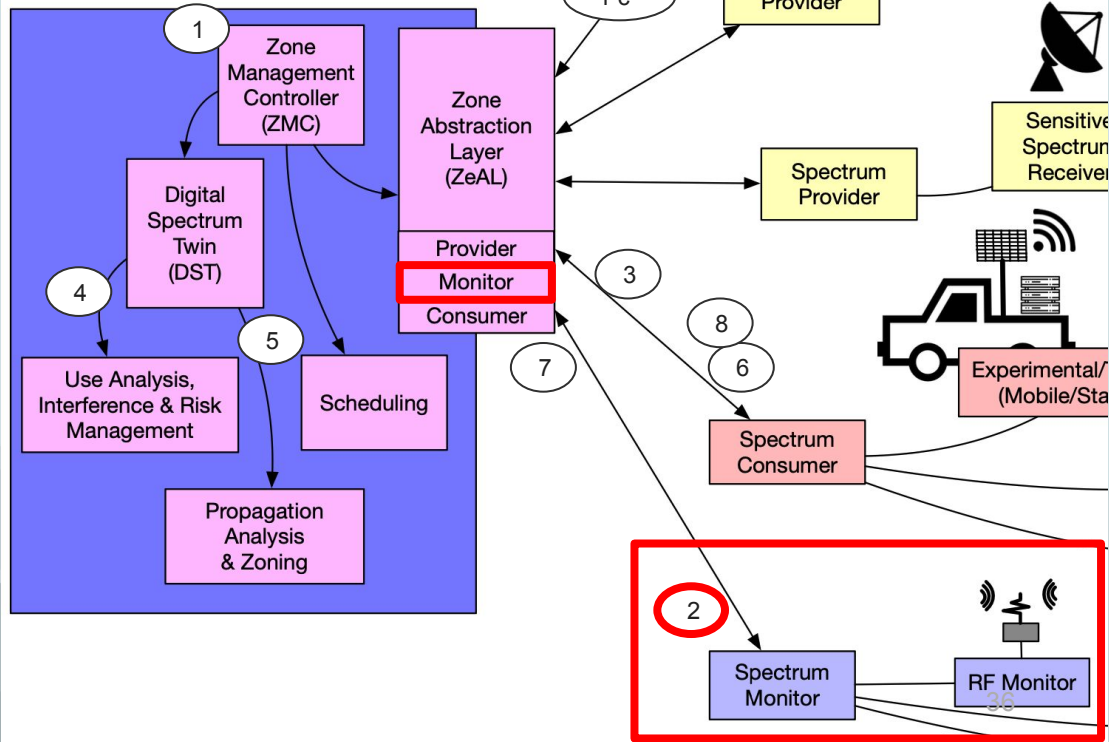

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4. Use monitor data to determine if/where request fits *(in ZMS)*
5. ***Use propagation analysis to ensure test will not interfere*** outside RDZ *(in ZMS)*
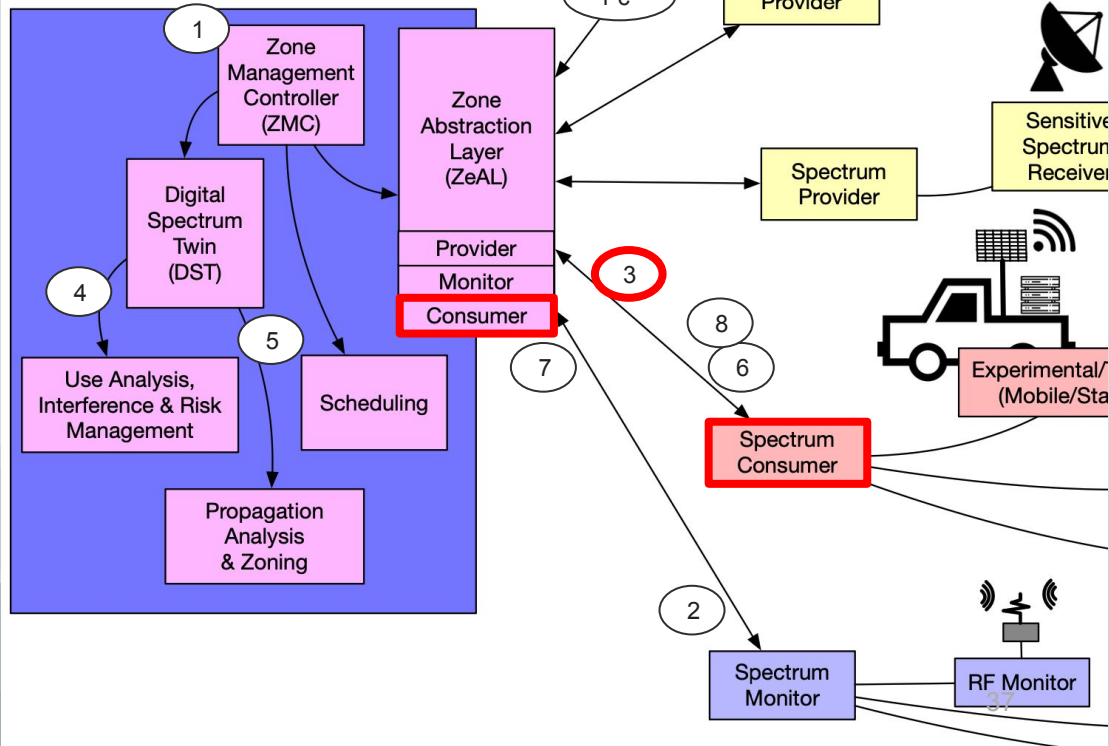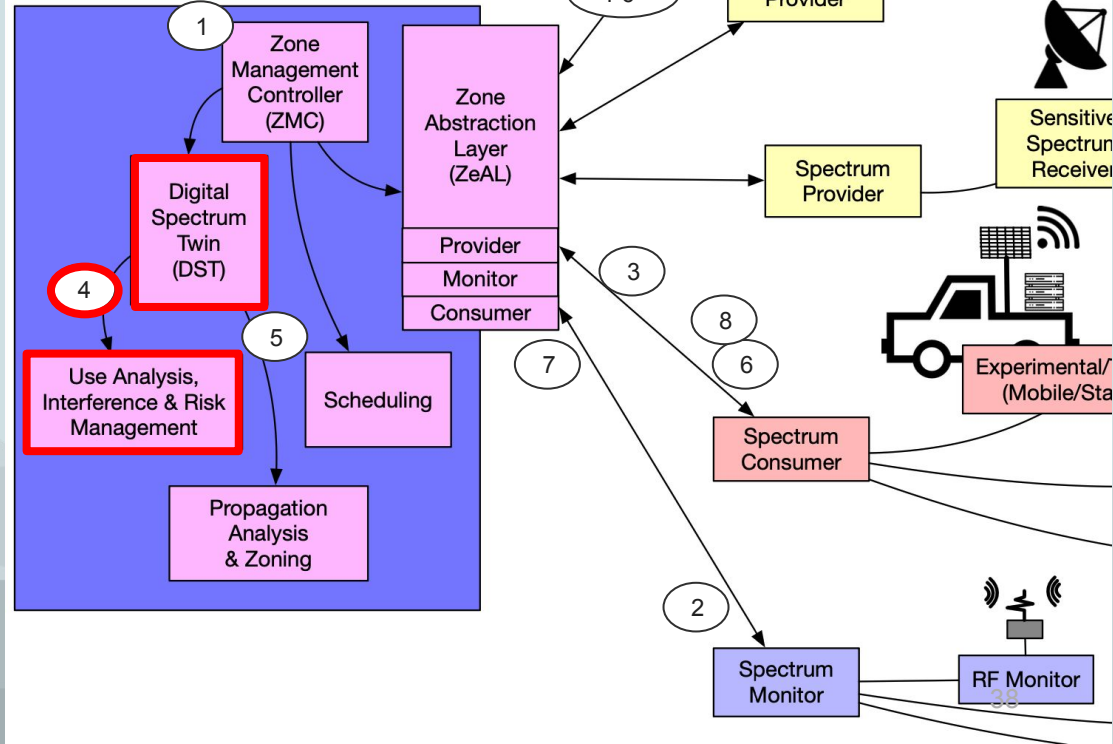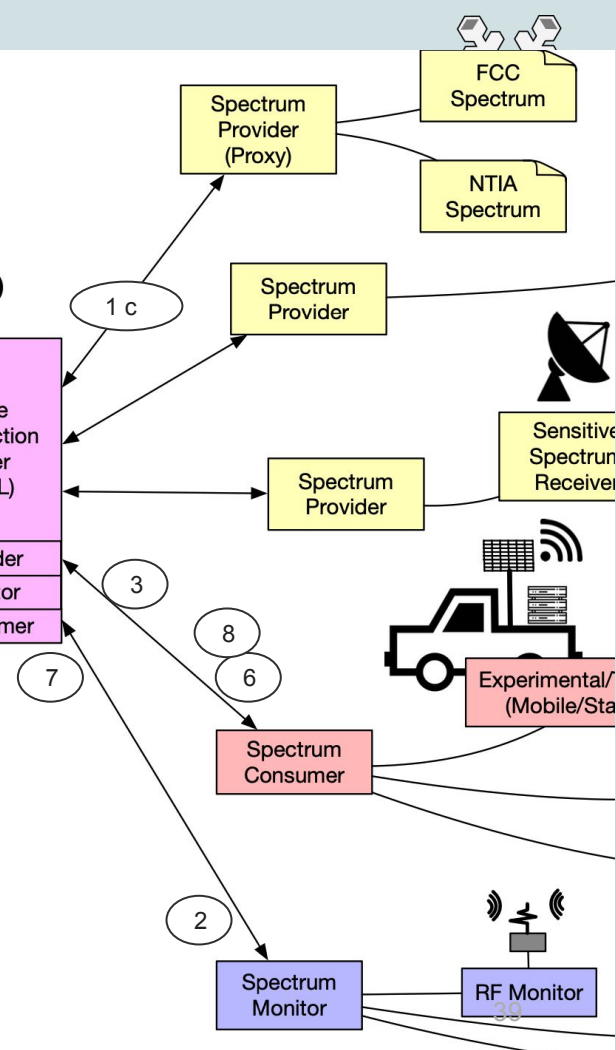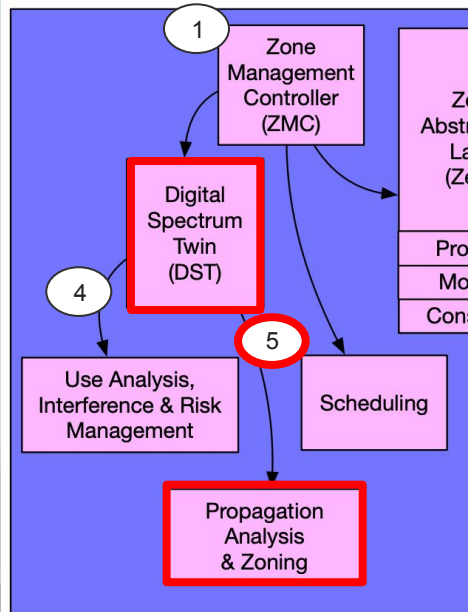

Open Zone Management System (OPENZMS)

Use case: PEL Workflow

Program Experimental License (PEL)
1. Initialization
   a. Role/element player registration
   b. Initial RDZ geography, models
   c. Spectrum available through PEL
2. ZMS observes PEL spectrum range *(monitor),* data into DST *(in ZMS)*
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)*
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6. ***Notify platform (consumer) to proceed***

Open Zone Management System (OPENZMS)
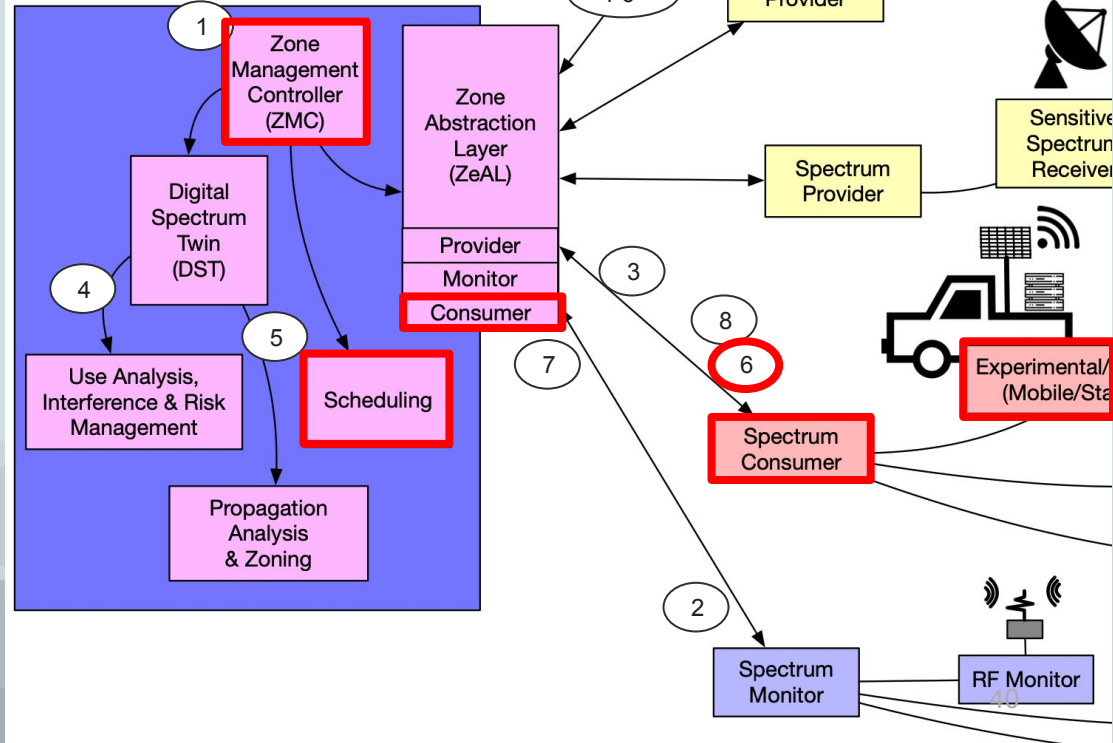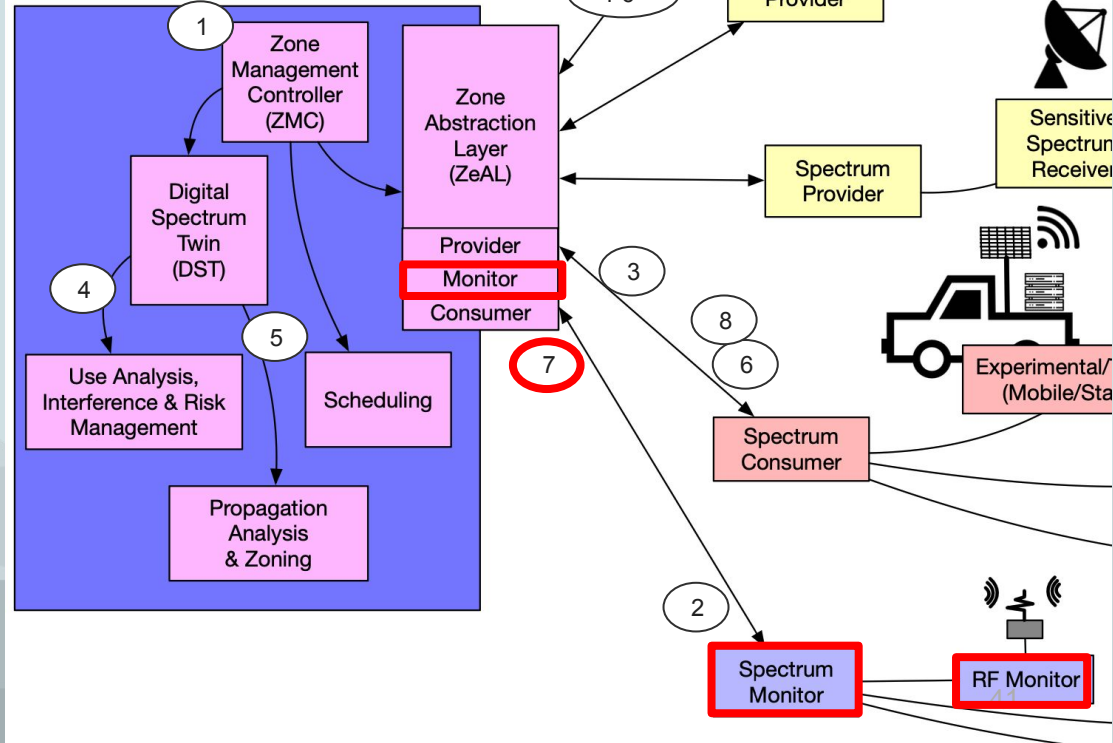
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7. ***If spectrum monitor (monitor) indicates interference…***

Open Zone Management System (OPENZMS)

FCC Spectrum

Spectrum Provider (Proxy)

NTIA Spectrum

Spectrum Provider

1 c

Zone Management Controller (ZMC)

Zone Abstraction Layer (ZeAL)

Provider
Monitor
Consumer

Digital Spectrum Twin (DST)

Use Analysis, Interference & Risk Management

Scheduling

Propagation Analysis & Zoning

Sensitive Spectrum Receiver

Spectrum Provider

Spectrum Consumer

Experimental/ (Mobile/Sta

Spectrum Monitor

RF Monitor

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7. If spectrum monitor *(monitor)* indicates interference…
8. …***Instruct platform (consumer) to terminate transmission***

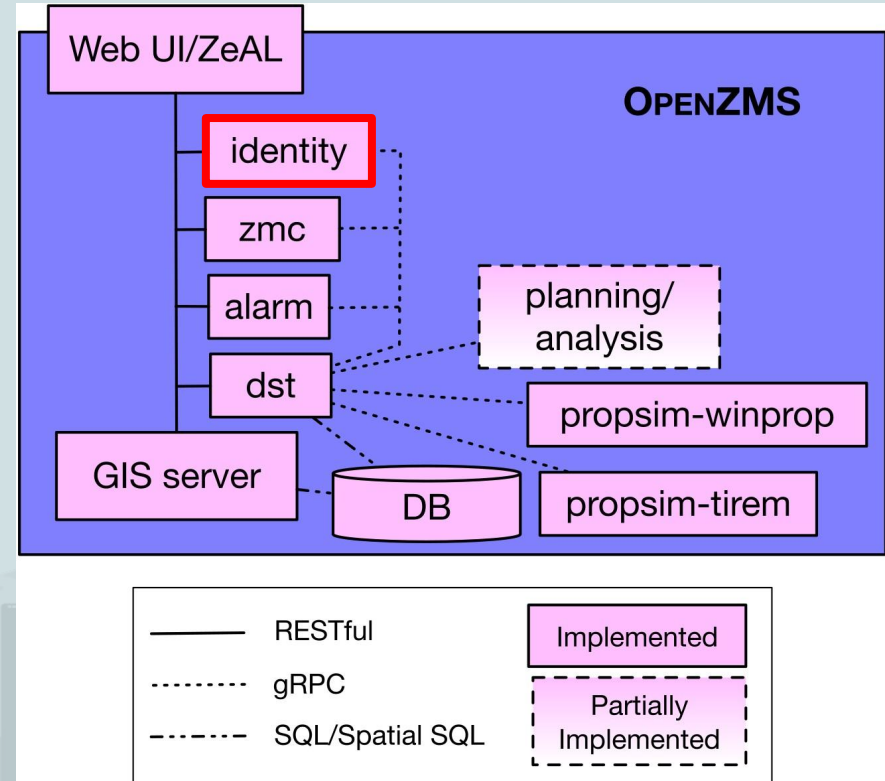**Open Zone Management System (OPENZMS)**

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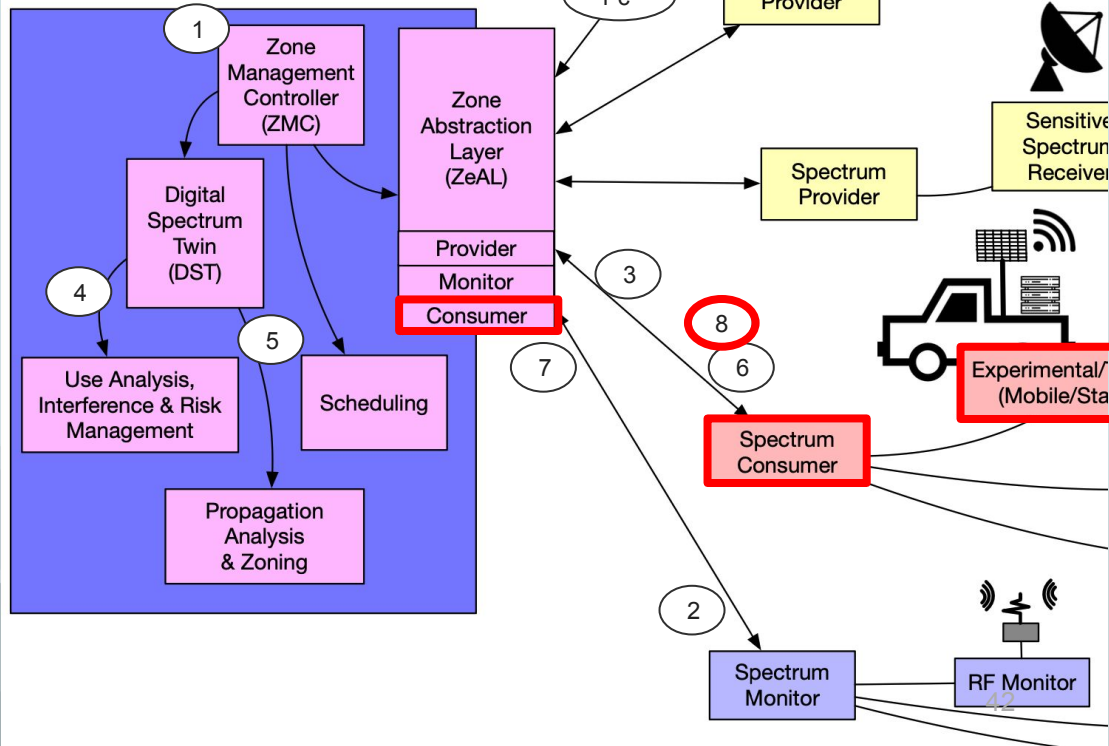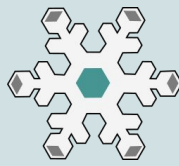
Implementation Details

OpenZMS Services

- ***Identity service***: provides role-based authz, SSO, API tokens, etc
  - Elements: participating spectrum role-playing organizations
- ZMC service: zone controller
  - Stores zone, radio, spectrum metadata
  - Grant scheduler and state mgmt
  - Models radios (tx, rx, antennas, etc) in detail for propagation simulation and analytics

OpenZMS Services

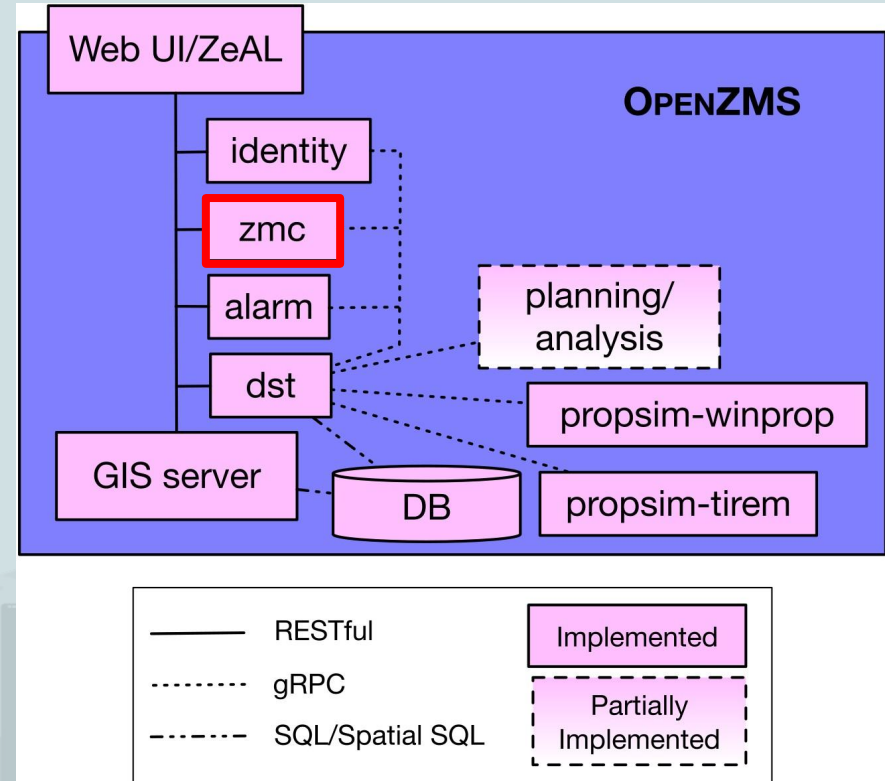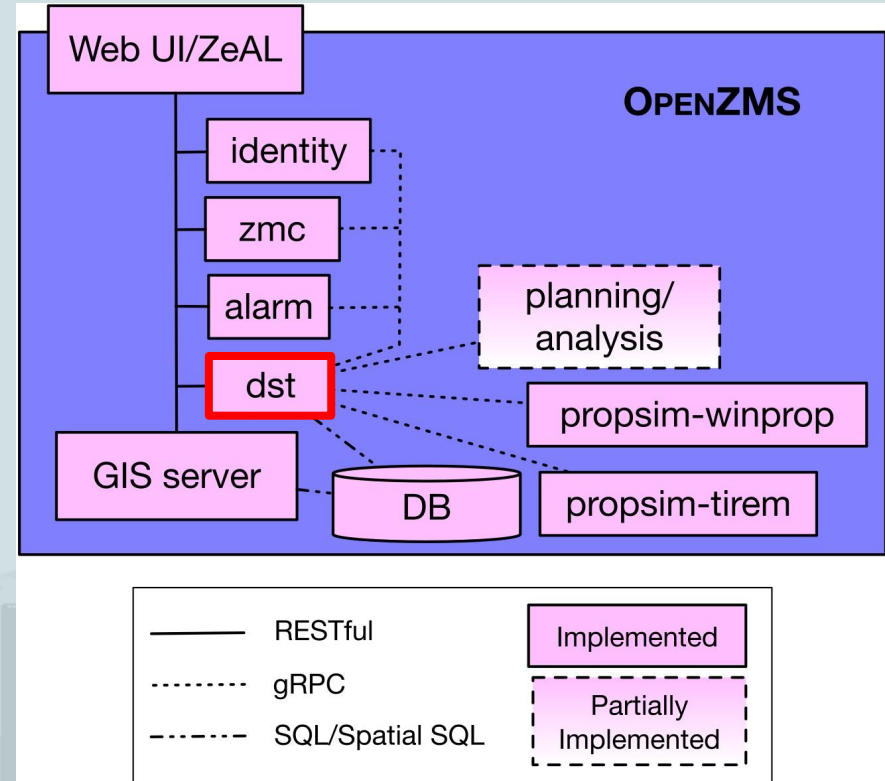- Identity service: provides role-based authz, SSO, API tokens, etc
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OpenZMS Services

- ***DST service***: a Digital Spectrum Twin storing models and data
  - Stores Observations sent by Monitors
  - Stores propagation simulations for each Radio
  - Provides query interfaces over both predictions and data
- Alarm service: risk and interference mitigation
  - Responds to observations that indicate interference, violations
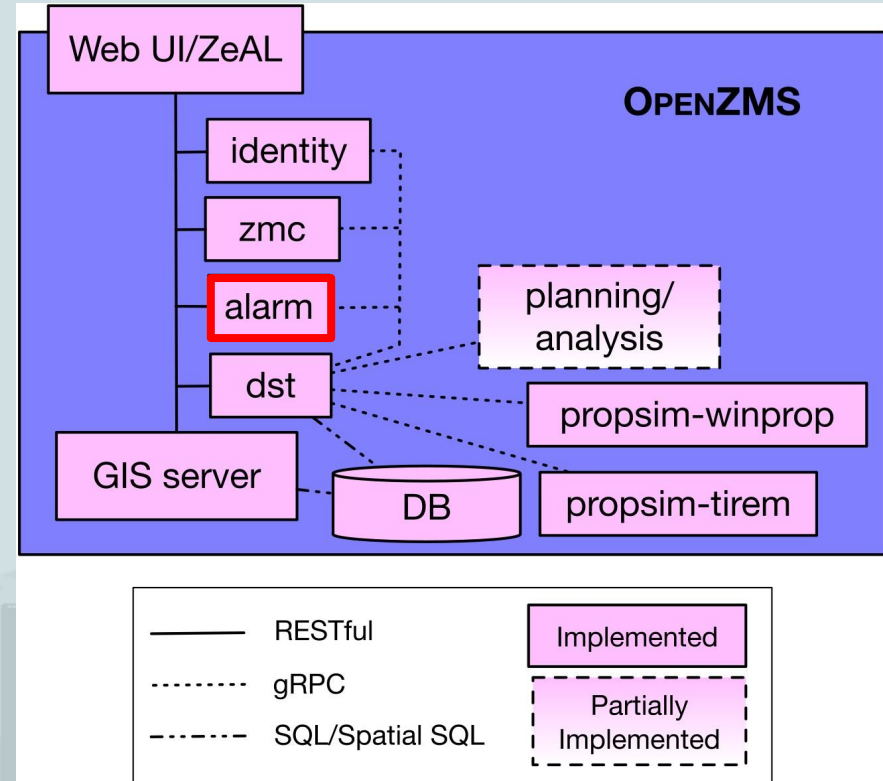- Propsim services: run propagation simulation jobs for DST

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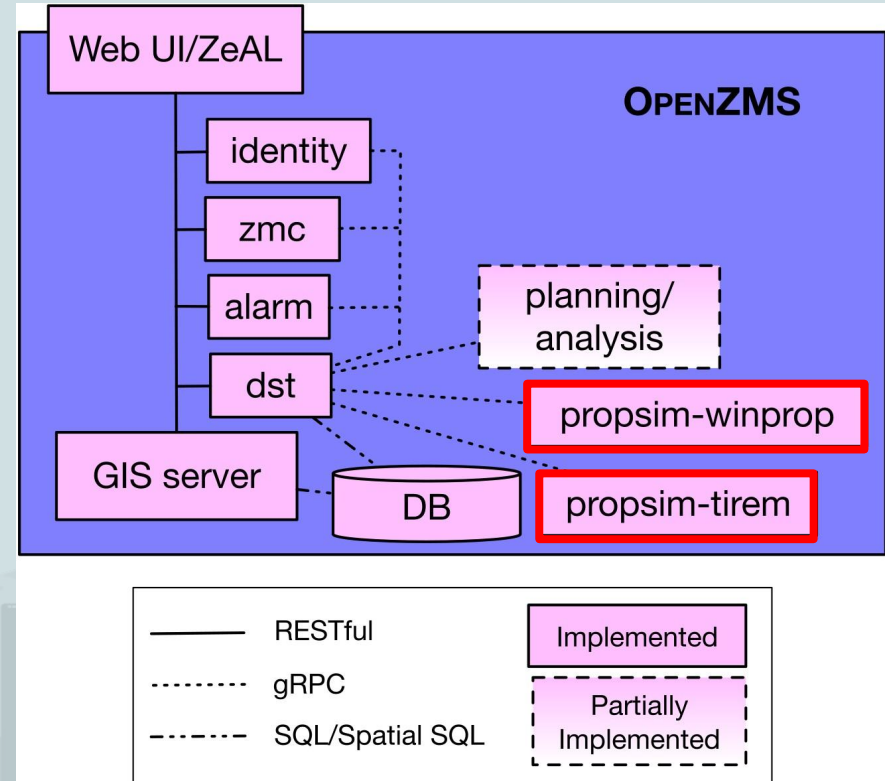- Propsim services: run propagation simulation jobs for DST

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- ***Propsim services*: run propagation simulation jobs for DST**

OpenZMS Implementation

- Core services: golang, python, JS
- APIs: RESTful user-facing (ZeAL); internal, trusted gRPC
- DST: uses PostGIS and GeoServer
  - Geospatial queries, mapping
- Two python-based propagation services:
  - TIREM-based, open-source
  - Altair FEKO WinProp
- Supported monitors:
  - POWDER SDR-based OTA sweep (PSD)
  - NTIA SCOS (beta)
  - CU Boulder RFS Sensors (contributed by CU)