



Spectrum Management Research in COSMOS

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Associate Professor – Syracuse University

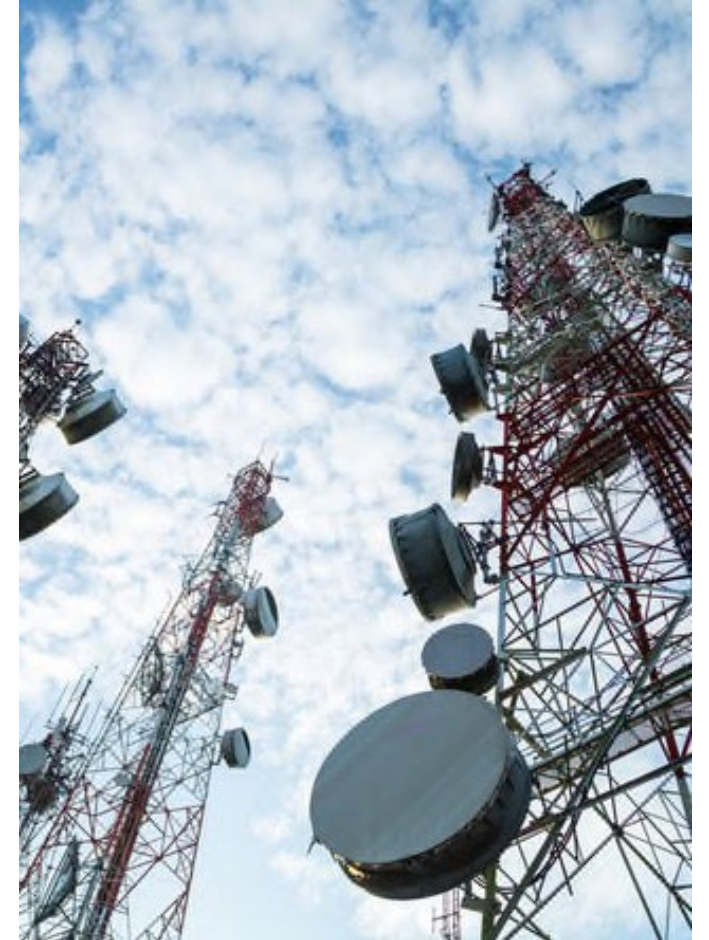
Director – Center for Emerging Network Technologies (CENT)

2026 PAWR PI Meeting, Washington D.C.



Dynamic Spectrum Access (DSA) - Motivation

- Due to the growth in the use of wireless services, spectrum management agencies and wireless service providers are determining ways to establish flexible spectrum assignment mechanisms to respond to the growing demand for spectrum resources.
- Many of these mechanisms focus on moving away from rigid spectrum management policies and embracing dynamic spectrum access (DSA) and spectrum sharing.
- Next-generation wireless services and applications, including AR, IoT, and Smart-Cities, will increasingly rely on Dynamic Spectrum Access (DSA) methods enabling heterogeneous devices to share limited spectrum resources and coexist harmoniously



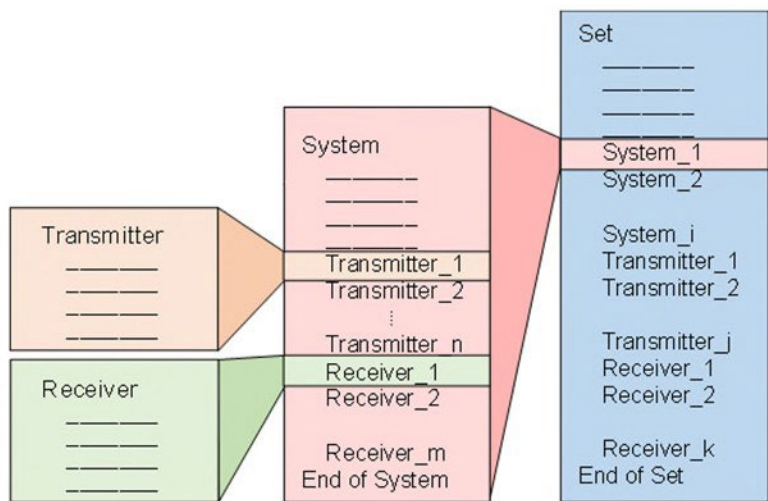
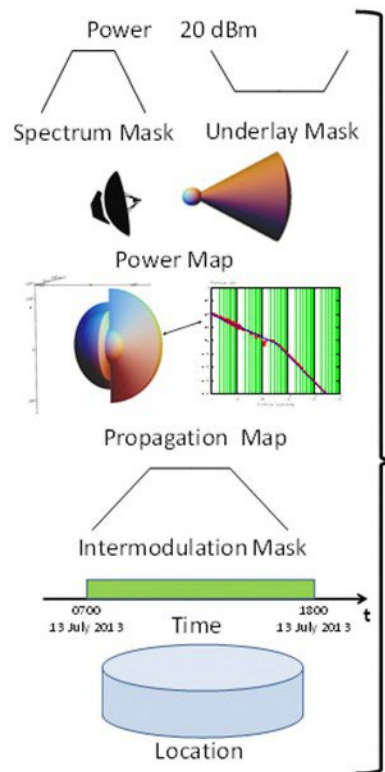
Background: Spectrum Consumption Models (SCMs)

- (Data model that)
Provides means to capture all the relevant parameters and phenomena that affect spectrum consumption for a device or spectrum-dependent system

SCM Constructs (IEEE 1900.5.2)

- Reference power
- Spectrum mask
- Underlay mask
- Power map
- Propagation map
- Intermodulation masks*
- Platform*
- Location
- Schedule
- Minimum power spectral flux density *
- Protocol or policy *

* Optional



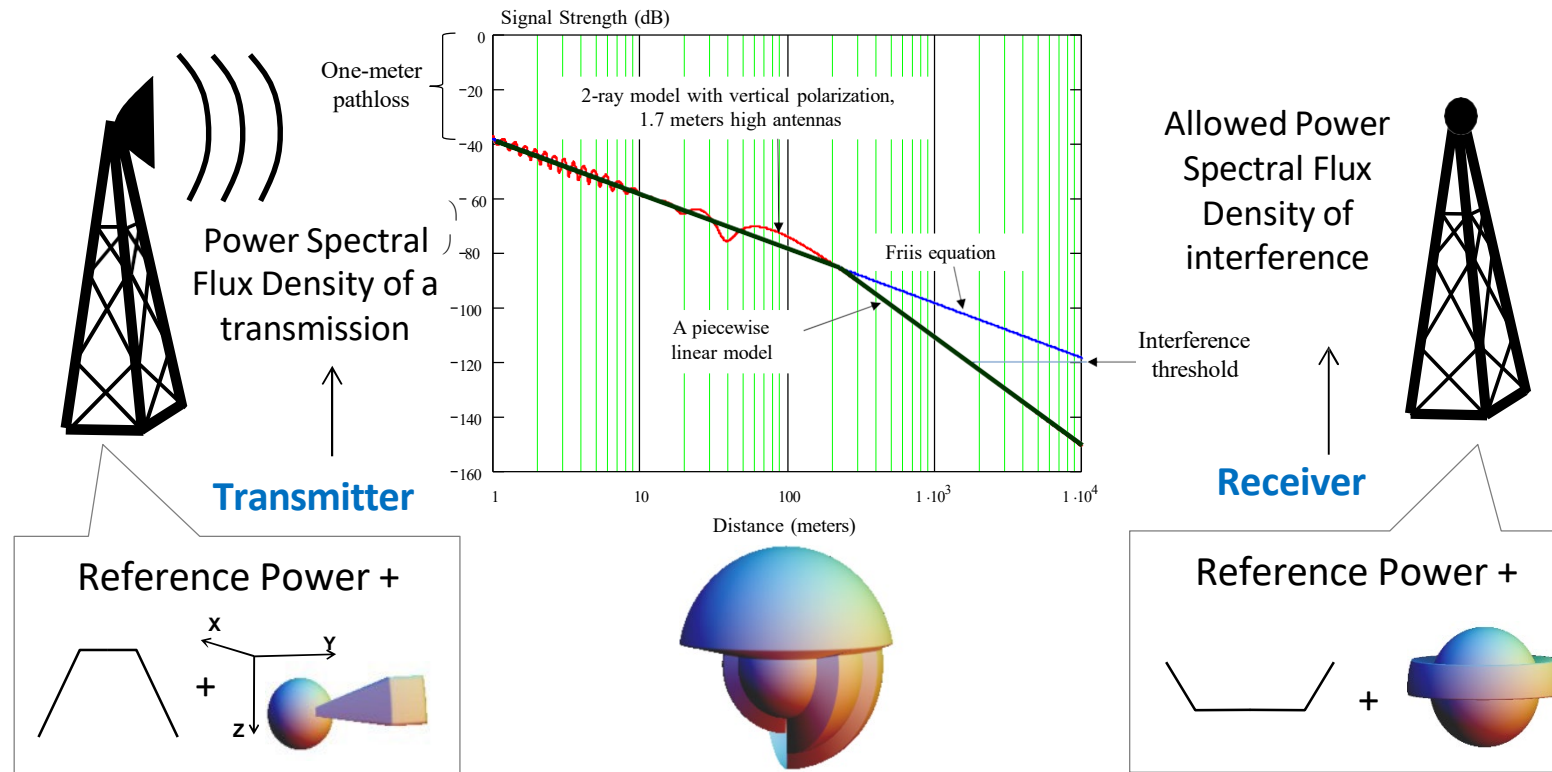
Types of Models

- Transmitter Model
- Receiver Model
- System Model
 - Consists of transmitter and receiver models that are part of a system
- Sets
 - Collective Consumption Set
 - Spectrum Authorization Set
 - Spectrum Constraint Set

Roles of Models

- Consumption
- Authorization
- Constraint
- Request
- Configuration Options

Compatibility Computations



- Constructs are a means to specify the factors that determine a link budget in all directions
- Modelers build SCMs to identify the power spectral flux density of transmissions and allowed interference

Experimental Setup: COSMOS Sandbox



**MIMO Rack
24-5**

**MIMO Rack
24-11**



3 WDs (Tx-Rx pairs) were enabled. They will interfere with each other if on the same channel

D. Stojadinovic, P. Netalkar, C. Caicedo Bastidas, I. Kadota, G. Zussman, I. Seskar, and D. Raychaudhuri, "A Spectrum Consumption Model-based Framework for DSA Experimentation on the COSMOS Testbed". In Proc. of the 15th ACM Workshop on Wireless Network Testbeds, Experimental evaluation and CHaracterization (WiNTECH) 2022

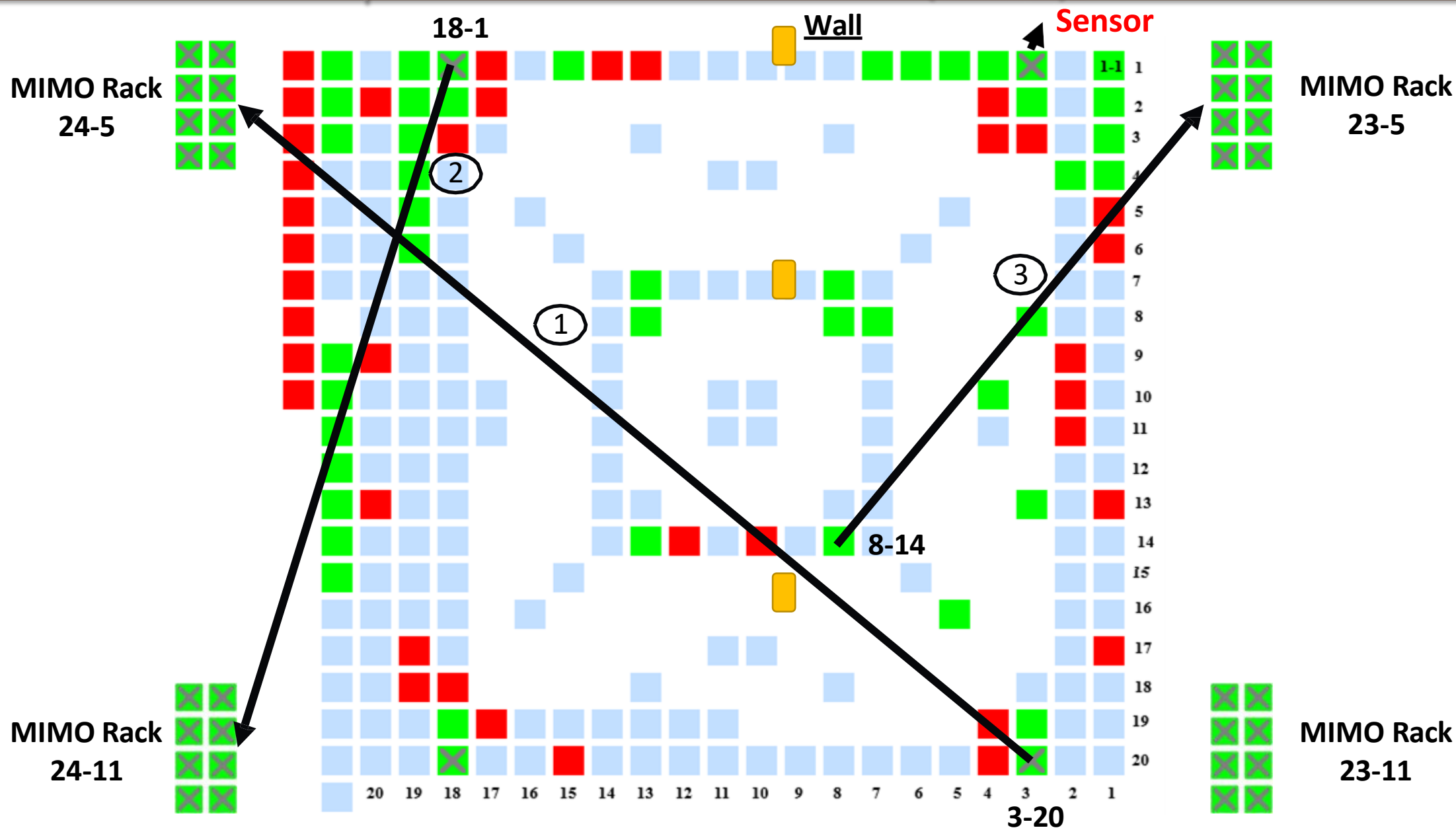


**MIMO Rack
23-5**

**MIMO Rack
23-11**



Experimental Setup in COSMOS testbed (2021)



```

[array([[1998.8, -19.45879996, 1999.4, -28.01239996,
1999.2, -31.30829996, 1999.4, -32.38089996,
1999.6, -33.01029996, 1999.8, -33.01029996,
2000.0, -33.01029996, 2000.2, -33.01029996,
2000.4, -33.01029996, 2000.6, -32.38089996,
2000.8, -31.30829996, 2001.0, -28.01239996,
2001.2, -19.45879996]])]

##### SPECTRUM MASK #####
[array([[1999.71, -62.79076676, 1999.6125, -57.79076676,
1999.71, -29.34076676, 2000.29, -29.34076676,
2000.3875, -57.79076676, 2001.0, -62.79076676]])]

##### UNDERLAY MASK #####
[array([[1998.8, -19.45879996, 1999.4, -28.01239996,
1999.2, -31.30829996, 1999.4, -32.38089996,
1999.6, -33.01029996, 1999.8, -33.01029996,
2000.0, -33.01029996, 2000.2, -33.01029996,
2000.4, -33.01029996, 2000.6, -32.38089996,
2000.8, -31.30829996, 2001.0, -28.01239996,
2001.2, -19.45879996]])]

##### SPECTRUM MASK #####
[array([[1999.71, -36.50274674, 1999.6125, -31.50274674,
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##### UNDERLAY MASK #####
[array([[1997.8, -19.45879996, 1998.4, -28.01239996,
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1998.6, -33.01029996, 1998.8, -33.01029996,
1999.0, -33.01029996, 1999.2, -33.01029996,
1999.4, -33.01029996, 1999.6, -32.38089996,
1999.8, -31.30829996, 2000.0, -28.01239996,
2000.2, -19.45879996]])]

##### SPECTRUM MASK #####
[array([[1999.71, -41.07684168, 1999.6125, -36.07684168,
1999.71, -7.62684168, 2000.29, -7.62684168,
2000.3875, -36.07684168, 2001.0, -41.07684168]])]

##### UNDERLAY MASK #####
[array([[1998.8, -19.45879996, 1999.4, -28.01239996,
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1999.6, -33.01029996, 1999.8, -33.01029996,
2000.0, -33.01029996, 2000.2, -33.01029996,
2000.4, -33.01029996, 2000.6, -32.38089996,
2000.8, -31.30829996, 2001.0, -28.01239996,
2001.2, -19.45879996]])]

INFO:cil_collab_client:##### TX NOT COMPATIBLE : DIFFERENT FREQUENCY SELECTED 2001000000.000000#####
INFO:cil_collab_client:#####Test done#####

```

Test 1: Rx3-Tx2

Test 2: Rx3-Tx1

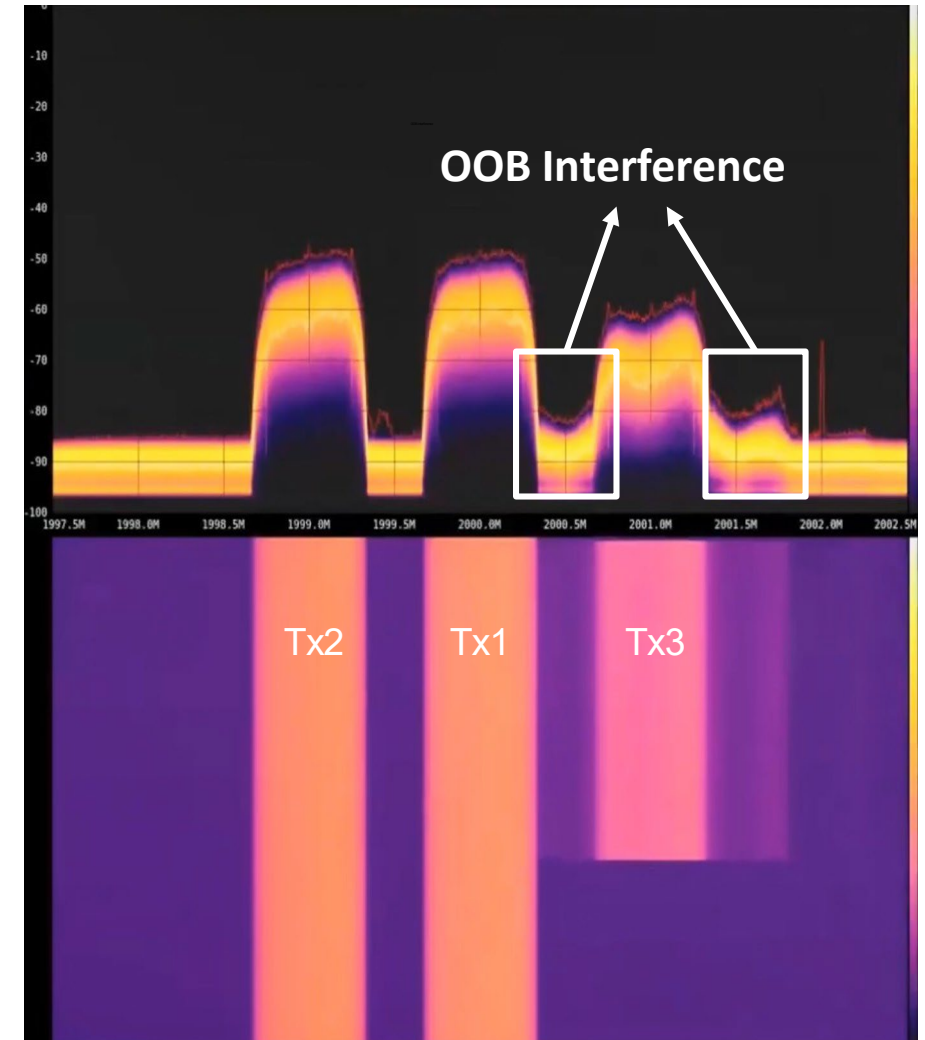
Test 3: Tx3-Rx2

Test 4: Tx3-Rx1

List of compatibility tests between WD3's devices (Tx3 and Rx3) and existing Tx/Rx devices

Full demo and concepts video (2021):

<https://www.youtube.com/watch?v=7Ra1n5cV8sw>



Fosphor visualization showing the spectrum occupancy when third network start operating

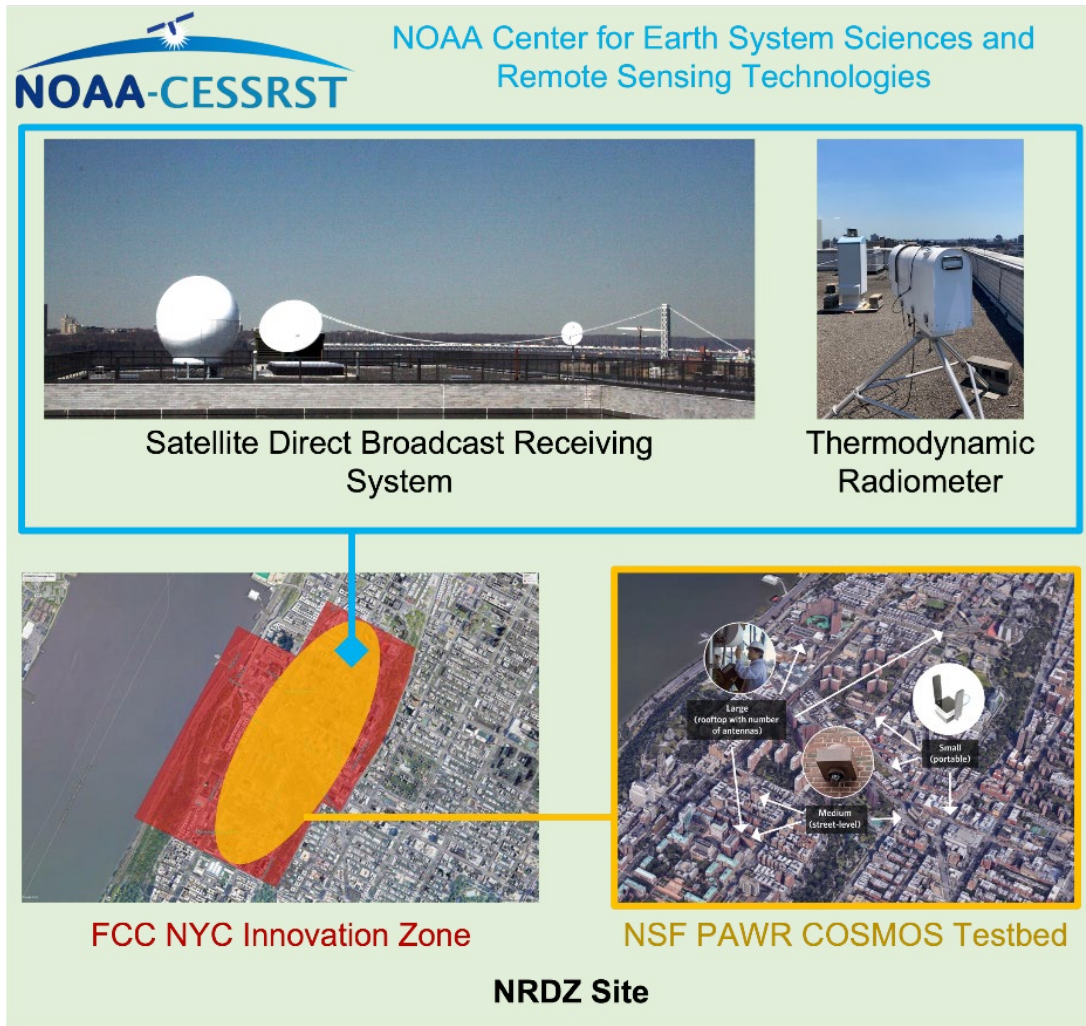


SII-NRDZ: Spectrum Sharing via Consumption Models and Telemetry - Prototyping and Field Testing in an Urban FCC Innovation Zone

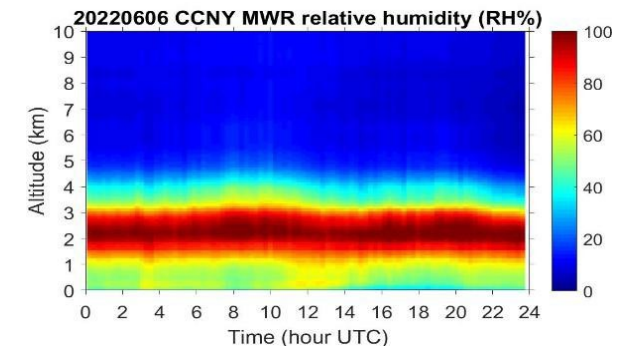
Carlos E. Caicedo Bastidas¹, Tingjun Chen², Kyle Jamieson⁴, Fred Moshary³,
Dipankar Raychaudhuri⁵, Ivan Seskar⁵, Gil Zussman⁶ (PI)

¹Syracuse, ²Duke, ³City College of New York and NOAA-CESSRST,
⁴Princeton, ⁵Rutgers, ⁶Columbia

Overview: Considered Scenarios/Applications



- Protection of passive receivers in the NOAA-CESSRST center at 27–29 GHz (for part of the operating band of a radiometer used in weather monitoring).
 - Overlaps with the mmWave frequency range used in COSMOS and 5G
- Protection of passive receivers in the NOAA-CESSRST center that operate at 1.7 GHz and 7.7–8.2 GHz (for reception from a polar orbiting satellite)
-



ZMS: Main Functional Areas

Device Management

Web-based SCM creation, edit, search, and batch import from FCC ULS.

Spectrum Coordination

On-demand and automated daily compatibility tests; alert generation.

Monitoring & Reporting

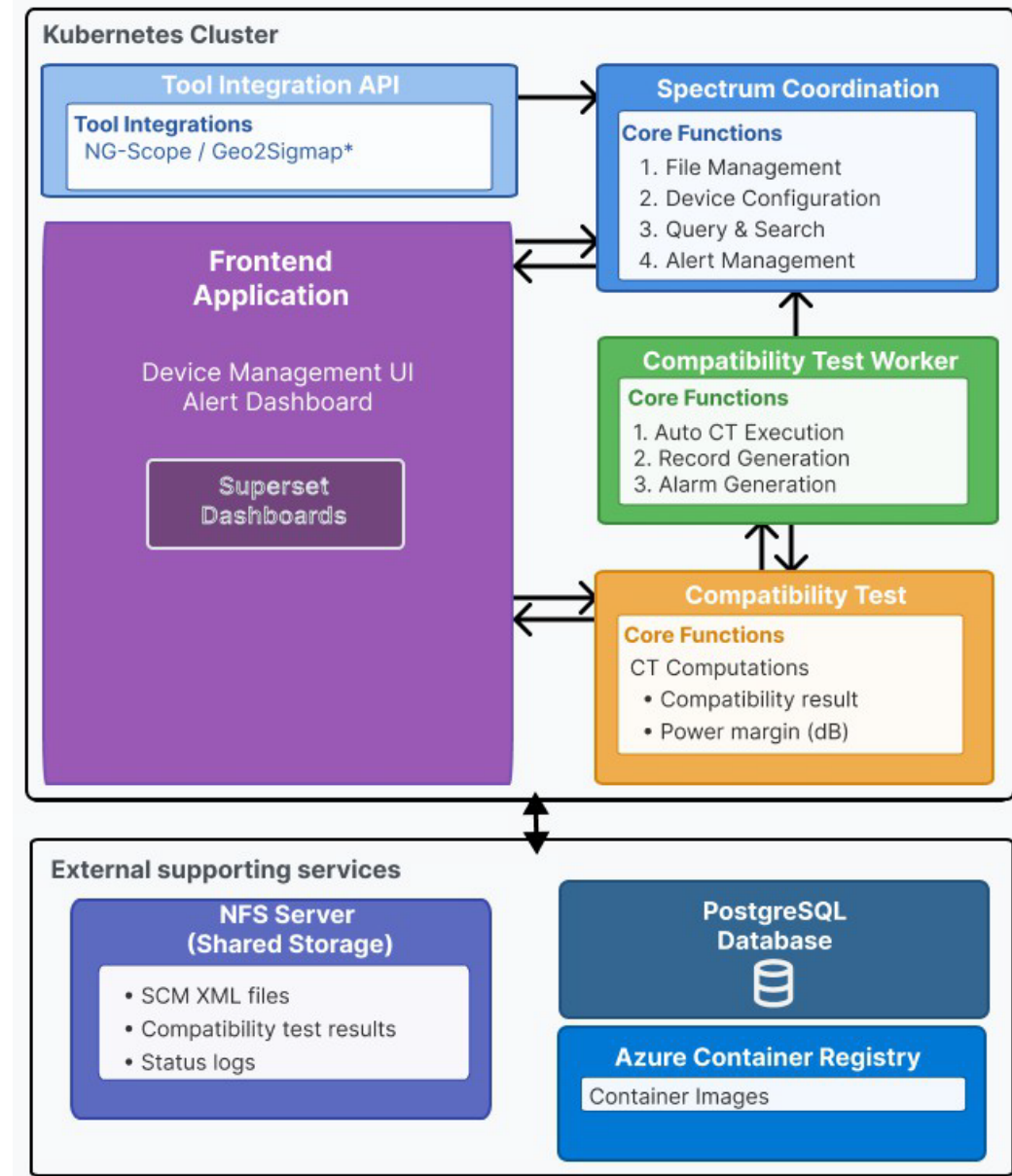
Map-based dashboards for device locations, alarms, and event logs.

Integrations

APIs to NG-Scope (LTE telemetry);
Geo2SigMap & *SDR sensors (ongoing)*.

ZMS – Components

- Kubernetes cluster
 - Includes load balancer / ingress controller
 - One master node, two worker nodes
- NFS storage server
- SCM Database server
 - Postgres database server with integrated GIS elements



Not Secure http://cosmoszms.local

COSMOS

ZONE MANAGEMENT SYSTEM

JD John Doe Administrator

- Register RF Devices → Register/Add new RF devices to ZMS
- Manage RF Devices → View/Query/Edit RF device characteristics
- Spectrum Coordination → Spectrum use compatibility tests/calculations
- Spectrum Reports → View/Query spectrum use, interference alarms/events
- User management → Creation/Mgmt of ZMS user and organization accounts
- Experiment registration → Experiment registration/management ?? (Future ?)

Welcome to COSMOS ZMS

Use the sidebar menu for additional RF device and spectrum management capabilities.

ZMS Dashboard

Register new Device
(upload SCM)

View/Edit Devices

RF Device Interference Test

Logout

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

RUTGERS

The City College
of New York

Duke
UNIVERSITY

PRINCETON
UNIVERSITY

Syracuse
University

NOAA-CESSRST

Funded by the National Science Foundation

Add RF Devices

 Register RF Devices ^

 Upload new device's SCM

 Clone Existing Devices

 Create SCM

Model: Tx_DemoTest01

Configure the parameters for this device model

General ^

Model Name
Tx_DemoTest01

Device Type
Transmitter

General Transmitter Parameters v

Spectrum Mask v

Propagation Map v

Power Map v

Location v

Schedule v

Cancel

 Save SCM

Manage RF Devices (1)



Manage RF Devices

SCM Devices

Search by Model Name and Device Type

Model Name

Select Type

Search by Reference Frequency

Min Ref Freq

MHz

Max Ref Freq

MHz

Search by Location

Latitude

Longitude

Radius

in

Kilometers

Search by SCM Creation Date

mm / dd / yyyy

mm / dd / yyyy

Last 24 hours

Last Week

Last Month

Reset

Search Devices

Manage RF Devices (2)



Manage RF Devices

Device Details

Download SCM

Details

Antenna Pattern

Basic Information

Name NR_BS_31

Type Transmitter

Purpose CONSUMPTION

General Transmitter Parameters

Power Level 3W

Reference Frequency 1945.35 MHz

Spectrum Mask Resolution 1 MHz

Location

Latitude

Longitude 68

Altitude

Schedule

Start Time 1/1/2025, 12:00:00 AM

End Time 12/31/2030, 11:59:59 PM

Timezone UTC-05:00

Spectrum Mask



Close

Spectrum Coordination

 Spectrum Coordination

 RDZ interference Management

 COSMOS

ZONE MANAGEMENT SYSTEM

JD John Doe
Administrator

Run Compatibility Test

TEST COMPATIBILITY?	DEVICE NAME	REFERENCE FREQUENCY (MHZ)	MIN FREQUENCY (MHZ)	MAX FREQUENCY (MHZ)
☒	TX_Small_BPSK_ct-test	2000	1999	2001

...Display all selected entries

TEST COMPATIBILITY?	DEVICE NAME	REFERENCE FREQUENCY (MHZ)	MIN FREQUENCY (MHZ)	MAX FREQUENCY (MHZ)
☒	RX_100m_BPSK	2000	1998.8	2001.2

...Display all selected entries

 Devices Not Compatible

Compatibility: Not Compatible

Power Margins: 16.26407178016656 dB

Do you want to register an Interference Alarm?

No, Thanks

Yes, Register Alarm

Back

Run 1to1 CT

 COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

 RUTGERS

 The City College
of New York

 Duke
UNIVERSITY

 PRINCETON
UNIVERSITY

 Syracuse
University

 NOAA-CESSRST

Funded by the National Science Foundation

Spectrum Reports (1)

Spectrum Reports

ZMS Dashboard

Interference Alarms Dashboard

Interference Alarms List

COSMOS

ZONE MANAGEMENT SYSTEM

JD

John Doe
Administrator

Filters

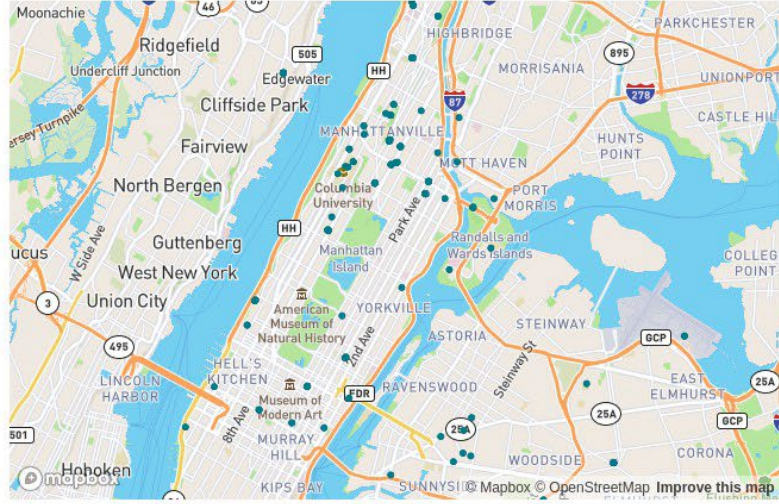
Min Freq

Max Freq

System ID

846 options

SCM Locations



SCM Locations Table

Show 200 entries

System ID	Model	Ref Power	Ref Freq
MW3251712_WQNC238_NULL_P1_T1_R1_RX	receiver	0	19548.9
MW3445921_WQQQ652_NULL_P12_T12_R2_RX	receiver	0	19646.3
Tx_28GHz_JNT_NE_Dyspan-test	transmitter	17	28000
TX_Small_BPSK-demo-Columbia	transmitter	1.5	2000
MW1032884_WNTZ387_64QAM_P13_T13_R1_TX	transmitter	60.5	6308.679999999999
MW3184211_WQLR409_4096QA_P9_T9_R1_TX_min	transmitter	55.5	17880.906666666667
MW3197320_WQLW888_NULL_P8_T8_R4_RX	receiver	0	23348.9
MW3457777_WQQW939_NULL_P13_T13_R1_RX	receiver	0	22500
MW3597097_WQUA446_NULL_P10_T10_R1_RX	receiver	0	11193.1
RX_100m_BPSK	receiver	0	2000
ITF_DS_SSC_110_700	transmitter	20	1000

Spectrum Reports (3)

Spectrum Reports

ZMS Dashboard

Interference Alarms Dashboard

Interference Alarms List

COSMOS

COLUMBIA

IN THE CITY

Not Secure

http://cosmoszms.local/status-alerts

COSMOS

ZONE MANAGEMENT SYSTEM

JD

John Doe

Administrator

Interference Alarm Dashboard

Create Alarm

Search alarms...

ALARM ID	INTERFERING DEVICE	INTERFERED DEVICE	START TIME	STATUS	PROGRESS	LAST UPDATE	ACTIONS
2	TX_Small_BPSK_ct-test	RX_100m_BPSK_ct_test-2	10/14/2025, 4:21:48 PM	Resolved	resolved	10/21/2025, 5:31:14 PM	View Report Update Alarm
3	TX_Small_BPSK_ct-test	RX_100m_BPSK_ct_test-2	10/14/2025, 4:25:24 PM	Resolved	resolved	10/21/2025, 5:31:27 PM	View Report Update Alarm
...							
15	TX_Small_BPSK-demo	RX_100m_BPSK_ct_test	12/5/2025, 2:12:15 PM	Active	New interference alarm created. Power margin: 15.864071780166844	12/5/2025, 2:12:15 PM	View Report Update Alarm
16	TX_Small_BPSK-demo	RX_100m_BPSK_test-rx	12/5/2025, 2:12:32 PM	Resolved	resolved by user Jay	2/2/2026, 3:44:29 PM	View Report Update Alarm
17	TX_Small_BPSK-demo-Columbia	RX_100m_BPSK_columbia	2/18/2026, 8:52:20 PM	Active	New interference alarm created. Power margin: 17.876732380826887	2/18/2026, 8:52:20 PM	View Report Update Alarm

COSMOS

COLUMBIA

IN THE CITY

UNIVERSITY

NOAA

CLIMATE

ZMS – Integrations

NG-Scope and NR-Scope: Cellular network monitoring tools

- NG-Scope and NR-Scope make **the ZMS 4G and 5G network-aware**
- Upgraded NG-Scope code base to pass detected base station information to COSMOS ZMS
 - Monitor base station's spectrum use, power levels, activity, etc.
- Currently upgrading NR-Scope code base for ZMS interactions
- Ongoing tests:
 - Running NG-Scope on multiple COSMOS nodes (5) simultaneously
 - Detected 5+ base stations
 - Conducting several 24+ hour cellular activity characterization runs
 - Relaying of base station operational characteristics/activity to ZMS via periodically updated SCMs.

Integration of Geo2SigMap

- Path loss data/computations that can be incorporated into SCM propagation map constructs
- (Future) Display of propagation details/coverage in the ZMS UI

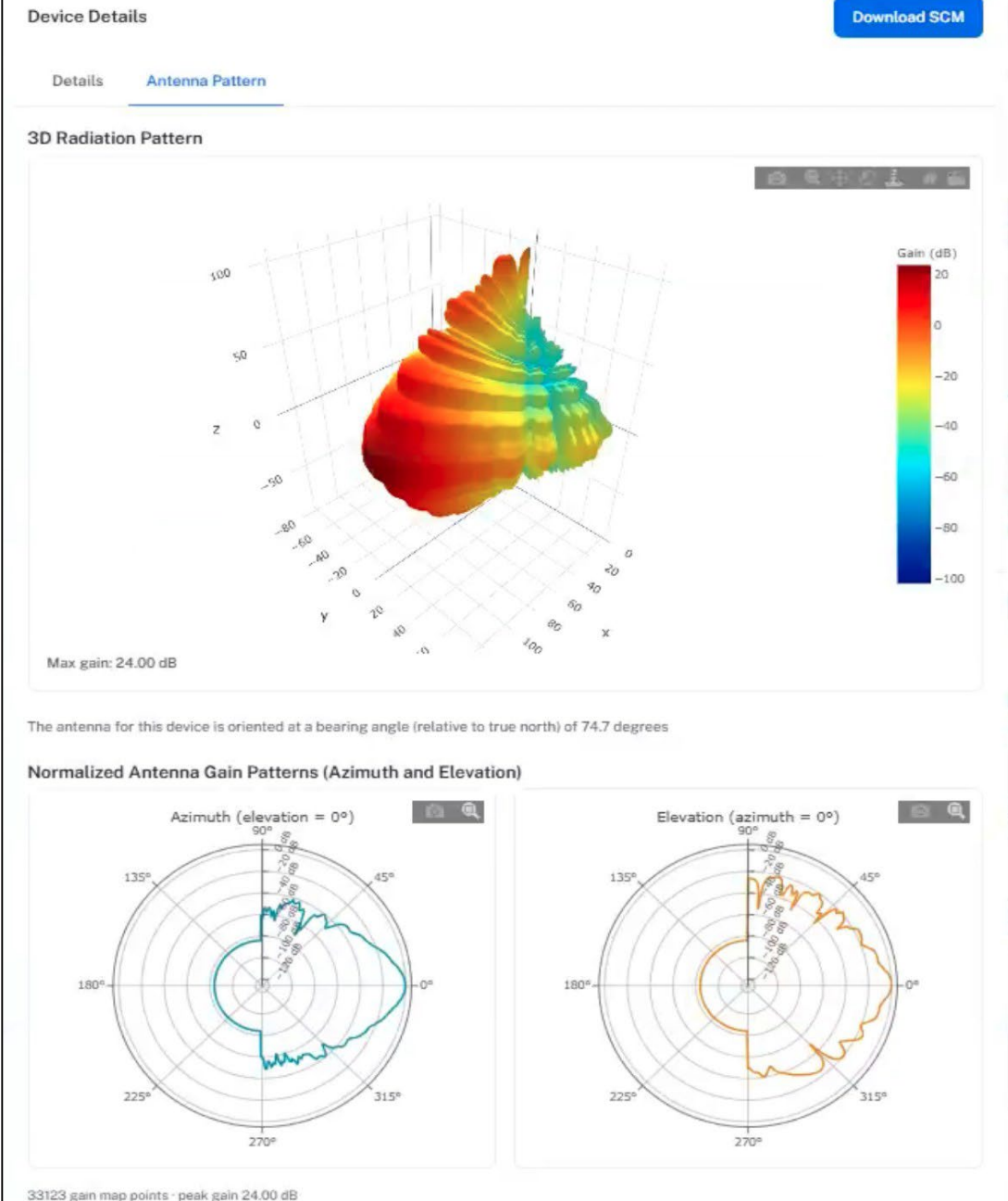
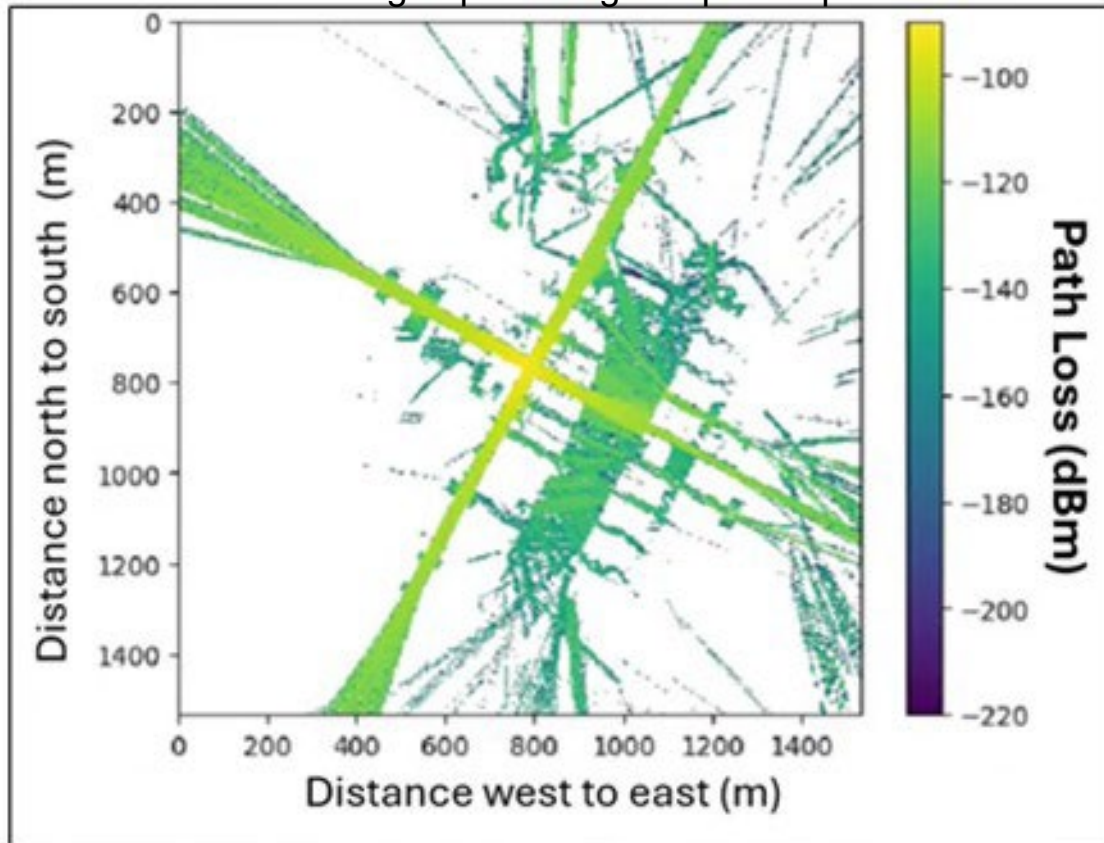
- Y. Xie and K. Jamieson, "NG-Scope: Fine-grained telemetry for NextG cellular networks," Proceedings of the ACM on Measurement and Analysis of Computing Systems, vol. 6, no. 1, Mar. 2022.
- H. Wan, X. Cao, A. Marder, and K. Jamieson, "NR-Scope: A practical 5G standalone telemetry tool," in Proceedings of the 20th International Conference on Emerging Networking Experiments and Technologies, ser. CoNEXT '24. New York, NY, USA: Association for Computing Machinery, 2024, p. 73–80
- Y. Li, Z. Li, Z. Gao, and T. Chen, "Geo2SigMap: High-Fidelity RF Signal Mapping Using Geographic Databases," in *Proc. IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN'24)*, 2024.

Additional capabilities (in development)

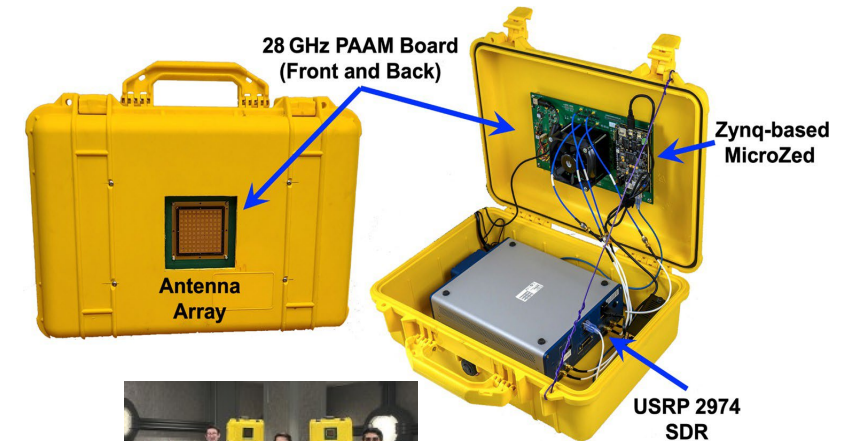
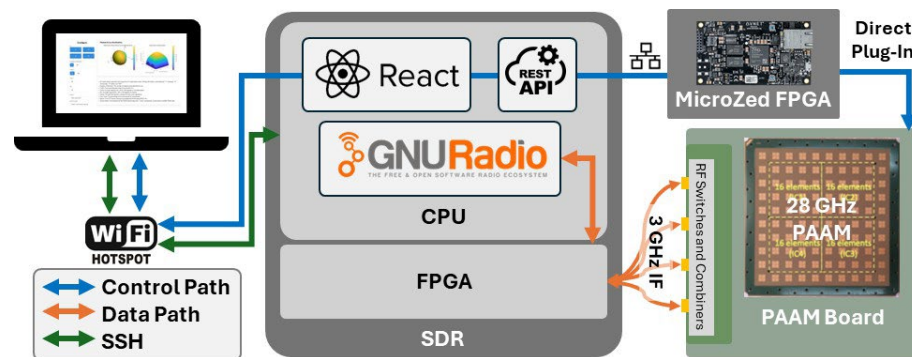
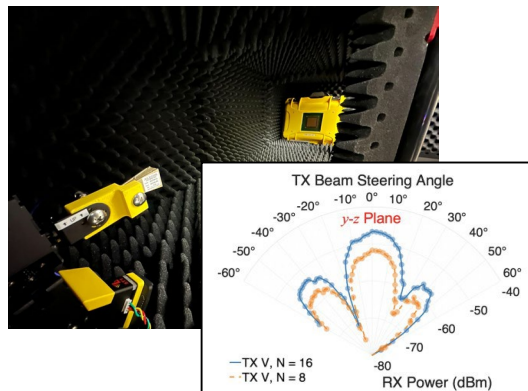
Antenna radiation pattern visualization
(from the PowerMap data in an SCM)



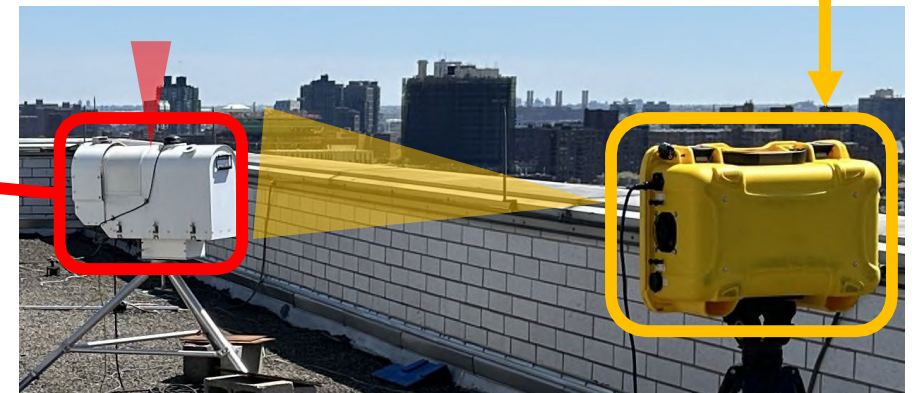
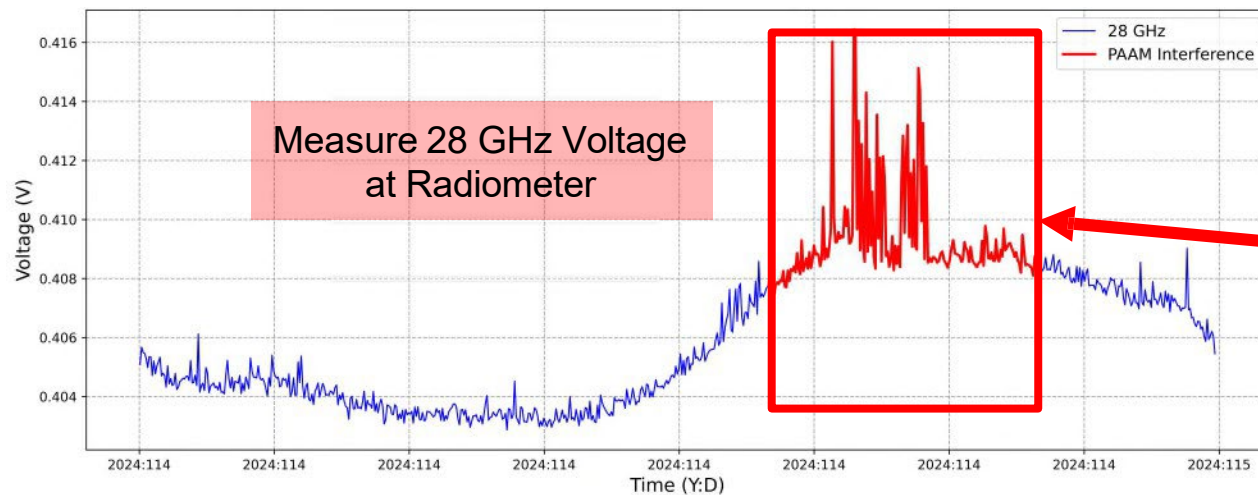
Geo2Sitemap coverage map example



5G base station represented as 28 GHz mobile SDR

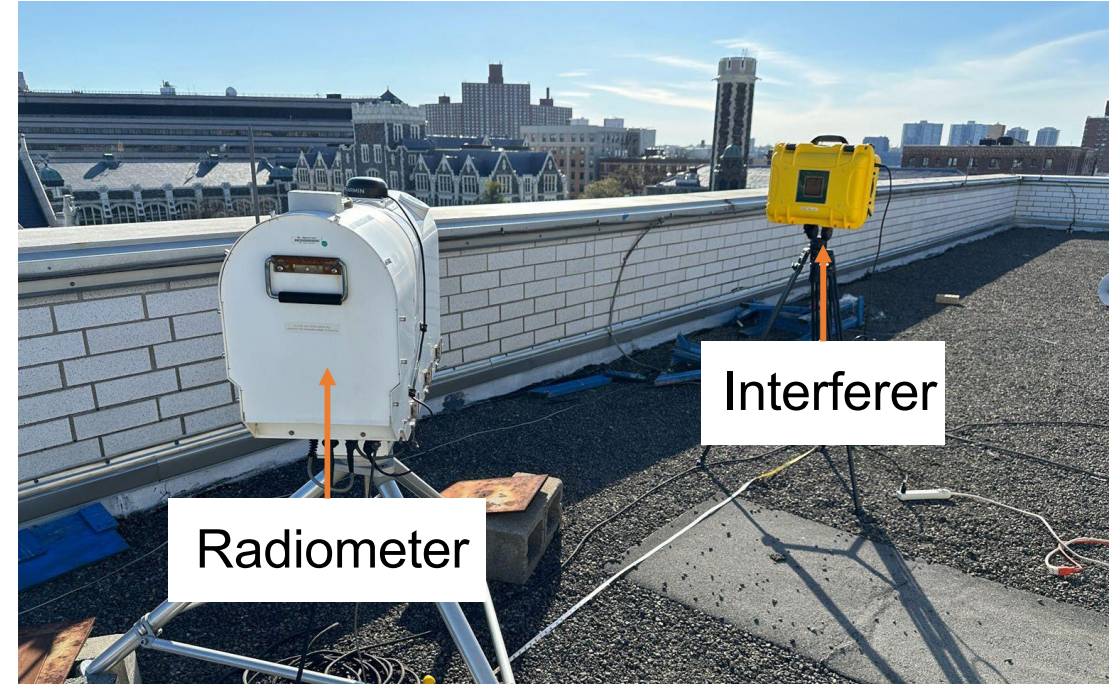


Generate
28 GHz Interference



Building an SCM for a Microwave Radiometer

- To protect the radiometer from harmful interference, we will build a receiver SCM
- Minimum Constructs Needed:
 - Reference Power
 - Underlay Mask
 - Power Map
 - Propagation Map
 - Location
 - Schedule
- Experiments were conducted to gather the information for these constructs
- Radiometer's SCM has been registered into the ZMS
 - Modeled several interference protection scenarios
 - Designed experimental (on the ground) test to validate protection mechanisms



C. Caicedo, J. Doshi, et.al, "COSMOS ZMS: A Radio Dynamic Zone Management System Using the COSMOS Platform", IEEE Dynamic Spectrum Access Networks Symposium (DySPAN), May, 2026



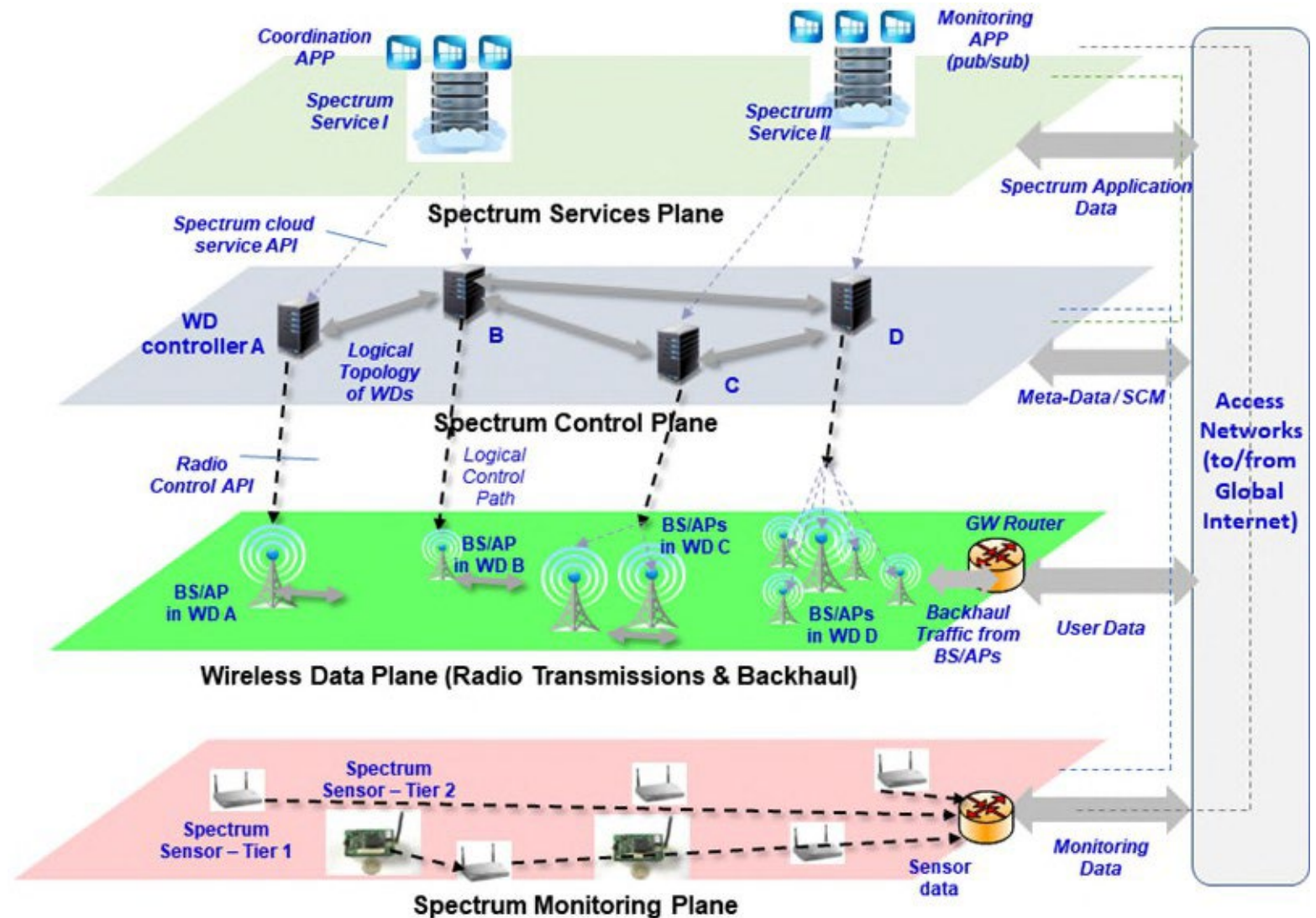
NewSpectrum: Distributed Data-Driven Spectrum Management Architecture

Carlos E. Caicedo Bastidas (PI)*, Dipankar Raychaudhuri**, Ivan Seskar**

*Syracuse University, **Rutgers University

The D3SM Architecture

This project focuses on the design and validation of a distributed and data-driven architecture for dynamic spectrum management among decentralized and heterogeneous wireless systems: *The distributed data-driven spectrum management (D3SM) architecture*

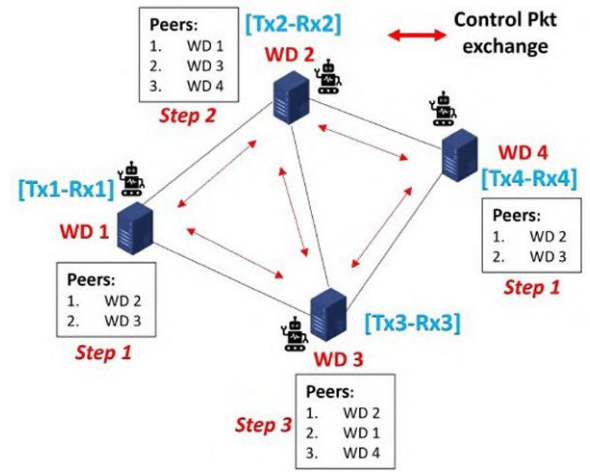
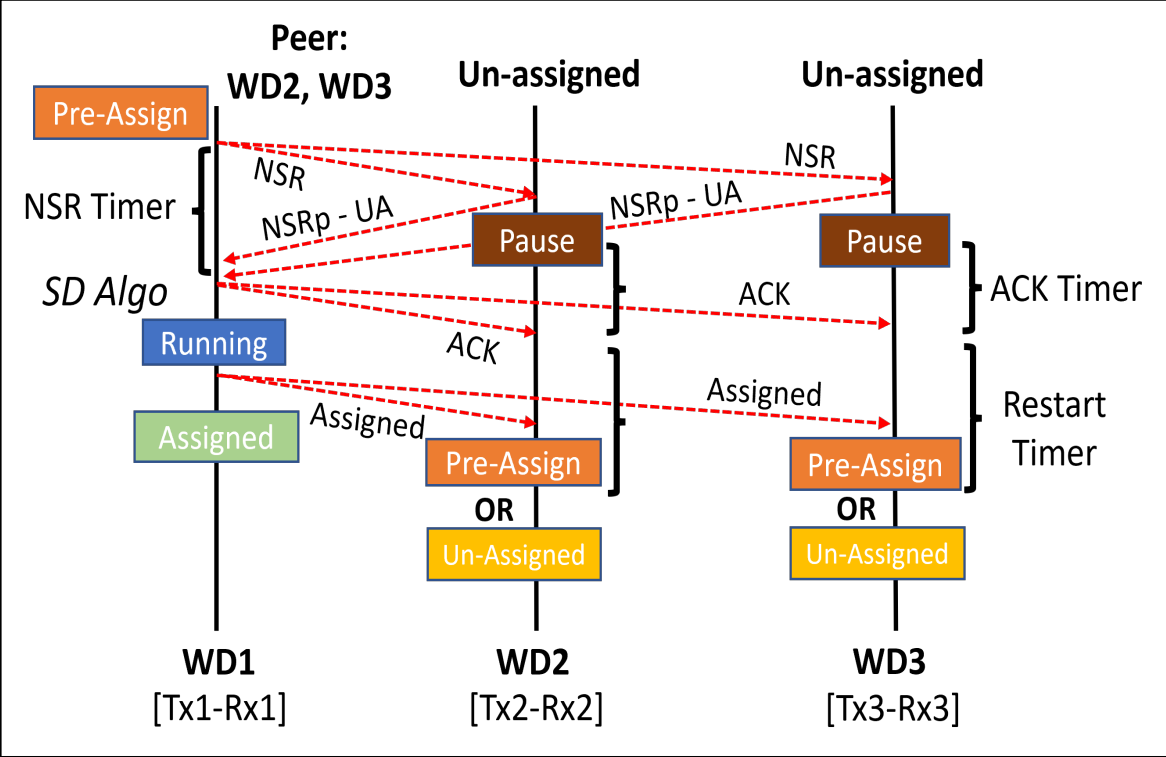
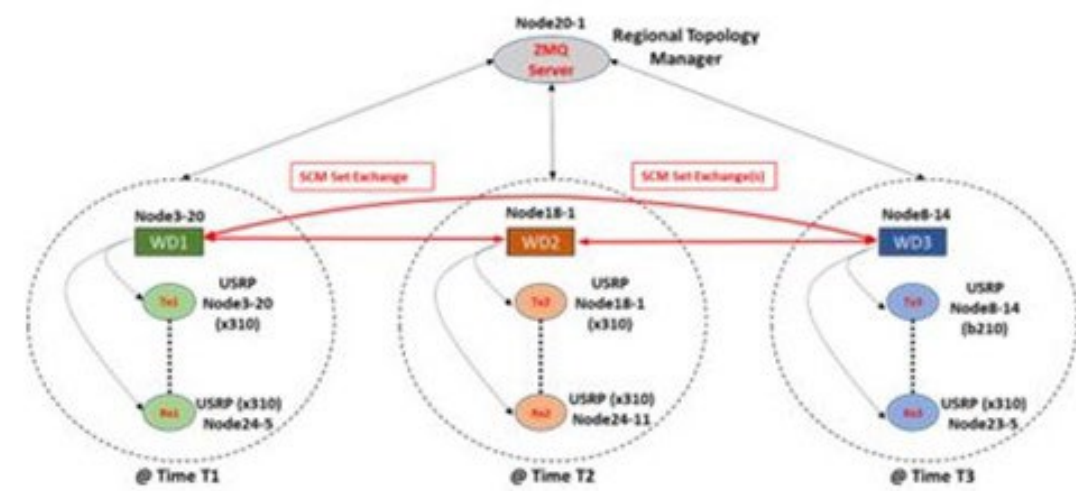
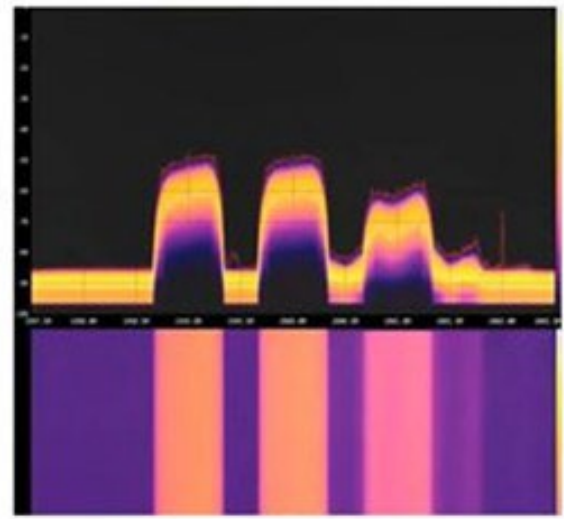
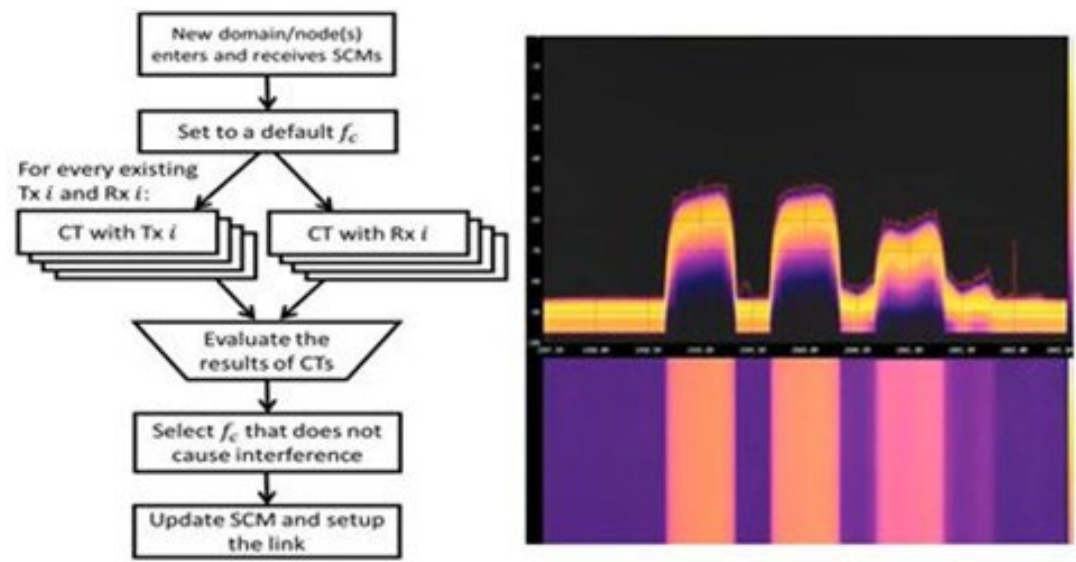


Main Objectives

Collaboratively develop and experimentally validate a distributed data-driven spectrum management architecture that will enable dynamic, and fine-grained flexible spectrum management interactions for:

- a) Spectrum sharing and co-existence among heterogeneous devices/systems
- b) Fine-grained management of interference, including aggregate interference effects to support high spectrum efficiency/reuse
- c) Supporting centralized and distributed spectrum sharing coordination methods
- d) Enabling experimental validation of methods and algorithms proposed to meet the previous listed goals (a) to (c).

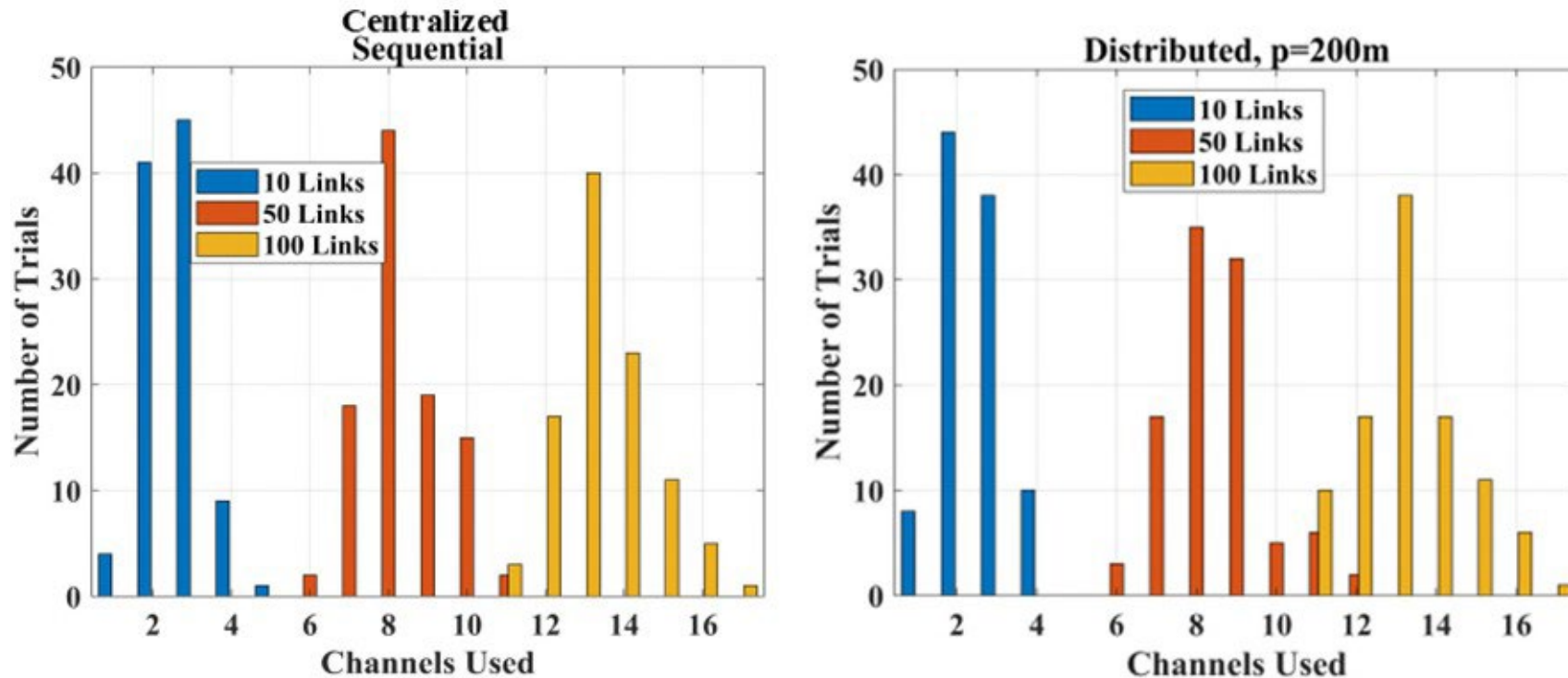
From centralized to distributed spectrum use deconfliction



NSR: Node Status Request
NSRp: Node Status Response
UA: Unassigned
A: Assigned
ACK: Acknowledgement

(Preliminary results/work)

Distributed spectrum use deconfliction algorithms



Channel allocation of sequential (centralized) vs. Distributed spectrum assignment schemes for networks of different sizes deployed in a 0.5 sq. mile area (across 100 trials)

Distributed spectrum deconfliction algorithm with neighborhood distance $p=200m$ achieves a global compatibility error of 0% just like a centralized algorithm would.

Distributed spectrum use deconfliction (1)

Our development and validation of distributed spectrum deconfliction methods currently follows three phases:

Phase I:

- WD Neighbor determination
 - Bootstrapping / Beacons

Phase II:

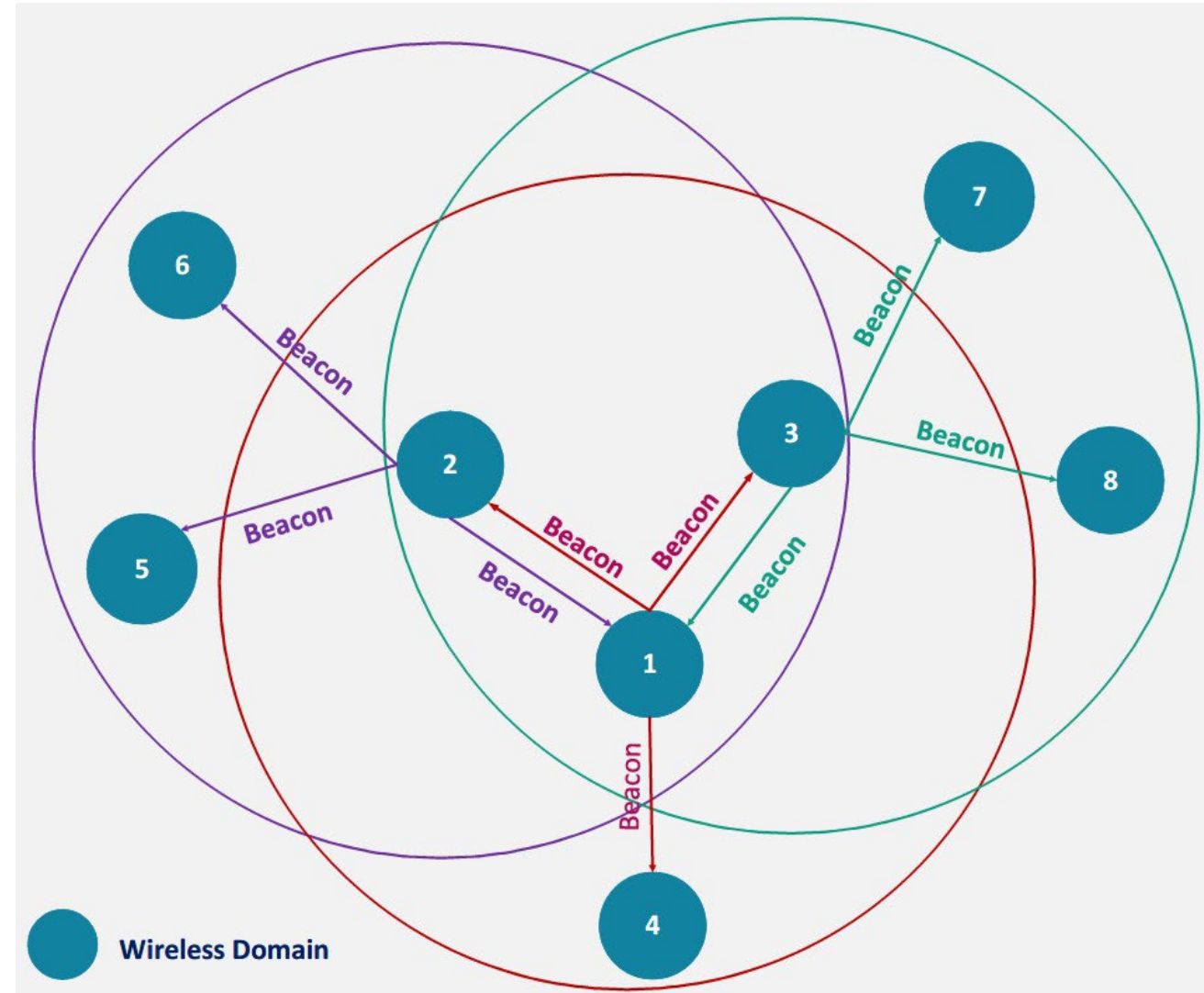
- Spectrum Consumption model exchange
- Spectrum Deconfliction with SCMs

Phase III

- Account/adapt for mobility and/or propagation changes

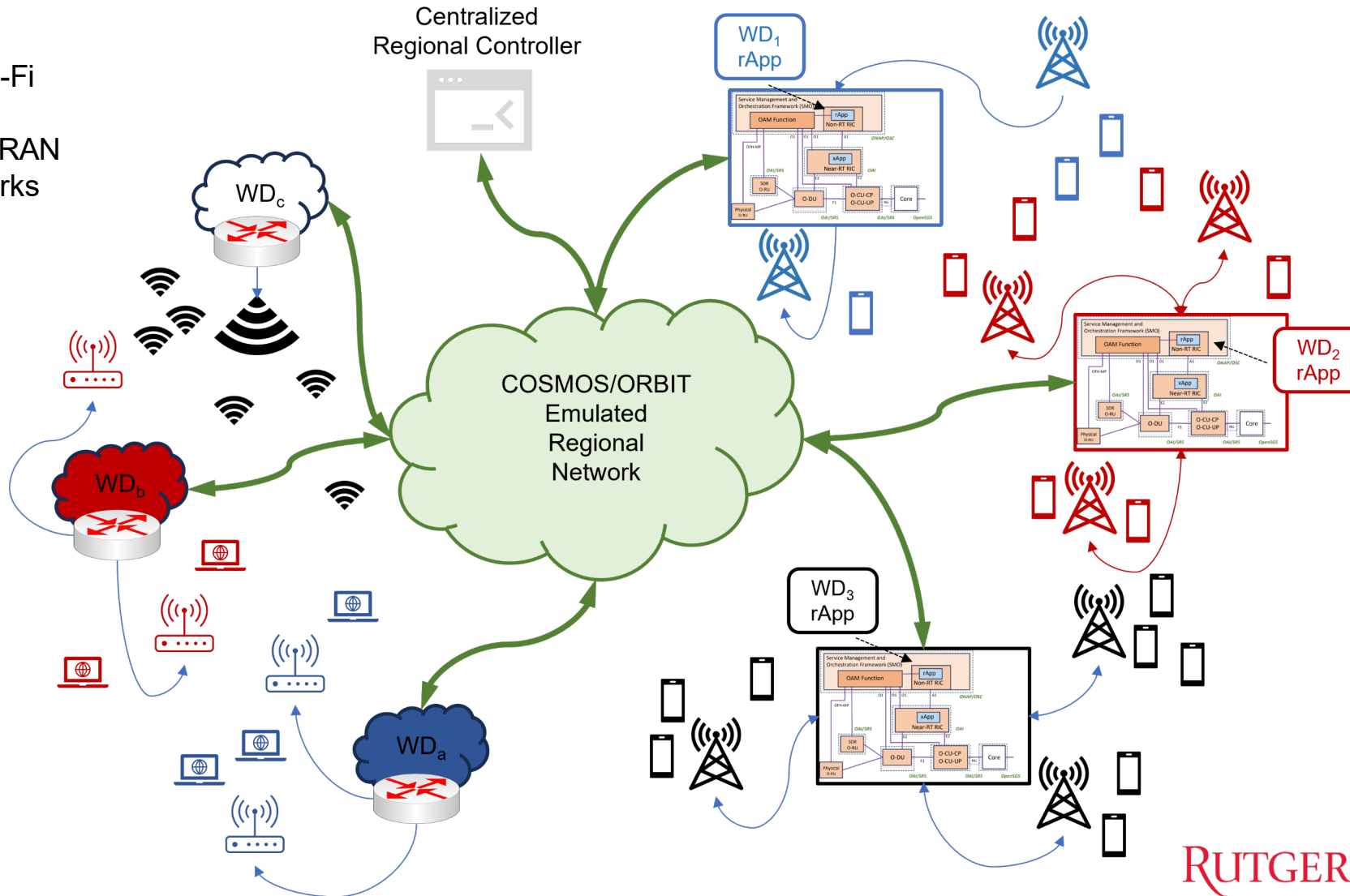
Message exchanges/interactions take place in the *control plane* of the architecture

Note: For any particular WD, the Beacon transmission range > RF device tx range



Experimental Testing and Validation

Case 1: WDs are Wi-Fi based systems
Case 2: WDs are O-RAN based cellular networks



Conclusions

- The COSMOS testbed provides a realistic, reconfigurable environment for DSA research — from controlled sandbox experiments to rooftop mmWave deployments — enabling SCM-based coexistence methods to be validated experimentally, not just in simulation.
- Built on COSMOS, the Zone Management System (ZMS) turns IEEE 1900.5.2 SCMs into a deployable, cloud-native coordination platform with device management, automated compatibility testing, interference alarms, and map-based monitoring.
- COSMOS resources let the ZMS protect real incumbents — the NOAA-CESSRST passive receivers, including the 27–29 GHz radiometer overlapping COSMOS/5G mmWave bands — using receiver SCMs built from actual field measurements.
- COSMOS's programmable nodes and SDRs enable realistic DSA integrations: NG-Scope for live 4G/5G base-station awareness, mobile 28 GHz phased-array SDRs to emulate 5G interferers, and Geo2SigMap for high-fidelity path loss in SCM propagation maps.
- The platform also supports the shift from centralized to distributed spectrum use coordination with COSMOS assisting in the design and validation of distributed spectrum deconfliction algorithms.



Contact information:

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