

The COSMOS Testbed – A Platform for Advanced Wireless, Optical, and Edge Cloud Experimentation

EUCNC

June 7, 2022

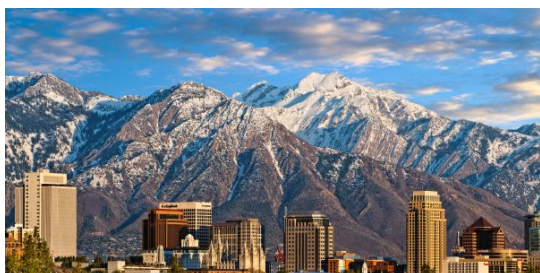
Ivan Seskar

seskar@winlab.rutgers.edu

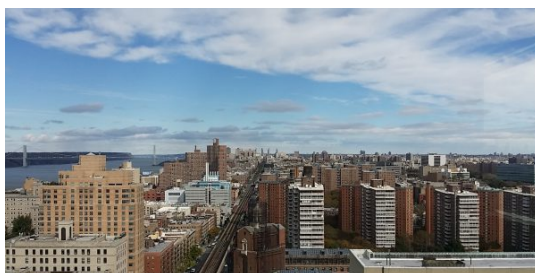


Platforms for Advanced Wireless Research (PAWR)

- NSF public/private program (\$50M + \$50M)
- Managed by PAWR Project Office (NEU/US-Ignite)
- Build four “city scale” platforms in US
- Enable core wireless and mobile research
- Enable research related to services/applications that rely on wireless and mobile



POWDER
Salt Lake City



COSMOS
New York City



AIRPAW
Research Triangle



ARA
Central Iowa

First round completed in early 2018:

- POWDER-RENEW (University of Utah, Rice University)
- COSMOS (Rutgers University, Columbia University, New York University)

Second round winner early 2020:

- AERPAW (North Carolina State University, Mississippi State University, RENC)

Third round winner July 2021:

- ARA (Iowa State University)

Additional facilities and resources:

- Colosseum - The world's most powerful wireless network emulator
- OpenAirX-Labs (OAX) - An end-to-end open source 5G software lab

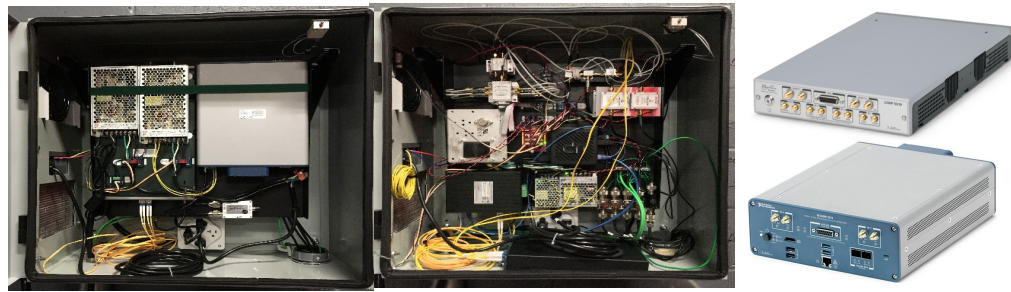


**Platforms for Advanced
Wireless Research**

COSMOS Key Technologies

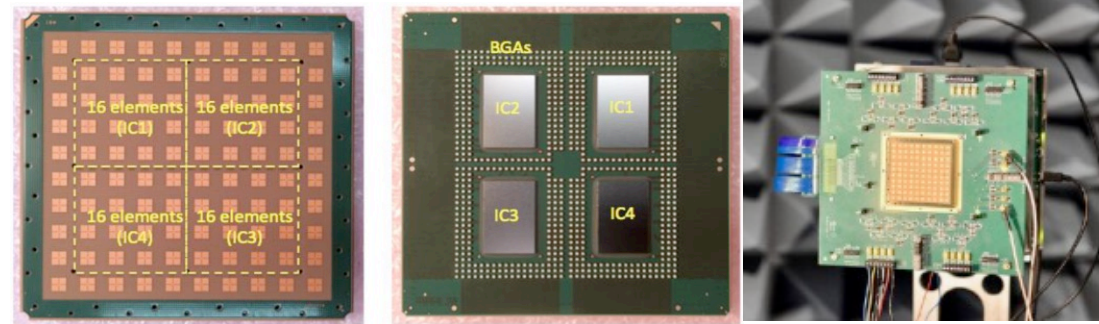
SDR

Design goal: 400 Mhz – 6 Ghz + 28 Ghz and 60 Ghz bands, ~500 Mhz BW, Gbps



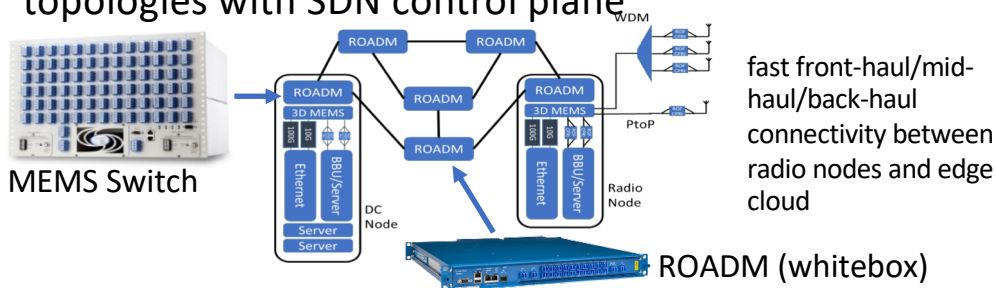
mmWave

IBM 28 GHz mmWave phased arrays (64 antennas with 1 or 8 beams)



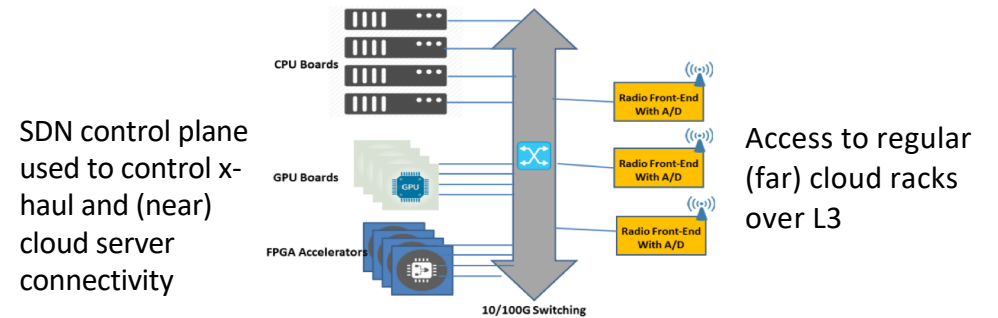
Optical Networking

Fast and low latency optical x-haul network using 3D MEMS switch and WDM ROADM - wide range of topologies with SDN control plane



SDN and (distributed) Cloud

Compute clusters with choice of CPU, GPU and FPGA proc.

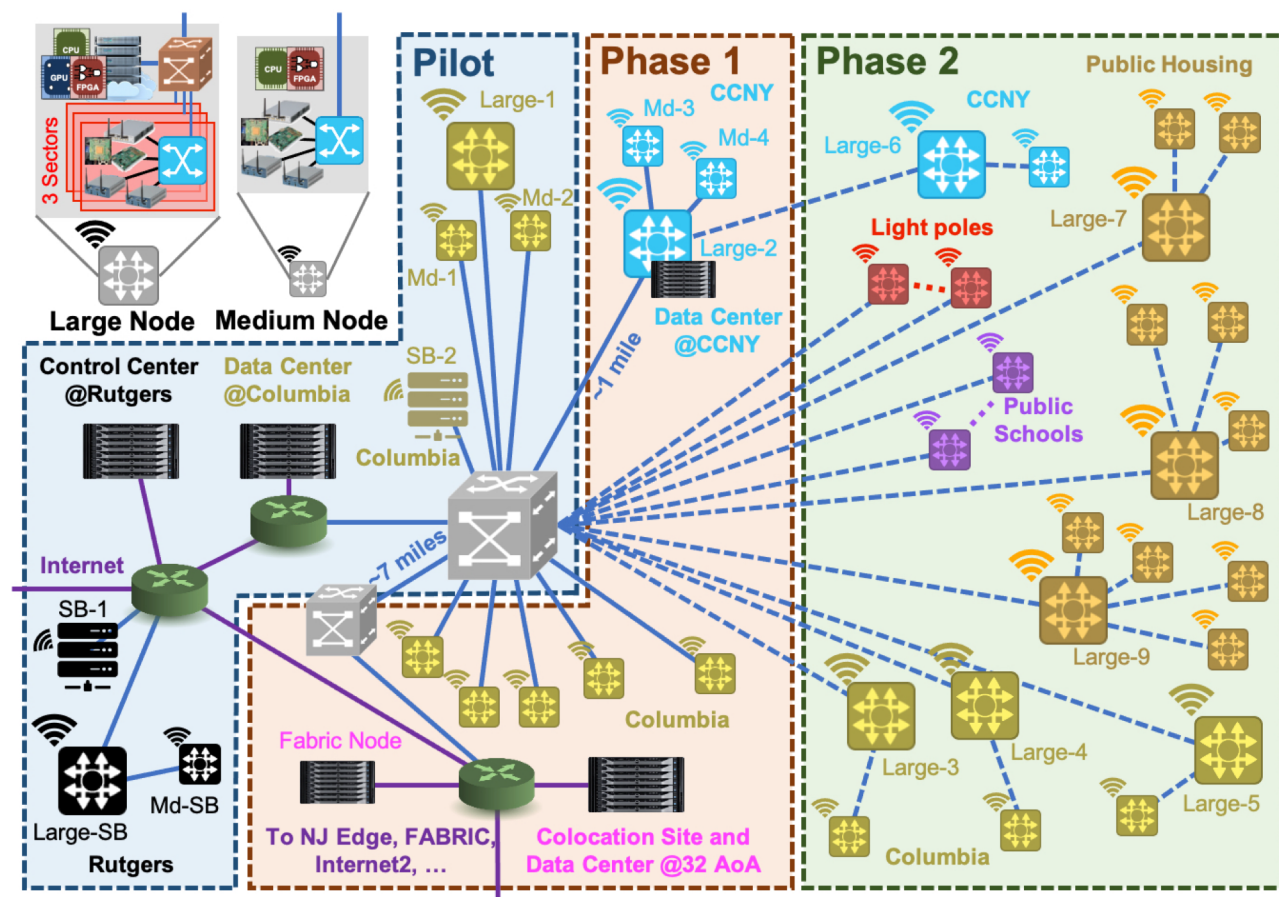


COSMOS: Envisioned Deployment

- A phased approach:
 - Oct. 2017: Dark fiber between Columbia and 32AoA lit up
 - Apr. 2018: Project start
 - May 2019: Pilot completion
 - Sept. 2019: FCC Innovation Zone
 - June 2020: General Available
 - Sept. 2020: IBM PAAM boards delivered
 - Dec. 2021: Dark fiber between Columbia and CCNY lit up
 - During 2022*: Phase 1 completion

*Deployments affected by the COVID-19 pandemic

- Fiber optic connections from most sites
- Fiber connection to Rutgers, 32 Ave. of Americas, CCNY, FABRIC, COSM-IC.



Industrial Lab Extension (Weeks Hall)

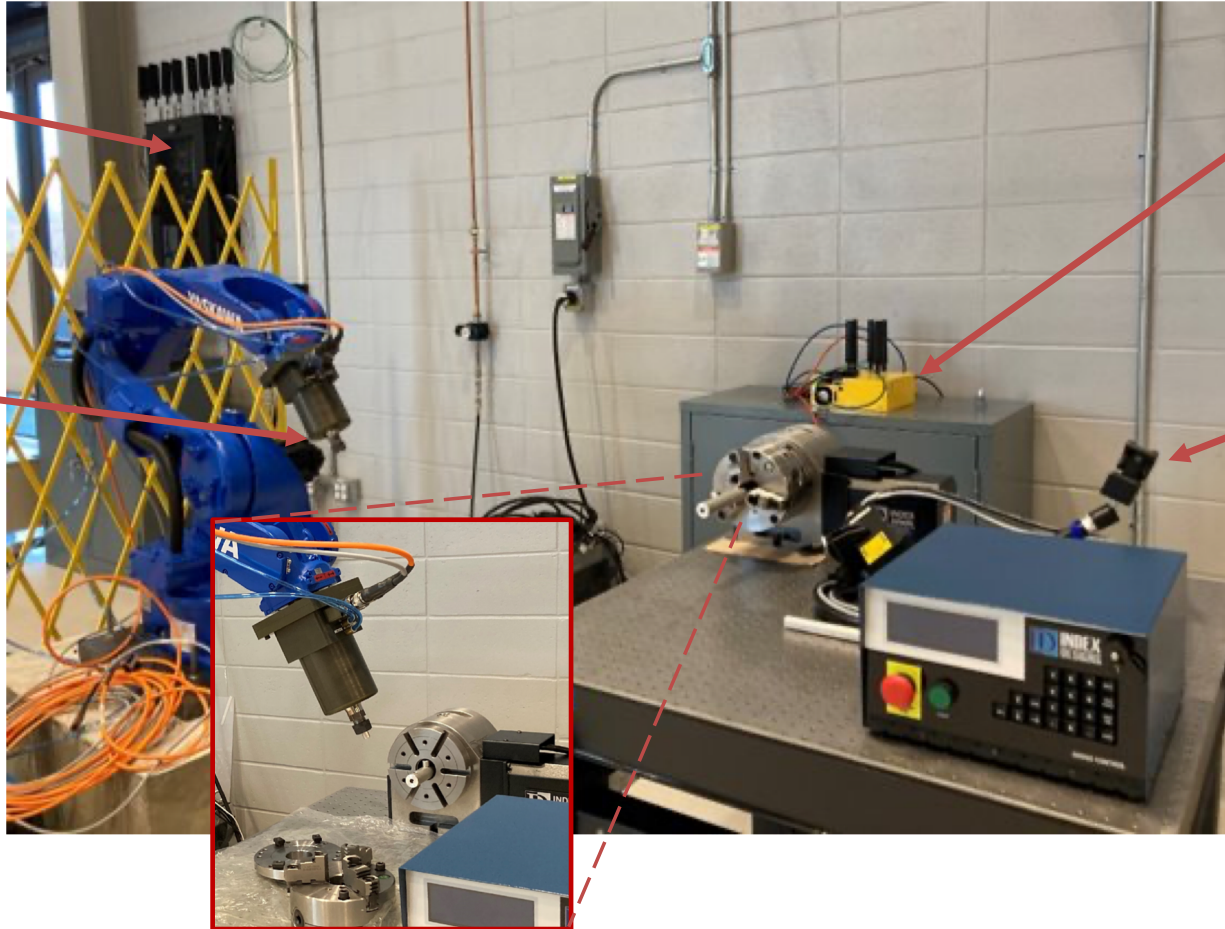
(RU Collaboration with Siemens)

**COSMOS
Large node**

**Robot
Manufacturing
Setup**

**COSMOS
Small Node**

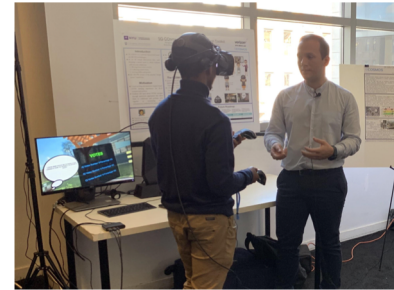
**Surface
Inspection
Camera**



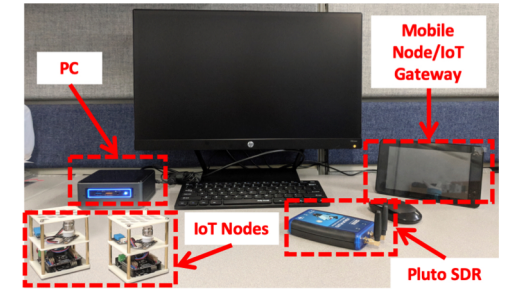
Education and Outreach



- COSMOS education toolkit: A small pre-configured COSMOS node (developed in Summers 2018–2022 RET programs) offering 100+ K–12 educational labs in Math/Science/CS
- Numerous education and outreach activities



5G COVET



COSMOS education toolkit



COSMOS Research Experiences for Teachers (RET) program



Columbia Girls' Science Day



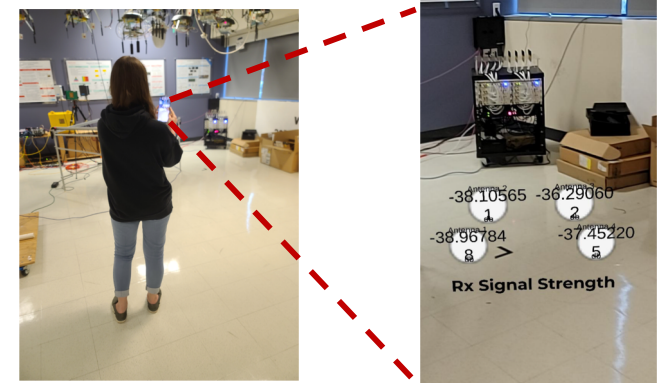
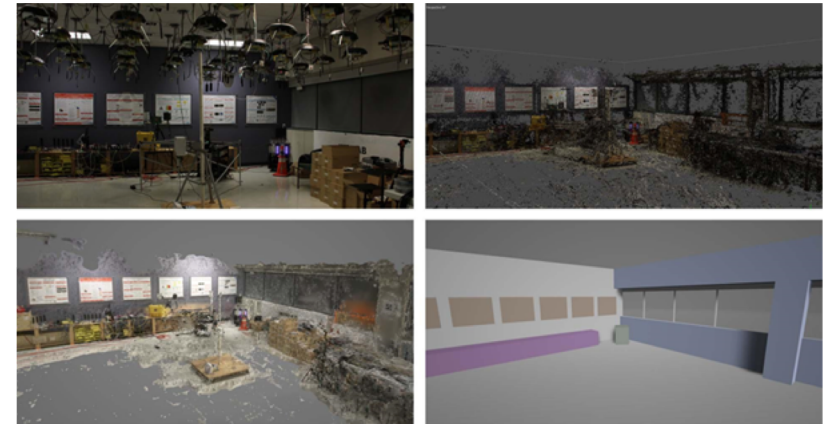
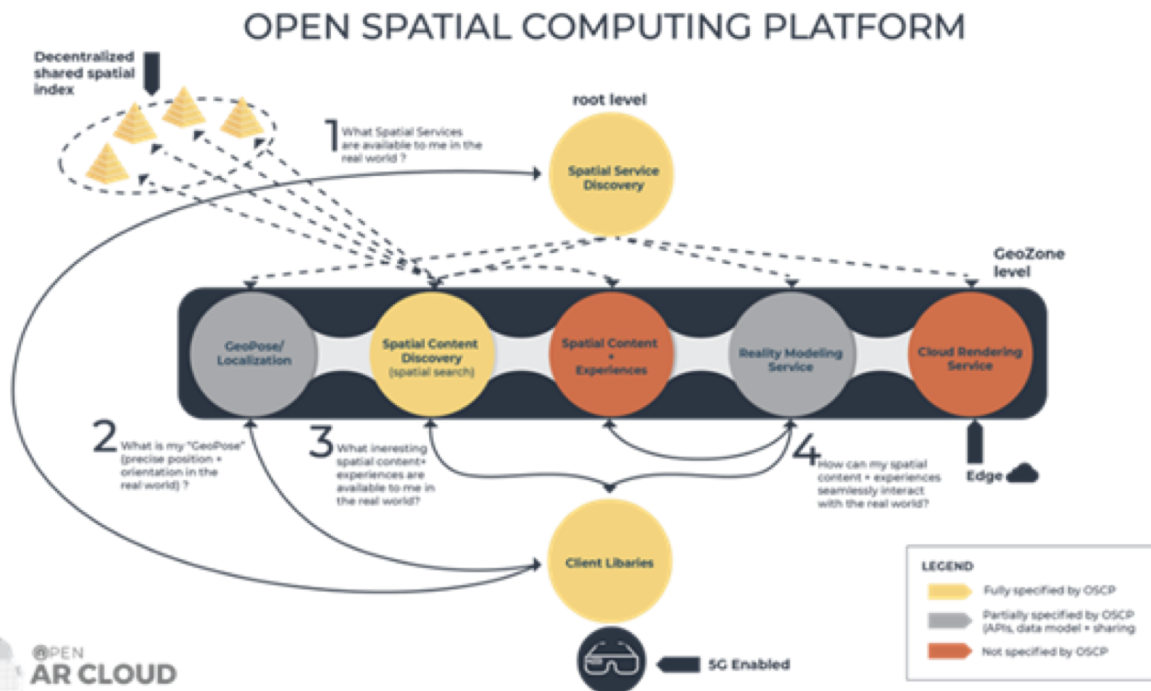
Students in Frederick Douglass Academy using the COSMOS toolkit

- P. Skrimponis, N. Makris, K. Cheng, J. Ostrometzky, Z. Kostic, G. Zussman, T. Korakis, and S. Borges Rajguru, "Evaluation: A teacher professional development program using wireless communications and NGSS to enhance STEM teaching & learning," in *Proc. ASEE Annual Conference*, 2020.
- P. Skrimponis, N. Makris, S. Borges Rajguru, K. Cheng, J. Ostrometzky, E. Ford, Z. Kostic, G. Zussman, and T. Korakis, "COSMOS educational toolkit: Using experimental wireless networking to enhance middle/high school STEM education," *ACM SIGCOMM Computer Communication Review*, vol. 50, no. 4, pp. 58–65, 2020.

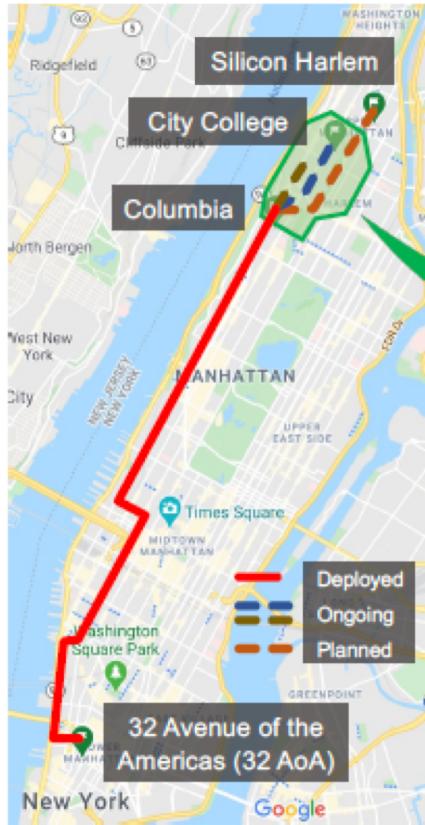
NGIAtlantic Project: OpenAR

Deployment and Evaluation of a 5G Open Spatial Computing Platform in a Dense Urban Environment

Indoor Operation



NGIAtlantic Project: FEDERATING TWO IMPORTANT CITY SCALE TESTBEDS



NGIATLANTIC: COMMON ANALYSIS TOOL ACROSS FEDERATED TESTBEDS



Low Speed Alert			Traffic speed is 0miles/h for more than 3 minutes			Too Crowded Notification		
Time	ngi_intersection.direction	ngi_intersection.speed	Time	ngi_intersection.average_speed		Time	ngi_intersection.direction	ngi_intersection.speed
18/31/2021 20:20:29	0.00	2.18	18/31/2021 20:18:00	2.18		18/31/2021 20:24:35	270.00	1.1
18/31/2021 20:22:21	99.00	2.96	18/31/2021 20:21:00	2.96		18/31/2021 20:26:11	99.00	1.1
18/31/2021 20:23:11	270.00	1.38	18/31/2021 20:24:00	1.38		18/31/2021 20:28:16	99.00	1.1
18/31/2021 20:24:51	270.00	1.80	18/31/2021 20:27:00	1.80		18/31/2021 20:34:52	270.00	1.1
18/31/2021 20:28:51	270.00	2.77	18/31/2021 20:30:00	2.77		18/31/2021 20:45:29	270.00	1.1
18/31/2021 20:30:13	0.00	4.00	18/31/2021 20:33:00	4.00		18/31/2021 20:46:54	0.00	1.1
18/31/2021 20:31:00	99.00	3.11	18/31/2021 20:36:00	3.11		18/31/2021 21:18:48	180.00	1.1
18/31/2021 20:31:53	180.00	4.1	18/31/2021 20:39:00	4.1		18/31/2021 21:18:57	99.00	1.1
18/31/2021 20:35:35	180.00	2.18	18/31/2021 20:47:00	2.18		18/31/2021 21:19:36	180.00	1.1

sensiNact
data platform

Unified access to real-time and historic data via well-defined APIs and data structures

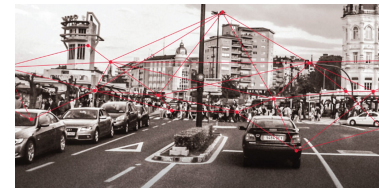


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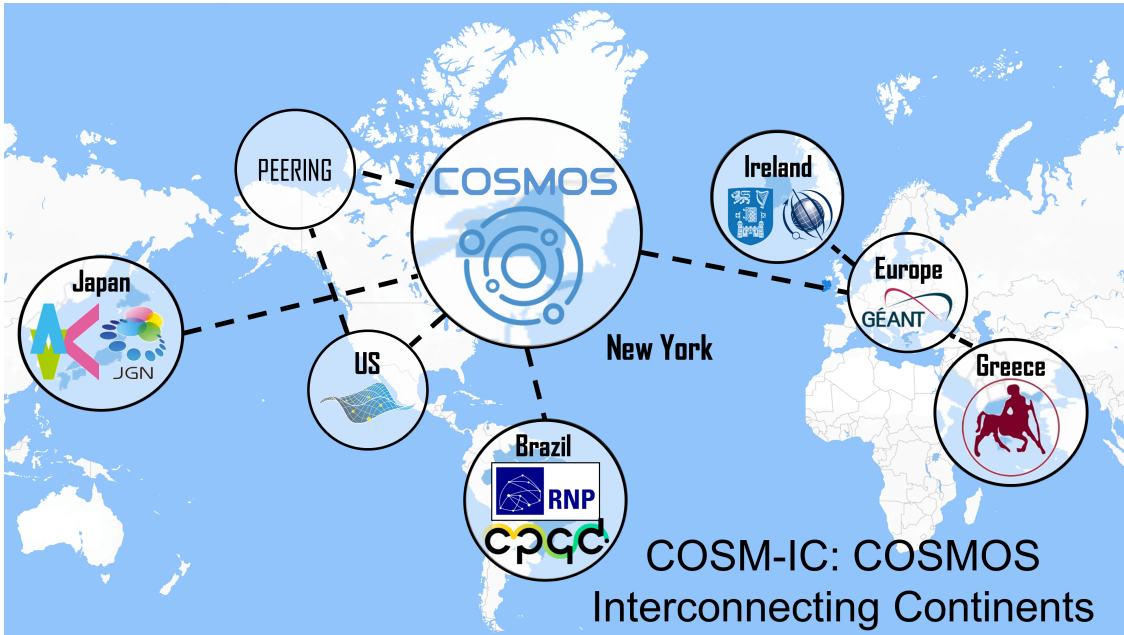
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person 0.0 0.0 0.0 903.281250 637.968750 925.781250 710.625000 0.0 0.0 0.0 0.0 0.0 0.0 0.0
person 0.0 0.0 0.0 933.750000 636.093750 960.000000 711.562500 0.0 0.0 0.0 0.0 0.0 0.0 0.0
person 0.0 0.0 0.0 3189.375000 900.937500 3226.875000 967.500000 0.0 0.0 0.0 0.0 0.0 0.0 0.0
car 0.0 0.0 0.0 2805.000000 920.625000 3268.125000 1182.187500 0.0 0.0 0.0 0.0 0.0 0.0 0.0
car 0.0 0.0 0.0 3560.625000 1262.812500 3838.125000 1566.562500 0.0 0.0 0.0 0.0 0.0 0.0 0.0
car 0.0 0.0 0.0 3637.500000 1095.937500 3840.000000 1311.562500 0.0 0.0 0.0 0.0 0.0 0.0 0.0
car 0.0 0.0 0.0 2602.500000 476.484375 2696.250000 524.531250 0.0 0.0 0.0 0.0 0.0 0.0 0.0
    
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COSMOS Testbed

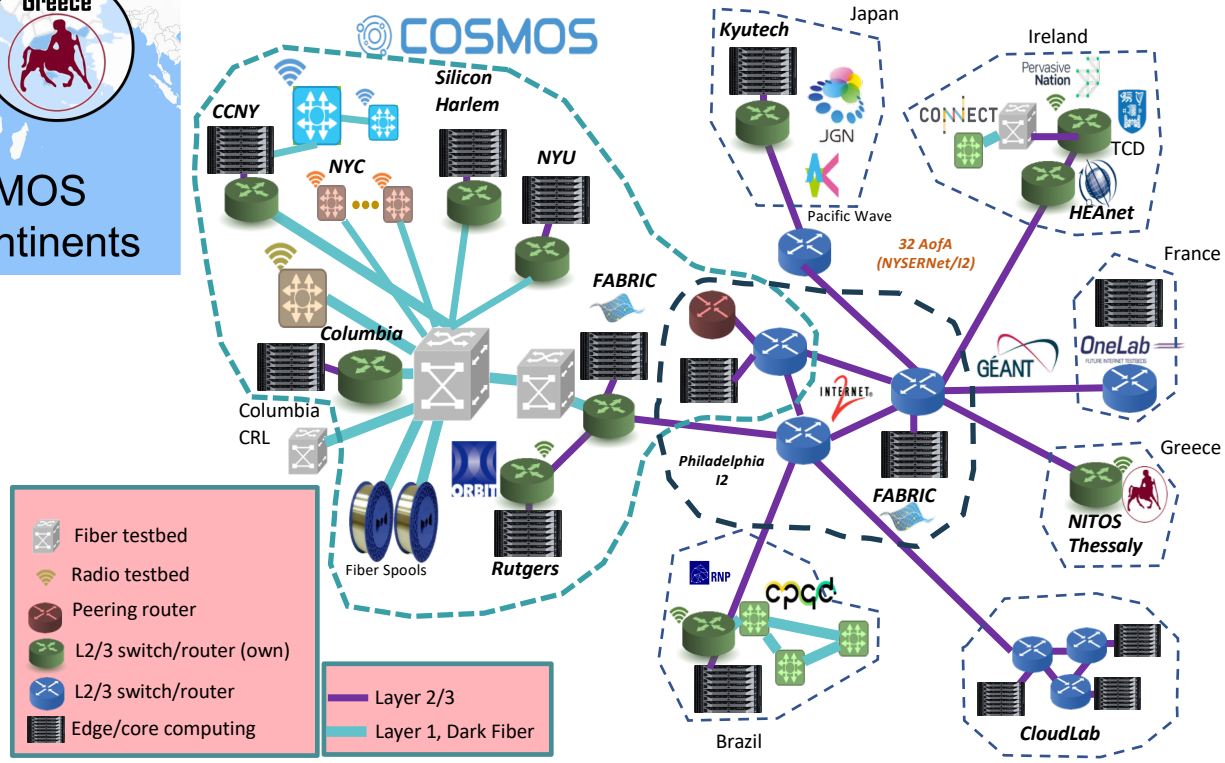


Smart Santander Testbed



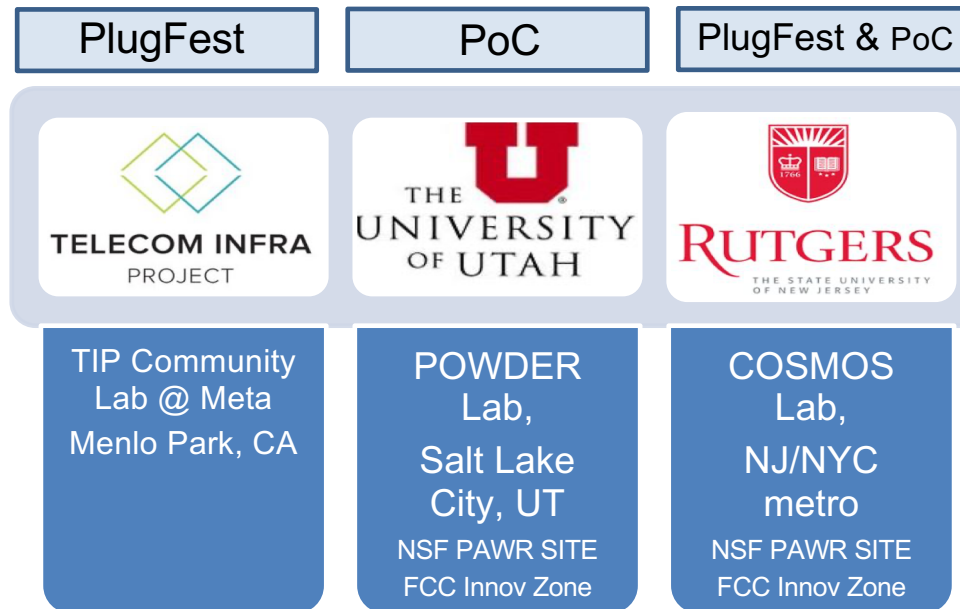
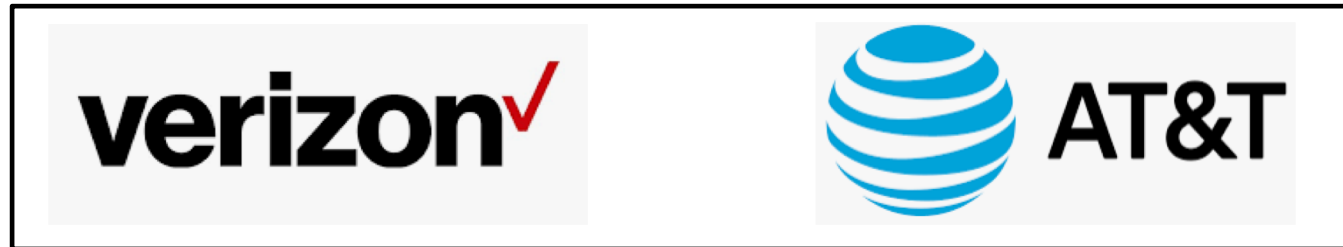
Implementation of connectivity between several wireless/optical/IoT testbeds to support global experimentation

- Research Plan:
- Cross Layer SDX Experimentation
 - Mininet Optical with Data-Driven Platform Models
 - Federating with and via PEERING
 - EIR (Edge Aware Interdomain Routing) Experimentation
 - Education and Outreach



O-RAN PlugFest and Proof-of-concept (#3)

North America PF#3 November 2021



RUTGERS

WINLAB | Wireless Information Network Laboratory

2021 JOINT



THE UNIVERSITY OF UTAH

PLUGFEST AND PROOF OF CONCEPT

Sponsored by:



PARTICIPANTS



WNRVVR

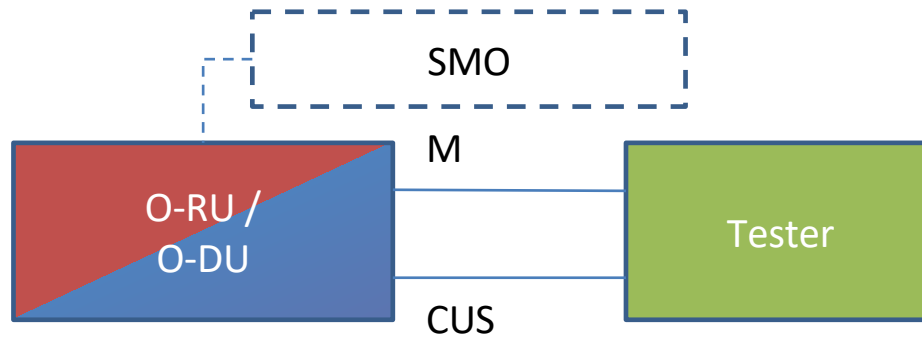
ROHDE & SCHWARZ



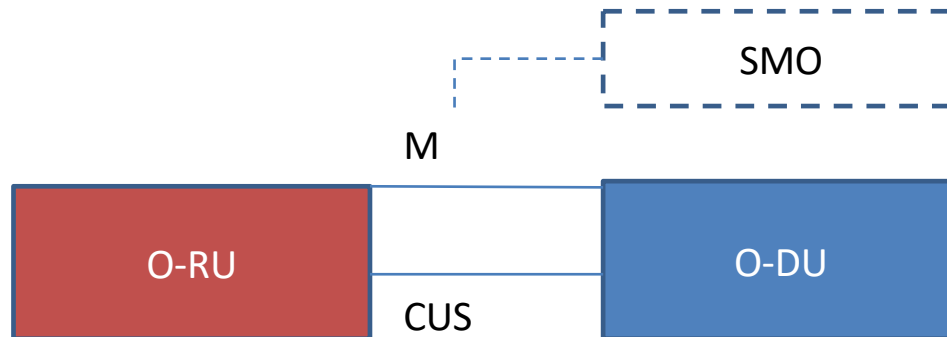
The City College of New York

2021 PlugFest #3

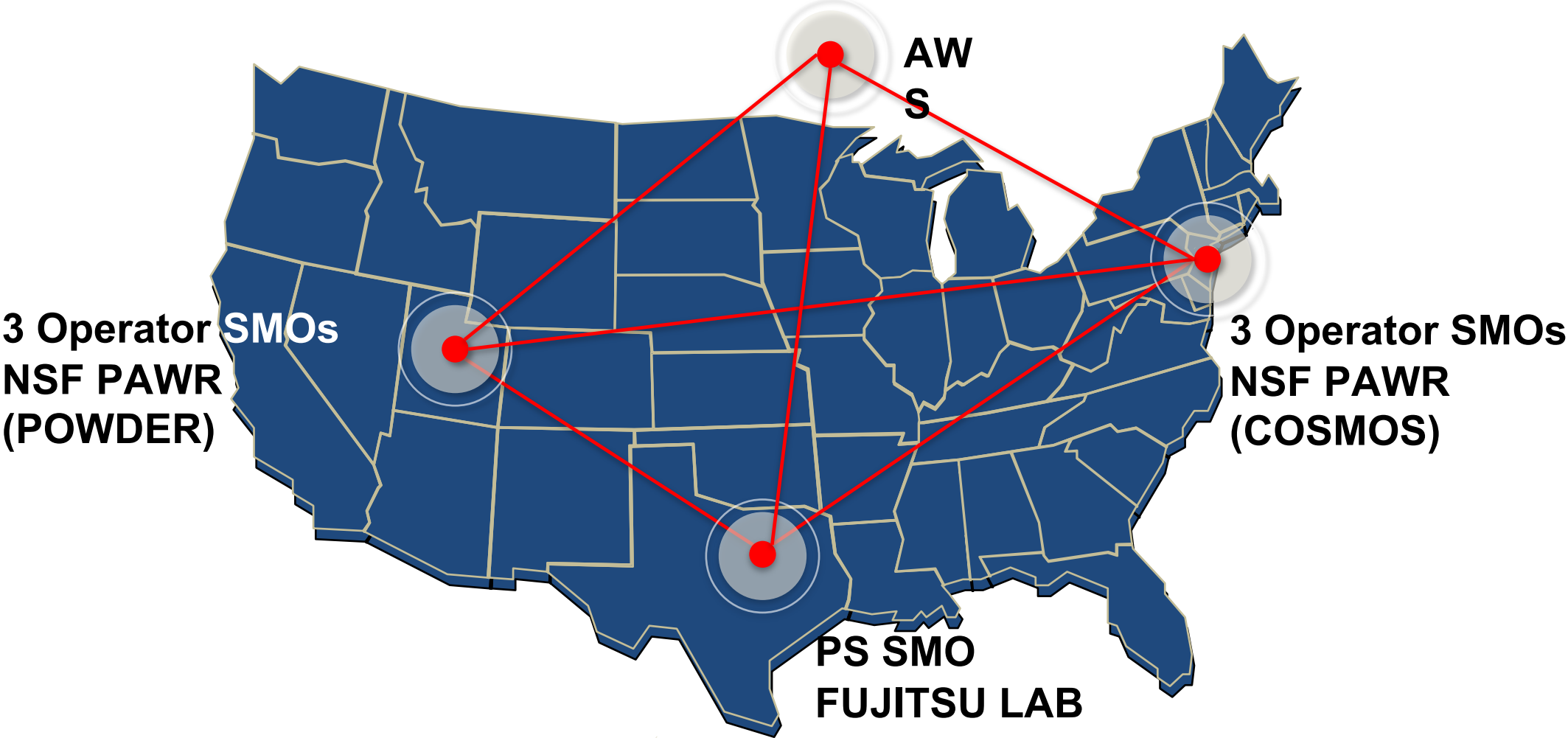
Conformance



Multi-vendor interoperability



PF3 PoC #3: SMO Deployments



PF4: Spring/Summer 2022 O-RAN “PoC-Fest”



4th Global O-RAN / LFN / ONF / TIP joint PoC/Plugfest – North America region; June 2022

Co-hosted by AT&T and DISH

PF4 “PoC-Fest” Labs:

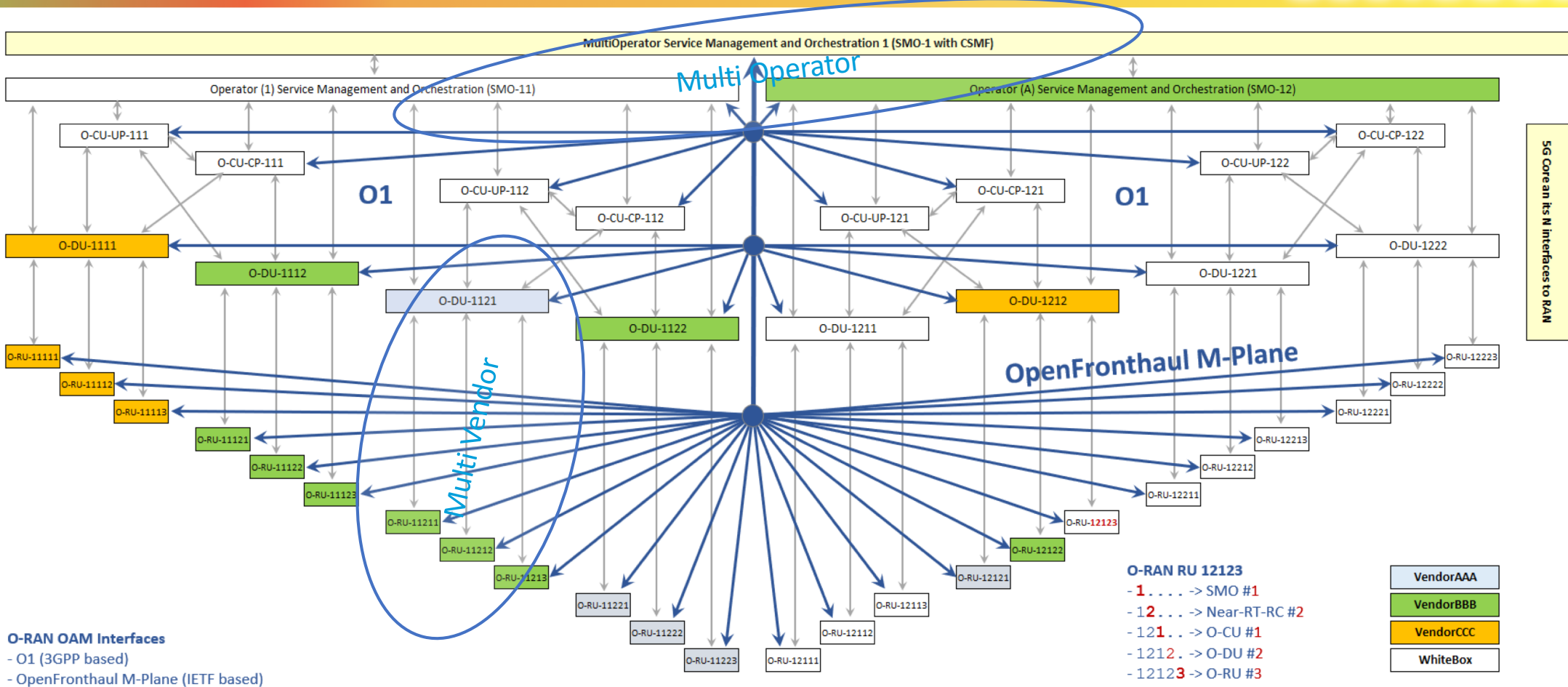
- **AT&T** Open Wireless Lab, Washington DC, USA
- **Rutgers University**, National Science Foundation Platform for Advanced Wireless Research, Cloud Enhanced Open Software Defined Mobile Wireless Testbed for City-Scale Deployment (COSMOS) in NYC/NJ metro area, USA
- **University of Utah**, National Science Foundation Platform for Advanced Wireless Research, , Platform for Open Wireless Data-driven Experimental Research (POWDER) in Salt Lake City metro area, UT, USA
- **University of New Hampshire** InterOperability Laboratory (UNH-IOL) in Durham, NH, USA
- **Telecom Infra Project** (TIP / Meta, formerly Facebook) Community Lab in Melo Park, CA, USA

Spring/Summer 2022 O-RAN “PoC-Fest” High-level Scope



- *Demonstrations of use cases within O-RAN Use Cases Detailed Specification version 6.0 & 7.0*
 - *Energy Saving / Energy Efficiency (CR pending)*
 - *Flight Path Based Dynamic UAV Radio Resource Allocation*
 - *QoE/QoS Optimization*
 - *RAN Sharing*
 - *RAN Slice SLA Assurance*
 - *Multi-vendor slices*
 - *NSSI Resource Allocation Optimization*
- *Multi-vendor Interoperability and integration testing of O-RAN components in a lab environment*
 - *O-RAN specified End-to-end tests*
- *Open Fronthaul S-plane testing*
 - *Portions of O-RAN specified Open Fronthaul Conformance tests, with a focus on the S-Plane*

PF#4 PoC: O-RAN topology view (multi-operator/multi-vendor)



5G Core air N interfaces to RAN

Spring 2022 PoC-Fest use case: Multi-vendor Slices



The figure below depicts an architecture for multi-vendor slices use case. There are multiple slices which have vO-DU and vO-CU associated functions. As depicted, slice-1 is composed of vO-DU(s) and vO-CU(s) provided by vendor B, and slice-2 is composed of vO-DU(s) and vO-CU-UP(s) provided by vendor C.

Each vO-DU/scheduler and vO-CU function treats one slice as an example. O-RU provided by vendor A is shared between two vO-DU(s) supplied by two different vendors, vendor B and C.

The case of vO-DU and vO-CU from different vendors in a slice is for further study.

