The COSMOS Testbed – a Platform for Advanced Wireless, Smart Cities, Edge-cloud, and Optical Experimentation

MERIF Tutorial – Intro to COSMOS

May 23, 2023

The **COSMOS testbed design and deployment** is joint work with the COSMOS team (www.cosmos-lab.org)

Presenter Intro + Outline

- List of presenters
  - Abhishek Adhikari
  - Jennifer Shane
  - Manav Kohli
- How do you benefit from this tutorial?
  - Go to the wiki
  - Understand high level motivation
  - Try the SDRs
    - Outdoor/indoor at sub-6 and mmWave

	General
	Wireless

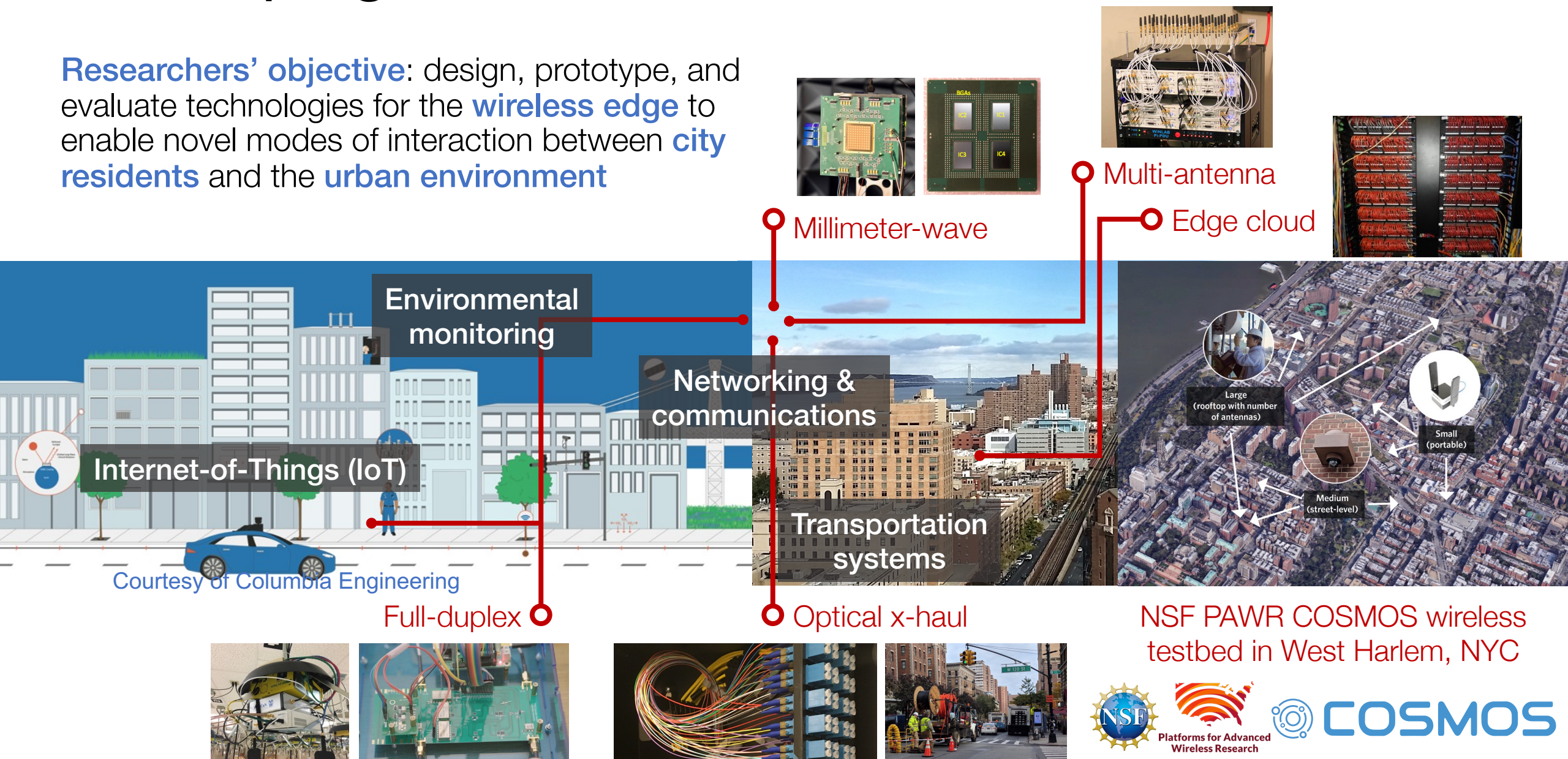| Before	Signup Instructions
(5min)	Brief COSMOS Testbed Recap (Abhi)
(15min)	Introduction to Experimentation (Jenny)
(40min)	Hello World SDR Experiment (Abhi, Jenny, Manav)
(10min)	28 GHz mmWave w/ IBM PAAMs in SB2 (Abhi)
(10min)	Full-Duplex Gen-2 in SB2 (Manav)
(5min)	COSMOS Educational Toolkit (Abhi, Manav)
(5min)	General Q/A (Abhi, Jenny, Manav)

Signup Instructions

- How many people did <u>not</u> go through the signup instructions?
  - If so, no worries! While we proceed with brief recap of COSMOS, Jenny and Manav will go around and help get you set up
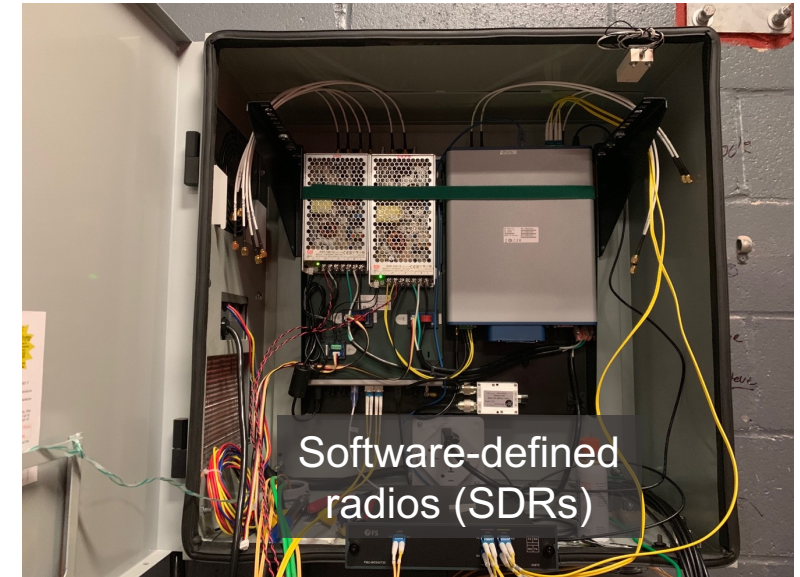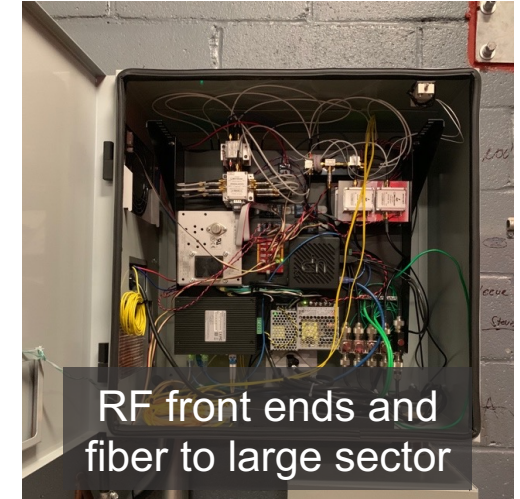
https://wiki.cosmos-lab.org/wiki/Workshops/MERIF2023/SignupInstructions

Developing Future Wireless Networks

Researchers' objective: design, prototype, and evaluate technologies for the **wireless edge** to enable novel modes of interaction between **city residents** and the **urban environment**
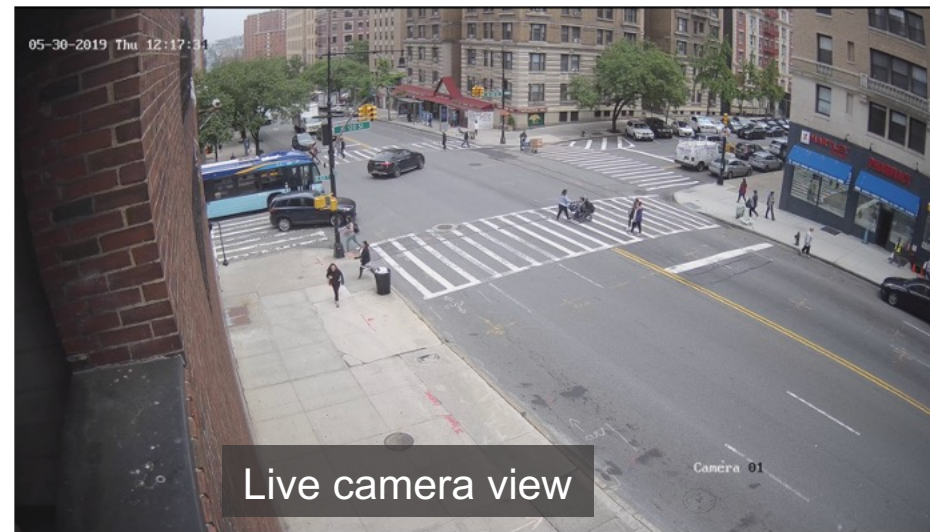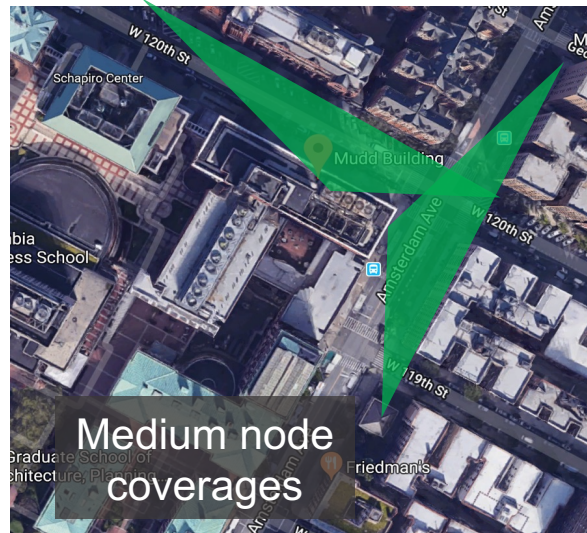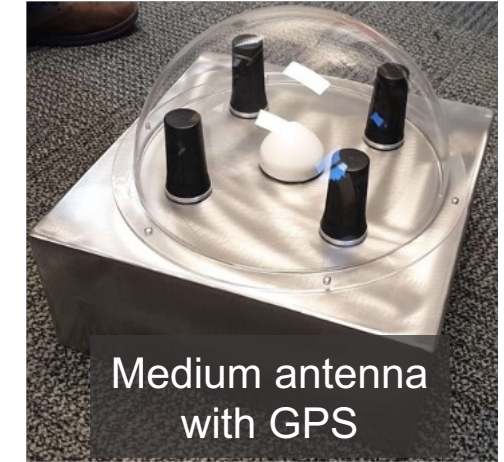
Millimeter-wave

Multi-antenna

Edge cloud

Environmental monitoring

Networking & communications

Internet-of-Things (IoT)

Transportation systems

Large (rooftop with number of antennas)

Small (portable)

Medium (street-level)

Courtesy of Columbia Engineering

Full-duplex

Optical x-haul

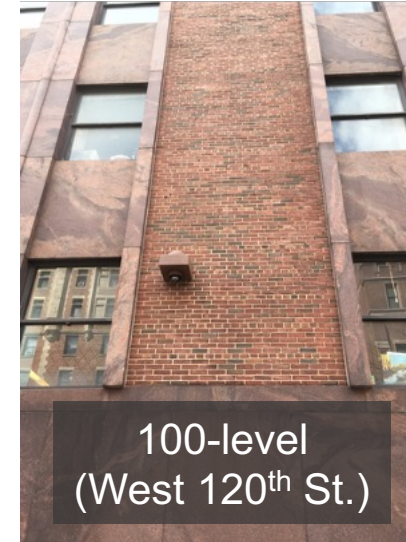NSF PAWR COSMOS wireless testbed in West Harlem, NYC

Platforms for Advanced Wireless Research

COSMOS

Columbia Large Node (lg1)

RF front ends and fiber to large sector

Large sectors

s2 s1

s3

Software-defined radios (SDRs)

Columbia Medium Nodes (md1 and md2)

200-level (Amsterdam Ave.)

100-level (West 120th St.)

Medium antenna with GPS

Medium node coverages

Live camera view

CCNY Large and Medium Nodes (md3 and md4)
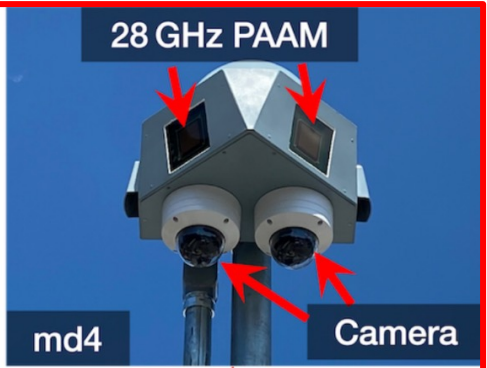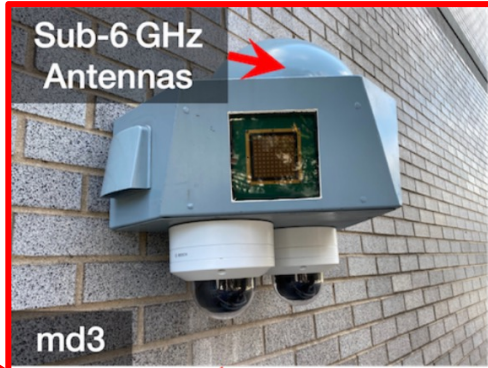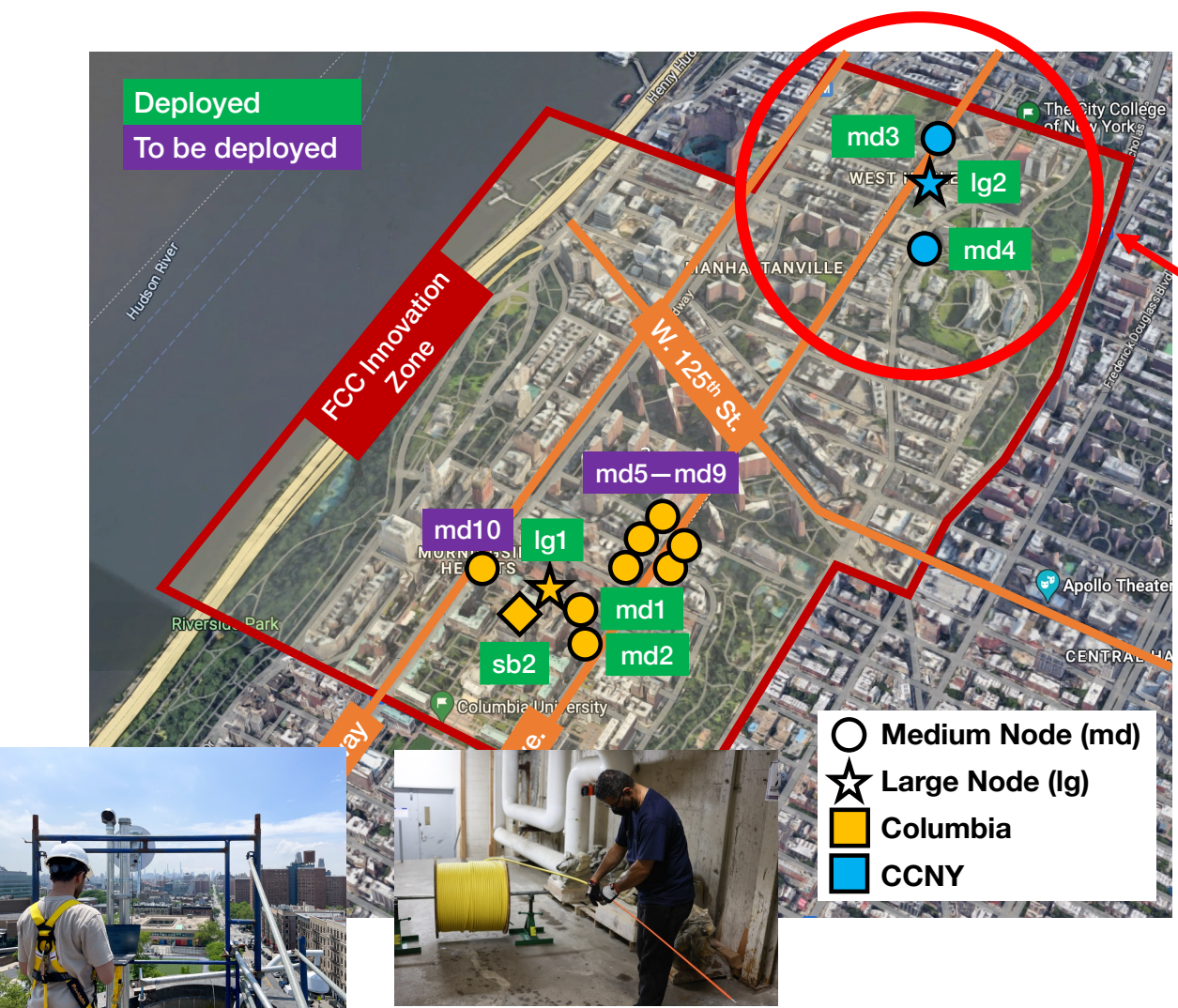
Key Technology: Software-Defined Radios

Sub-6 GHz RF Front End

Eth Switch & Chassis Manager

Fiber & Power Passthrough

Optical MUX/DEMUX
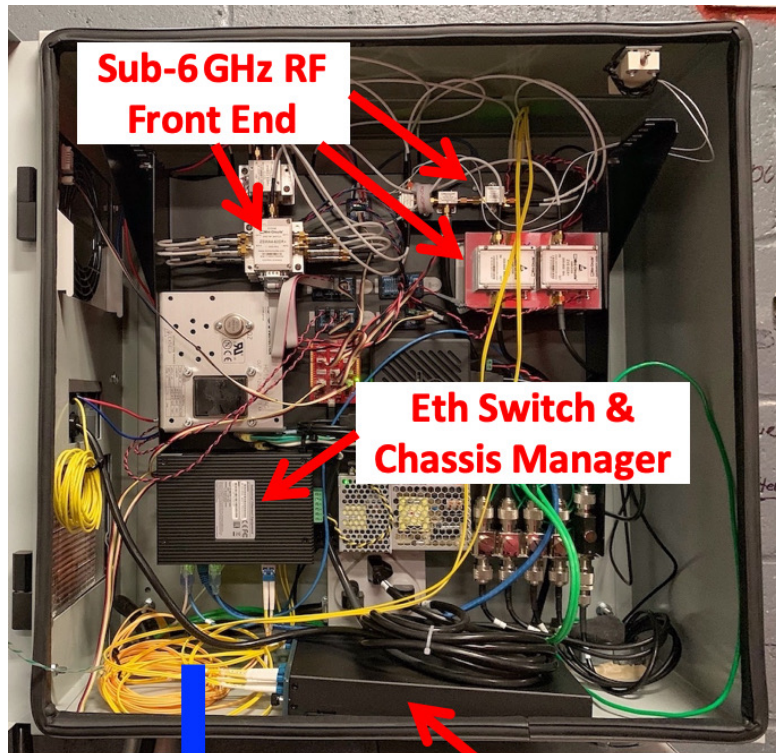
A large node sector or a medium node

Power Supply & Management

USRP N310

USRP-2974 (Krypton)
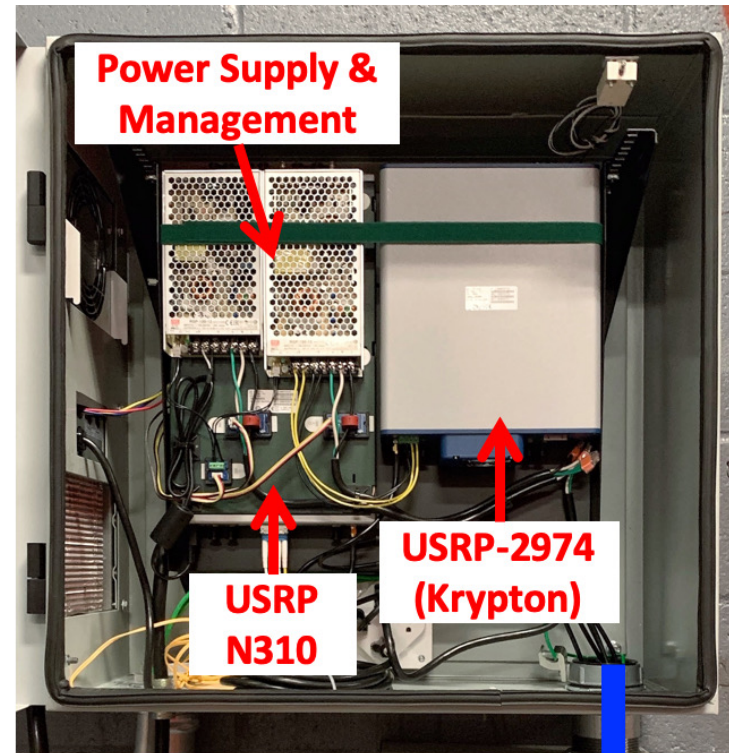
RF Cables Passthrough (to Tx/Rx Antennas)

Tx/Rx Antennas

RF Front End, RoF

USRP-2974 + USRP N310

Fiber & Power Passthroughs
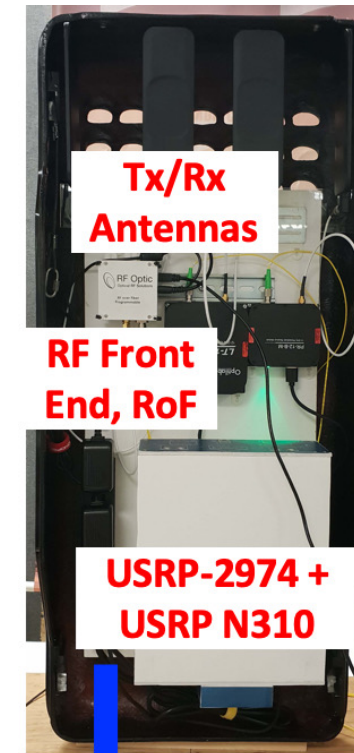
Medium-light node (lightpole-mounted)

Small portable

Hand-held

Small mobile node

Key Technology: mmWave

- **Programmable mmWave front ends with different baseband options:**
  - IBM 28 GHz 64-element PAAMs
   - Integrated in Sandbox 1 and 2
    - Up to ~500 MHz bandwidth using the Xilinx UltraScale+ RFSoC platform
    - Experiment with adaptive beamforming and mmWave MIMO communications
  - Sivers IMA 60 GHz WiGig transceiver

- **End-to-end mmWave systems:**
  - Facebook Terragraph 60 GHz radios
  - InterDigital 28 GHz 5G NR platform
  - InterDigital 60 GHz EdgeLink nodes

Millimeter-Wave Front Ends
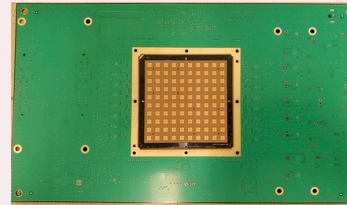
IBM 28 GHz Phased Array Antenna Module (PAAM)
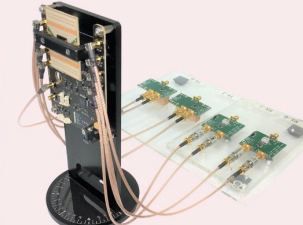
Sivers IMA 60 GHz Phased Array

SDR and Baseband

USRP 2974

USRP B210

USRP N310

Xilinx RFSoC

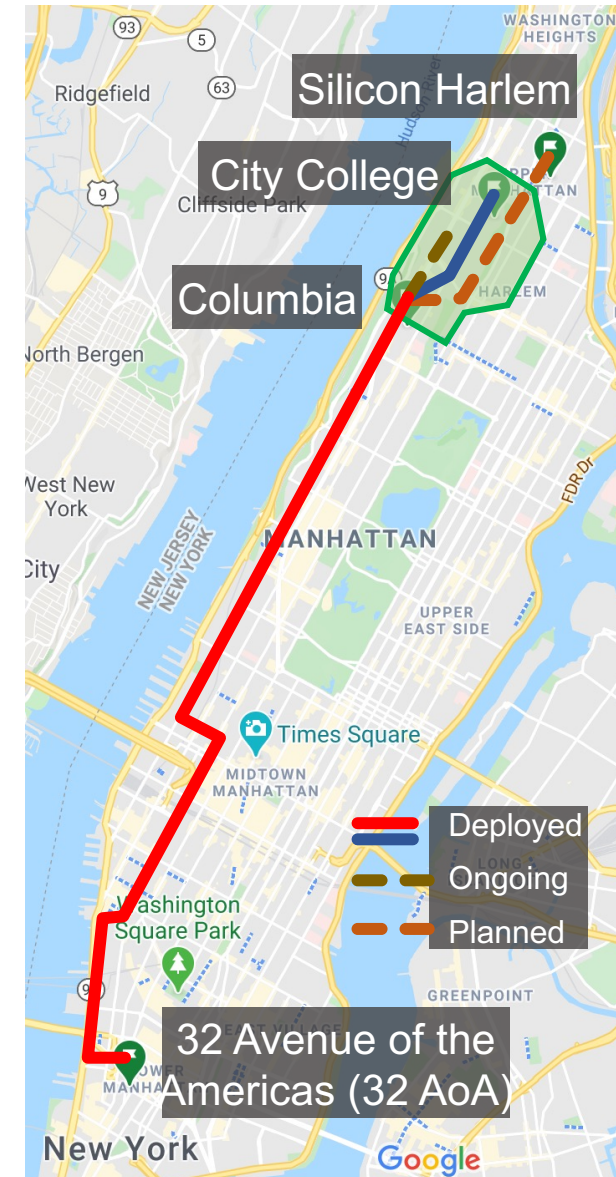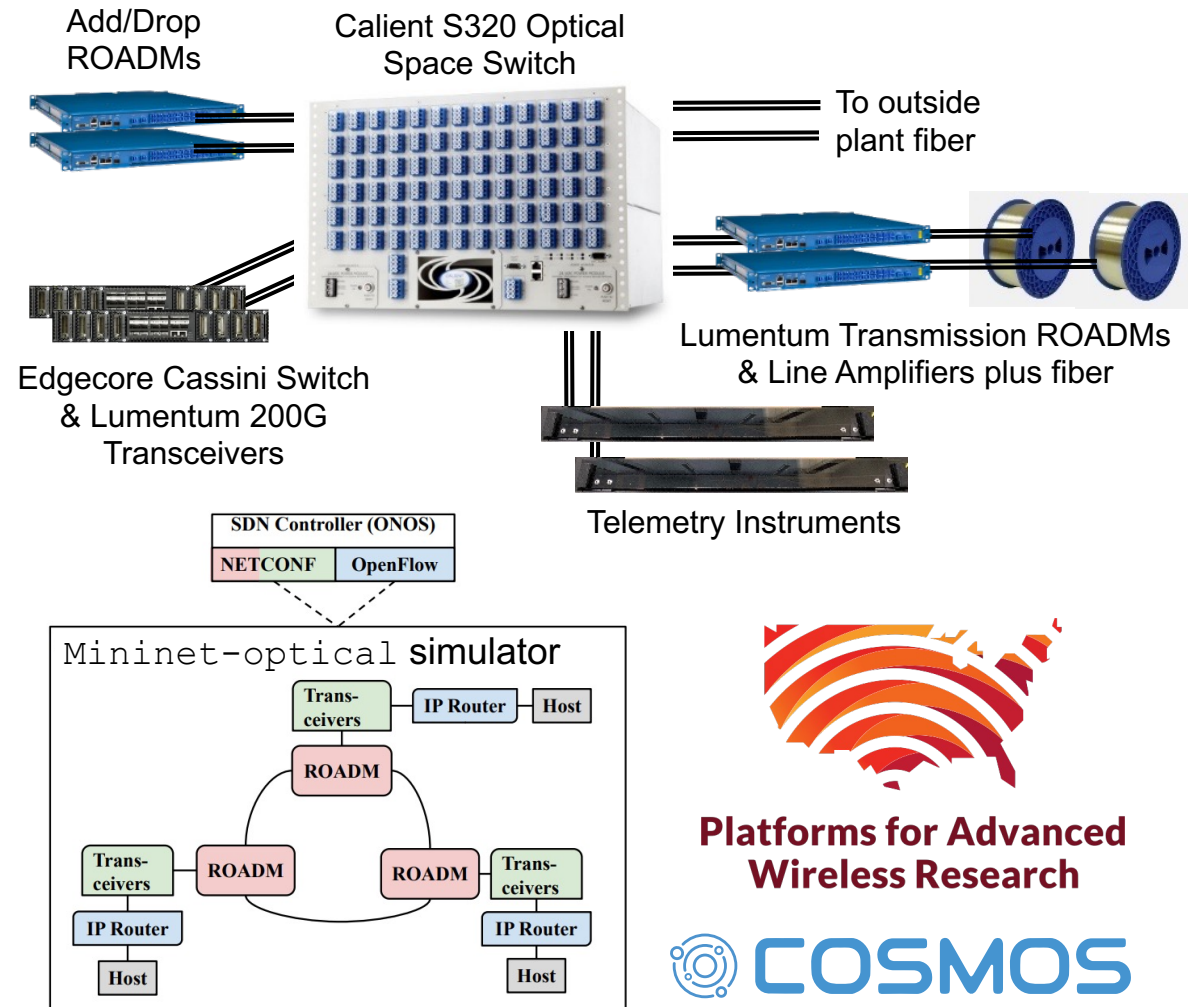**End-to-End Systems**

InterDigital 28 GHz 5G NR Platform

InterDigital 60 GHz EdgeLink Node

Facebook 60 GHz Terragraph Radio

- T. Chen, P. Maddala, P. Skrimponis, J. Kolodziejski, X. Gu, A. Paidimarri, S. Rangan, G. Zussman, and I. Seskar, "Programmable and open-access millimeter-wave radios in the PAWR COSMOS testbed," in *Proc. ACM MobiCom'21 Workshop on Wireless Network Testbeds, Experimental evaluation & CHaracterization (WiNTECH'21)*, 2021.
- X. Gu, A. Paidimarri, B. Sadhu, C. Baks, S. Lukashov, M. Yeck, Y. Kwark, T. Chen, G. Zussman, I. Seskar, and A. Valdes-Garcia, "Development of a compact 28-GHz software-defined phased array for a city-scale wireless research testbed," in *Proc. IEEE International Microwave Symposium (IMS'21)*, 2021. **Finalist of IMS'21 Advanced Practice Paper Competition (APPC)**

Key Technology: Optical Networking

Data Center @Columbia
- Patch panel
- Fiber spools
- Top of rack switches
- Space switch and ROADMs
- Compute servers
- Fiber spools

Add/Drop ROADMs

Calient S320 Optical Space Switch

To outside plant fiber

Lumentum Transmission ROADMs & Line Amplifiers plus fiber

Edgecore Cassini Switch & Lumentum 200G Transceivers

Telemetry Instruments

SDN Controller (ONOS)
NETCONF | OpenFlow

Mininet-optical simulator

Trans-ceivers — IP Router — Host
ROADM
Trans-ceivers — ROADM   ROADM — Trans-ceivers
IP Router   IP Router
Host   Host

Platforms for Advanced Wireless Research

COSMOS

Silicon Harlem
City College
Columbia
32 Avenue of the Americas (32 AoA)

Deployed
Ongoing
Planned

- T. Chen, J. Yu, A. Minakhmetov, C. Gutterman, M. Sherman, S. Zhu, S. Santaniello, A. Biswas, I. Seskar, G. Zussman, and D. Kilper, "A software-defined programmable testbed for beyond-5G optical-wireless experimentation at city-scale," *IEEE Network, Special Issue on Next-Generation Optical Access Networks to Support Super-Broadband Services and 5G/6G Mobile Networks*, Mar./Apr. 2022.