COSMOS: An Open, Programmable, City-Scale Wireless and Optical Testbed

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COSMOS: Project Vision

- **Latency** and **compute power** are two important dimensions and metrics
- **Edge computing** can enable real-time applications
- **Objective:** Real-world investigation or urban environments with
  - Ultra-high bandwidth (~Gbps)
  - Low latency (<5ms)
  - Bandwidth densities (~10Tbps/km²)
- **Enablers:**
  - 10s of 64-element millimeter-wave arrays
  - 10s of miles of Manhattan dark fiber
  - B5G edge cloud base stations
  - Programmability

Ultra-high bandwidth, low latency, and powerful edge computing will enable new classes of real-time applications. Domains including AR/VR, connected cars, smart city (with high-bandwidth sensing), and industrial control.
COSMOS: Envisioned Deployment

- West Harlem with an area of ~1 sq. mile
  - ~15 city blocks and ~5 city avenues

- ~9 Large sites
  - Rooftop base stations

- ~40 Medium sites
  - Building side- or lightpole-mounted

- ~200 Small nodes
  - Including vehicular and handheld
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.

MEMS Switch
fast front-haul/mid-haul/back-haul connectivity between radio nodes and edge cloud
ROADM (whitebox)

SDN control plane used to control x-haul and (near) cloud server connectivity
Access to regular (far) cloud racks over L3
COSMOS: Phased Deployment

- A phased approach:
  - May 2019: Pilot completion
  - Sept. 2019: FCC Innovation Zone
  - June 2020: General Available
  - During 2021*: Phase 1 completion

*Deployments affected by the COVID-19 pandemic

- Fiber connection to CCNY sites
- Fiber connection to Rutgers, NYU Data Center (at 32 Ave. of Americas), GENI, and Internet2, etc.
- Connections to international partners (COSM-IC Project)
COSMOS Experimental Licenses

FCC Innovation Zone: “The New York City Innovation Zone encompasses area bounded by W 120th Street on the south, Amsterdam Avenue to the east, W 136th Street to the north and Hudson River on the west”

<table>
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<th>Frequency Band</th>
<th>Type of operation</th>
<th>Allocation</th>
<th>Maximum EIRP (dBm)</th>
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<tr>
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<tr>
<td>38.6-40.0 GHz</td>
<td>Fixed</td>
<td>Non-federal</td>
<td>40*</td>
</tr>
</tbody>
</table>

(Additional) Program Experimental License: at Rutgers, Columbia and CCNY campuses
Nokia Bell Labs’ 28 GHz Measurement Campaign
(in collaboration with WiMNet Lab at Columbia)
Spring 2019-Spring 2022

• The COSMOS testbed deployment area and the FCC Innovation Zone are representative of a **dense urban street canyon** environment

• Representative (potential) deployment sites of mmWave BSs (building rooftops, street light poles, etc.)

• Extensive **outdoor** measurements on various **long sidewalks** (e.g., up to 1.1 km) with **fine-grained link step size** (e.g., 1.5/3 m)
  - Over **41 million** power measurements were collected from over **2,600 links** on **22 sidewalks** in **4 different sites** and in different settings

• (ongoing) Extensive outdoor-to-indoor measurements within buildings with **fine-grained link step size** (e.g., 1.5/3 m)
  - Over **45 million** power measurements were collected from over **2,837 links** in **9 different sites**

Composable X-Haul Networks

Use Calient switch to configure different network topologies, different add-drop configurations
Pilot: In lab + 32 AoA link
Full Deployment: Lab + Any large node
Optical Telemetry & Control Testing

- Disaggregated optical systems pose many challenges due to the lack of end-to-end system testing
- New telemetry methods combined with AI-based controls have potential to overcome these challenges
- Team of industry and university partners conducted experiments on optical telemetry and data collection for AI
Pilot Experiment: Remote-Processing

- Full-duplex radio integrated with COSMOS’ dark fiber-based optical x-haul network
- **Local** RF self-interference cancellation at the full-duplex radio
- **Remote** digital self-interference cancellation at the server (~14 miles away from the radio)

COSMOS dark fiber deployment and the supported Cloud-RAN applications

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Smart City Applications

Amsterdam Avenue and 120th St. Northeast corner of Mudd Engineering building.

Smart Intersection: Radios, cameras, edge cloud computing node, GPUs and FPGAs. AI/ML algorithms.

Detect and track objects. Broadcast to all: from inference node to vehicles and pedestrians, ...in real time. Target closed loop latency: 10ms. Video link.
COSMOS: Industrial Lab Extension (Weeks Hall)

- COSMOS Large node
- COSMOS Small Node
- Robot Manufacturing Setup
- Surface Inspection Camera

[Image of lab setup with COSMOS equipment]
O-RAN/ONAP (Candidate) OTIC

- Used for ONAP PoCs since 2017
- Environment
  - Entry point at console located at console.sb10.orbit-lab.org
  - 16 Ubuntu servers, all managed by OpenStack
  - Control Node and Compute Nodes
- Access Methods
  - Organizations can gain access by requesting an account – details at: https://wiki.onap.org/pages/viewpage.action?pageId=45298557
  - Tunnels to other testing and integration labs around the world
O-RAN Plugfest and Proof-of-concept (#3)

North America

- verizon
- AT&T

PlugFest
- TIP Community Lab @ Meta
- Menlo Park, CA

PoC
- POWDER Lab
- Salt Lake City, UT
- NSF PAWR SITE
- FCC Innov Zone

PlugFest & PoC
- COSMOS Lab
- NJ/NYC metro
- NSF PAWR SITE
- FCC Innov Zone
### Plugfest Participation

#### Comparison 2019, 2020, 2021

<table>
<thead>
<tr>
<th></th>
<th>Number of labs</th>
<th>Number of participating companies</th>
<th>Number of scenarios/setups</th>
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<tbody>
<tr>
<td>2019</td>
<td>1</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>2020</td>
<td>2</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td>2021</td>
<td>3</td>
<td>33</td>
<td>27</td>
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**2019:**
- UE Traffic re-prioritized by O-RAN O1 (pre-spec) interface configurations

**2020:**
- O-RAN O1 extension of 3GPP NRM configures 5G/LTE RAN Fault, Configuration, Performance Closed Loop use cases

**2021:**
- 3GPP NRM RAN Slicing control in a multi operator environment

*PoC = Proof of Concept*
PlugFest:
- Activities focused on conformance testing and multi-vendor interoperability – 16 unique test combinations across 2 labs.

Proofs of Concept (PoC):
- O-Cloud infrastructure behavior in latency sensitive applications
- RIC demonstration of successful E2AP procedures and measurement collection via E2 Service Model: Key Performance Metrics (E2SM KPM)
- RAN Slice Service Level Assurance (SLA)
- AI-enabled management of multiple-operator / multi-vendor RAN with O-RU pooling & multi-vendor slices (a series of demonstrations)
COSMOS Educational Toolkit – 2021 Enhancements

https://www.cosmos-lab.org/cosmos-toolkit/
COSMOS Wireless Testbed – Summary

- Focus on ultra-high bandwidth, ultra-low latency, and edge cloud
- Open platform integrating SDRs, mmWave, and optical x-haul
- 1 sq. mile densely populated area in West Harlem
- Industry and local community outreach

COSMOS website: https://cosmos-lab.org
Tutorials: https://wiki.cosmos-lab.org/wiki/tutorials
Twitter: #pawrcosmos

Related links:
- PAWR: https://advancedwireless.org/
- ORBIT: https://www.orbit-lab.org/
- O-RAN Pf/PoC: https://www.o-ran.org/testing-integration/#Anchor_PLUGFEST
- TMForum PoC: https://myaccount.tmforum.org/networks/25844/index.html
- Open Wireless Lab https://wiki.onap.org/display/DW/Open+Wireless+Lab