NSF Support for Next Generation Wireless Networks and Dynamic Spectrum Sharing

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National Science Foundation

Oct. 7, 2019

PAWR Project Office

Platforms for Advanced Wireless Research

Wireless Mid Scale Research Infrastructure for Research and Experimentation

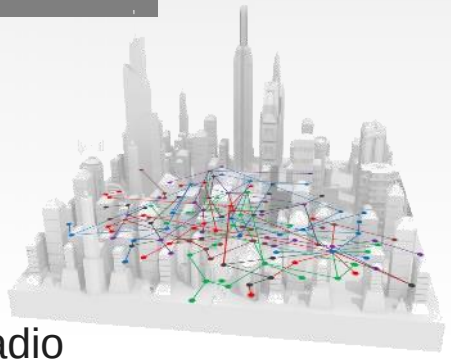
https://www.advancedwireless.org/

Charter Members

PPO is Looking for more Industry Partners….

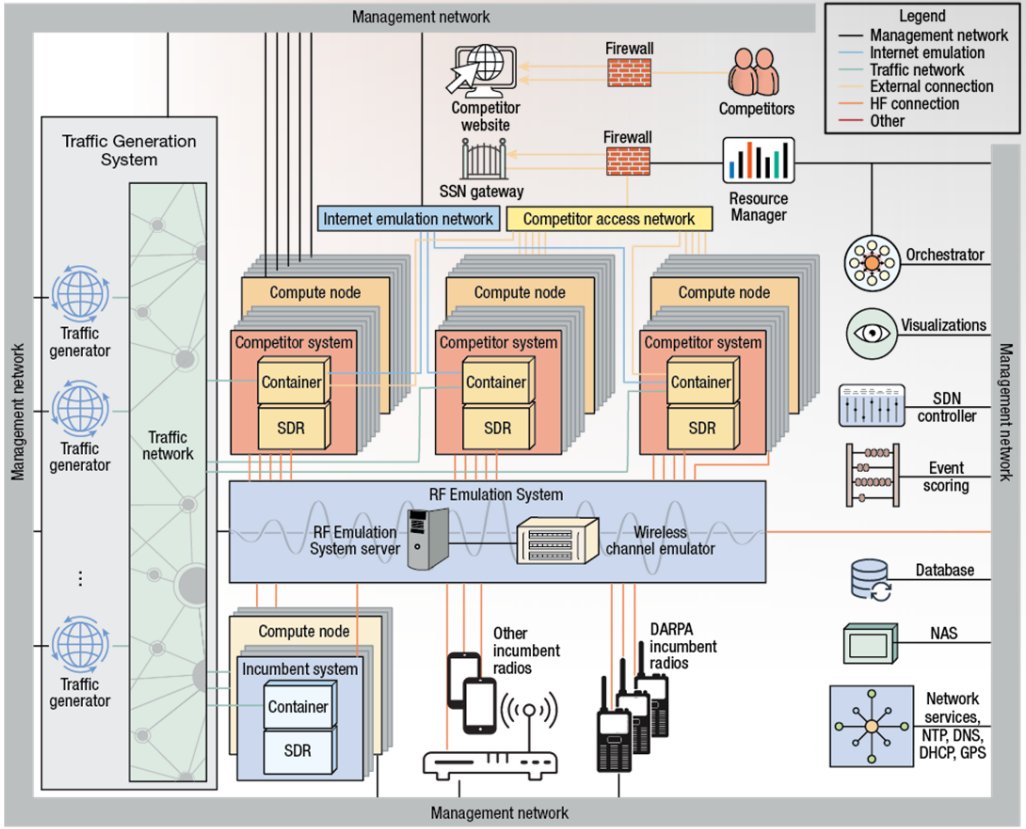
What is Colosseum?

Colosseum is the **world's largest** wireless network emulator with granularity at the RF signal level

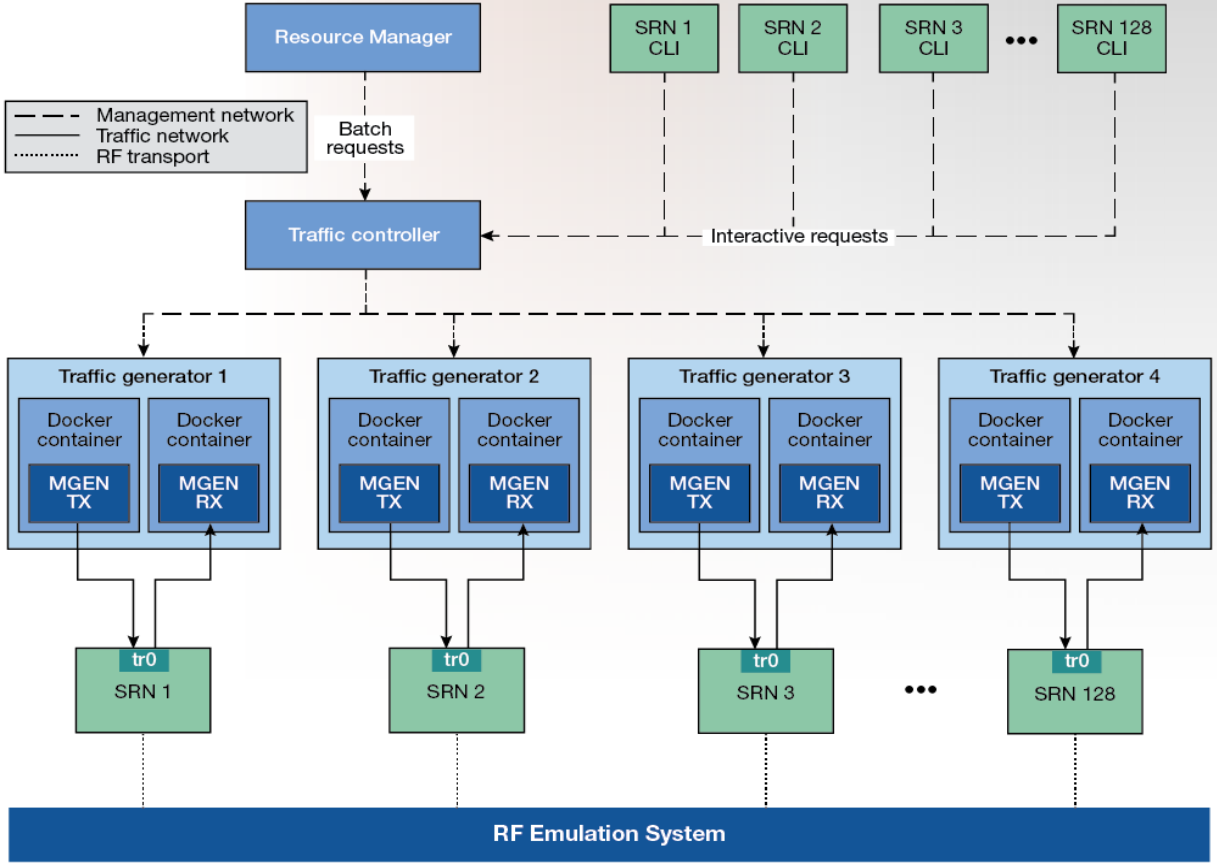


- 256 x 256 100 MHz RF channel emulation
- 128 Programmable Radio Nodes
- Computing resources (CPU, GPU, FPGA)
- Access control and scheduling infrastructure
- Supports remote shared access
- Colosseum is a General Purpose Cooperative Radio Development and Testing Environment
- https://www.darpa.mil/program/spectrum-collaboration-challenge

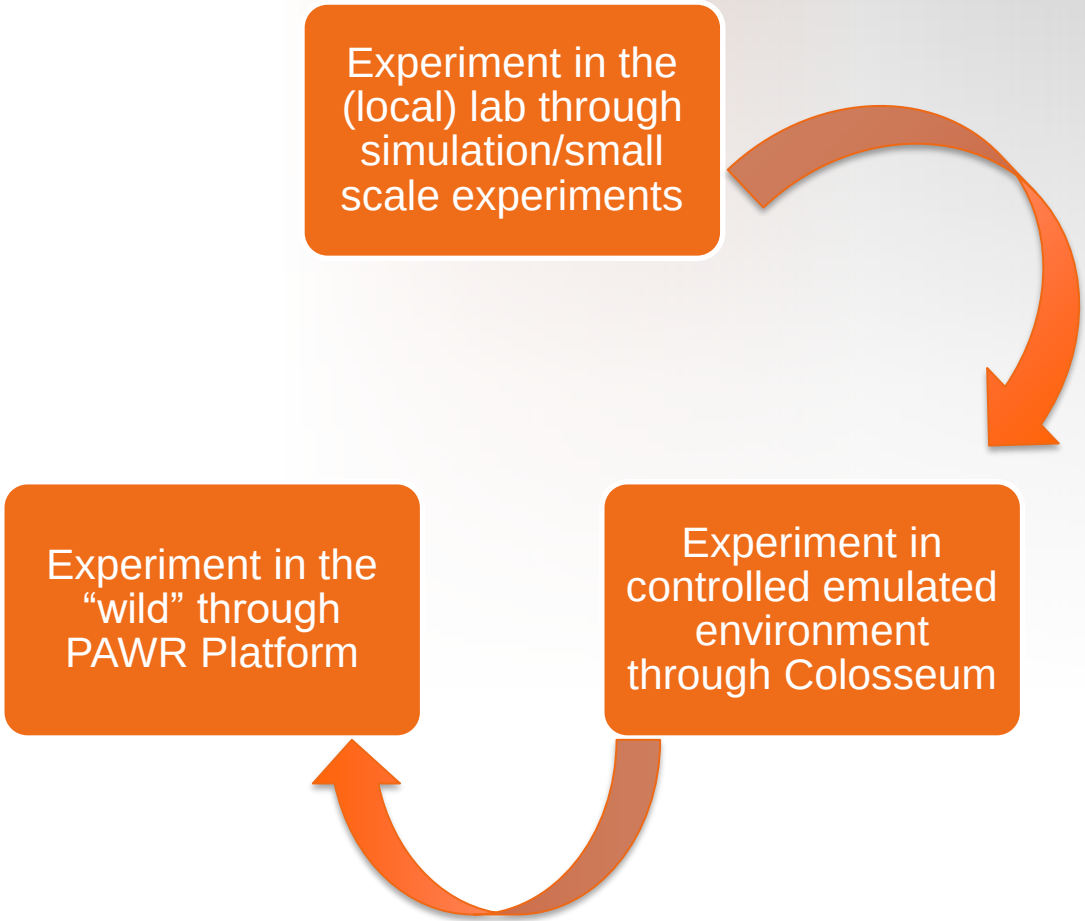
Colosseum Architecture



Traffic System



Envisioned Experiment LifeCycle



PAWR Awardees

Announced April 9 2018

Round I Platforms

Salt Lake City

New York City

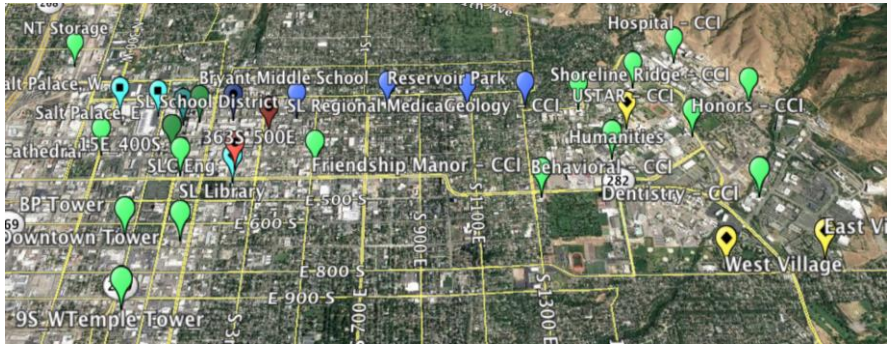
http://powderwireless.net

http://cosmos-lab.org

POWDER: Platform for Open Wireless Data-driven Experimental Research

- Next Generation Wireless Architecture
- Dynamic Spectrum Sharing
- Distinct environments: a dense urban downtown and a hilly campus environment.

Deployment Area: UofU Campus +Downtown SLC + Connected Corridor



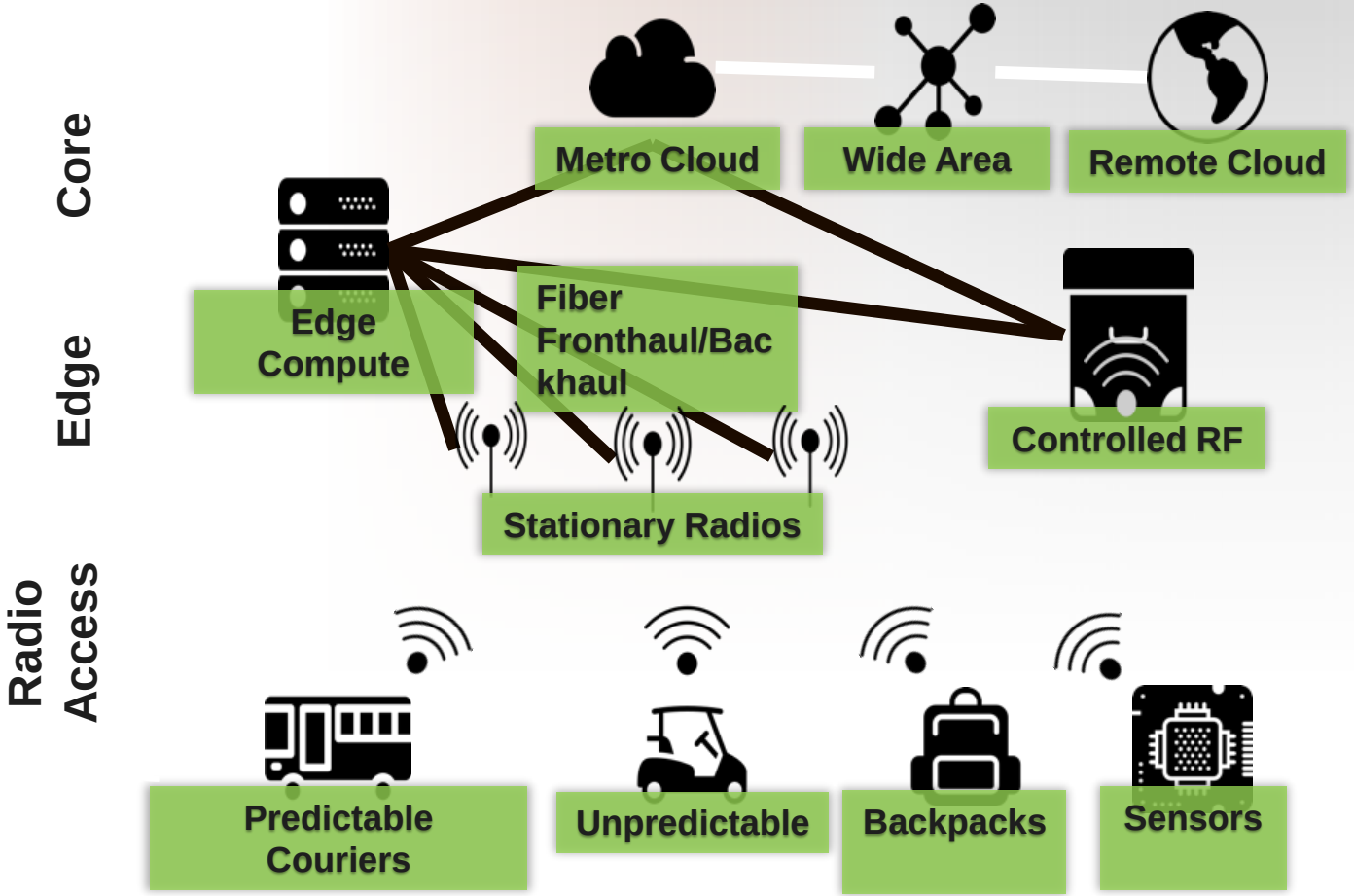
RENEW: A Reconfigurable Eco-system for Next-generation End-to-end Wireless

- RENEW Massive MIMO base station
- End-to-End Programmable
- Diverse Spectrum Access 50 MHz-3.8GHz
- Hybrid Edge computer composed of FPGA and GPU/CPU-based processing,
- Hub Board aggregates/distributes streams of radio samples

IRIS software-defined radio modules

Architectural view of RENEW base station

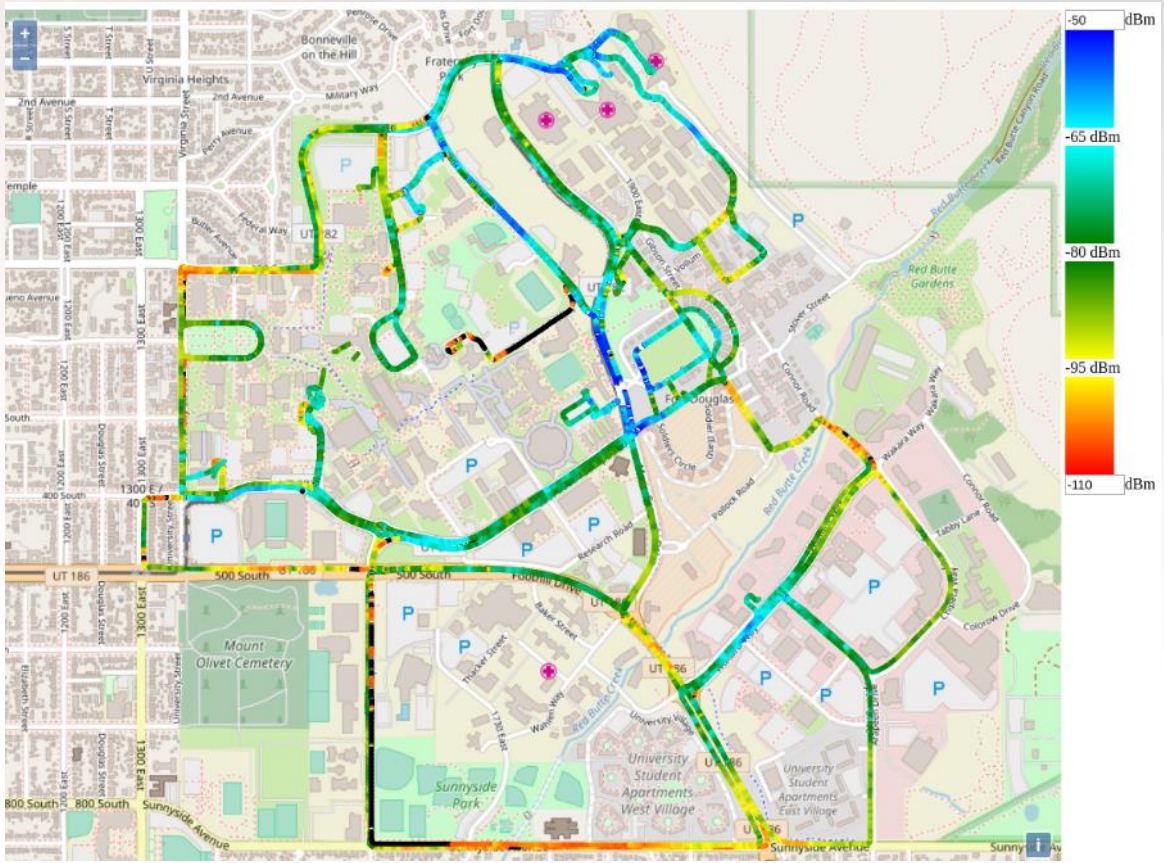
System Architecture



Truly City scale…

Basestation locations

Campus Shuttle Routes



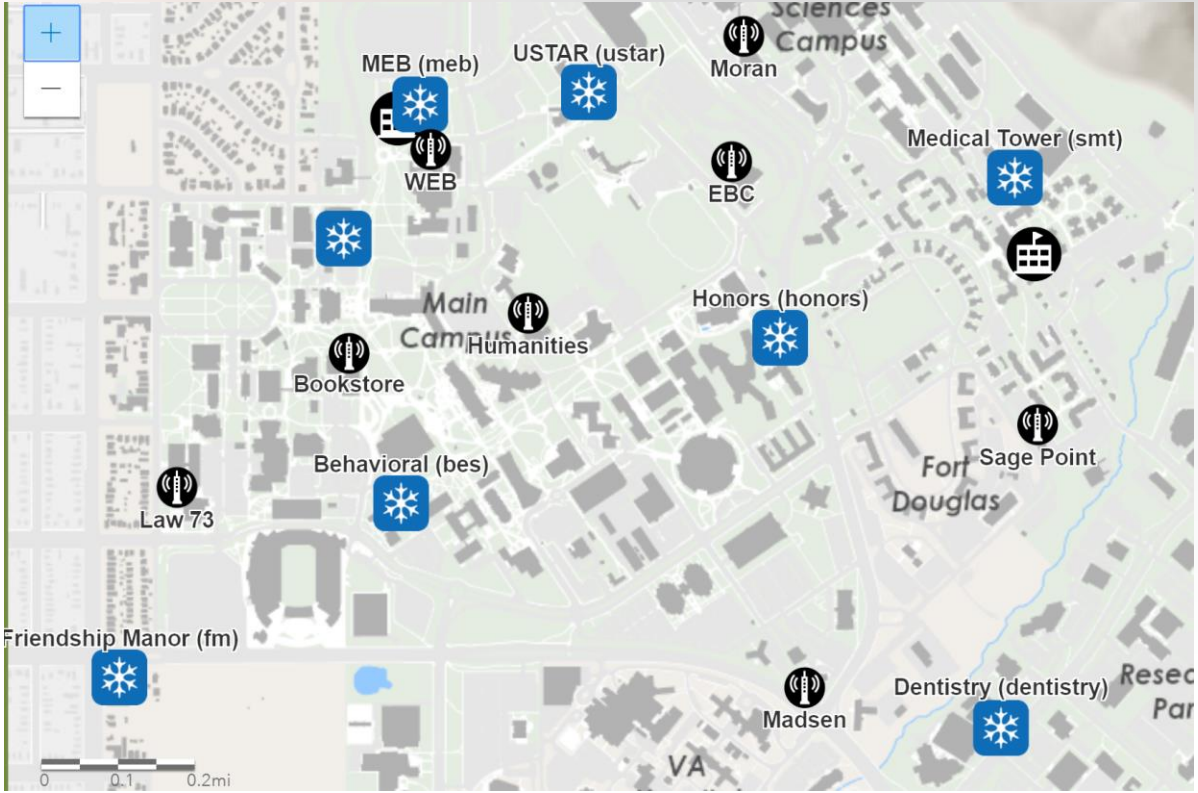
RENEW Massive-MIMO Base Stations

- Iris SDR is the building block
- 64-128 antennas
  - Next gen design targets 256-antennas
- 40 Gbps Ethernet backhaul through fiber
  - Next gen design targets 100Gbps link
- HW Built-in Clock Sync
  - Support for SyncE/PTP underway

Pilot POWDER Network (Available Today)

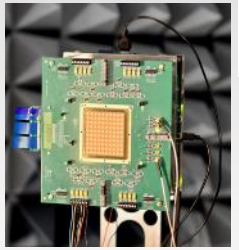
8 Rooftop Base station and Fixed End Point sites

Software Profiles Available:
- Open Air Interface
- Worked with ONF to provide basic XRAN functionality in OAI
- Open Network Automation Platform (ONAP) [LF]
- Converged Multi-Access and Core (COMAC)/Open Mobile Evolved Core (OMEC) [ONF]
- Akraino Edge Stack, Radio Edge Control (REC)
- RAN Intelligent Controller (RIC)
- O-RAN [O-RAN Alliance]

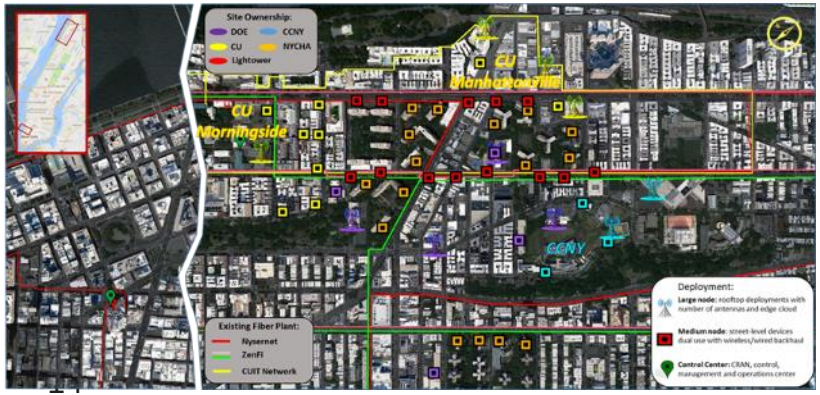


COSMOS:Cloud Enhanced Open Software Defined Mobile Wireless Testbed for City-Scale Deployment

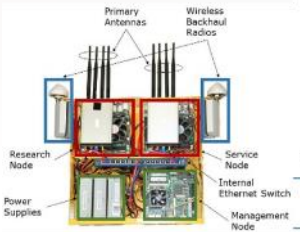
- A multi-layered computing system with an RF thin client; flexible signal processing; network function virtualization (NFV) between a local SDR (with FPGA assist) and a remote cloud radio access network (CRAN) with massive CPU/GPU and FPGA assist
- Deployed in New York City, one of the country's most populated urban centers
- Wideband radio signal processing (with bandwidths of ~500 MHz or more)
- Support for mmWave communication (28 and 60 GHz)
- Optical switching technology (~1µs) provides passive WDM switch fabrics and
- radio over fiber interfaces for ultra-low latency connections



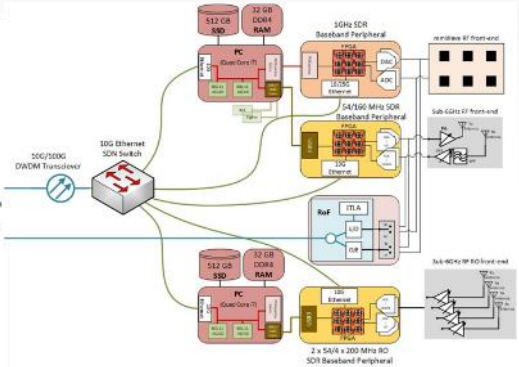
28GHz phased-array ICs and phased-array antenna modules (PAAM)



Deployment Area: West Manhattan/Harlem



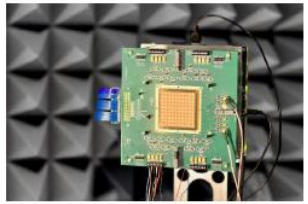
COSMOS Radio Site Design



All-Optical Network Design

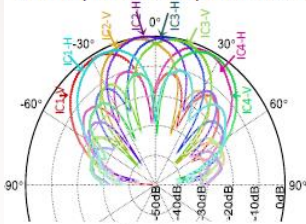
COSMOS mmWave Node Specifications

- 64-dual polarized antennas and 4 ICs each with 32 TRX elements
- 128 TRX elements in total
- 8 independent 16-element beamformers, each supporting 1 polarization of 16 ant.
- RF true time delay based architecture
- 28GHz RF, 5GHz ext. LO, 3GHz input/output IF
- 54dBm saturated EIRP on each polarization

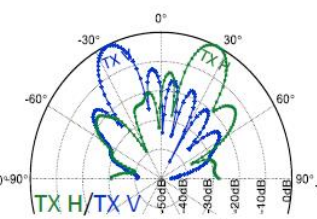


28GHz phased array eval. board

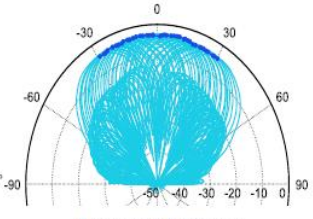
Example outdoor link experiment at IBM



Measured 8 simultaneous 16-element beams



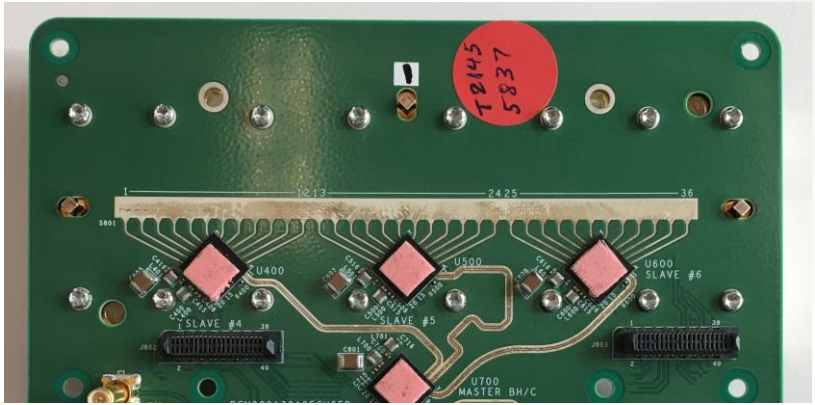
Measured 2 simultaneous 64-element beams



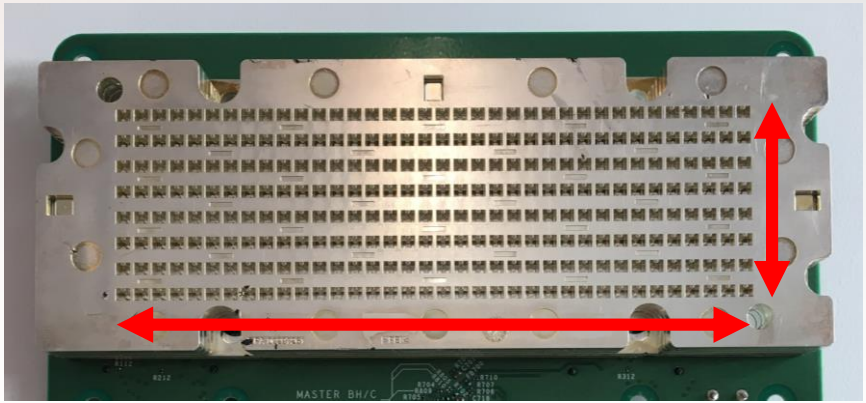
Measured Precise 1.4°/step beam steering

FaceBook TerraGraph 60GHz-Antenna Panel

Back: RFICs connecting to antenna feeds



Front: Phased array antenna



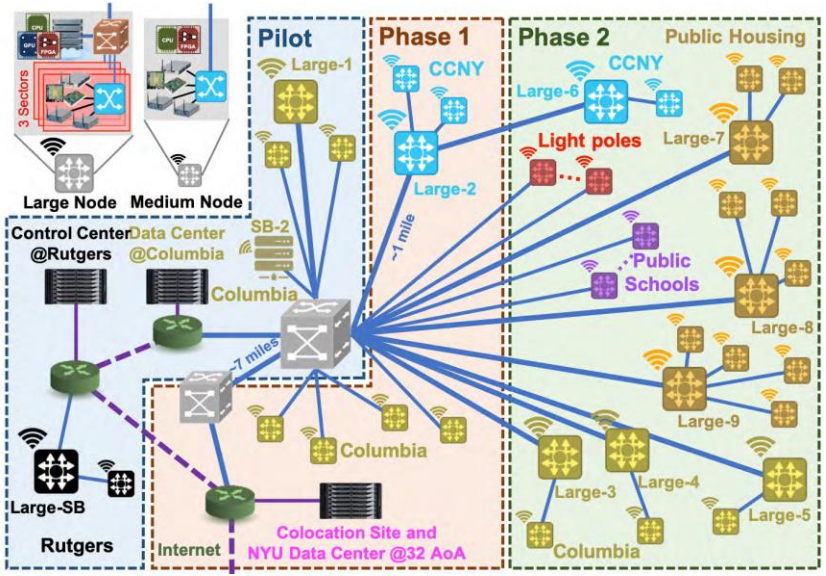
8-Elements
(corporate feed)

36 RF feeds
(independently controlled phase shifters)

Pilot COSMOS Network (Available Today)

Base Configuration

- 2 Large and 3 Medium Nodes
- 16 port Space Switch
  - ROADMs: 1 fiber pair each, 2 total
  - Direct CRF connections: 6 fiber pairs
  - Eth Switch: 2 fiber pairs



Round II PAWR Awardee

Announced September 18, 2019

Research Triangle

https://aerpaw.org/

Aerial Experimentation and Research Platform for Advanced Wireless (AERPAW)

Goals

- Accelerate the integration of UAS into the national air-space
- Enable new advanced wireless features for UAS platforms, including flying base stations for hot spot wireless connectivity

Focus areas

- Advanced wireless communication technologies that enable beyond-VLOS and autonomous UAS operations and three-dimensional mobility for UAS
- New use cases for advanced wireless technologies that are emerging in the unmanned aerial systems (UAS) space

Tactics

- Create a one-of-a-kind aerial wireless experimentation platform and a proving ground and technological enabler for emerging innovations, including package delivery platforms and urban air mobility
- Accelerate development, verification, and testing of transformative advances and breakthroughs in telecommunications, transportation, infrastructure monitoring, agriculture, and public safety

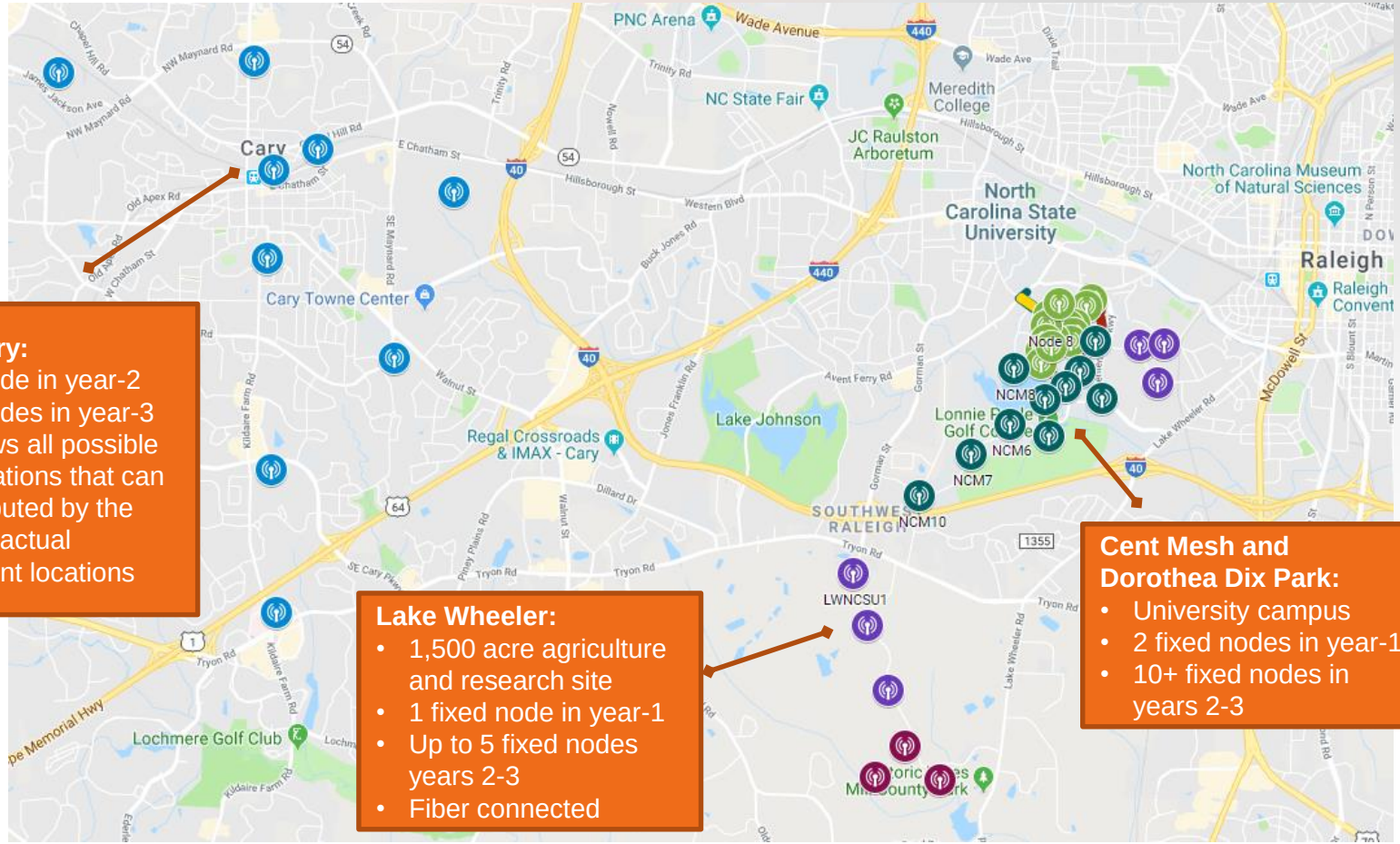
AERPAW at a glance

- Led by North Carolina State University (NCSU) with three other universities
- Start date 9/01/2019

- NSF award of $**9,094,403** over 5 years
- Estimated Industry Consortium cash and in-kind match of up to $**10M**, including major contributions from:
  - National Instruments, Keysight, Ericsson, Commscope
  - Private spectrum licensees

- Approximately 20 fixed nodes at 3 main sites in the RDU Triangle area
- 20+ unmanned autonomous vehicles (drones) with advanced wireless tech through the coverage area

AERPAW deployment plans



Town of Cary:

- 1 fixed node in year-2
- 3 fixed nodes in year-3
- Map shows all possible tower locations that can be contributed by the town, not actual deployment locations

Lake Wheeler:

- 1,500 acre agriculture and research site
- 1 fixed node in year-1
- Up to 5 fixed nodes years 2-3
- Fiber connected

Cent Mesh and Dorothea Dix Park:

- University campus
- 2 fixed nodes in year-1
- 10+ fixed nodes in years 2-3

Looking Ahead: Shift in Focus

Rural Broadband to drive Technical Requirements

- Open-ended for emerging and frontier ideas
- Focus on architectures – questions assumptions
- Provide solutions and specifications as well as relevant trade-offs and implications;
- Looking for various possible solutions to particular challenges

COME JOIN US

http://powderwireless.net

http://renew.rice.edu

POWDER-RENEW

http://cosmos-lab.org

COSMOS

http://aerpaw.org

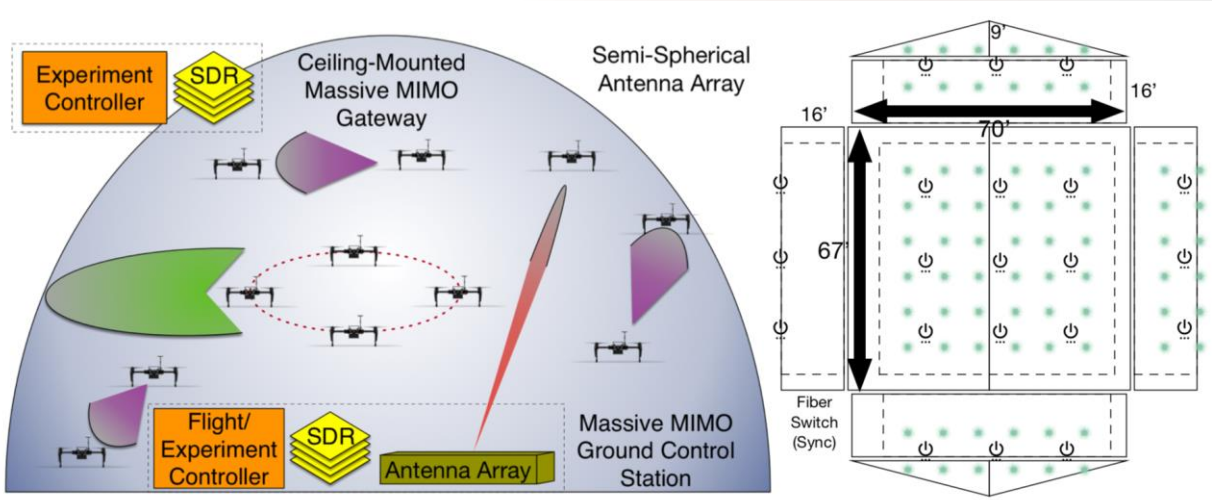
AERPAW

http://advancedwireless.org

PAWR Project

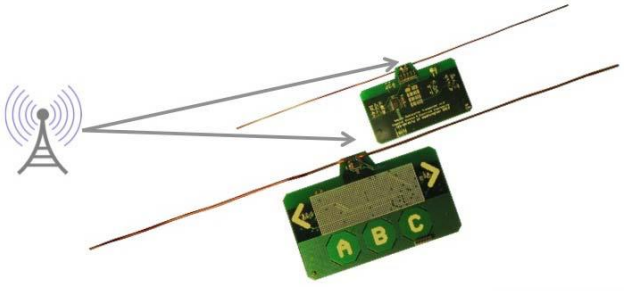
Multi-Dimensional Drone Communications Infrastructure (MuDDI)

PI: Joseph Camp, Southern Methodist University
http://muddi.lyle.smu.edu



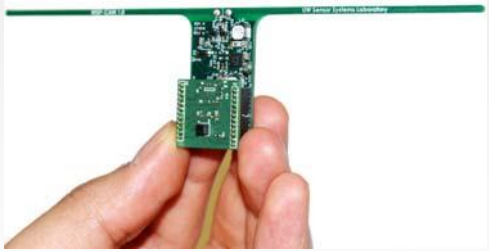
Next-Generation, Sustainable Infrastructure for the RF-Powered Computing Community

PI: Joshua Smith, University of Washington



(a) Ambient Backscatter devices

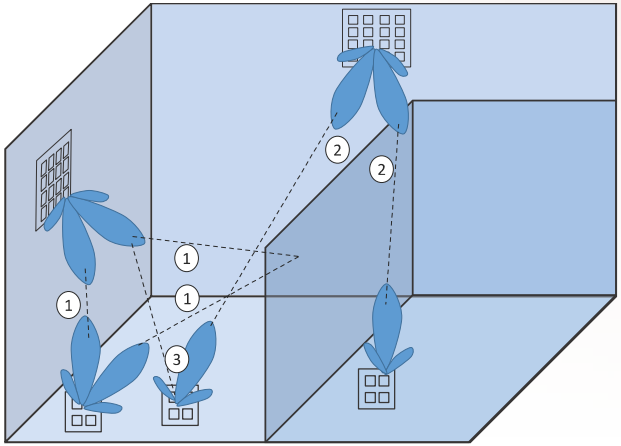
(b) Battery-free phone



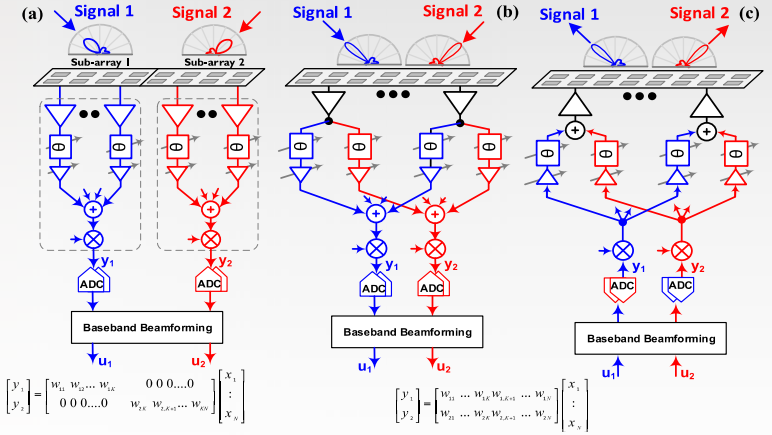
The WISPCam (Wireless Identification and Sensing Platform Camera) tag.

CRI: II-New: Mobile Millimeter-wave MIMO Network Based on CMU Chipscale Beamformers

PI: Larry Carley, Carnegie Mellon University



1 SU-MIMO 2 MU-MIMO 3 Interference cancellation (null-steering) Spatio-temporal equalization



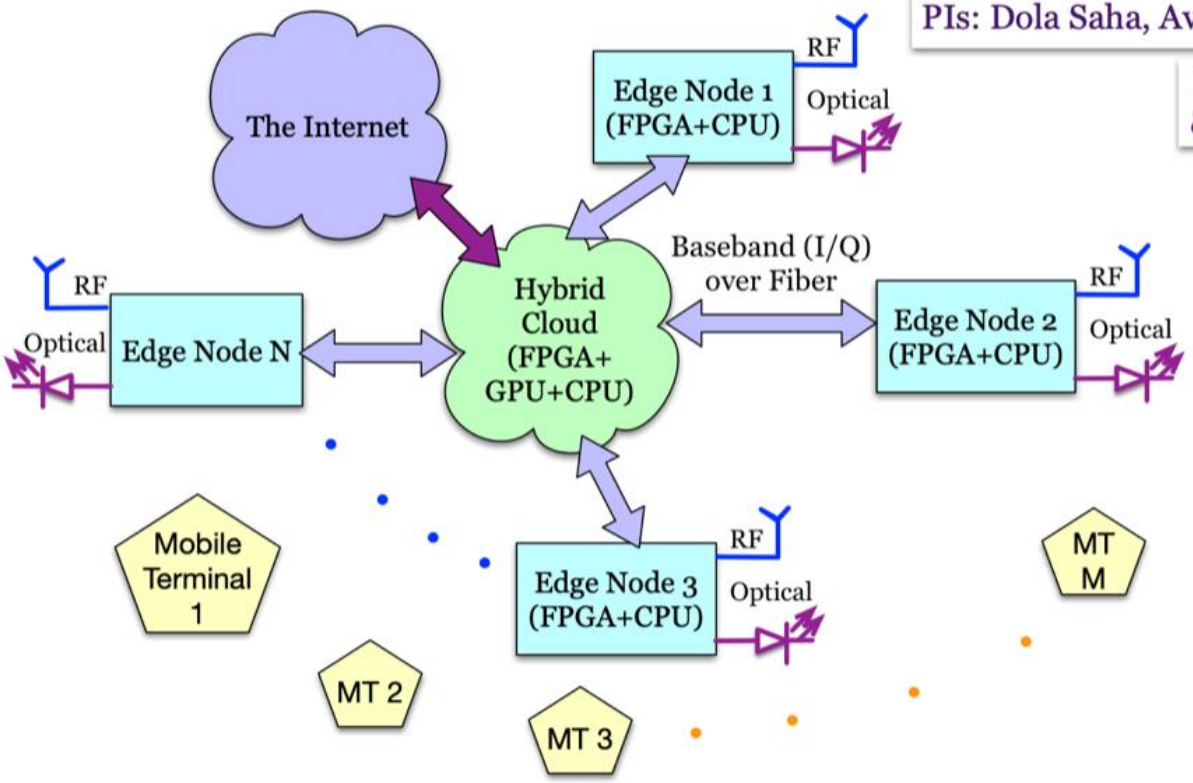
CMU Chipscale Beamforming Transceivers.

CHRONOS: A Cloud based Hybrid RF-Optical Network Over Synchronous Links

PIs: Dola Saha, Aveek Dutta & Hany Elgala

Department of Electrical & Computer Engineering

College of Engineering and Applied Sciences
University at Albany
State University of New York



Legend

- Hybrid Baseband Processor (HBP)
- Heterogeneous Network Edge (HNE)
- Heterogeneous Mobile Terminal (HMT)