An NSF PAWR Platform

RENEW

POWDER-RENEW:

A Shared Software-defined massive MIMO testbed

Rahman Doost-MOHAMMADY
Electrical & Computer Eng.
Rice University

THE UNIVERSITY OF UTAH®

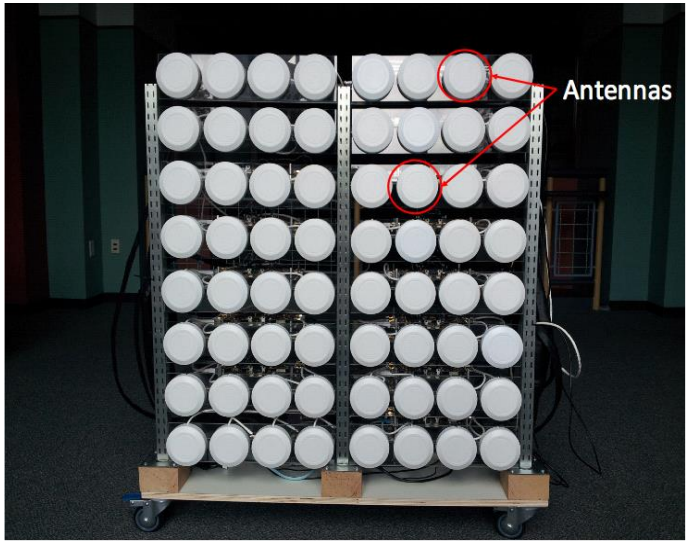
RICE®

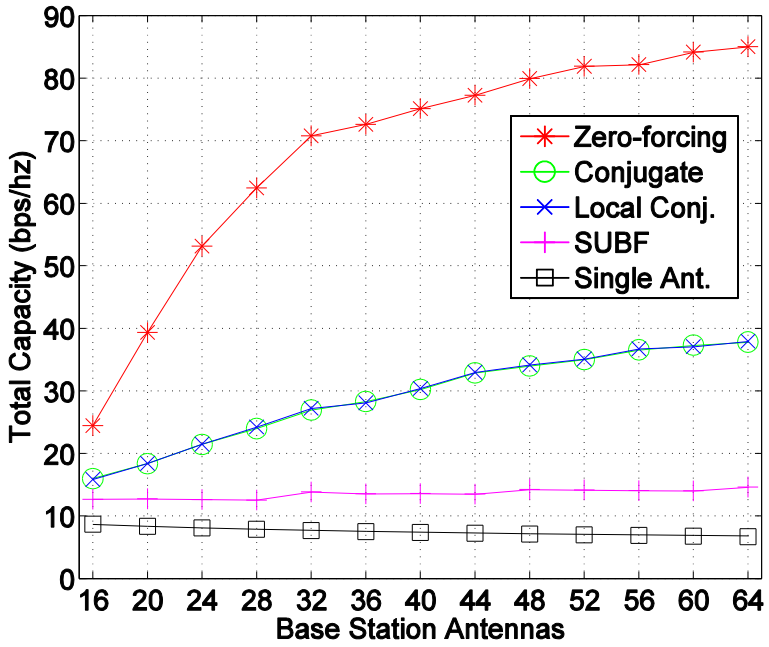
UNIVERSITY OF MICHIGAN

TSU
Texas Southern University

Theory → Experiment Example

Rice Argos v1





- Experimental results validated theory and showed technology is *feasible*!

Experiment → Theory Example

Achieving Single Channel, Full Duplex Wireless Communication

Jung Il Choi†, Mayank Jain†, Kannan Srinivasan†, Philip Levis, Sachin Katti
Stanford University
California, USA
{jungilchoi,mayjain,srikank}@stanford.edu, pal@cs.stanford.edu, skatti@stanford.edu
†Co-primary authors

Full-Duplex Wireless Communications Using Off-The-Shelf Radios: Feasibility and First Results

Melissa Duarte and Ashutosh Sabharwal
Department of Electrical and Computer Engineering, Rice University, Houston, TX 77005
Email: {mduarte, ashu}@rice.edu

Two Experimental Demonstrations in 2010
(People paid attention because of experimental evidence)

Open-Source Unleashed Innovation!

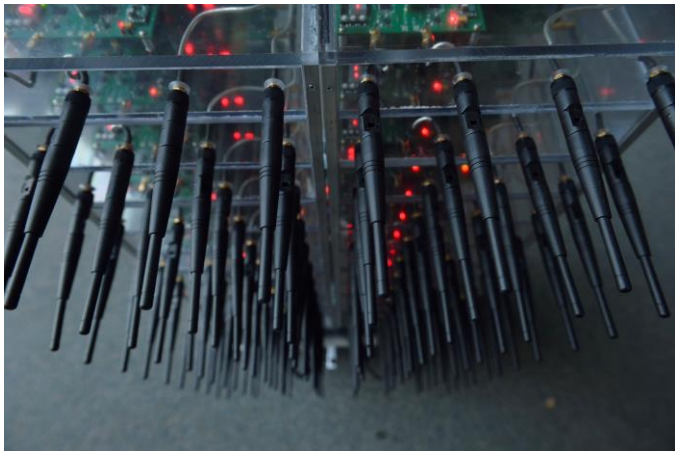
GNURadio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

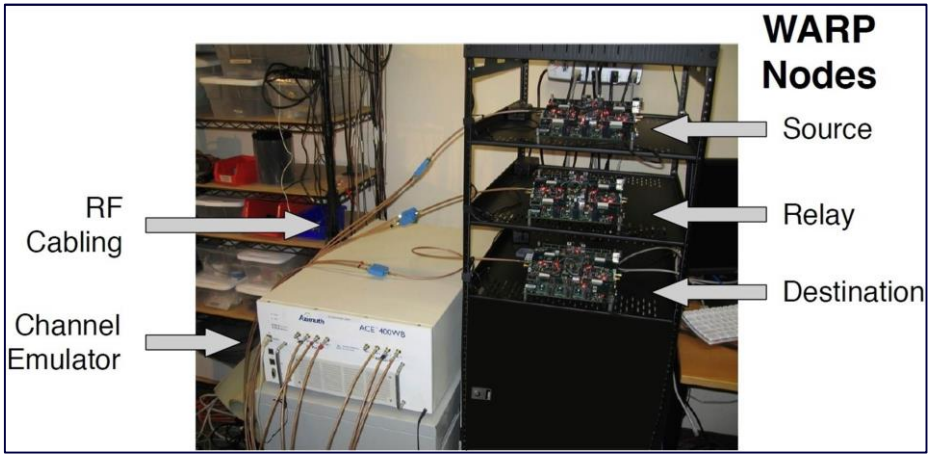
WARP
WIRELESS OPEN-ACCESS
RESEARCH PLATFORM

OPEN AIR
INTERFACE

Experimental research accelerated by **open-source** stacks running on cheap hardware

Replicable & Reproducible Experiments - Hard Today!





SDRs improved the overall access

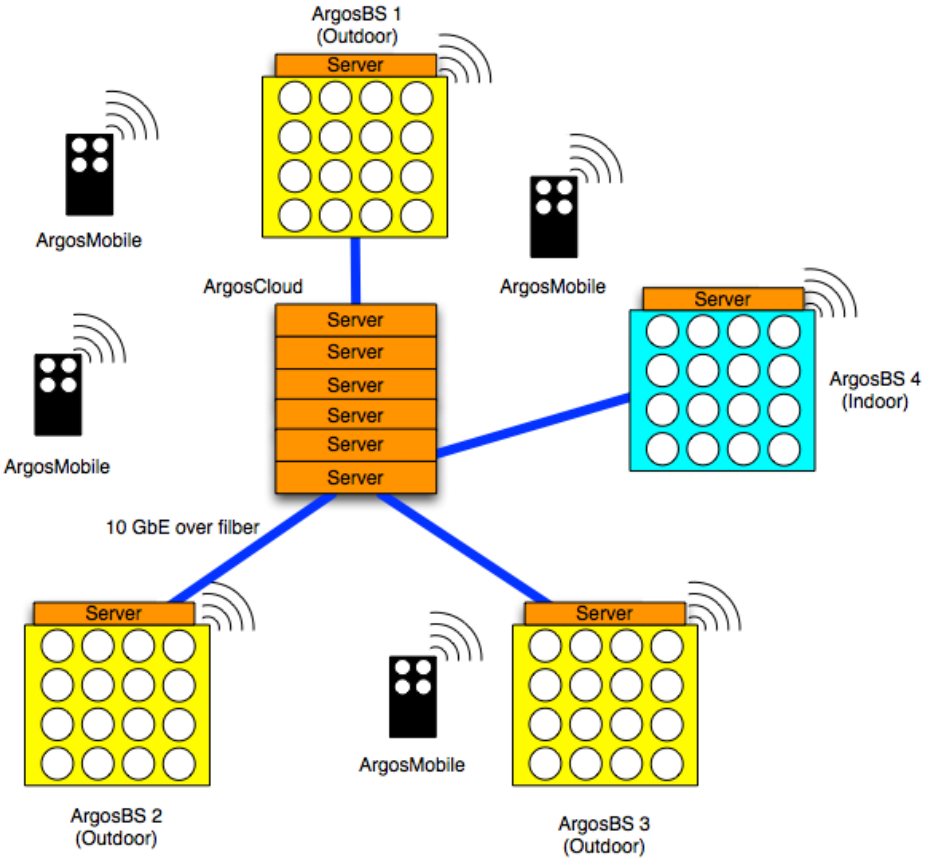
- ✓ Experiments became possible and led to many good work
- × Replicability – incremental research hardly possible!
- × Reproducibility – many setup-dependent results or not applicable in the field

Real need for **open experimentation** on **shared at-scale** testbeds

Experiments on At-Scale Testbeds

ArgosNet: Massive MIMO Field Deployment

Argos V3
Scalable solution to extend to hundred of antennas



- World's first base-station class 3.5 GHz SDR testbed
- World's first multi-cell testbed for massive MU-MIMO

Opportunity with Shared Testbeds

Platforms for Advanced Wireless Research

POWDER – RENEW

***POWDER**: Platform for Open Wireless Data-driven Experimental Research*

***RENEW**: Reconfigurable Ecosystem for Next-gen End-to-end Wireless*

powderwireless.net

renew.rice.edu

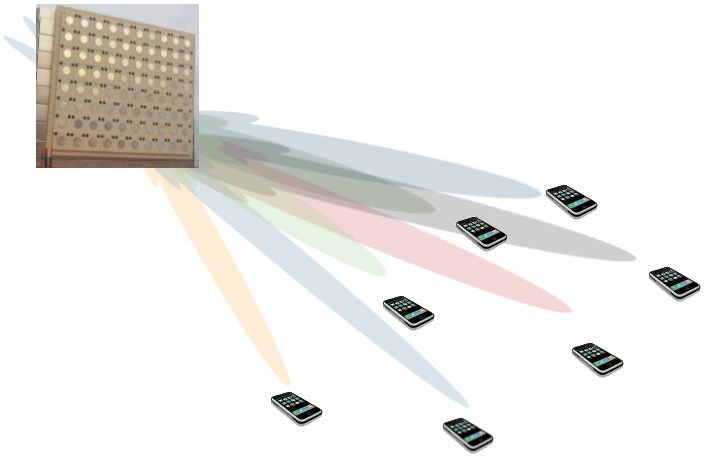
THE UNIVERSITY OF UTAH

RICE

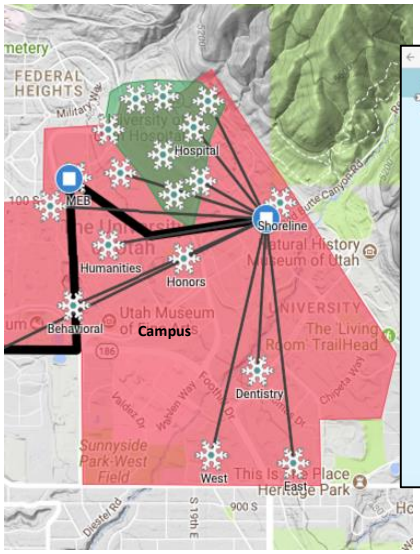
UNIVERSITY OF MICHIGAN

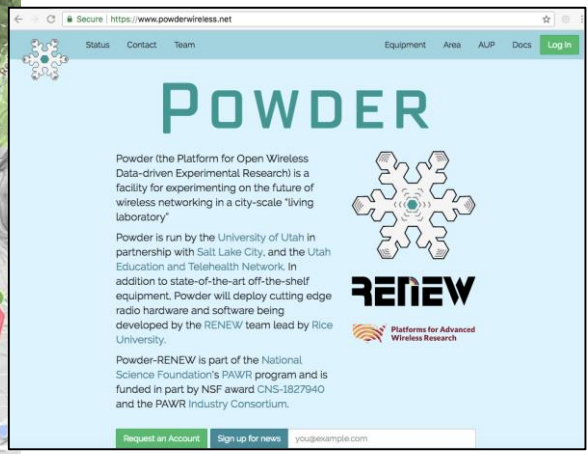
TSU
TEXAS SOUTHERN UNIVERSITY

Open Experiments Vision



RENEW Open-source mMIMO Stacks

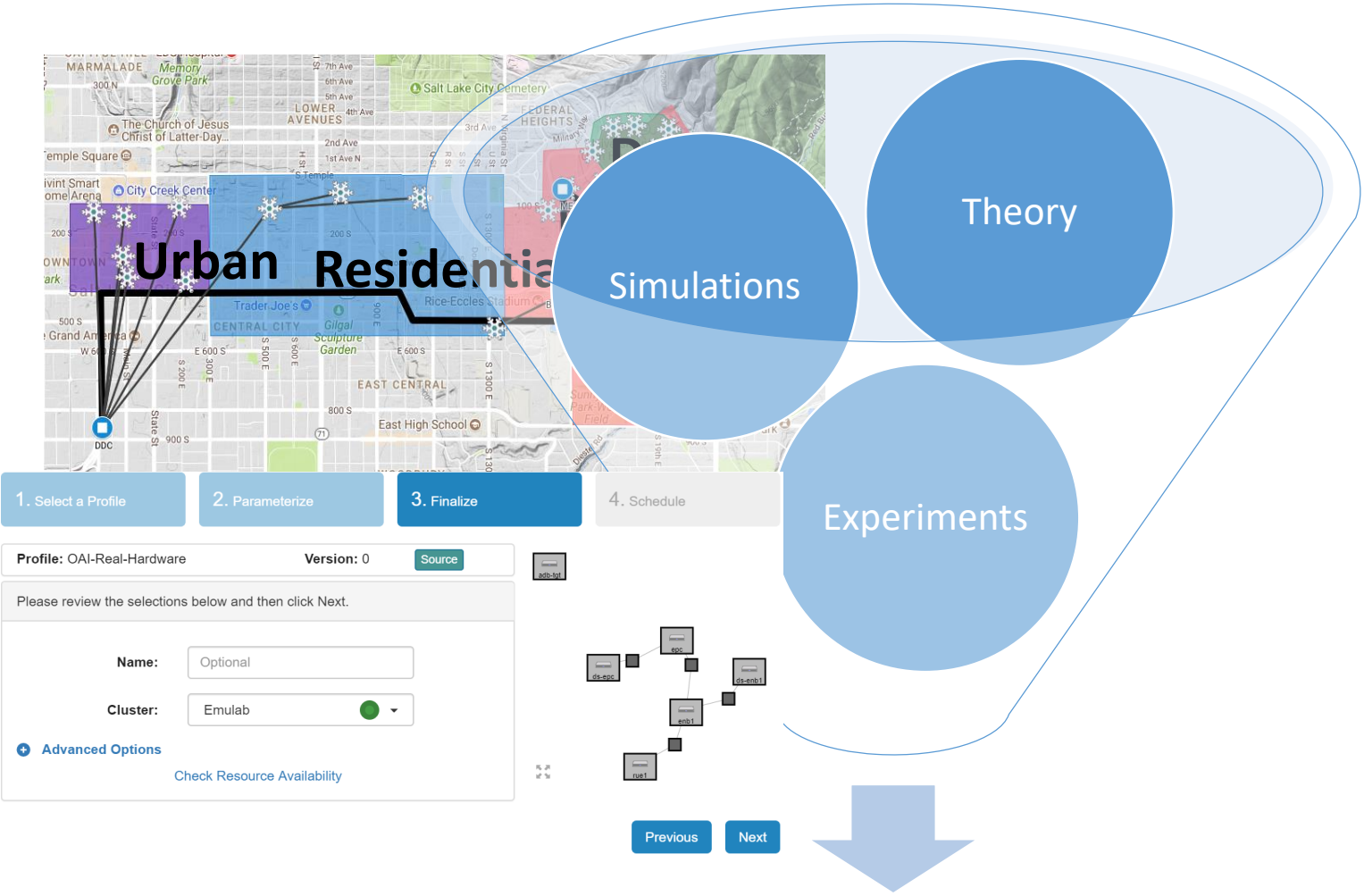




POWDER: Shared Research Infrastructure

- **Experiment Profile:** Specific set of hardware resources and code – share a profile to share an experiment
- **Replicability:** Statistical repeatability feasible – use the same wireless nodes to validate experimental results
- **Reproducibility:** Test on different experiment setups, i.e. base stations/clients, etc

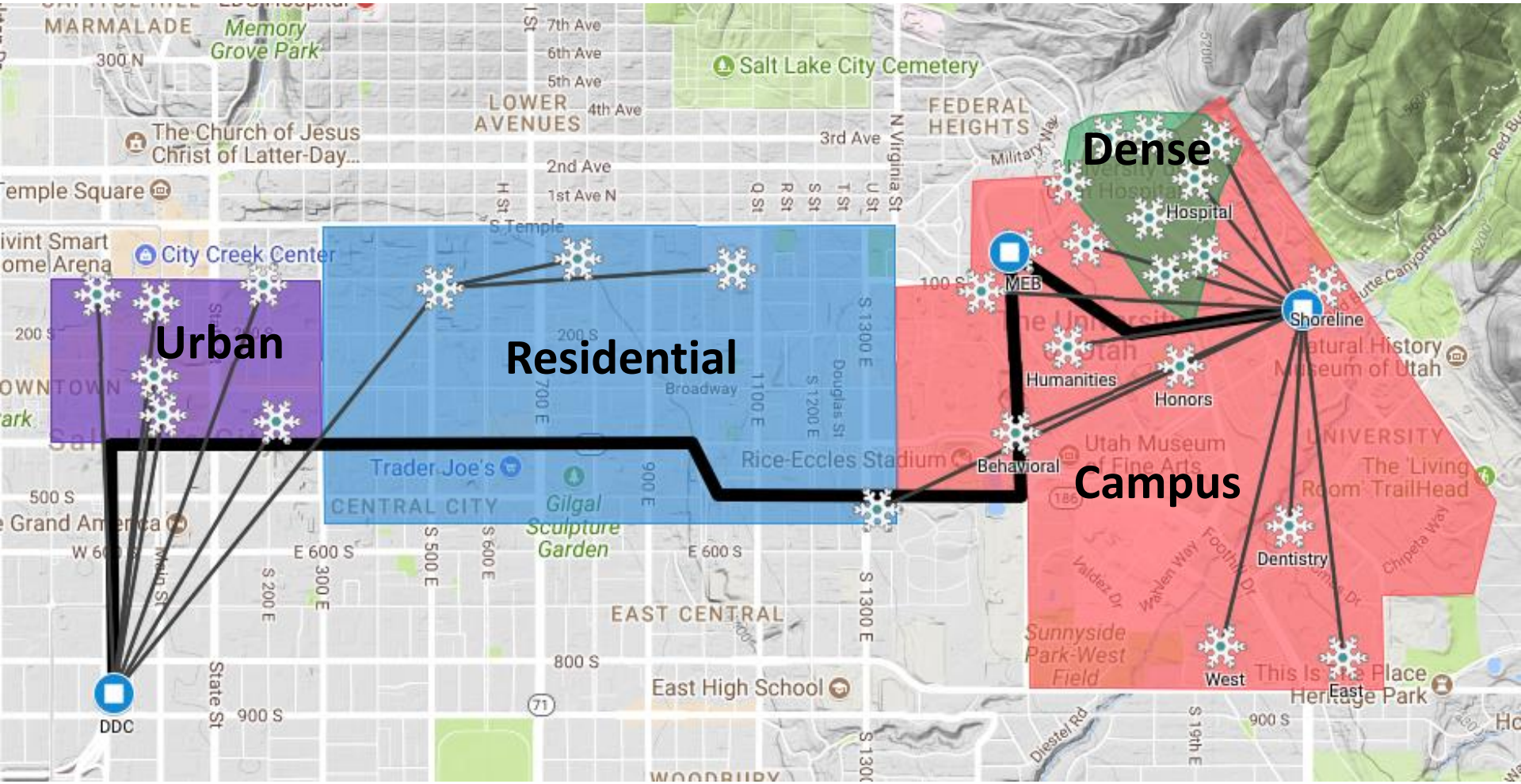
Replicable & Reproducible Experiments – Straightforward Soon!



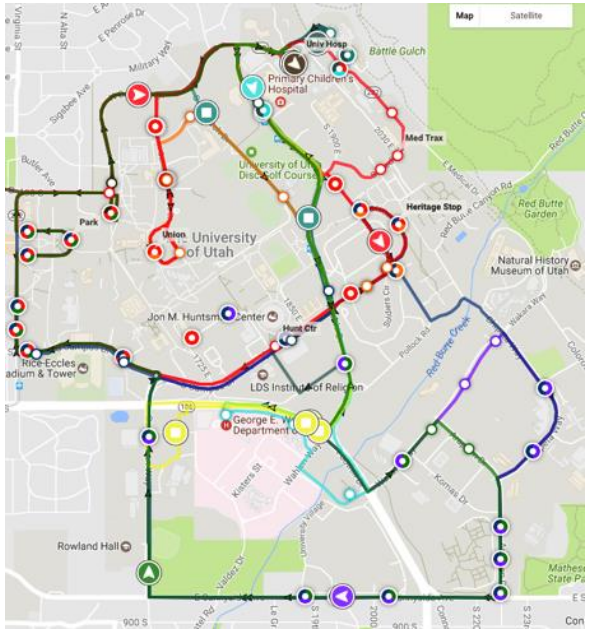
Experiments: Code, Nodes, Data can all be shared with one weblink.

As simple as sending link to a paper

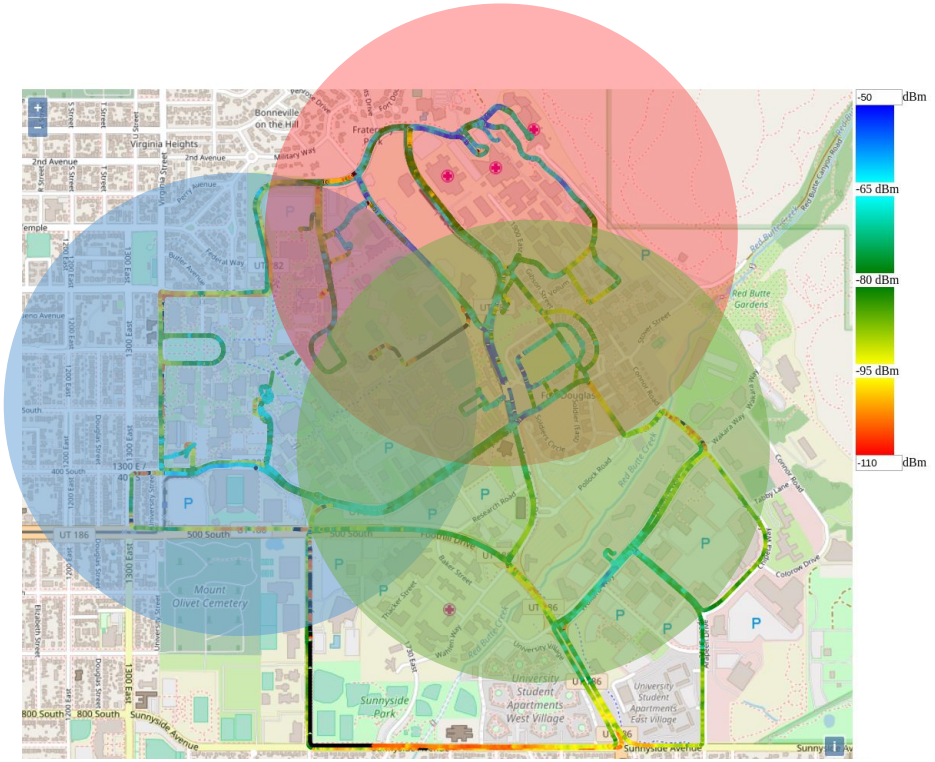
POWDER@University of Utah: Large-scale SDR Deployment



POWDER Deployment Scenarios



UofU Shuttle deployments for observable mobility



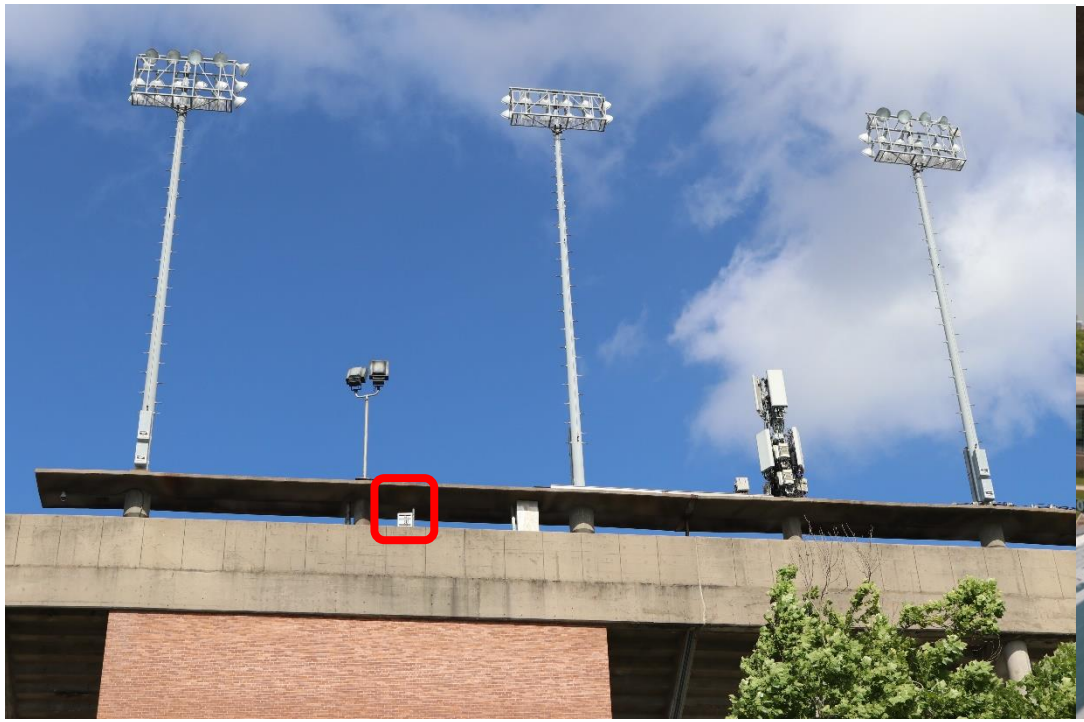
Cell overlap for CoMP

POWDER: Planned Spectrum Coverage

Range (MHz)	
698-806	Commercial/Public Safety
902-928	Industrial, scientific and medical (ISM)
1710-1755	Extended Advanced Wireless Services (EAWS) uplink
2110-2155	Extended Advanced Wireless Services (EAWS) downlink
3550-3650	Citizens Broadband Service (CBRS)
5150-5925	Unlicensed National Information Infrastructure (U-NII)

- Broad range of frequencies, sub-6GHz focus
- Program license streamlines spectrum licensing
- Experiment Isolation Mechanisms

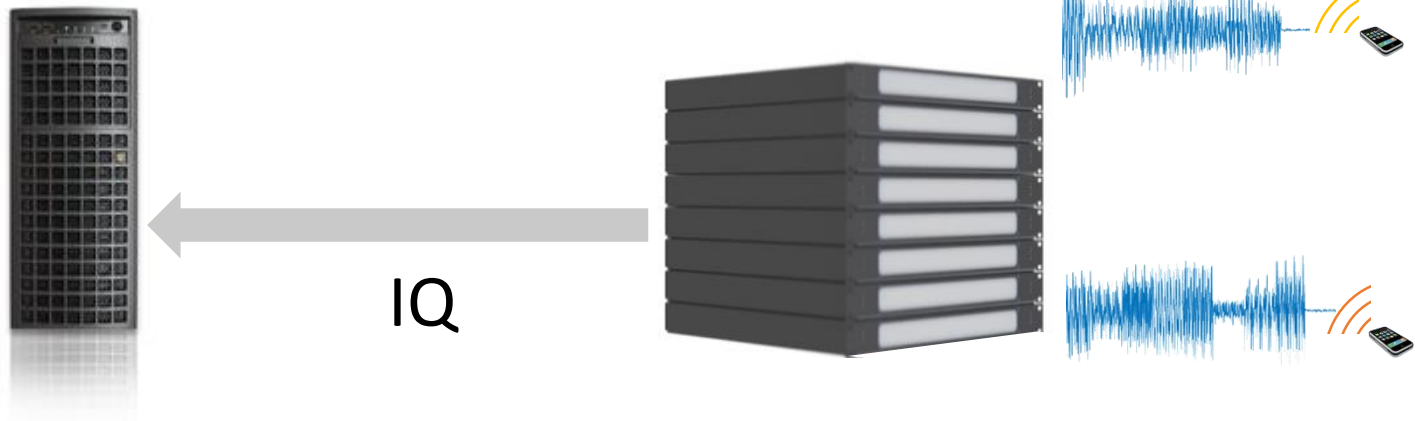
FAROS: Software-defined Massive MIMO Base-stations

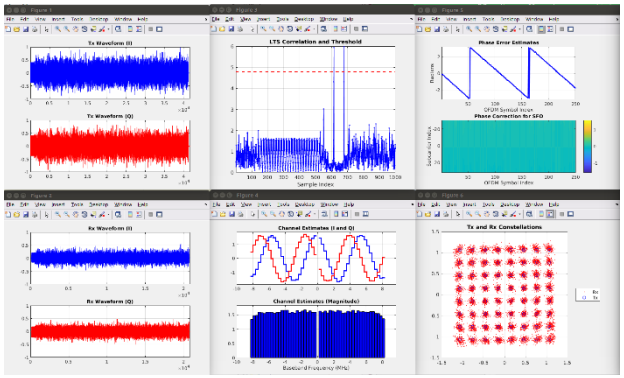


- 64-96 Antennas
- UHF, 2.5 and 3.5GHz Configurations
- 4x 10G Ethernet Backhaul
- SyncE and PTP-like support
- Compact, Remotely monitored

Commercially available from Skylark Wireless (Rice spin-off)

RENEW Design Flows

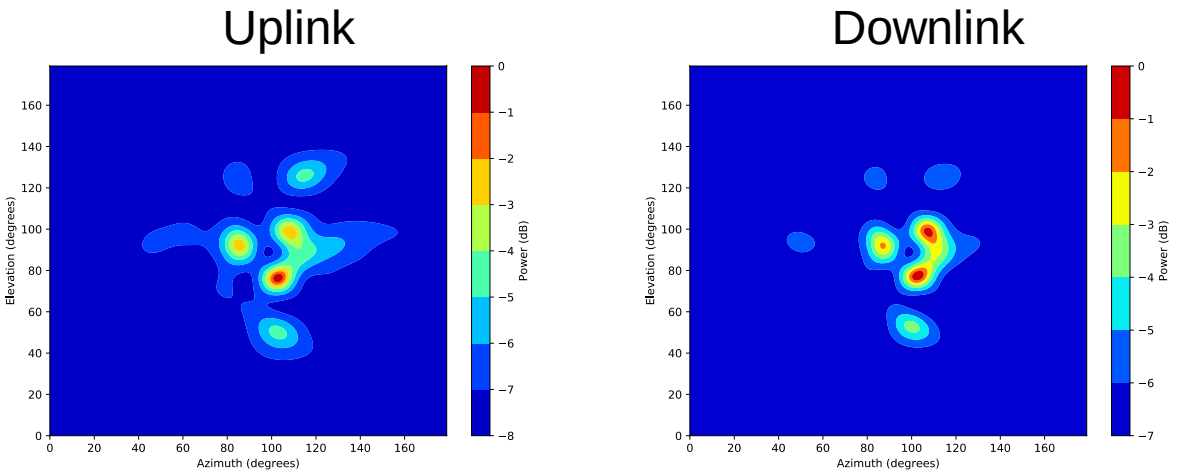




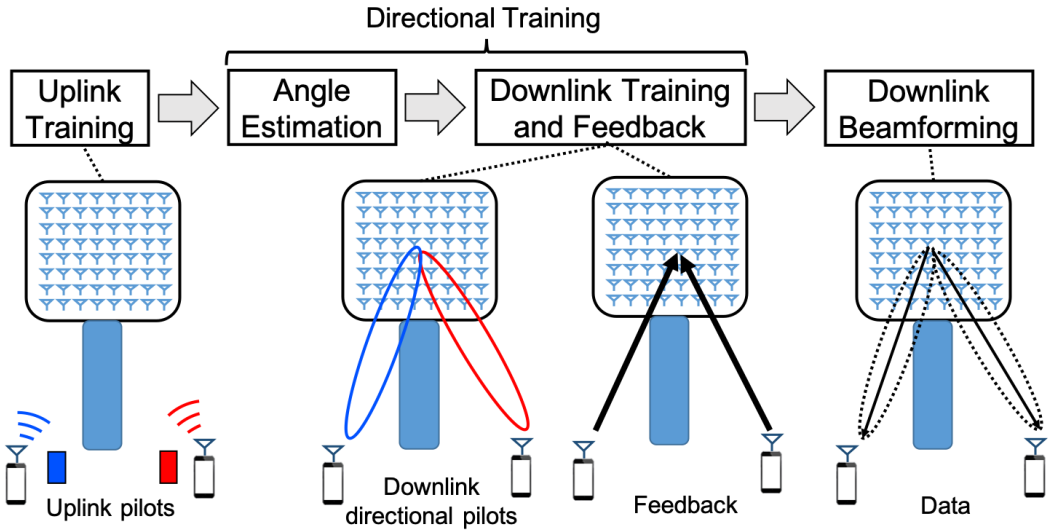
- Multiple Experimentation Design Flows inc. MATLAB
- Channel Measurement Framework

- Firmware Built-in Features
  - Flexible Framing
  - Over-the-Air Sync
  - Power Control
  - AGC

Research Example I: FDD Massive MIMO



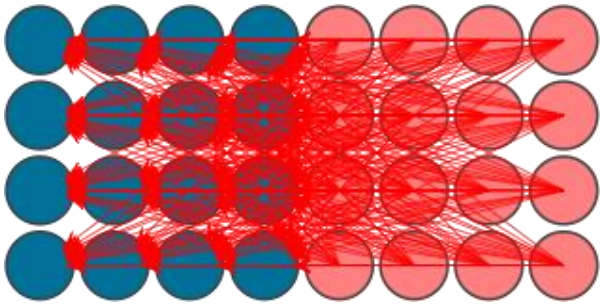
- ✓ # dominant angles << # antennas (channel low-dim in angle space)
- ✓ Uplink/downlink channel angle correlation is high

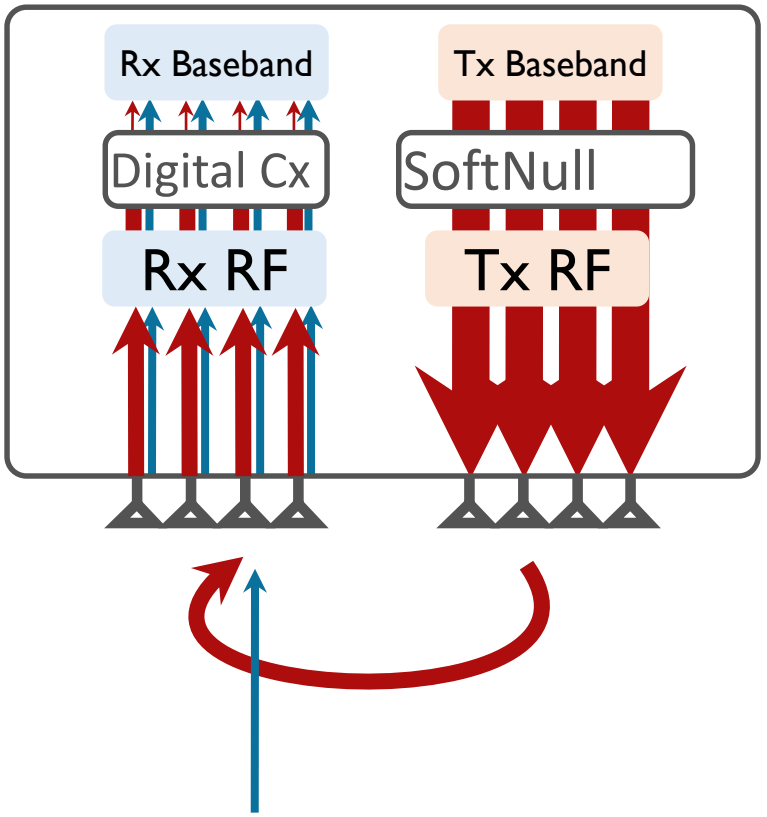


"Directional Training for FDD Massive MIMO", X. Zhang, et al., IEEE Trans. On Wireless Comm., 2018.

Research Example II: Full Duplex Massive MIMO

Dense self-interference





- For 2D arrays, many direct self-interference path
- Remove the Need for Analog Cancellation with TX beamforming

"SoftNull: Many-Antenna Full duplex Wireless via Digital Beamforming", E. Everett, et al., IEEE Trans. On Wireless Comm., 2016.

More Possible Experiments on POWDER with RENEW Development

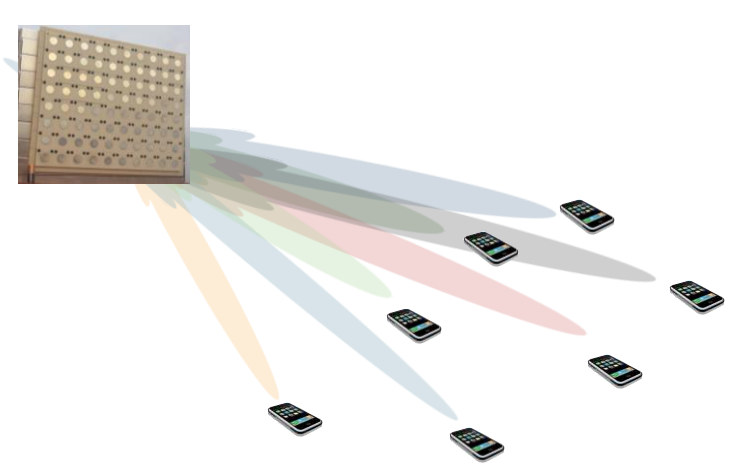
Y1
- Deployment of at least ONE Argos Base Station at POWDER
- Fully Integrated Channel Sounding Framework

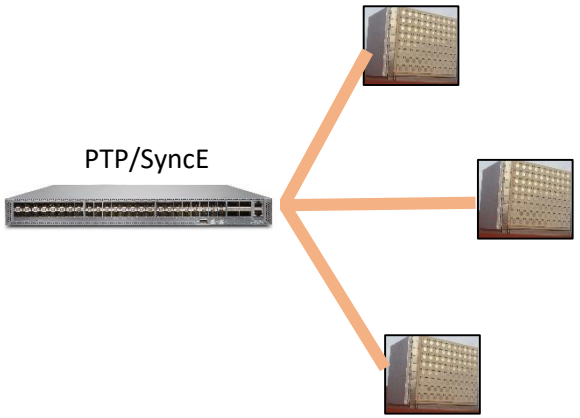
Y2
- Addition of THREE more base stations on POWDER
- A Configurable Real-time Massive MIMO PHY (UL & DL)

Y3
- Full Stack: Experimental Scheduler / CoMP / C-RAN
- Core Network / Mobility / NFV / Measurement tools

Y4
- 3GPP Compatibility and 5G waveforms
- 802.11ac/ax support on Argos

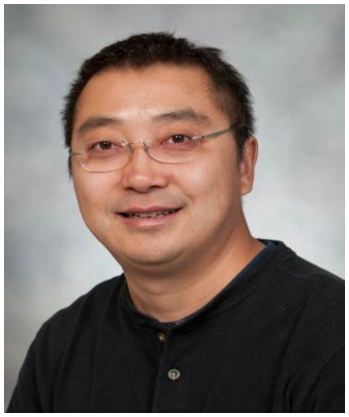
Y5
- End-to-end applications, Edge Services
- Beyond 5G Research And Development





RENEW Team (Rice, UMich, TSU)


Ashu Sabharwal

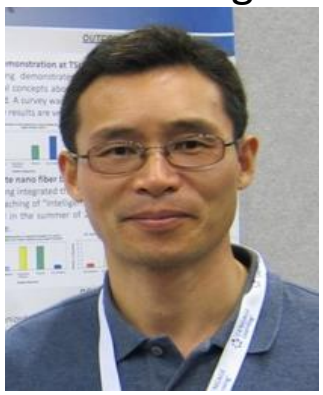

Lin Zhong


Edward Knightly

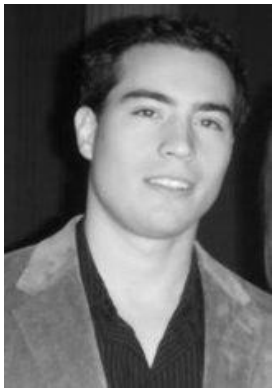

Joe Cavallaro


Morley Mao


Wei Li


Xuemin Chen


Rahman Doost-Mohammady


Oscar Bejarano


C. Nicolas Barati

Thank You!

renew.rice.edu
powderwireless.net

RENEW