POWDER: *Platform for Open Wireless Data-driven Experimental Research*
RENEW: *Reconfigurable Ecosystem for Next-gen End-to-end Wireless*
powderwireless.net
renew.rice.edu

Status — May 2019

Broader Context
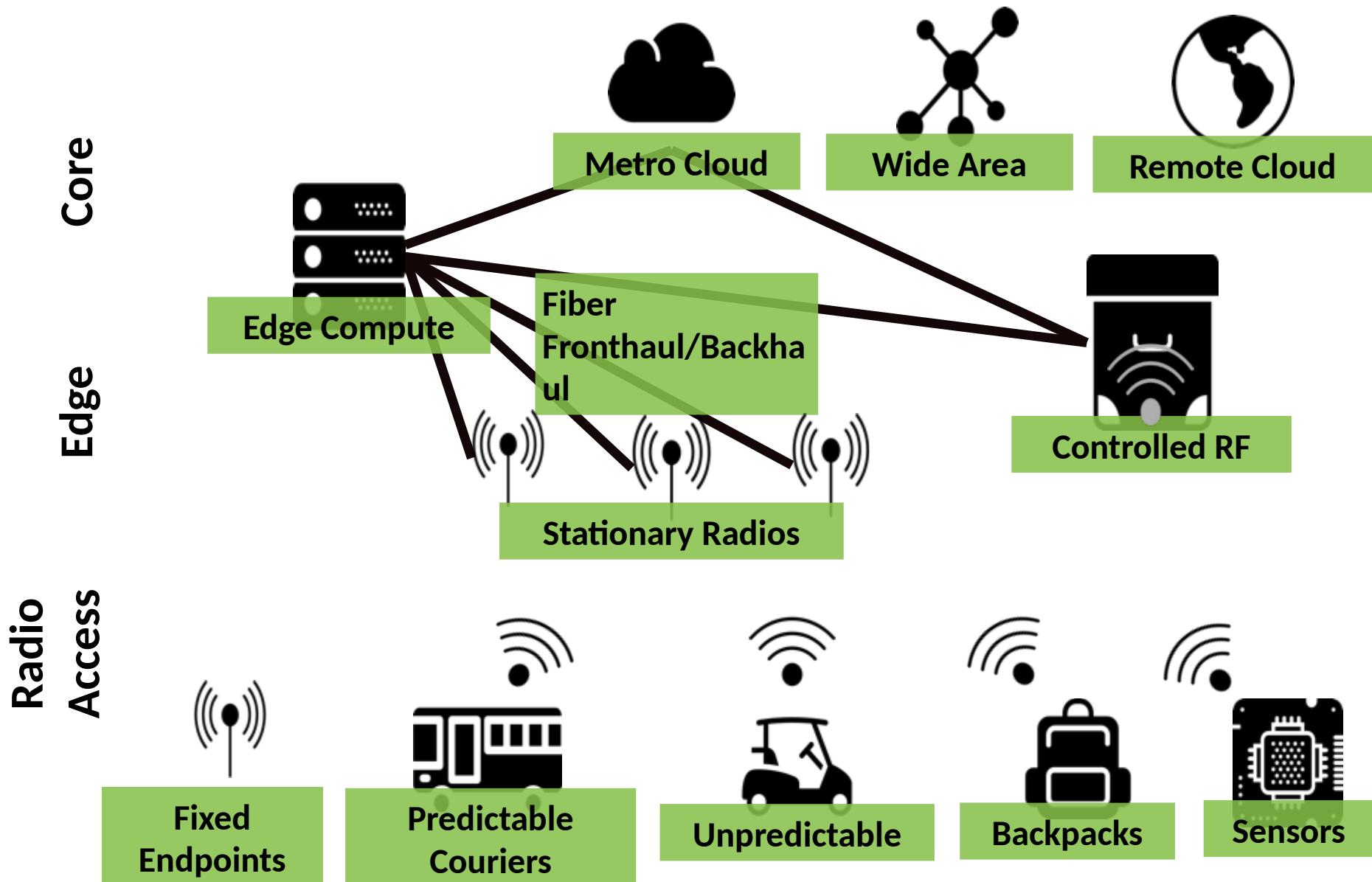
- **POWDER-RENEW** is a project under the National Science Foundation (NSF) PAWR program
  - **POWDER** (U of U) is a living lab research platform we are building in Salt Lake City
  - **RENEW** (Rice) is proving additional equipment for POWDER
- **PAWR**:
  - Platforms for Advanced Wireless Research
  - NSF public/private program ($100M)
  - 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
- First round completed in early 2018:
  - POWDER-RENEW (U of U with Rice) selected as one of the platforms
  - COSMOS (Rutgers, Columbia, NYU) other first round platform

Platforms for Advanced Wireless Research
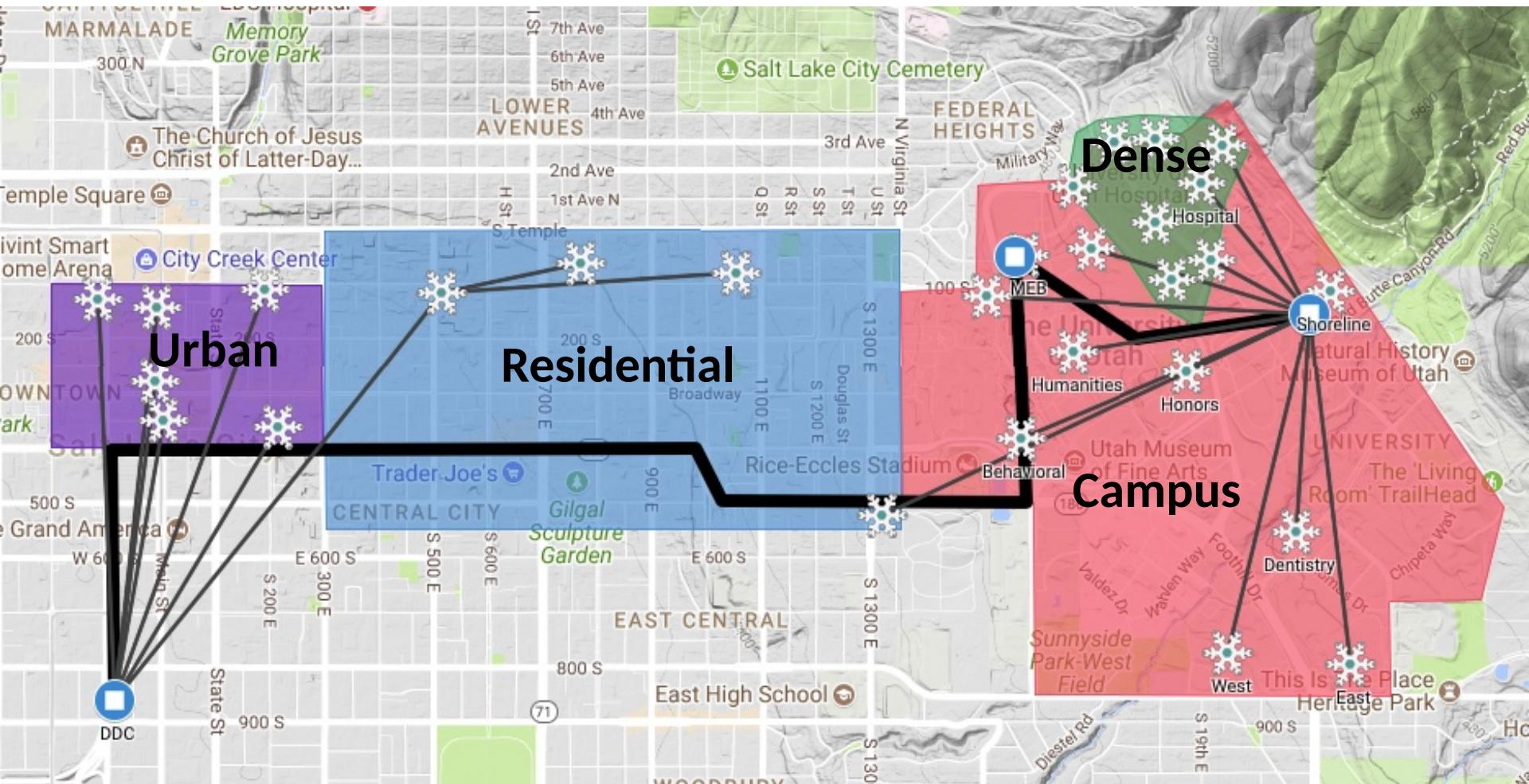
# POWDER Overview

Planned POWDER Footprint
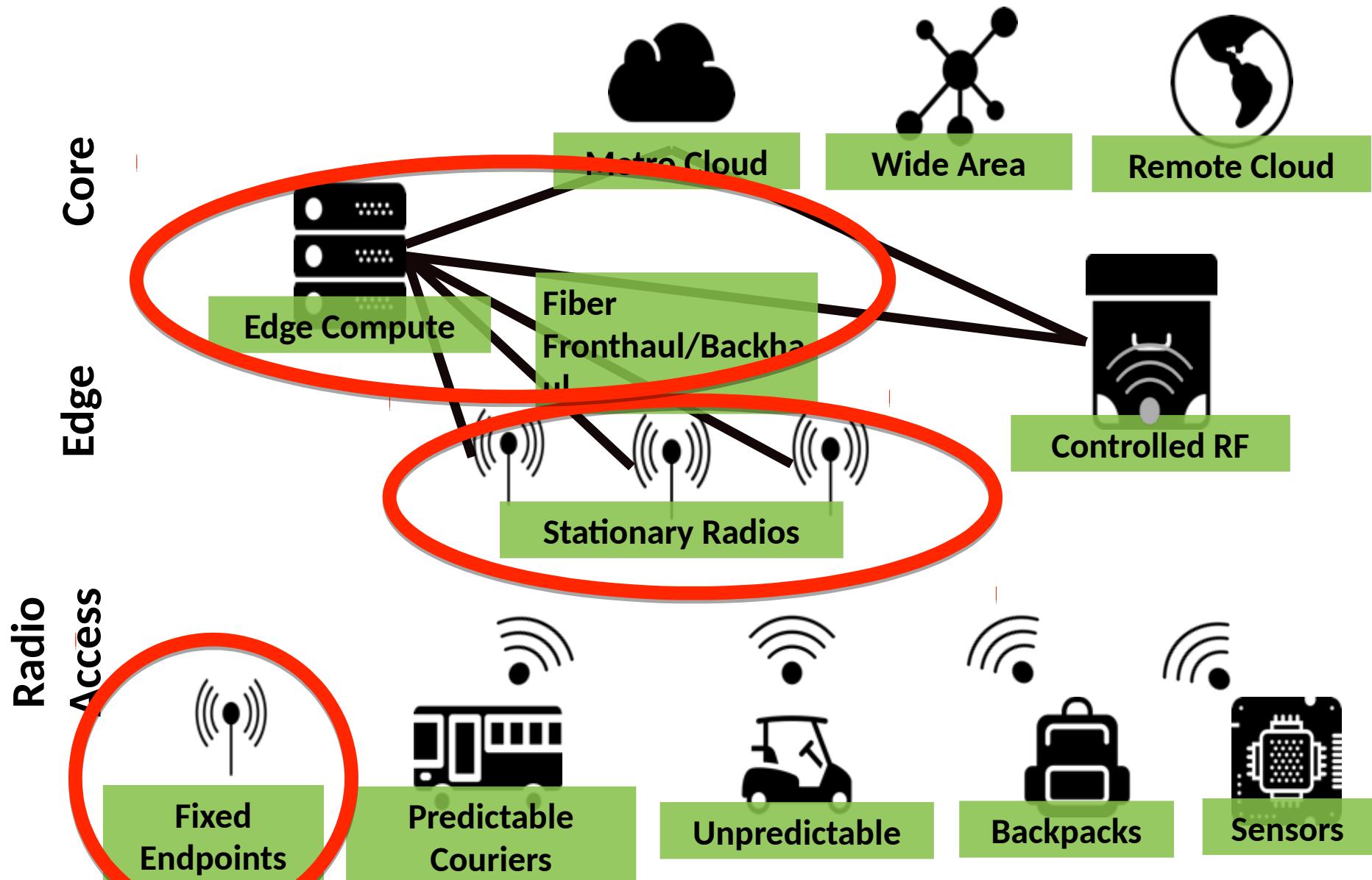
Supported Research Domains

- Industrial and academic research

- **Wireless communication**
  - 100X wireless data rates, ultra reliability, dynamic spectrum access, spectral efficiencies
- **Wireless and mobile networking**
  - Network densification, network virtualization, network management and operation, mobile edge cloud
- **Security and privacy**
  - Jamming detection/prevention, data/location privacy
- **Applications and services**
  - IoT, public safety, augmented/virtual reality, vehicular/drone communication

# YEAR 1: PROCESS & STATUS
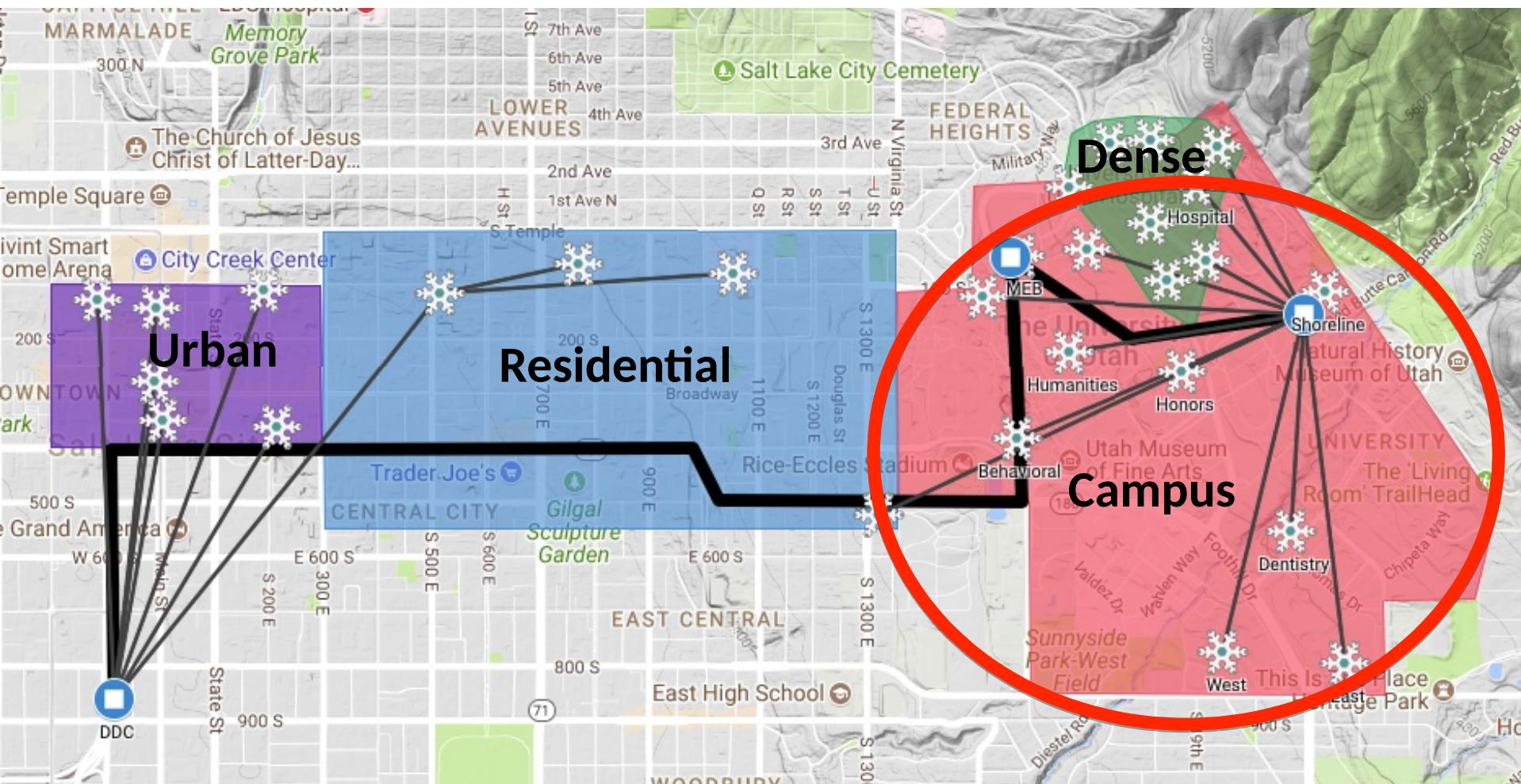
Campus fixed deployment
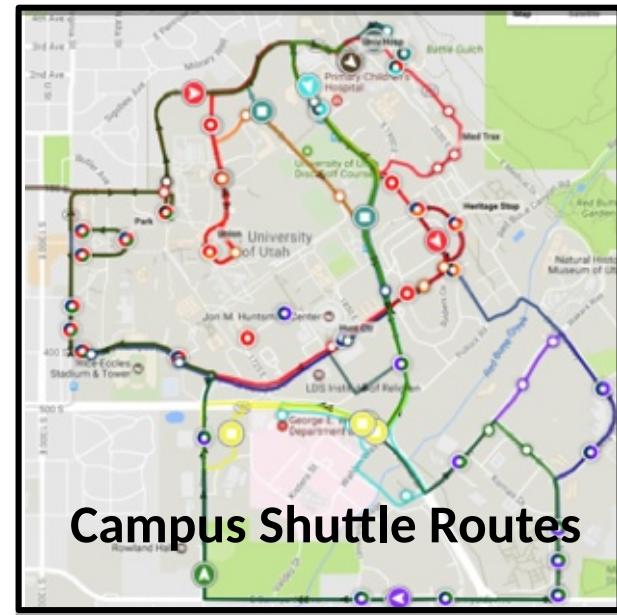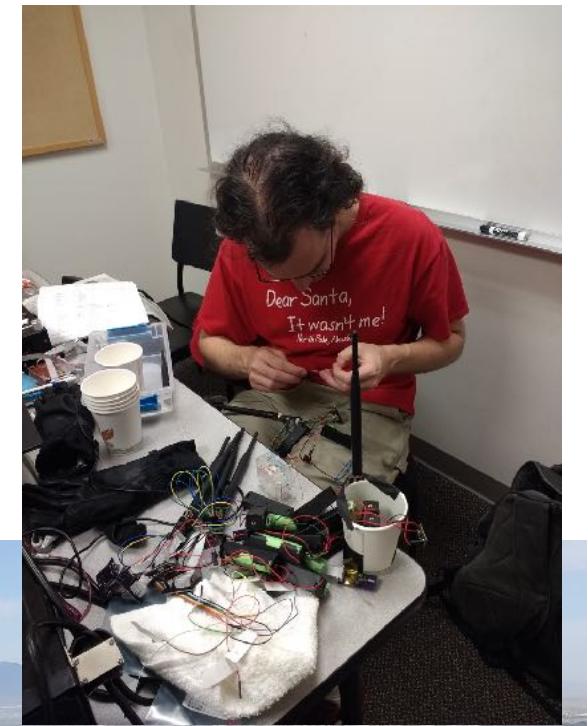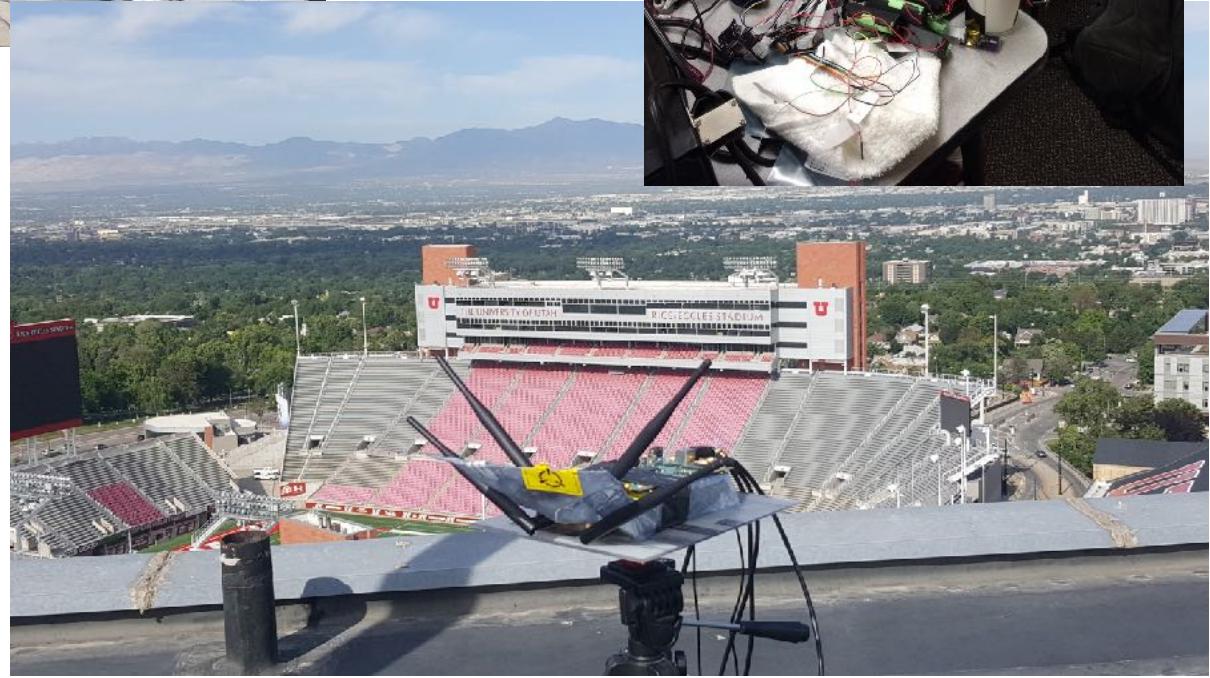
Core

Metro Cloud

Wide Area

Remote Cloud

Edge Compute

Fiber Fronthaul/Backhaul

Controlled RF

Edge

Stationary Radios

Radio Access

Fixed Endpoints

Predictable Couriers

Unpredictable

Backpacks

Sensors

Campus fixed deployment

Finding target locations

Basestation locations

Campus Shuttle Routes

RF measurements from target locations

RF measurements from target locations

Basestation locations

Campus Shuttle Routes
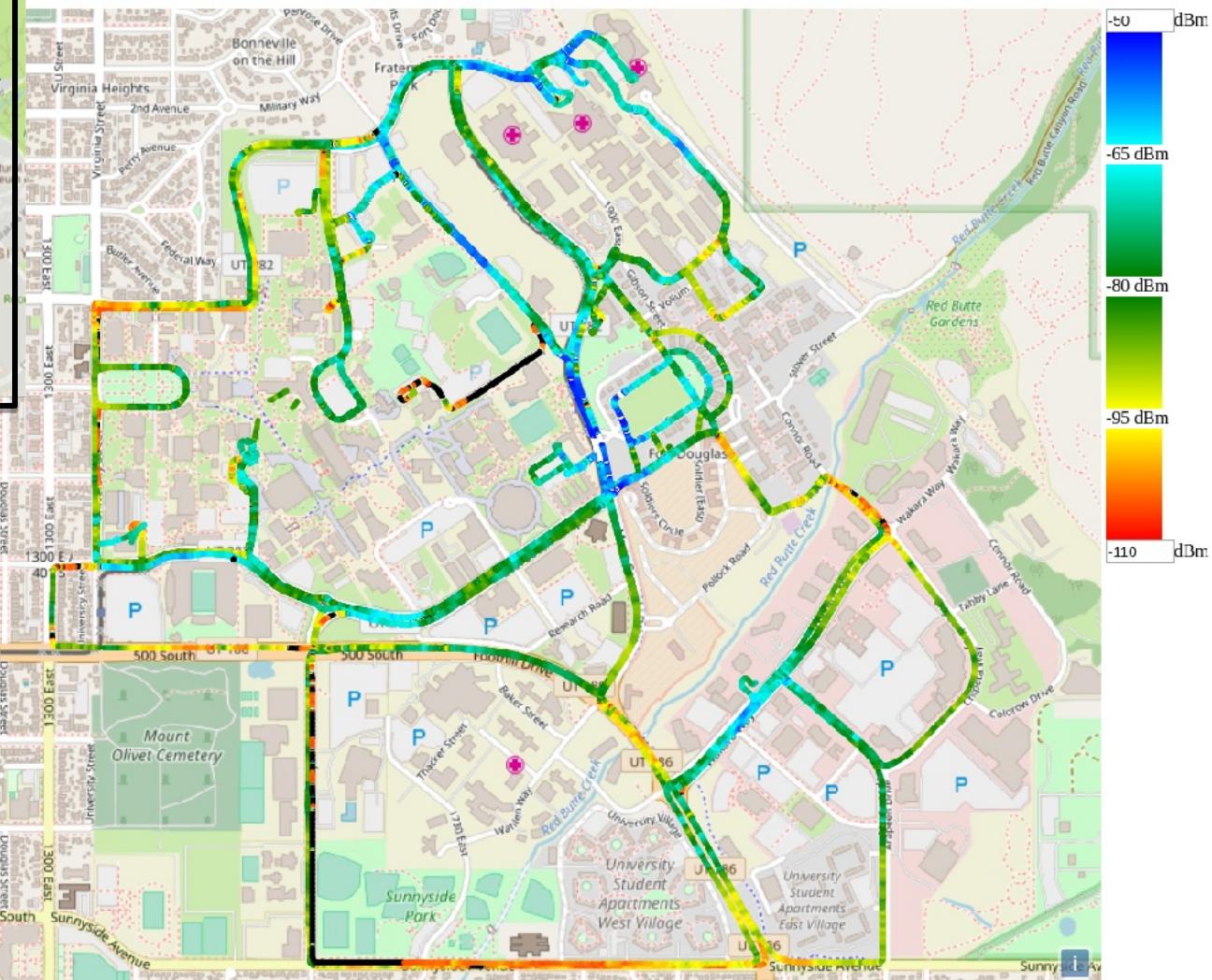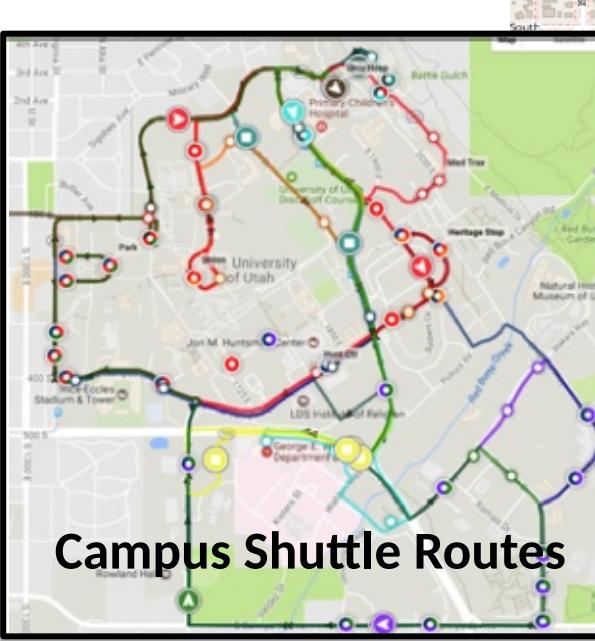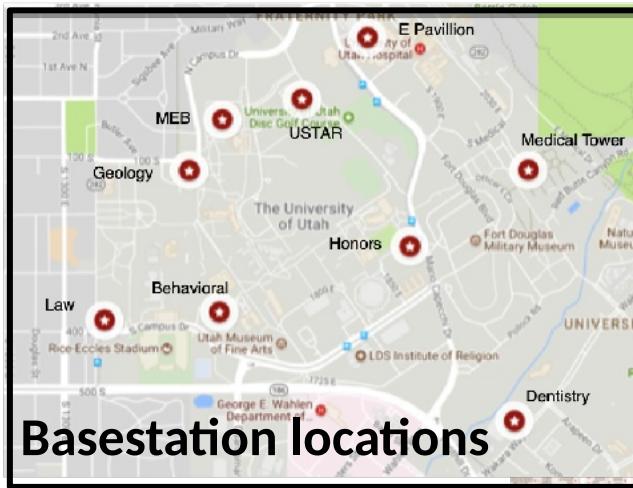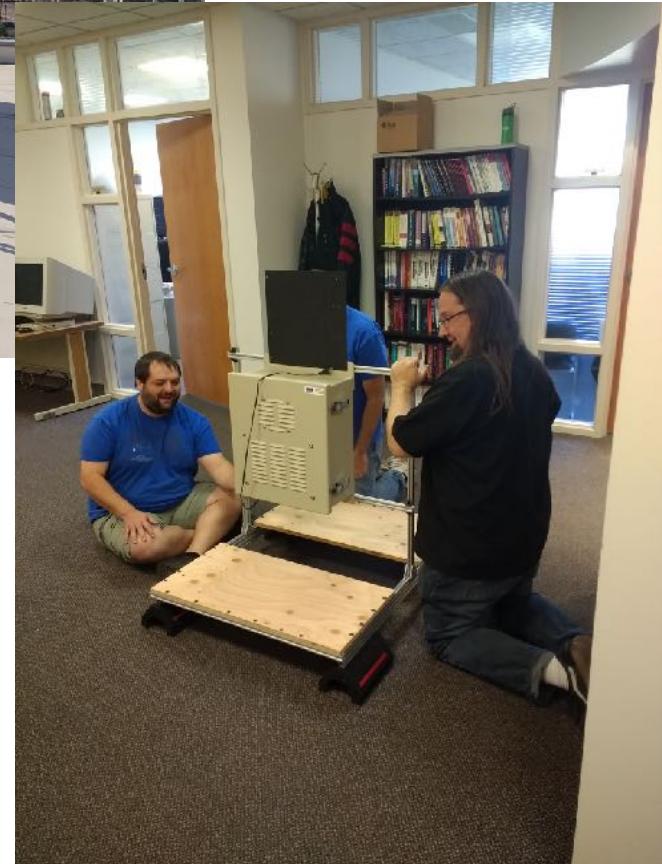
Site surveys…

Prototyping...
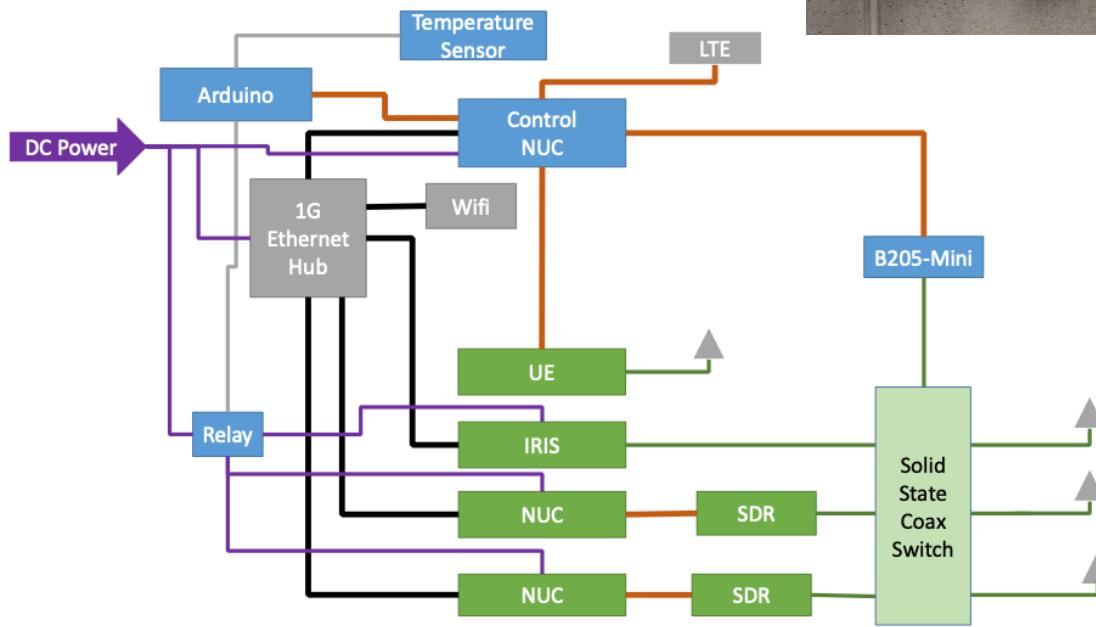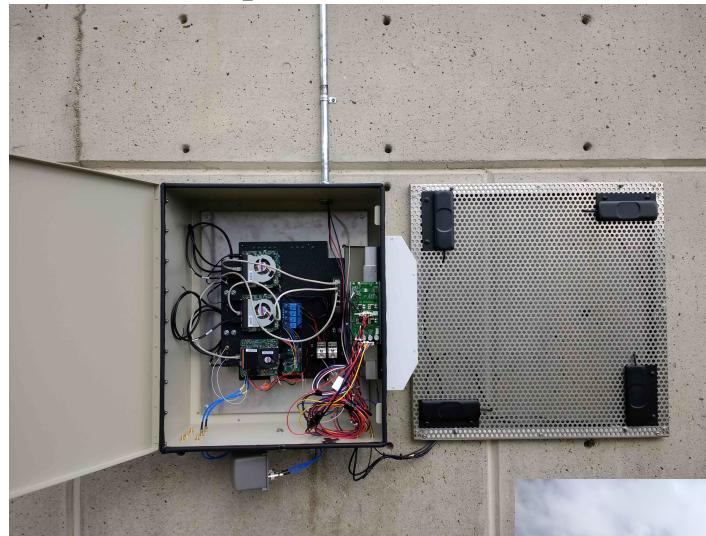
Equipment arriving…
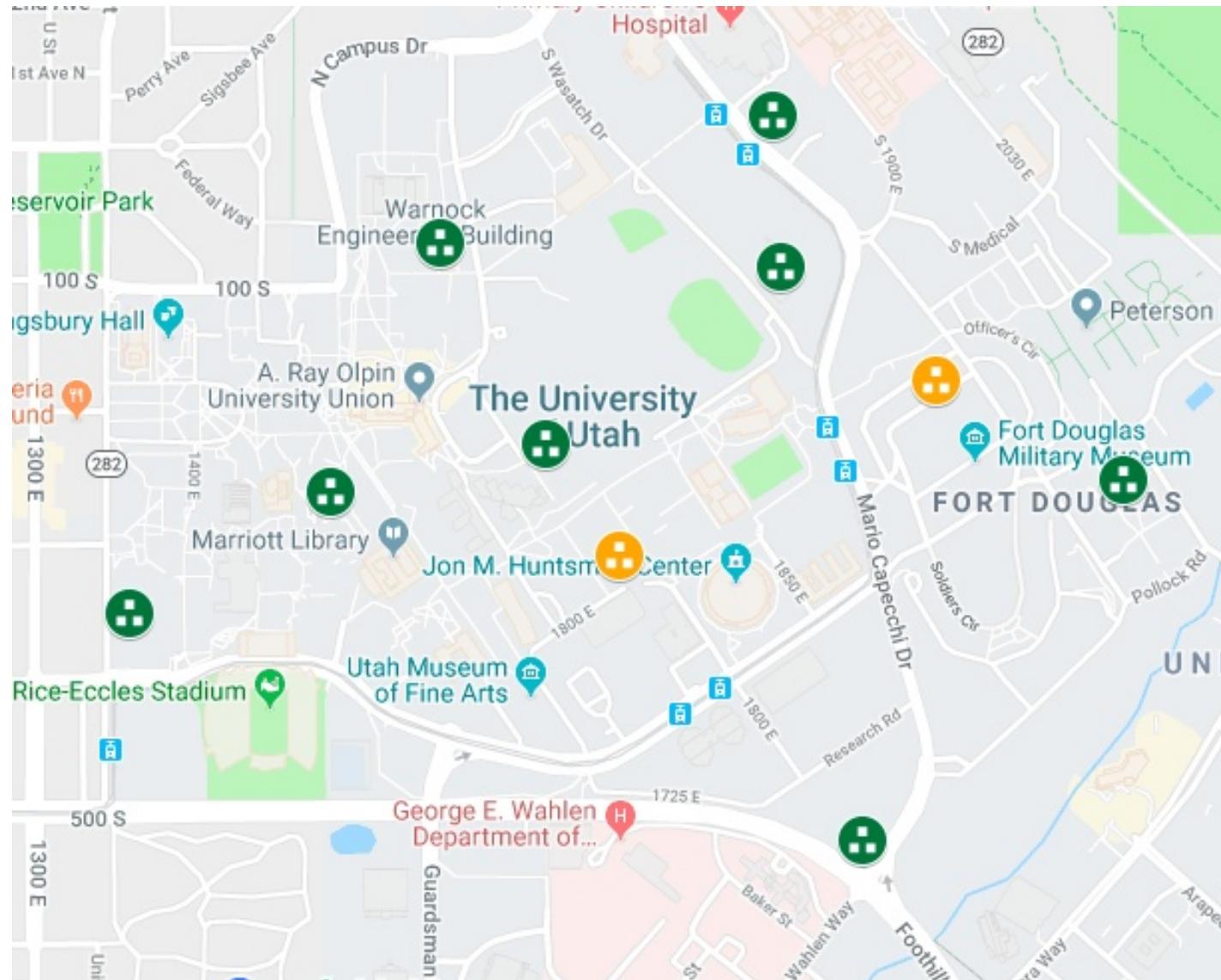
Fixed-endpoint
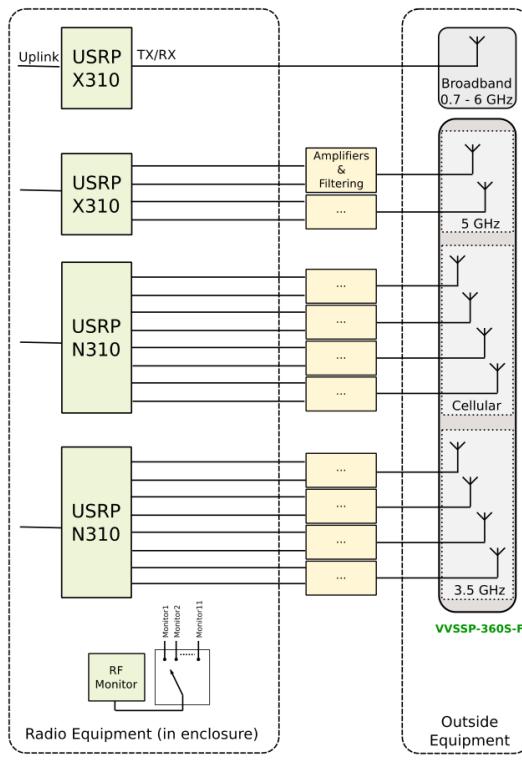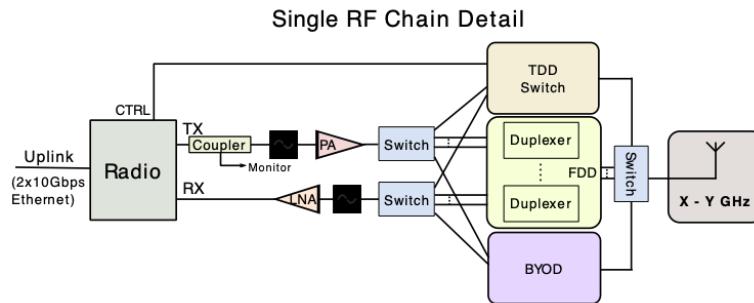
Fixed-endpoint
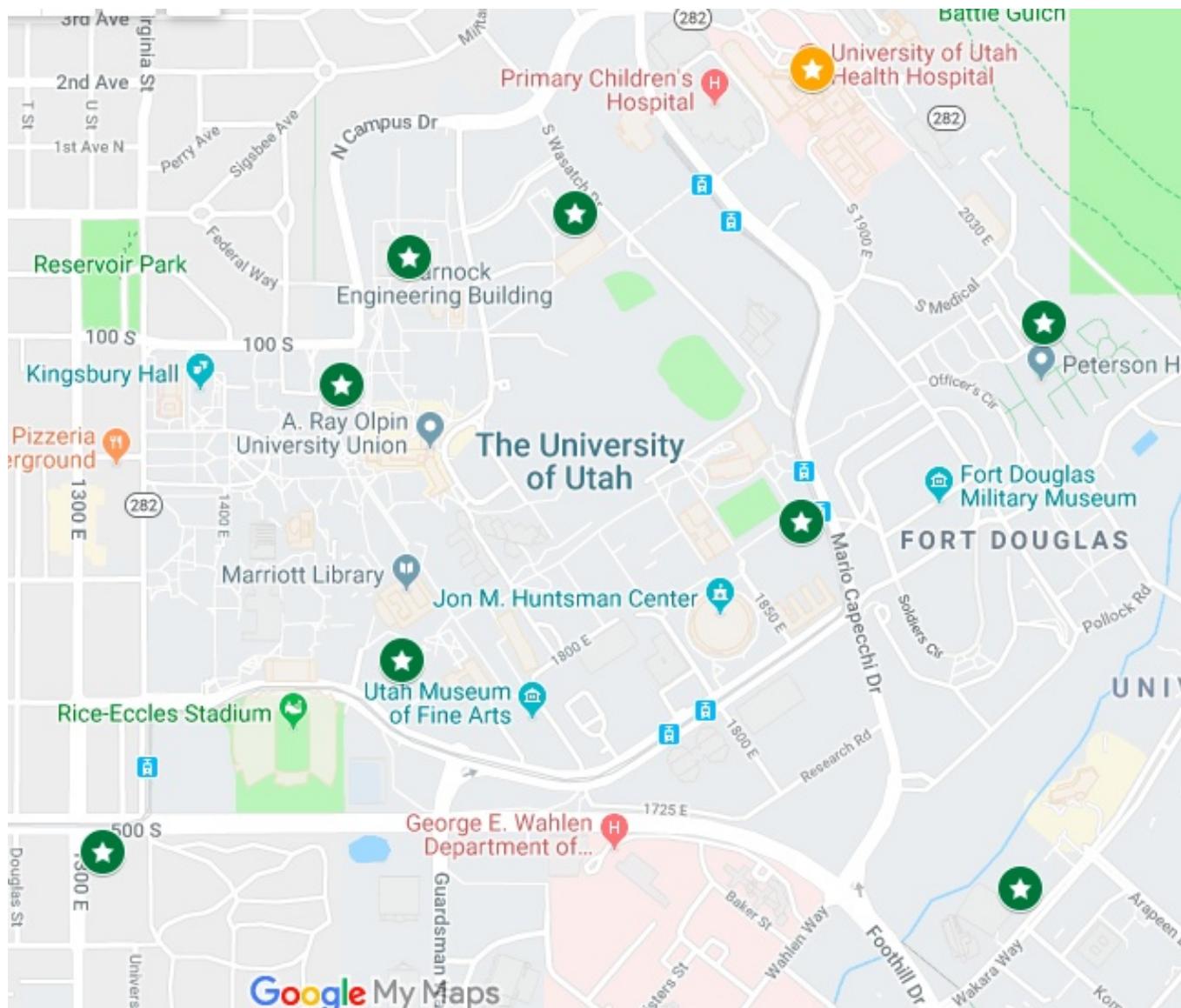
Stationary Radio (Rooftop Basestation)
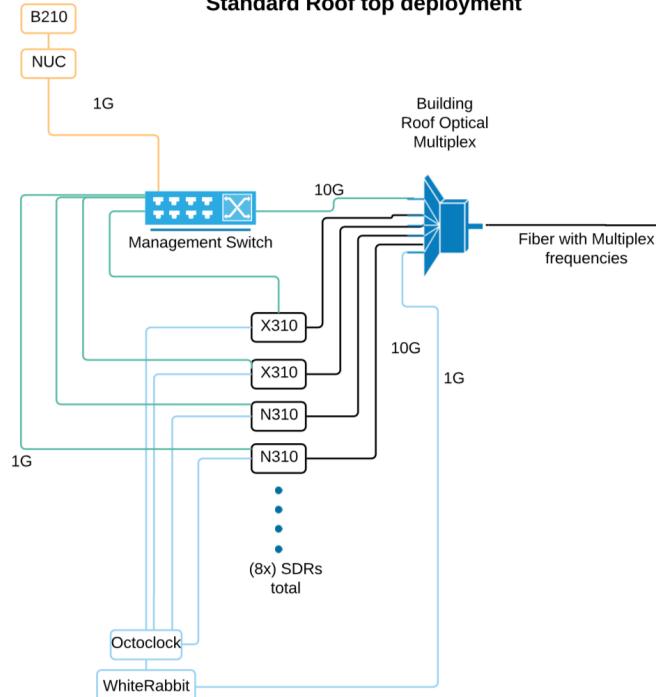
Stationary Radio (Rooftop Basestation)
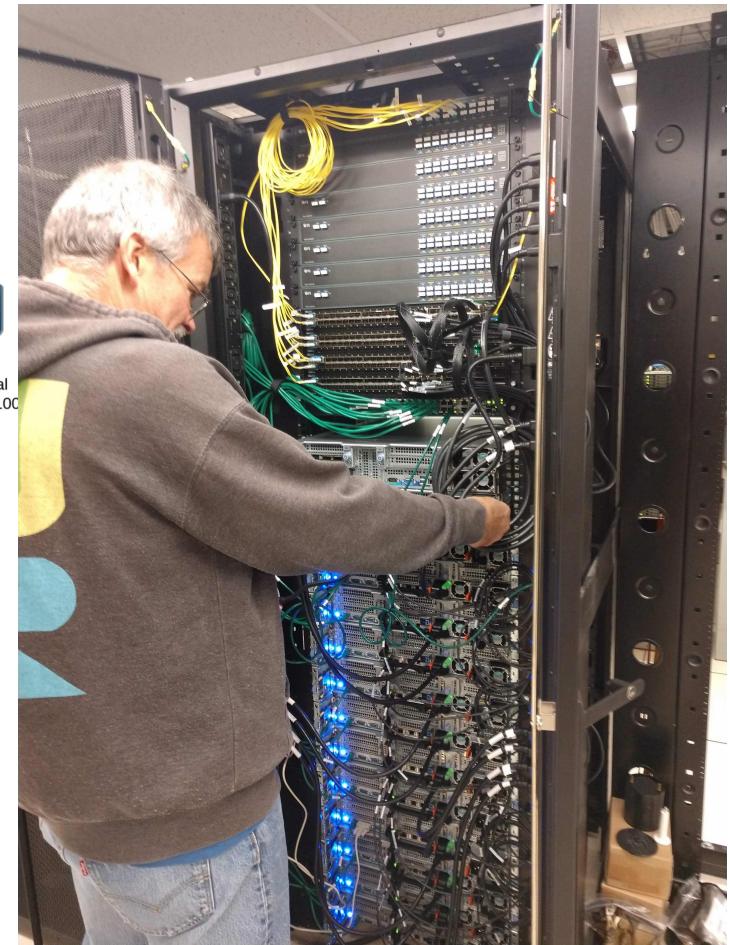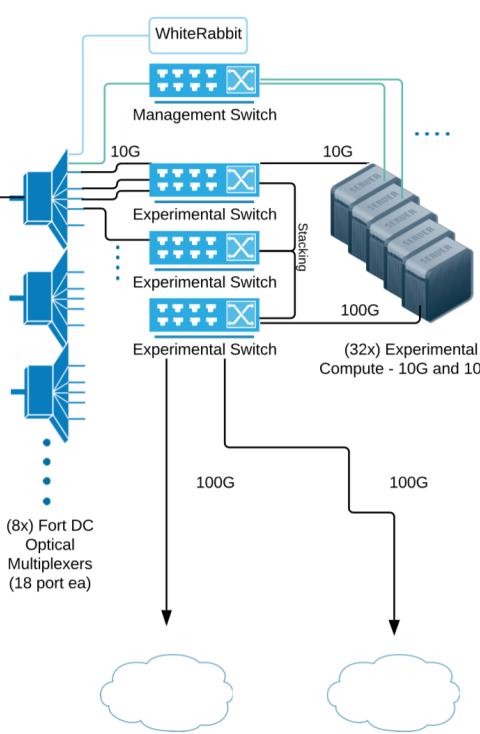
Edge compute, fiber fronthaul/backhaul

Standard Roof top deployment

B210
NUC
1G

Building
Roof Optical
Multiplex

Management Switch
10G

X310
X310
N310
N310
10G
1G
1G

(8x) SDRs
total

Octoclock
WhiteRabbit

Fiber with Multiplex
frequencies
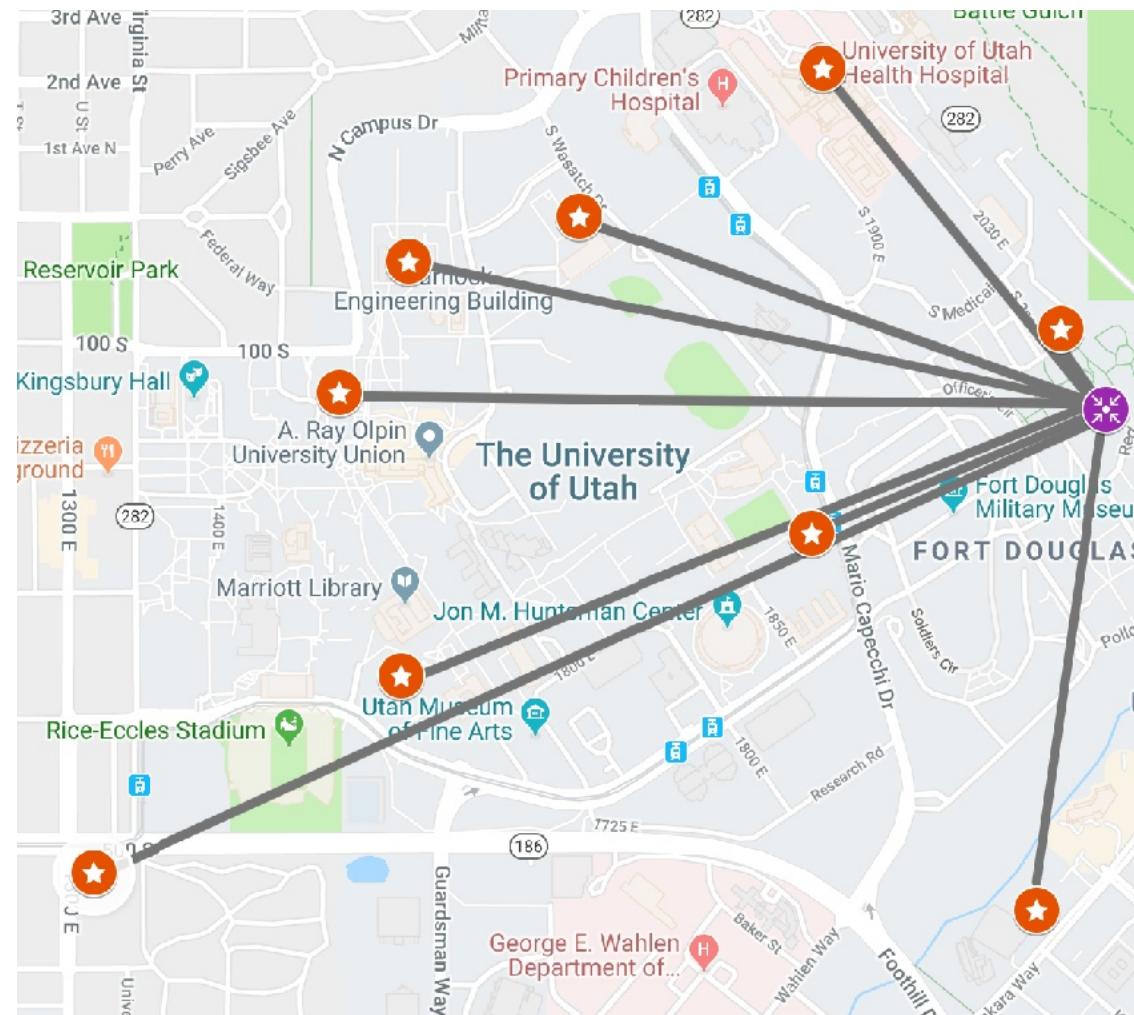
Fort Data Center deployment

WhiteRabbit

Management Switch
10G

Experimental Switch
Experimental Switch
Stacking
Experimental Switch
10G
100G

(32x) Experimental
Compute - 10G and 100

(8x) Fort DC
Optical
Multiplexers
(18 port ea)

100G
100G

Merrill Engineering
Building

Downtown Data
Center

Legend

Monitoring
Management
Experimental/Data
Clock synchronization
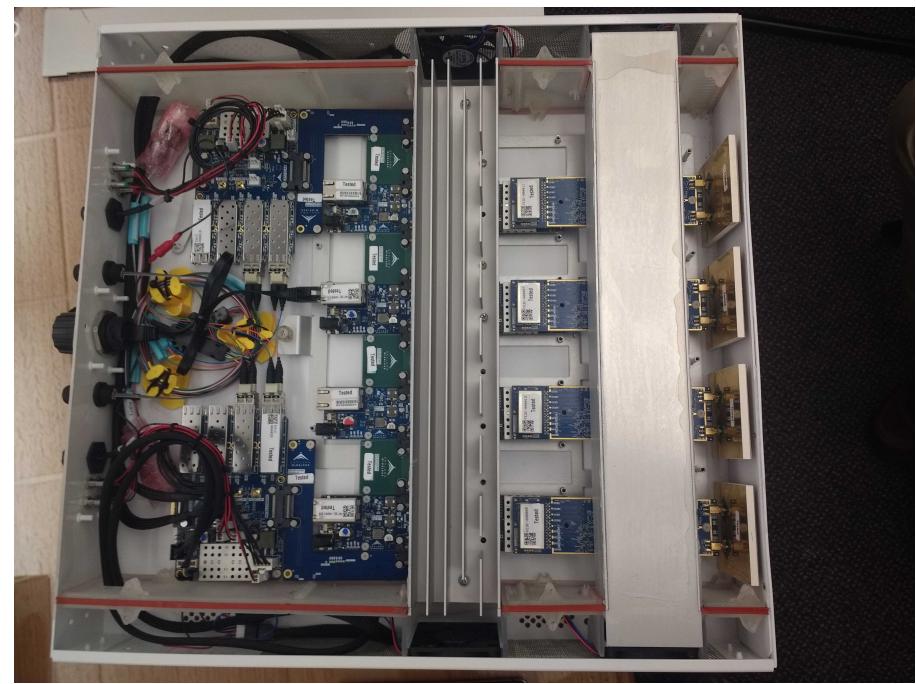
Edge compute, fiber fronthaul/backhaul

Massive MIMO

Software

- Profiles available on POWDER
  - Openstack
  - ONAP
  - srsLTE
  - Open Air Interface
    - 4G and 5G
  - GNU Radio

ACKNOWLEDGEMENT...
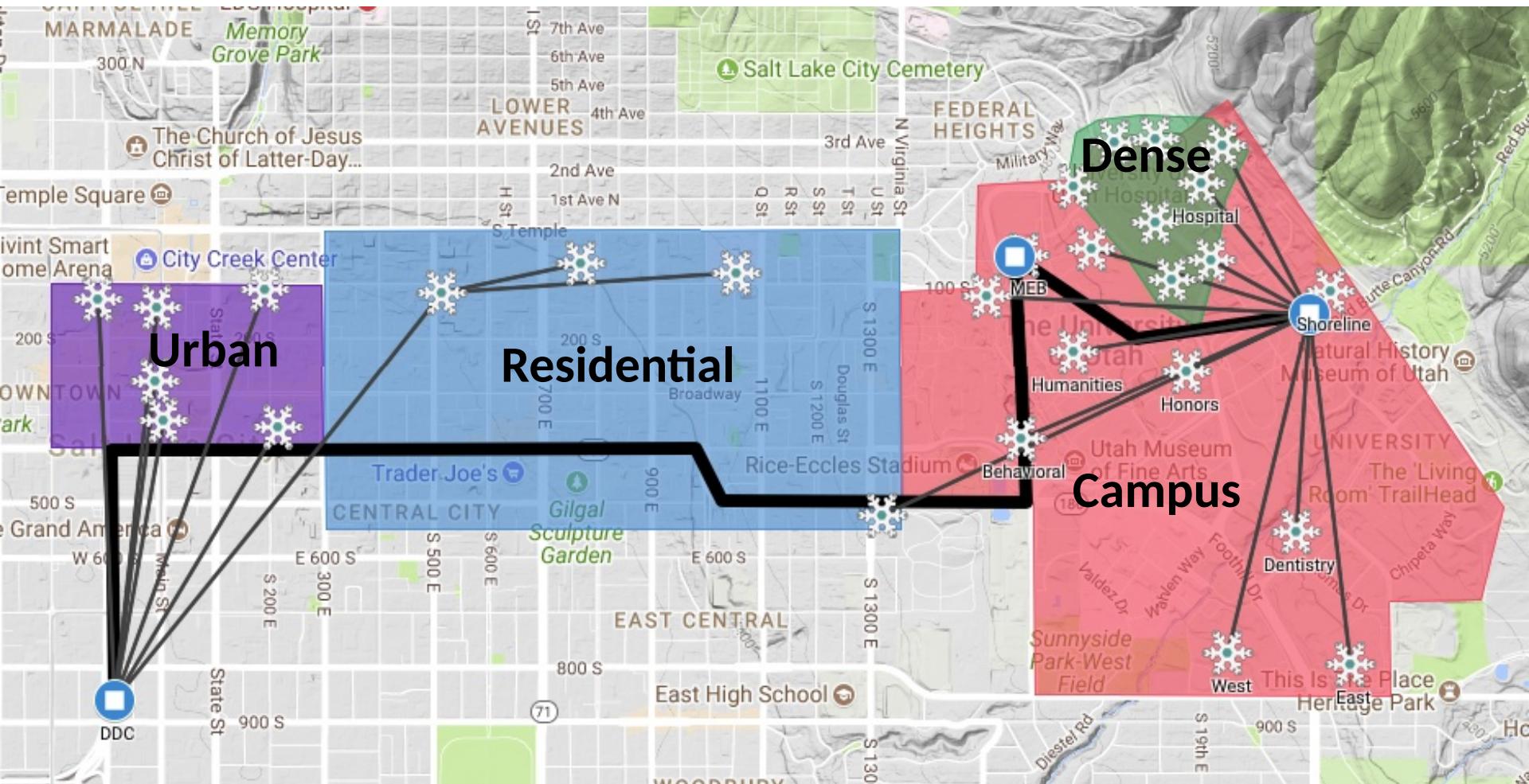
UofU partners

- UETN
- UIT (PM, fiber, security, communications)
- Campus Facilities(Electrical shop, Building Management, Rooftop group, Keyshop)
- GIS
- Student Housing
- Medical Student Housing
- Moran Eye Center Facilities
- Hospital Facilities
- Commuter Service
- Legal

Backup slides

City scale...
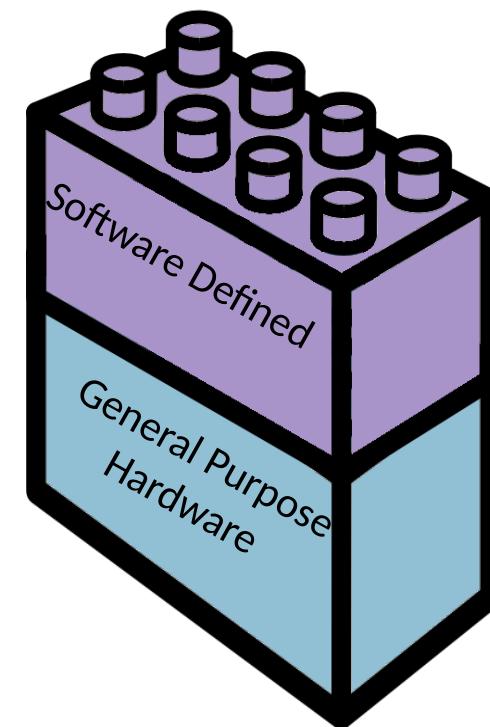
City scale…

Software defined…
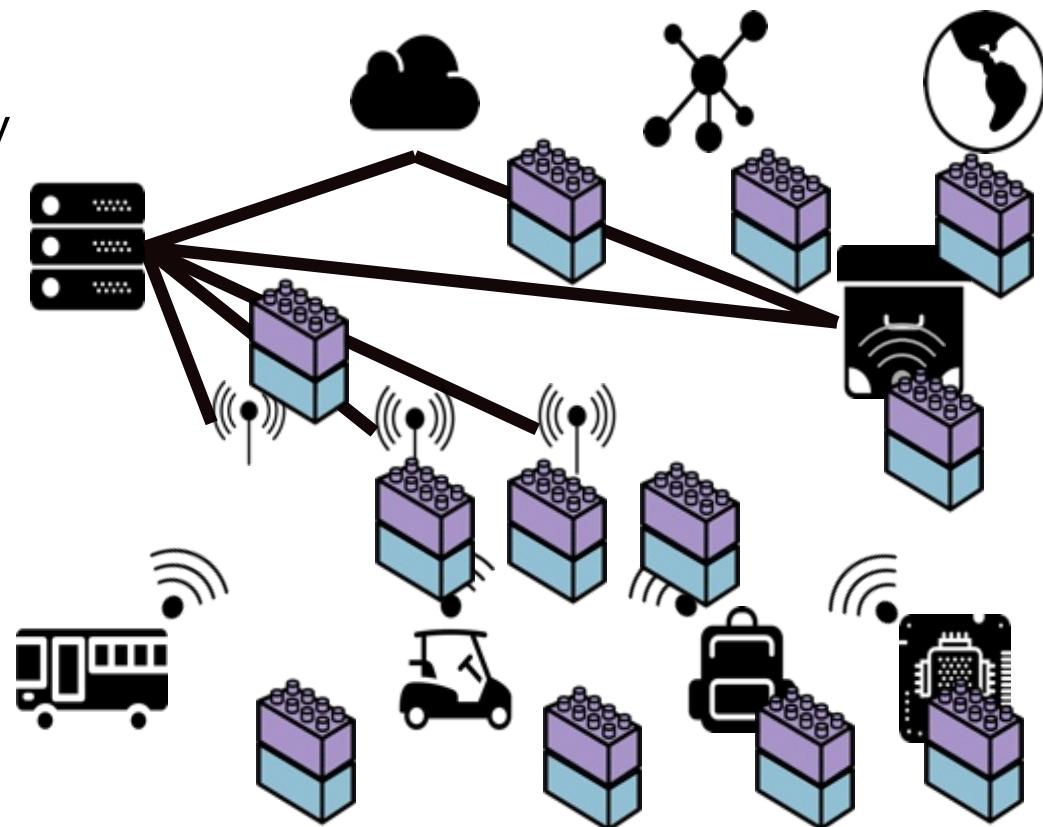
- **Basic Functionality:**
  - General purpose hardware
  - Functionality determined by software you add

Software defined...
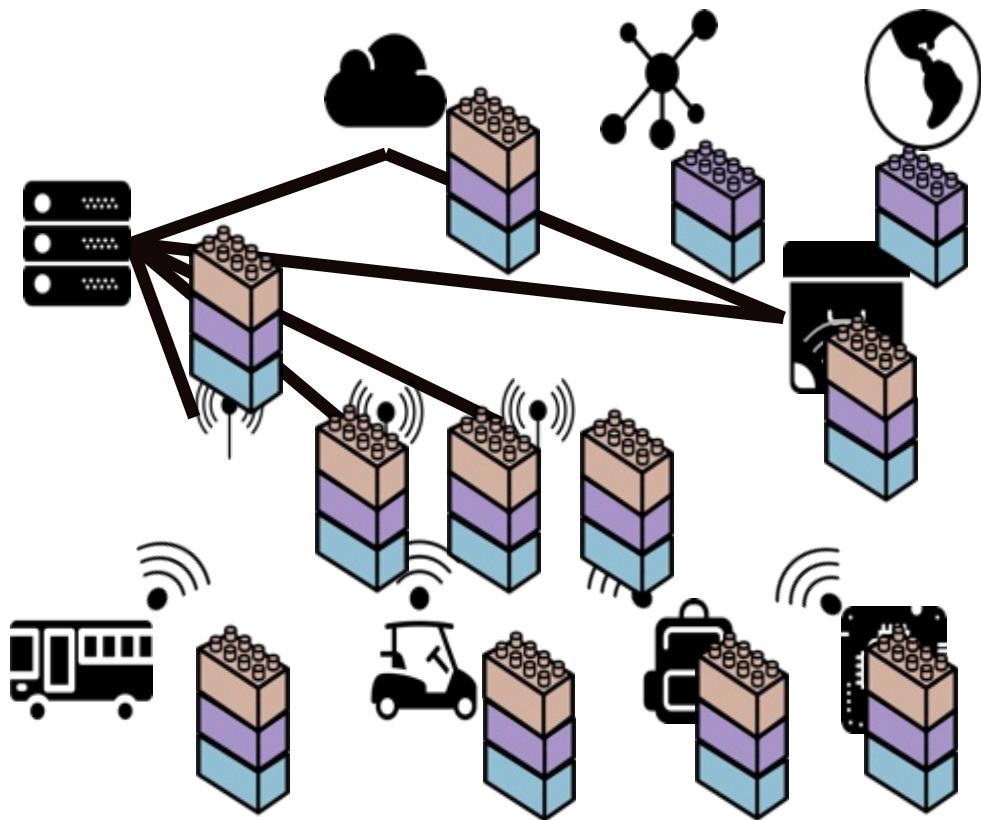
- **Basic Functionality:**
  - General purpose hardware
  - Functionality determined by software you add

  - Do this end-to-end
    - Offers great flexibility in enabled research

Novice through expert…
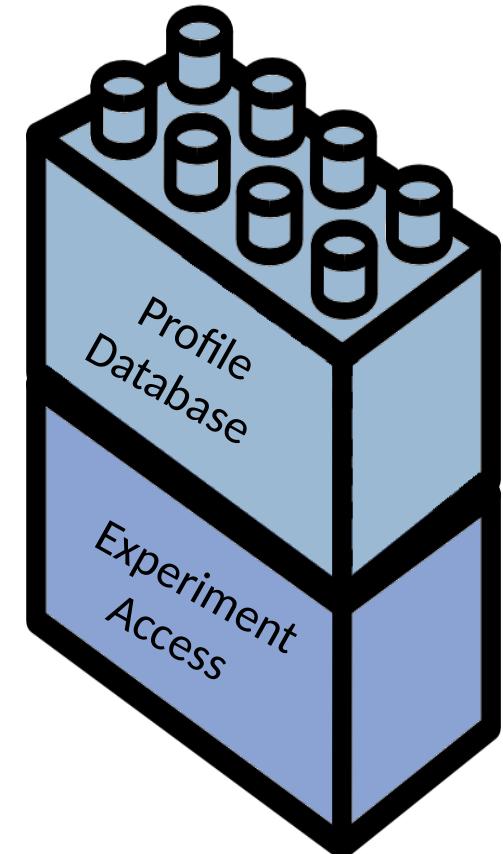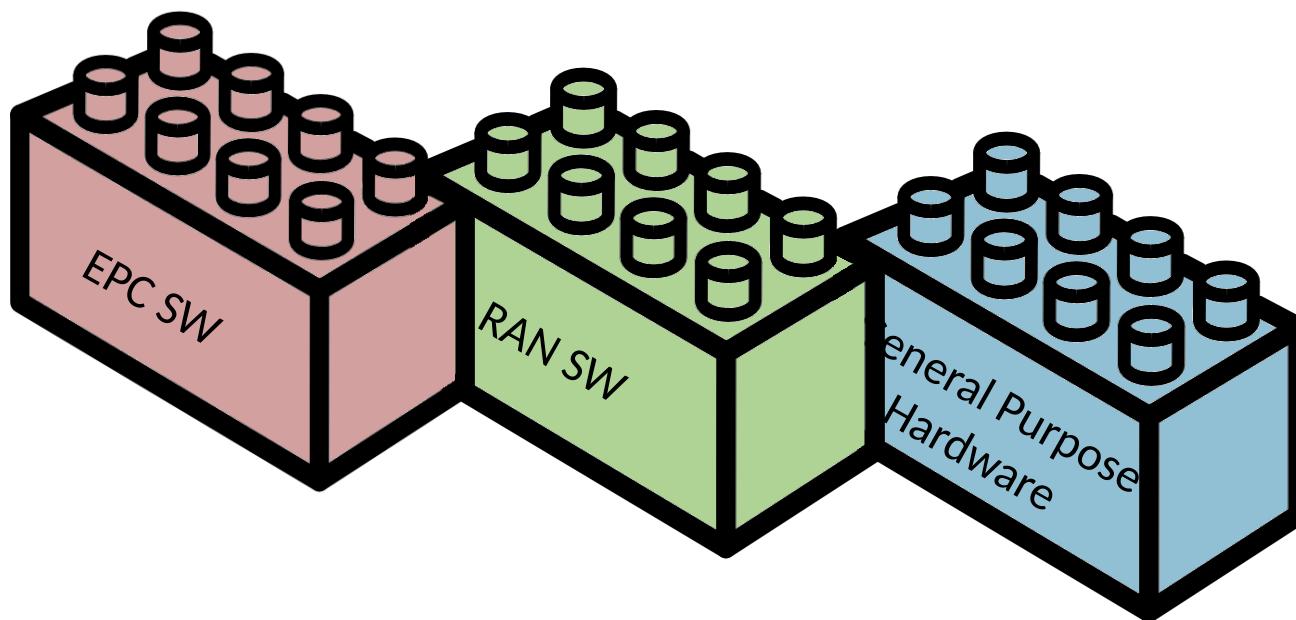
- **Basic Functionality:**
  - General purpose hardware
  - Functionality determined by software you add

  - Do this end-to-end
    - Offers great flexibility in enabled research
- **Extended functionality:**
  - Bring-your-own-device research
  - All layers of the architecture

Novice through expert...
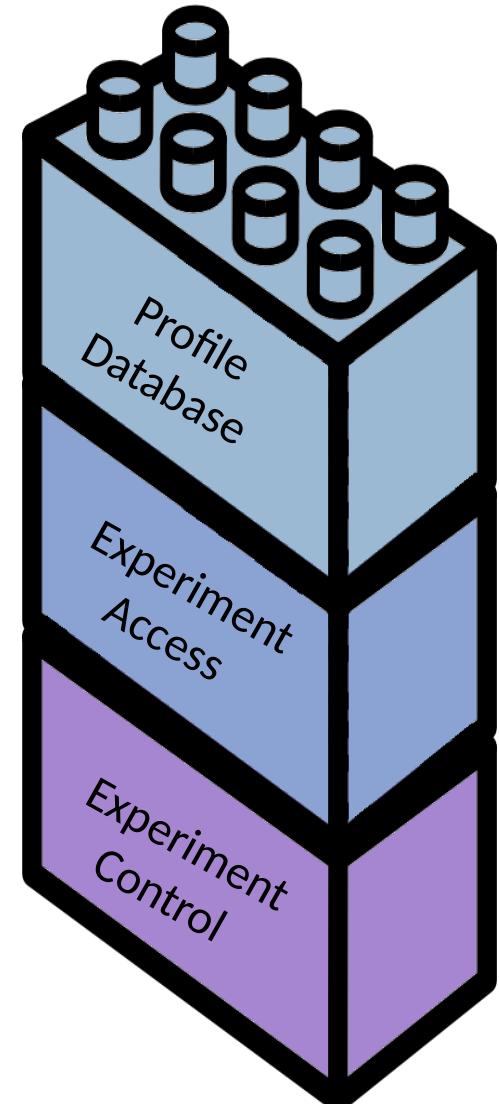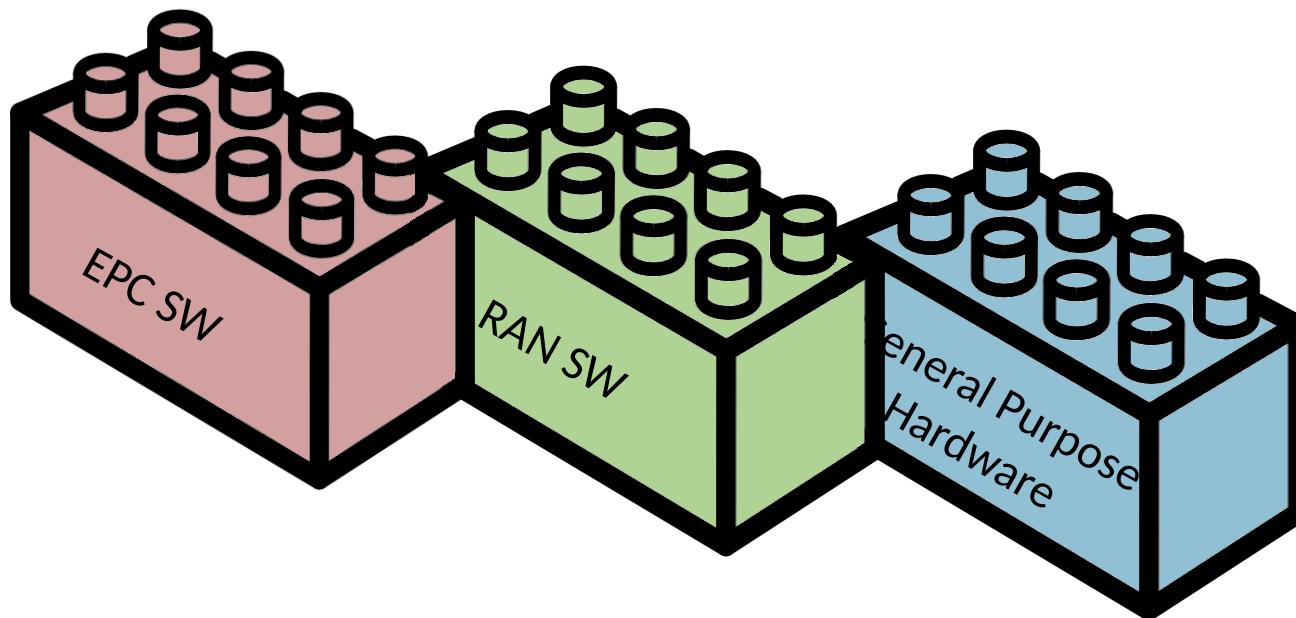
- **Research/experiment Composition**
  - Building block approach
  - Many existing blocks (novice)
  - Build your own blocks (expert)
  - End-to-end recipes called **profiles** (novice and expert)

Repeatable…
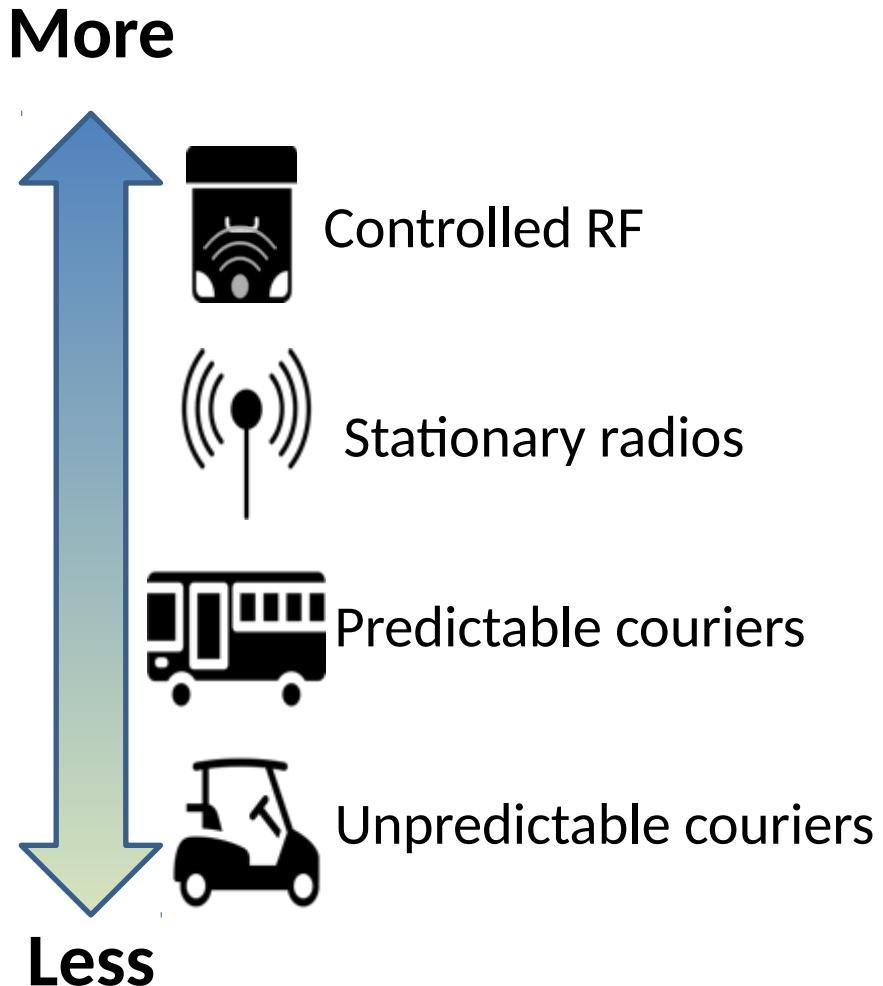
- **Execution**
  - Sophisticated control framework
  - Profile mechanism (again)

Repeatable…

More
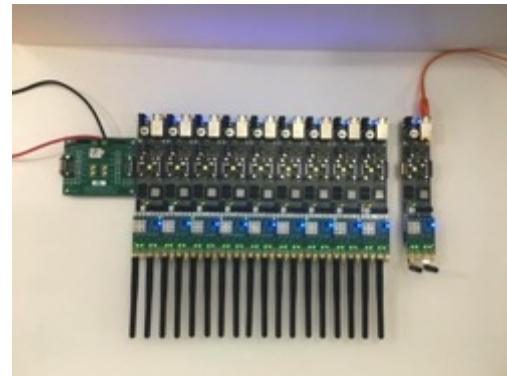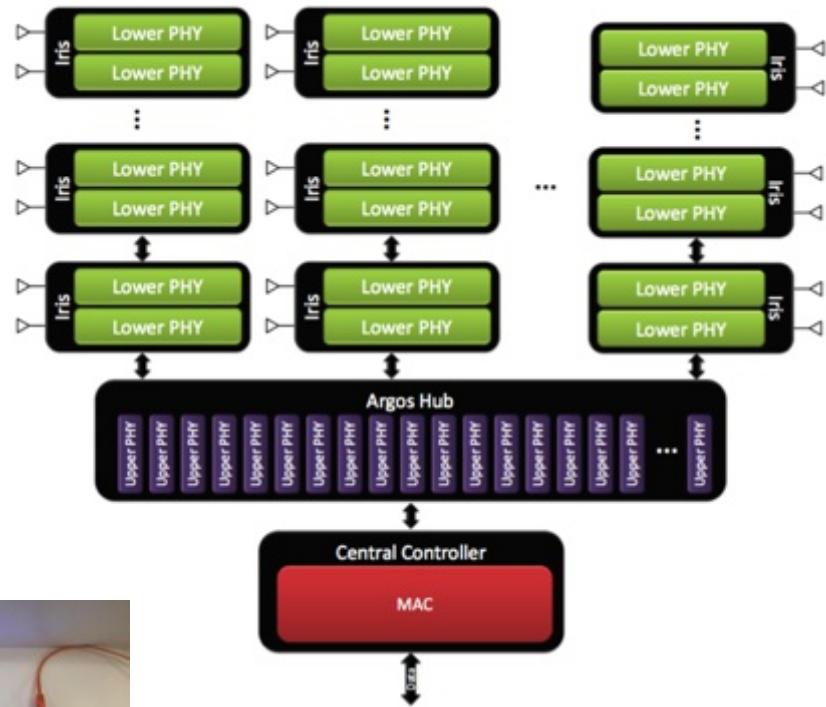
- **Execution**
  - Sophisticated control framework
  - Profile mechanism (again)
- **Mobility:**
  - range of options

Controlled RF

Stationary radios

Predictable couriers

Unpredictable couriers

Less

Fully programmable & observable massive MIMO platform
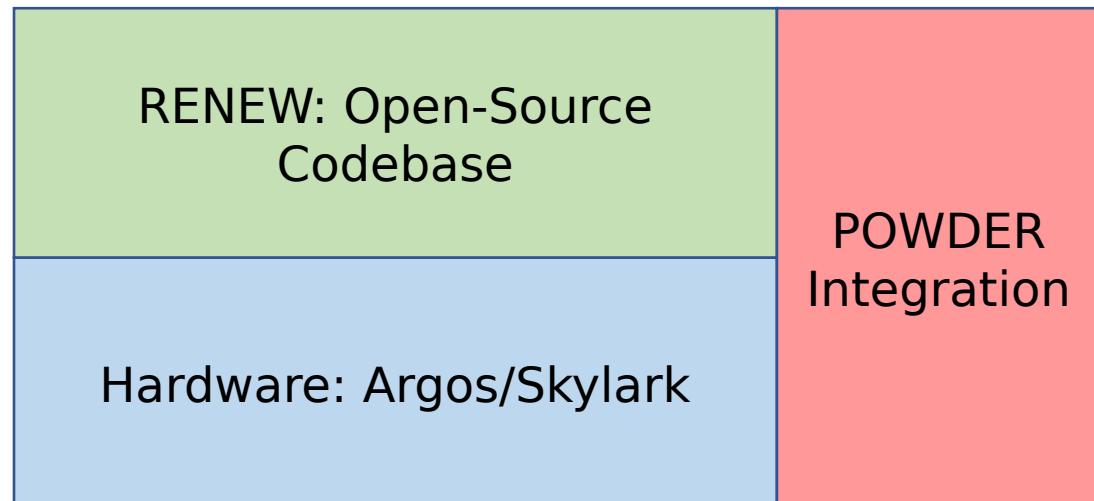
- Hardware from Rice's Argos platform
  - Now Skylark Wireless

Open-access complete Massive MIMO stack

- Argos/Skylark hardware

- Soapy Ecosystem

- Software

  - mMIMO PHY

  - 5G waveforms

  - 802.11 ac/ax

  - End-to-end 3GPP-like stack

- Integration POWDER platform

	POWDER Integration
RENEW: Open-Source Codebase	
Hardware: Argos/Skylark	
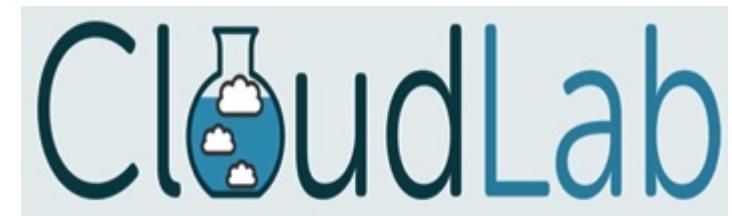
OTHER DETAIL

Datacenter/cloud

- University of Utah Datacenter
- Cloudlab facility
  - **Utah**/Clemson/Wisconsin
  - 5,000 cores; 500 TB storage
    - UT: 300 servers; 2,500 cores
  - Existing profiles for popular cloud stacks: OpenStack, CORD etc.

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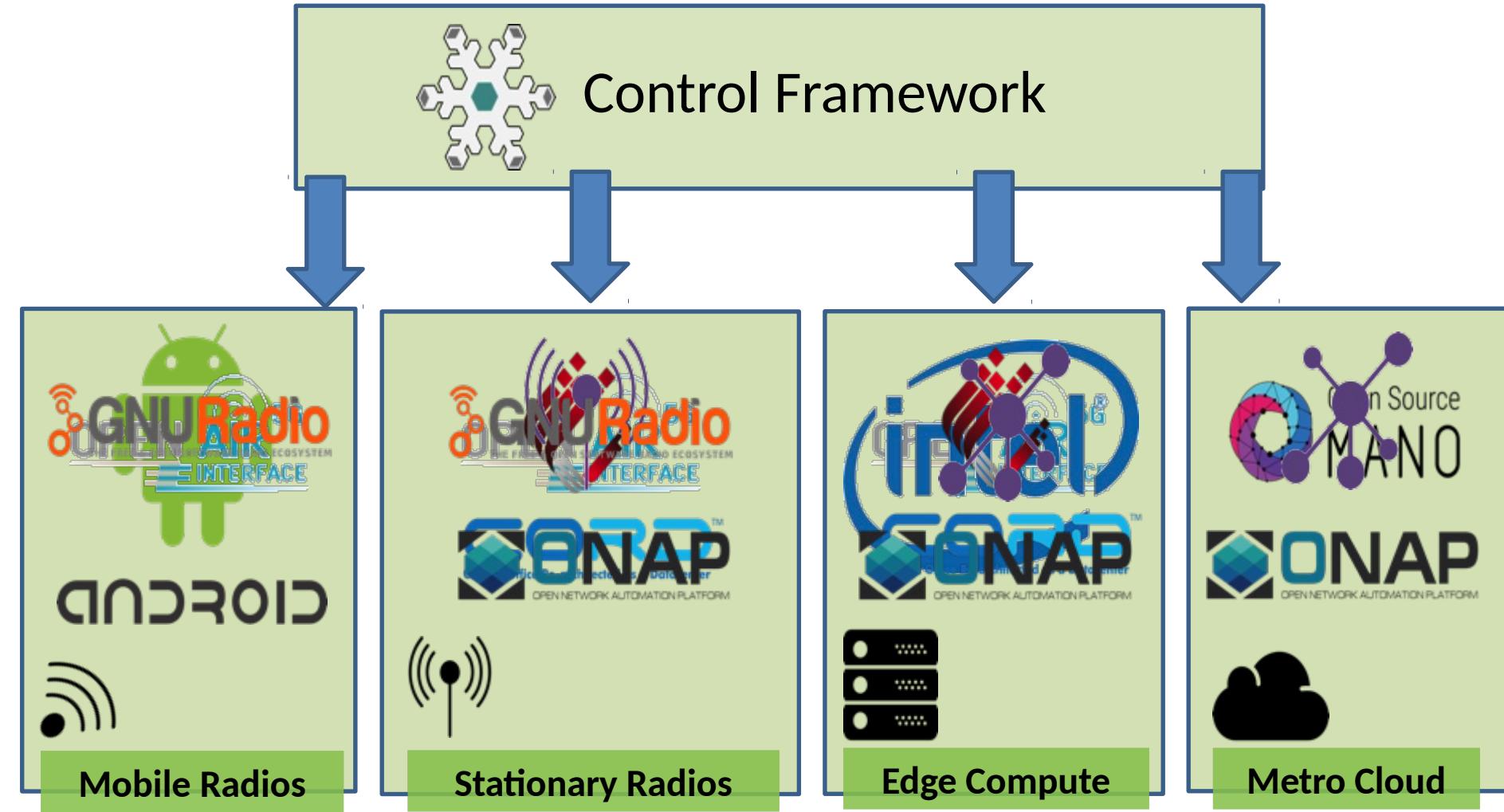
Range (MHz)	
698-806	Commercial/Public Safety
902-928	Industrial, scientific and medical (ISM)
1710-1755	Extended Advanced Wireless Services (EAWS) uplink
2110-2155	Extended Advanced Wireless Services (EAWS) downlink
3550-3650	Citizens Broadband Service
5150-5925	Unlicensed National Information Infrastructure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

- Broad range of frequencies
- **Program license/Innovation zone**
- Dynamic spectrum access system: federated wireless

POWDER EXPERIMENTAL PROCESS

POWDER experimental process

POWDER Experimental Process

- Build profile from scratch (using existing building blocks), or, start with existing profile (close to target profile, or use "raw" resource profile)
- Install software needed, make new images
- Add to profile and save as new profile
- Repeat…
- Publish "final" profile as supporting artifact

Experimental workflow – ONAP
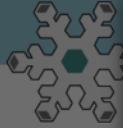
1. Select a Profile   2. Parameterize   3. Finalize   4. Schedule

Selected Profile: OAI-Real-Hardware (Repohash: 05c8dce8)

Use this profile to instantiate an experiment using Open Air Interface to realize an end-to-end SDR-based mobile network. This profile includes the following resources:

Off-the-shelf Nexus 5 UE running Android 4.4.4 KitKat ('rue1')
SDR eNodeB (Intel NUC + USRP B210) running OAI on Ubuntu 16 ('enb1')
All-in-one EPC node (HSS, MME, SPGW) running OAI on Ubuntu 16 ('epc')
A node providing out-of-band ADB access to the UE ('adb-tgt')
PhantomNet startup scripts automatically configure OAI for the specific allocated resources.

For more detailed information:

Getting Started

Show Profile   Change Profile

Previous   Next

Select a Profile

ONAP-OpenStack
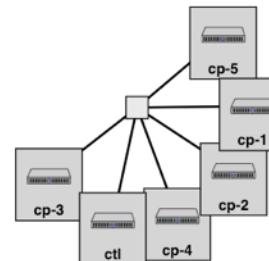
- utahstud -
- knownet -
- cs6480-2017-cl -
- PowderProfiles -
- SafeEdge -
- cs6480-2017-pnet -
- PowderTeam -
- CS4480-2018 -
- Policy -
- PhantomSandbox -
- geni -
- cs6480-2016-pnet -
- KExplore -
- GLOBECOMTutorial -
- cs6480-2016 -
- SIGCOMMTutorial -
- cs6480-2015 -
- Default Profiles -
- **ONAP-OpenStack**
- Other Profiles -

ONAP-OpenStack

★ Add to Favorites

Created By:	johnsond
Project:	emulab-ops
Latest Version:	0
Repo Based?:	Yes
Repo Hash:	05d9153b
Last Updated:	2018-10-19 15:20:23
Description:	This profile provides an ONAP instance that runs in containers deployed in a custom-built, configurable OpenStack instance. We have tested ONAP with the OpenStack Queens release, but you can try to instantiate with other OpenStack releases if you like by changing the release parameter. This profile is an extension of the standard OpenStack profile, so first OpenStack is configured, then ONAP is installed. When you click the Instantiate button, you'll be presented with a list of parameters that you can change to control what ONAP and your OpenStack instance will look like; **carefully** read the parameter documentation on that page (or in the Instructions) to understand the various features available to you. The Instructions shown on your

Select Profile   Cancel

1. Select a Profile   2. Parameterize   3. Finalize   4. Schedule

Selected Profile: ONAP-OpenStack (Repohash: 05d9153b)

This profile provides an ONAP instance that runs in containers deployed in a custom-built, configurable OpenStack instance. We have tested ONAP with the OpenStack Queens release, but you can try to instantiate with other OpenStack releases if you like by changing the release parameter. This profile is an extension of the standard OpenStack profile, so first OpenStack is configured, then ONAP is installed. When you click the Instantiate button, you'll be presented with a list of parameters that you can change to control what ONAP and your OpenStack instance will look like; **carefully** read the parameter documentation on that page (or in the Instructions) to understand the various features available to you. The Instructions shown on your experiment's status page will provide URLs and a random password for you to login to both OpenStack and ONAP's Rancher instance. You

Show Profile   Change Profile

Previous   Next

1. Select a Profile   **2. Parameterize**   3. Finalize   4. Schedule

This profile is parameterized; please make your selections below, and then click to continue.

⊕ **Show All Parameter Help**

| ONAP External Network ❓ | flat-lan-1-net ⬍ |

| OpenStack Release ❓ | Queens ⬍ |

| Keystone API Version ❓ | v3 ⬍ |

| Number of compute nodes | 5 |

| Number of public IP addresses ❓ | 6 |

| Hardware Type ❓ | d430 ⓘ |

| Experiment Link Speed ❓ | Any ⬍ |

| ML2 Plugin ❓ | OpenVSwitch ⬍ |

| Extra VM Image URLs ❓ | |

| Experiment Firewall ❓ | ☐ |

1. Select a Profile

2. Parameterize

3. Finalize

4. Schedule

Profile: ONAP-OpenStack   **Version:** 0   Source

Please review the selections below and then click Next.

Name: onap

Project: PowderSandbox

⊕ **Advanced Options**

Check Resource Availability

Previous   Next

1. Select a Profile   **2. Parameterize**   **3. Finalize**   **4. Schedule**

Please select when you would like to start this experiment and then click Finish.

Start immediately
☑
or
Start on date/time
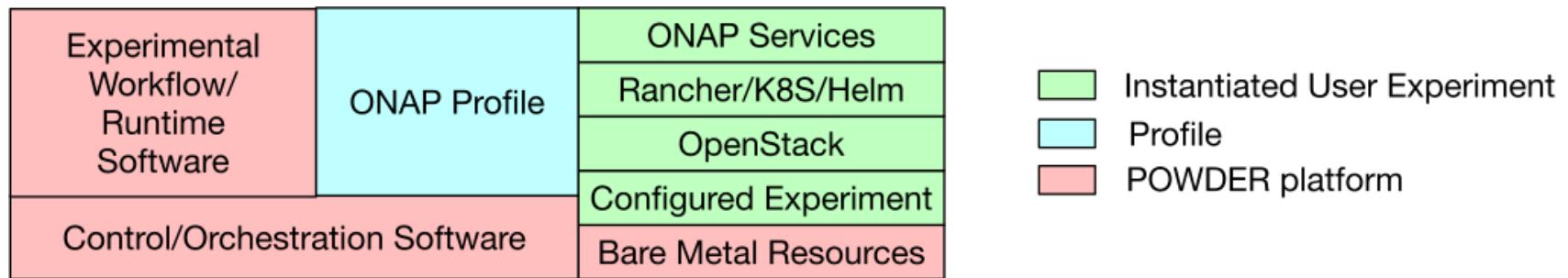
MM/DD/YYYY   Time ↕   ❓
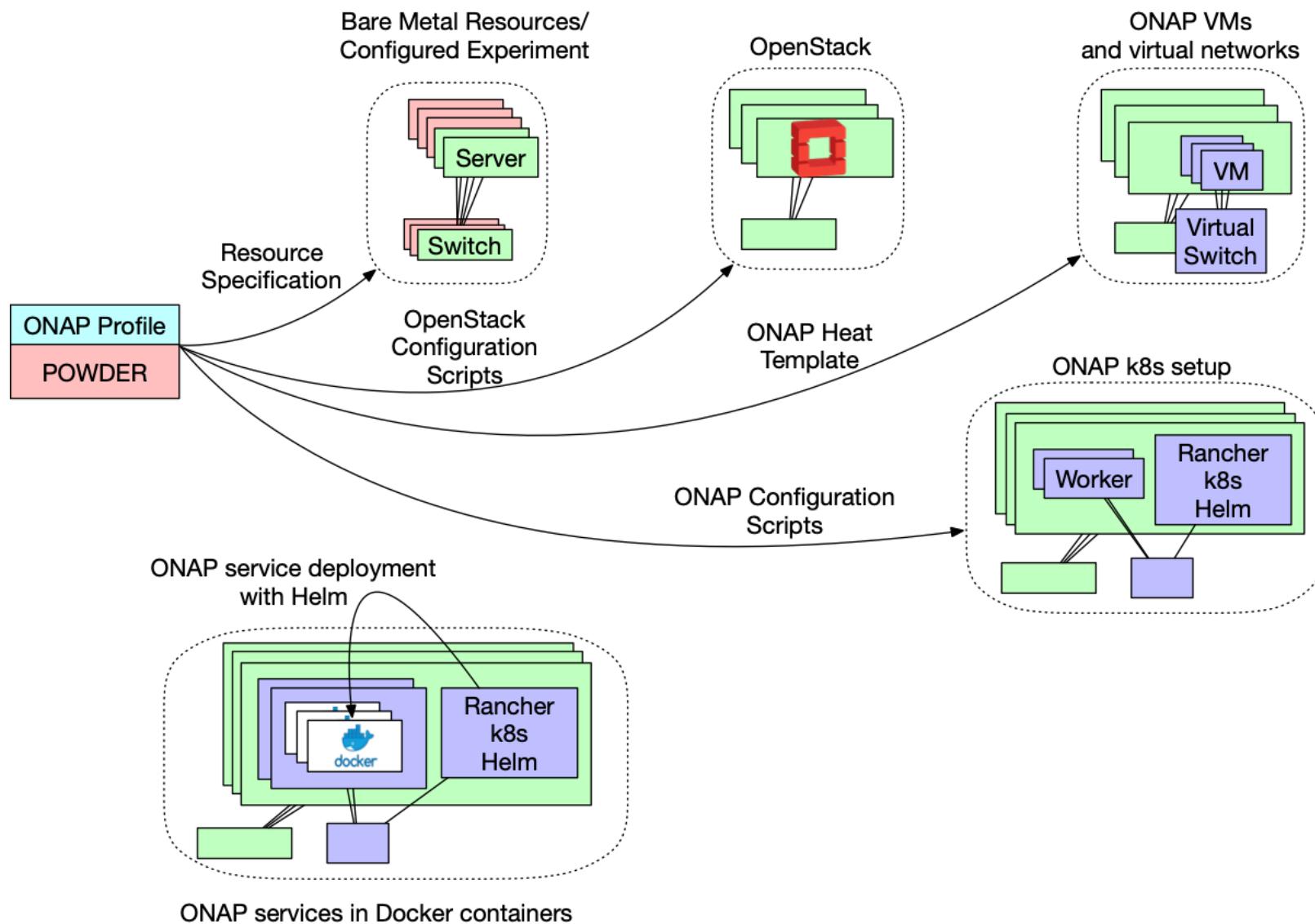
Experiment Duration

16   hours   ❓

Previous   Finish

ONAP on POWDER

ONAP on POWDER

Other existing profiles

GNU Radio Profile

GNU Radio Profile

```python
#!/usr/bin/python

"""
Two SDR nodes running GNU Radio with an RF link.

Instructions:
Once the experiment is ready, choose one node in the experiment and
open a shell.  Within the shell, execute:

   /share/phantomnet/bin/runvnc.sh

Open the link given in the shell.  Within a terminal in the resulting
VNC desktop, you can open GNU Radio Companion flow graphs, e.g.:

   gnuradio-companion /share/phantomnet/grcon/rx.grc

Repeat the process of opening a shell and VNC desktop on the other
node, but this time bring up a complementary folw graph, e.g.:

   gnuradio-companion /share/phantomnet/grcon/tx.grc
"""
```

```python
import geni.portal as portal
import geni.rspec.pg as rspec
import geni.rspec.emulab.pnext as pn

request = portal.context.makeRequestRSpec()

node0 = request.RawPC( "node0" )
node0.hardware_type = "nuc5300"
node0.disk_image =
"urn:publicid:IDN+emulab.net+image+grcon2018:grcon2018"
node0if = node0.addInterface( "rf0" )

node1 = request.RawPC( "node1" )
node1.hardware_type = "nuc5300"
node1.disk_image =
"urn:publicid:IDN+emulab.net+image+grcon2018:grcon2018"
node1if = node1.addInterface( "rf0" )

rflink = request.RFLink( "rflink" )
rflink.addInterface( node0if )
rflink.addInterface( node1if )

portal.context.printRequestRSpec()
```

- Allocates two SDRs and associated compute
- With associated software
- Very simple profile

5G NR Profile

UE and gNB

Three node types:
- SDR (USRP)
- Compute (Rackmount server)
- Data store (OAI software stack)

Option to bind to specific hardware

LTE/EPC Profile

Four node types:

- OTS UE
- SDR and compute: eNodeB
- Compute (Rackmount server): EPC
- Data store (OAI software stack: RAN and core)

Options:

- Over-air
- Controlled RF
- Number of UEs/eNodeBs

OpenStack Profile

OpenStack instance in 15-20 minutes

Highly parameterized (58...):

- Version of Openstack
- Services to enable
- Number of compute nodes
- Hardware type
- Number public Ips
- Multi-site options
- Network options
- Use remote dataset
- etc.

ONAP OpenStack Profile

- Took existing OpenStack profile
- Added a post-deployment option: ONAP deployment script

PARTNERS

Key partners

Salt Lake City: "Crossroads of the West"
- Economic, Transportation, Networking, Cultural Hub
- *Use of City buildings and City vehicles as couriers*

UETN: Statewide Education and Health Network
- > 1,400 schools/libraries; > 75 healthcare facilities
- *Use of extensive fiber network and operations*

Utah Department of Transportation
- Fiber infrastructure; connected vehicle pioneer
- *Access to fiber and use of traffic signal poles*

Infrastructure partners
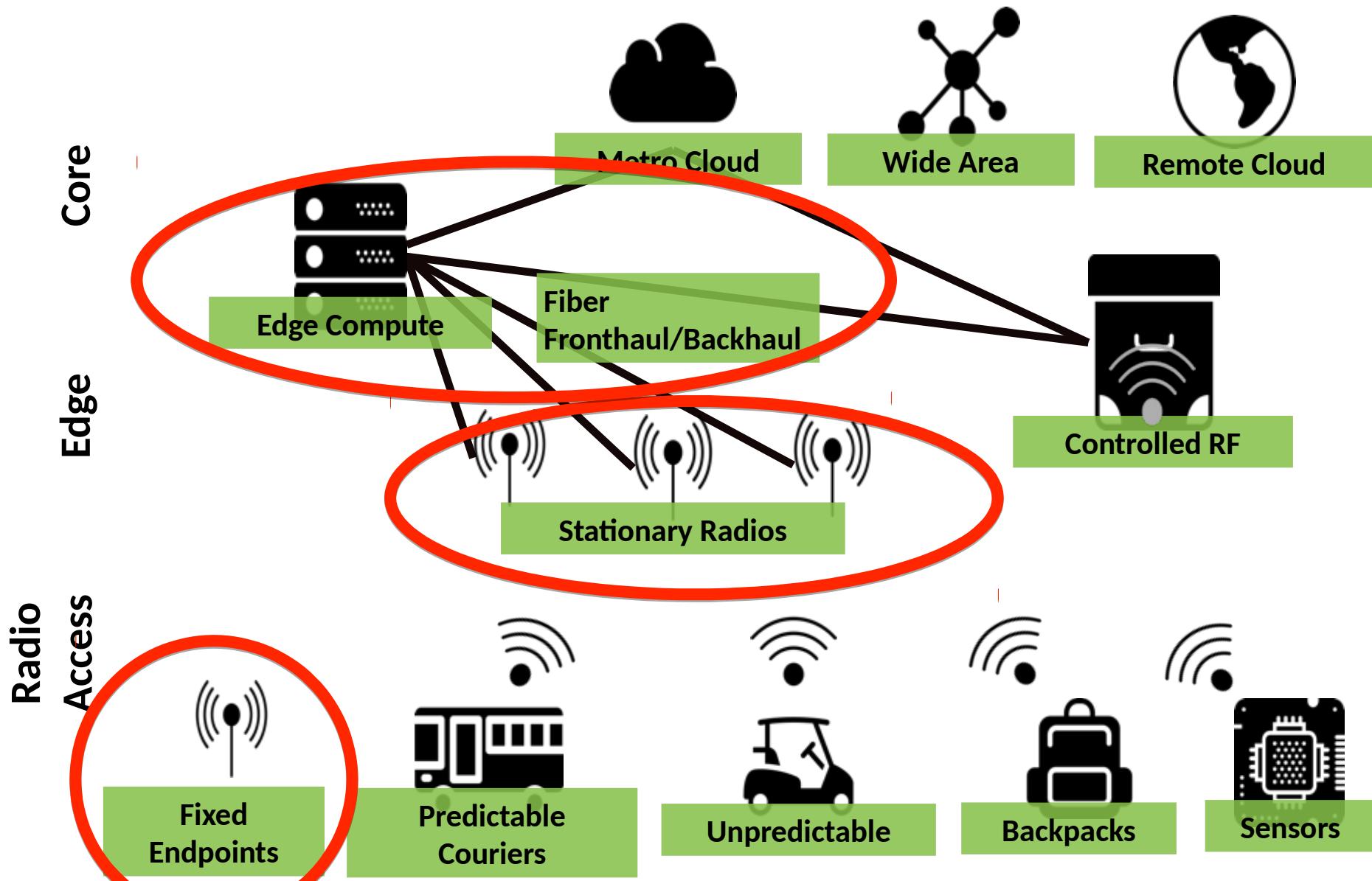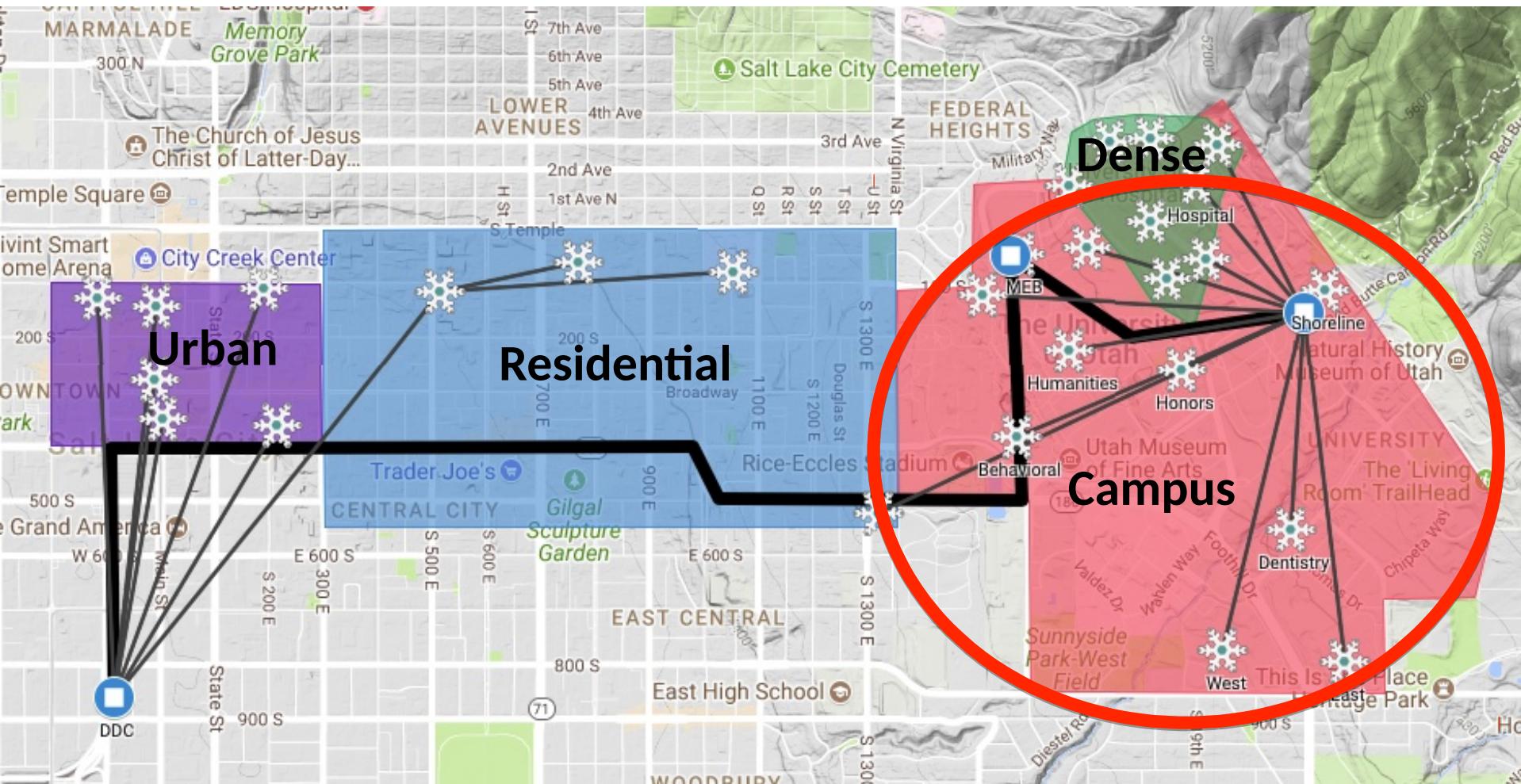
# PROCESS/STATUS

Campus fixed deployment
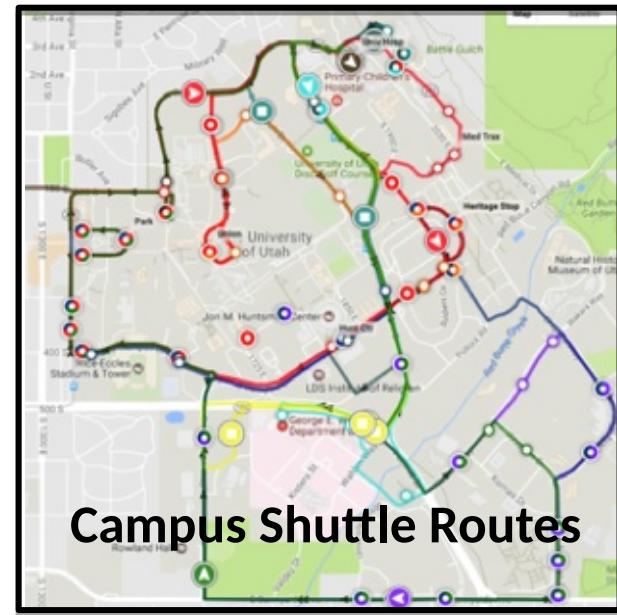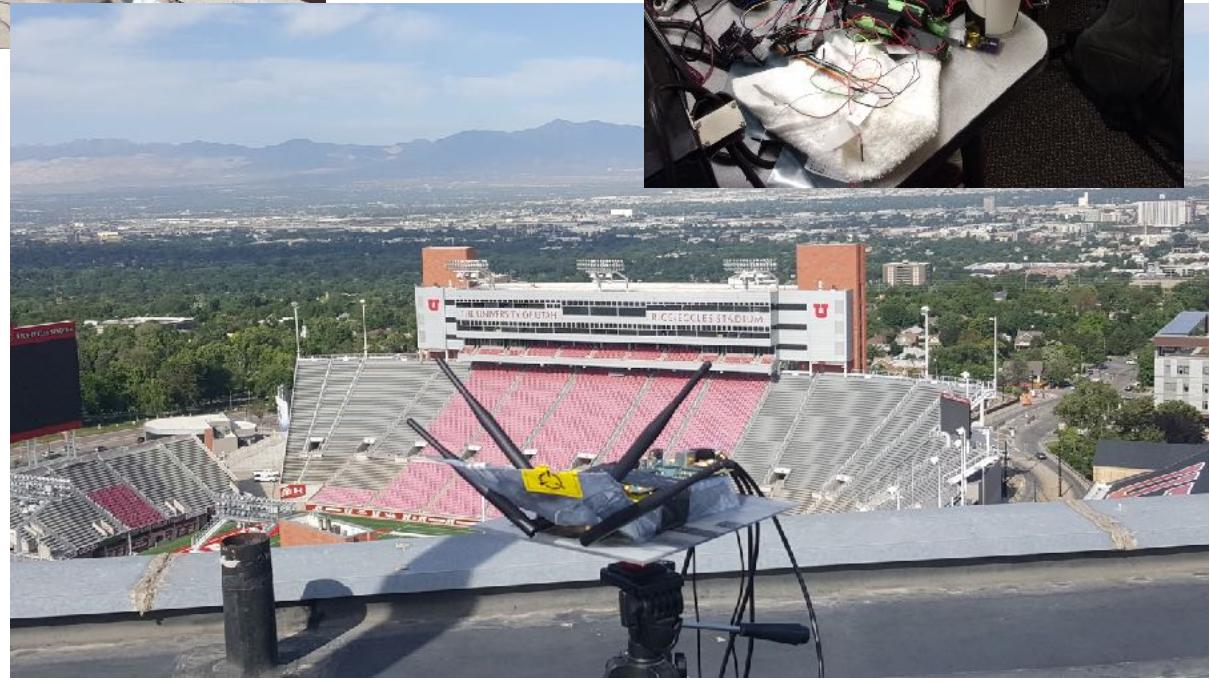
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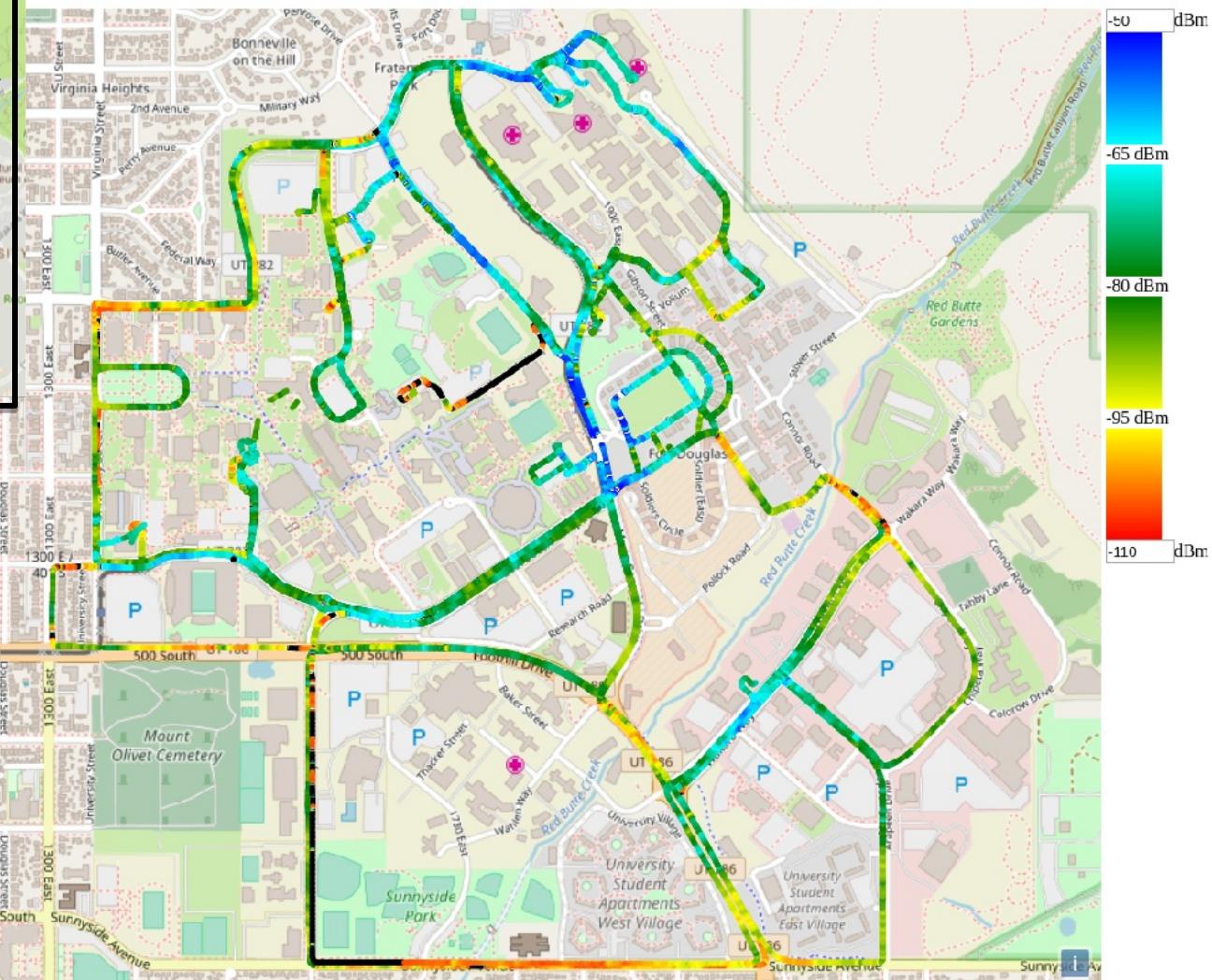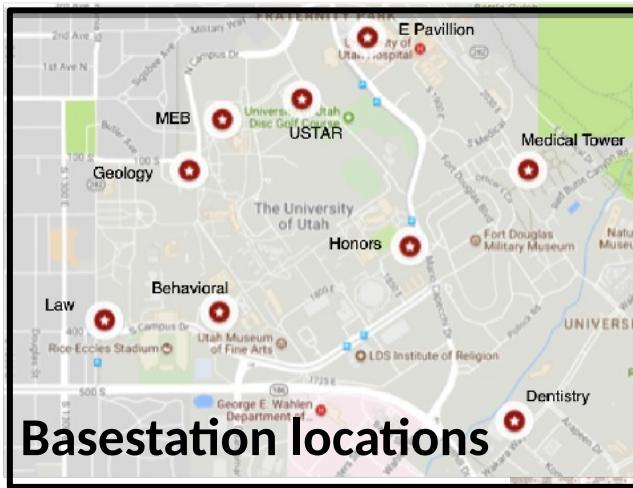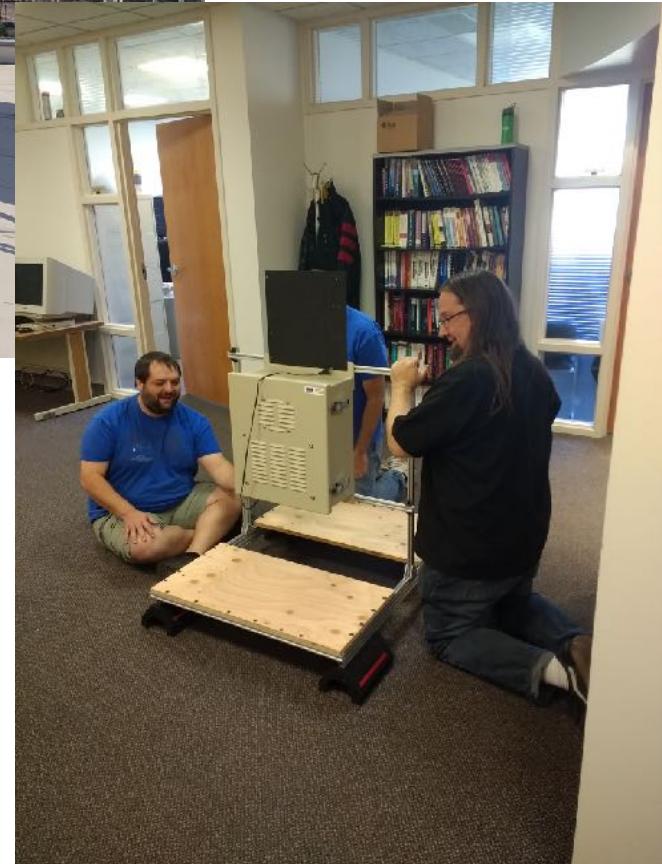
Site surveys…

Prototyping…

Equipment arriving…
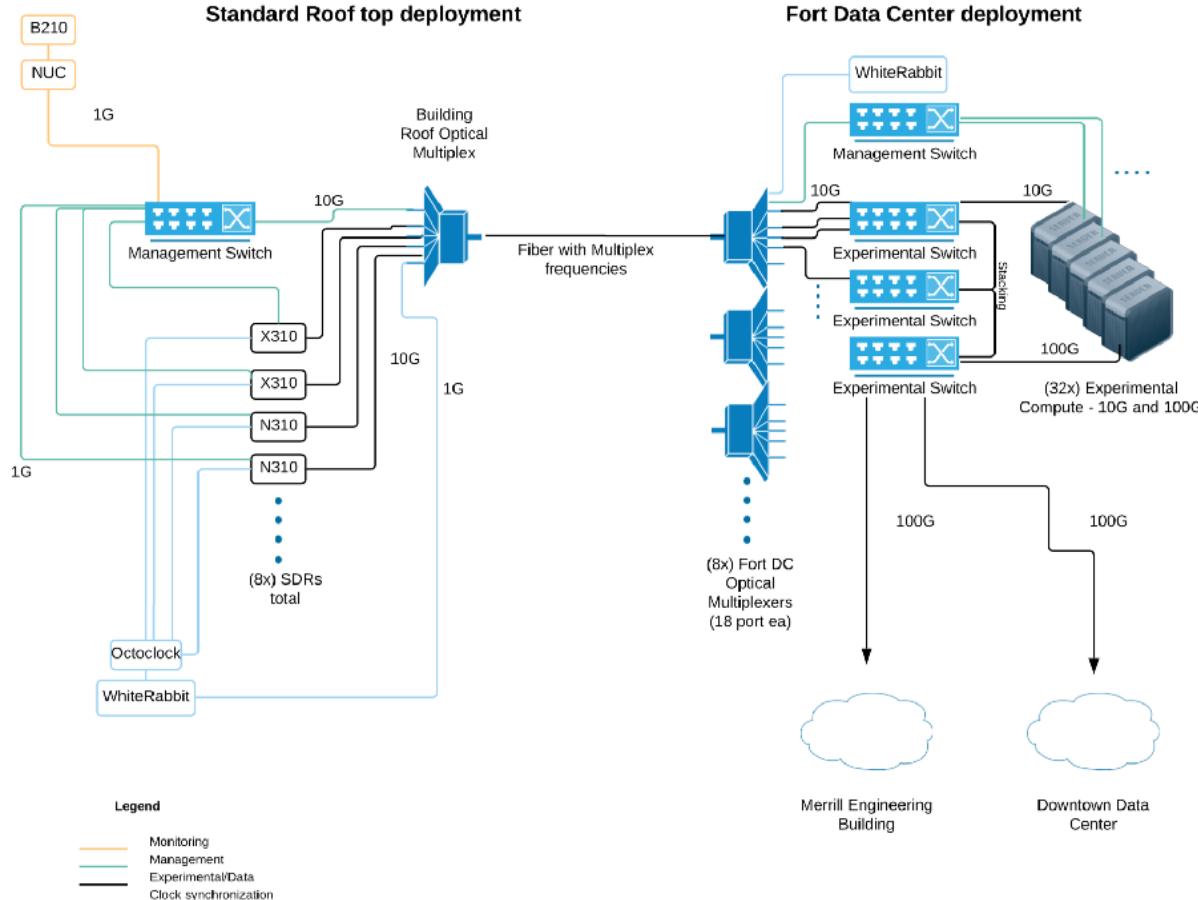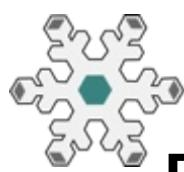
Deployment…
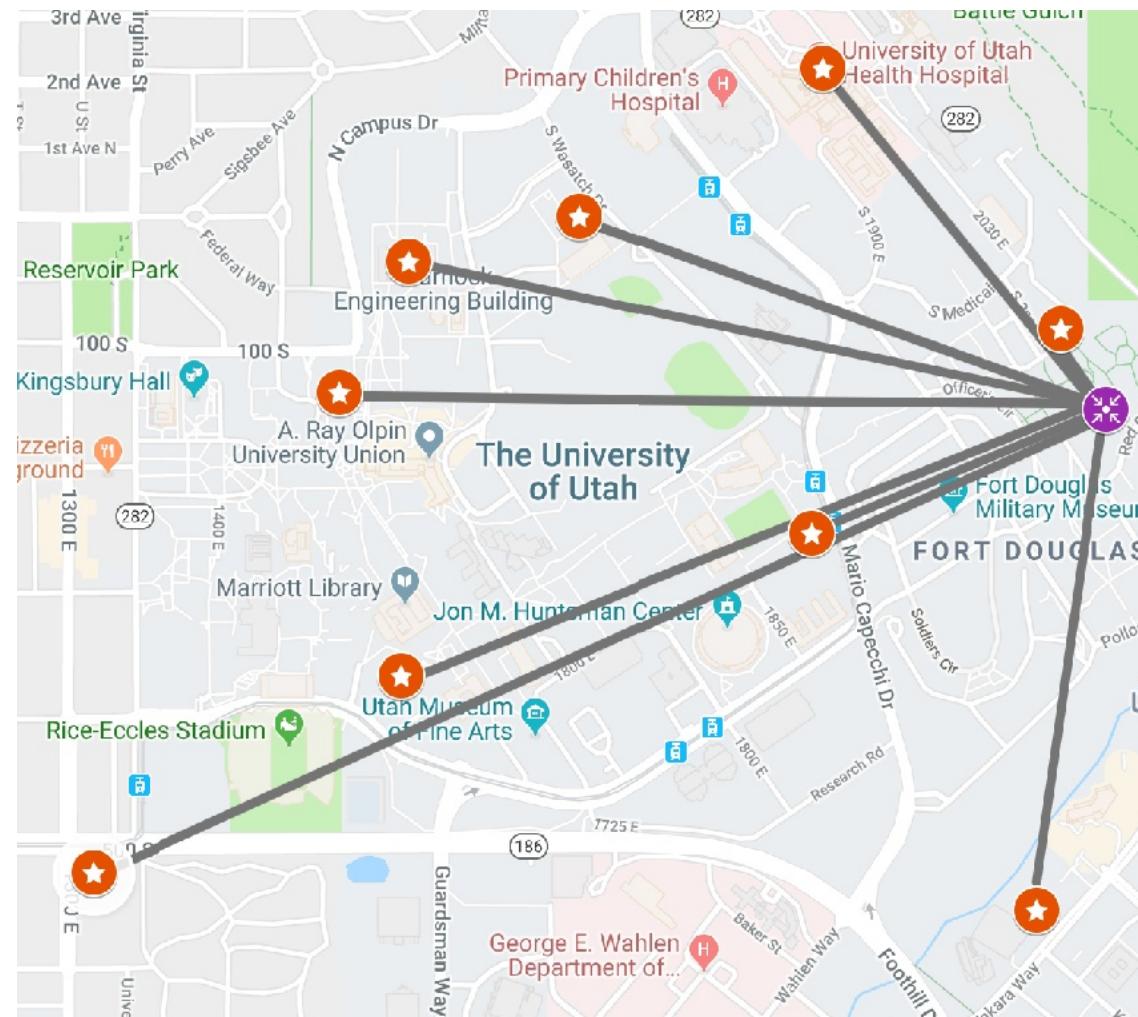
# Edge compute, fiber fronthaul/backhaul
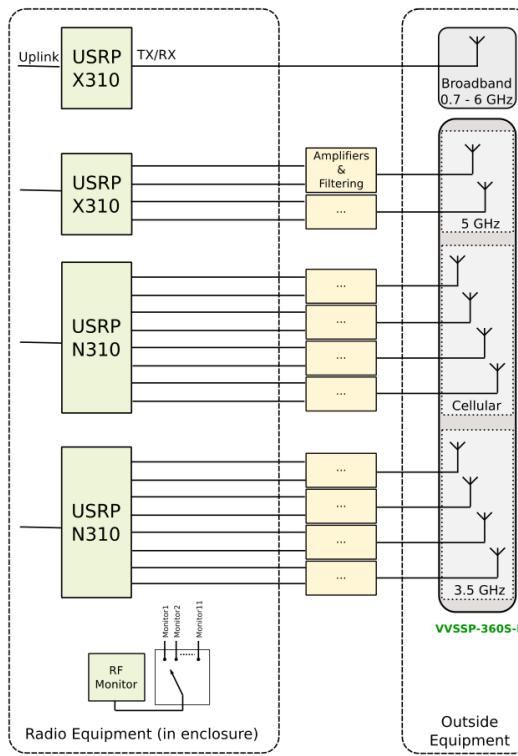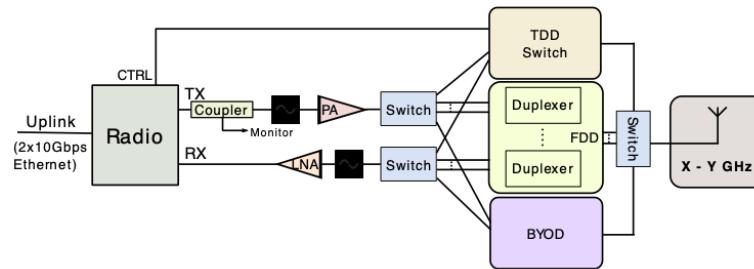
Edge compute, fiber fronthaul/backhaul

Stationary Radio (Rooftop Basestation)


Single RF Chain Detail
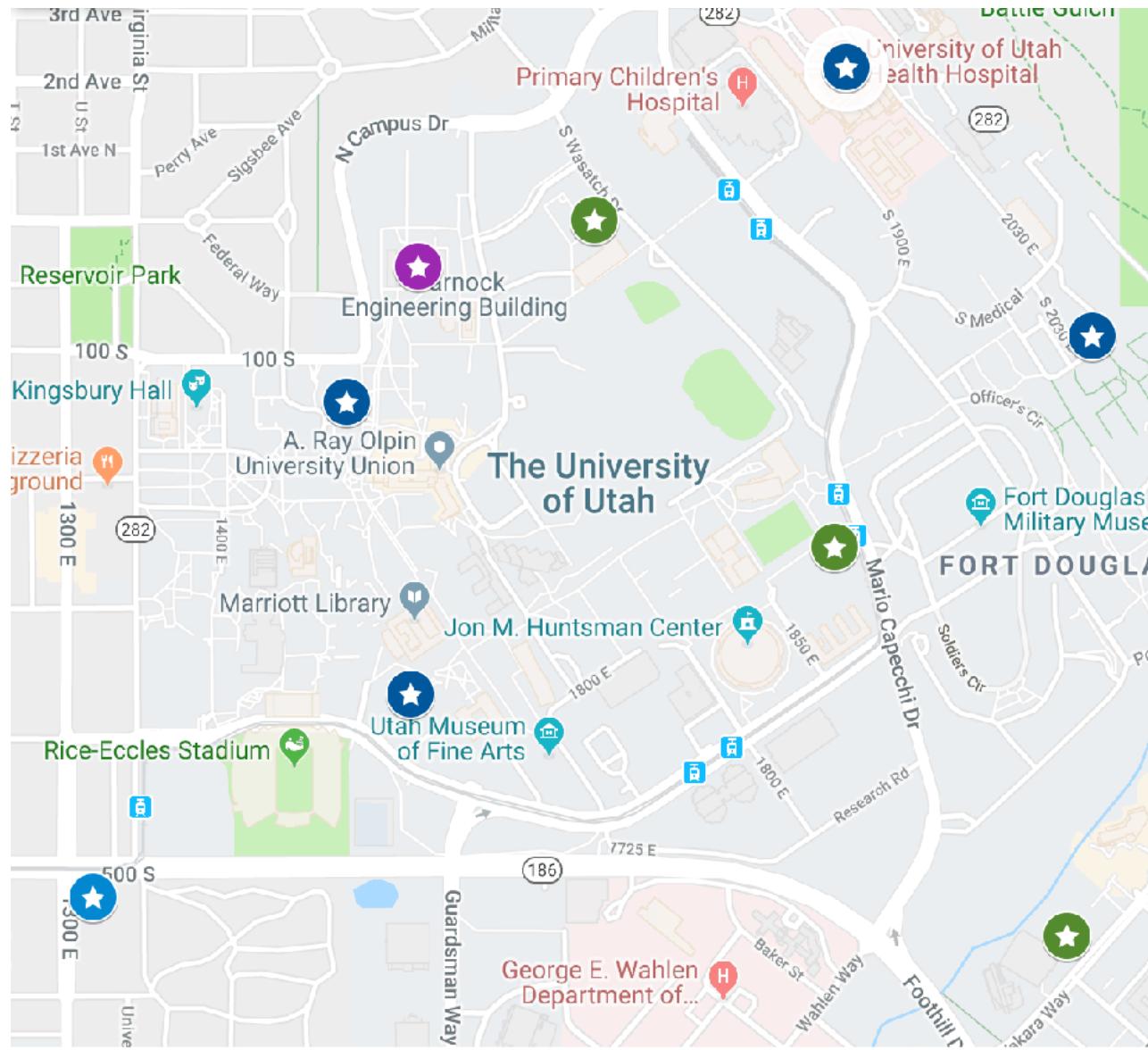
Powder Base Station RF Front-end
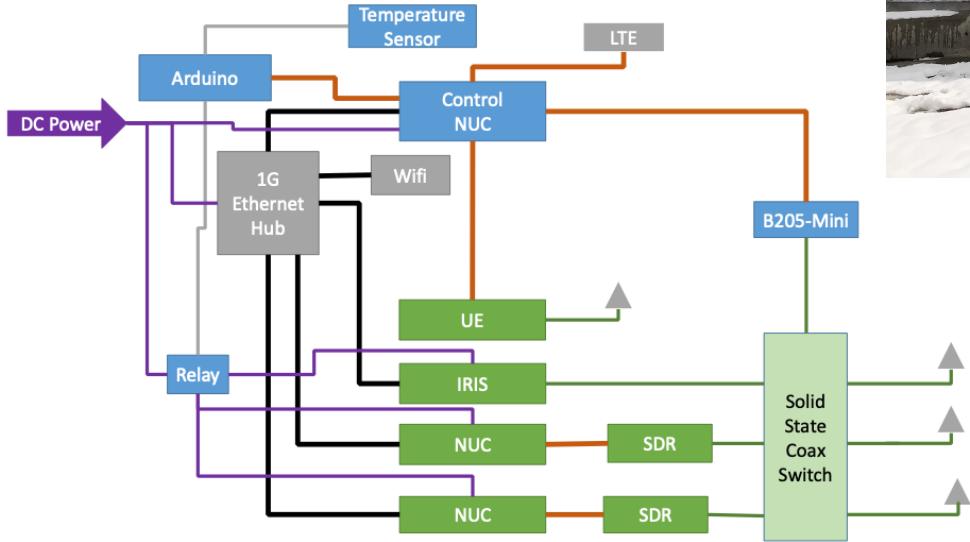
Stationary Radio (Rooftop Basestation)

Fixed-endpoint

Fixed-endpoint