Radio Frequency Propagation on POWDER

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Process

Using Shout to collect measurements

Using SPLAT! to predict RF propagation

Comparing and analyzing any differences

Background – Path Loss Exponent Model

$$P_r(\text{dBm}) = P_0(\text{dBm}) - 10\nu \log_{10} \frac{d}{d_0}$$

where $P_0(\text{dBm})$ is still given by the Friis equation,

$$P_0(\text{dBm}) = P_t(\text{dBm}) + G_t(\text{dB}) + G_r(\text{dB}) - 20 \log_{10} \left(\frac{4\pi d_0}{\lambda} \right)$$

- Non free-space propagation environment
- The value of v will be higher in dense cities

Background – Unknown Reference

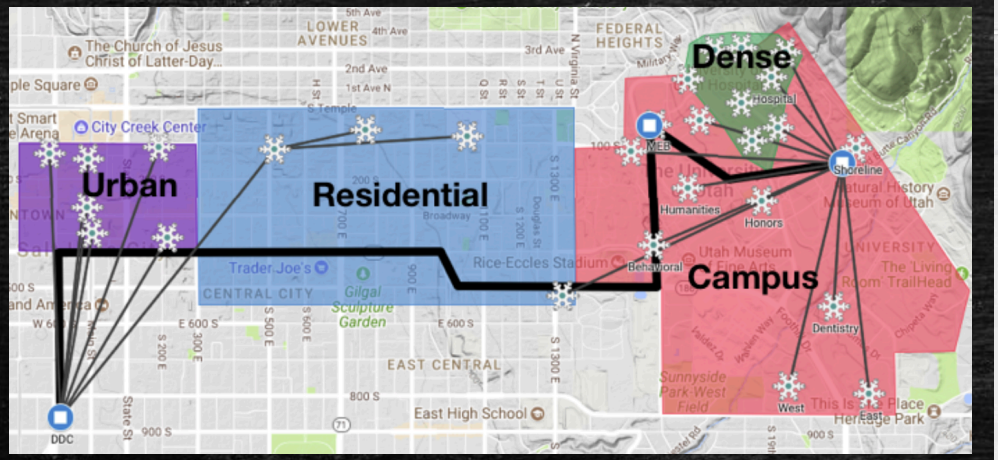
https://www.ettus.com/all-products/x310-kit/

X310

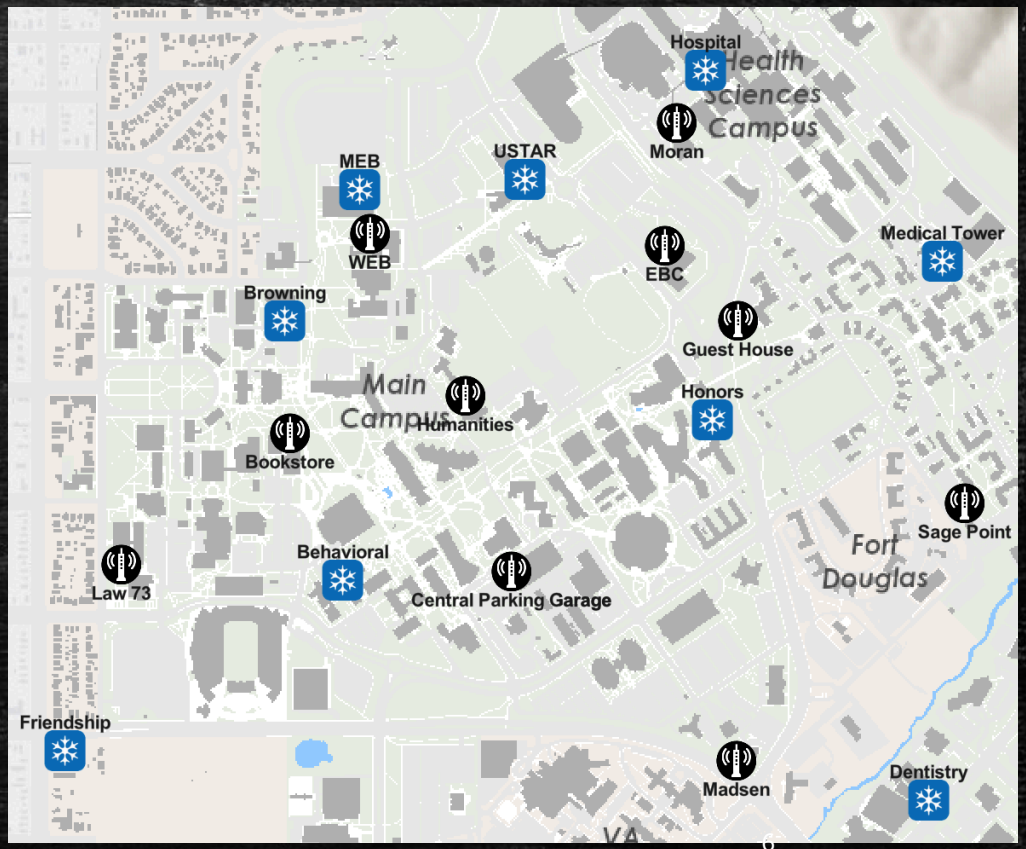
- POWDER uses SDRs
- They are uncalibrated
- There is no known reference

Measurement Methodology - POWDER

- General Purpose Base Stations
- Fixed Endpoint Nodes



https://dl.acm.org/doi/10.1145/3411276.3412204



https://www.powderwireless.net/map

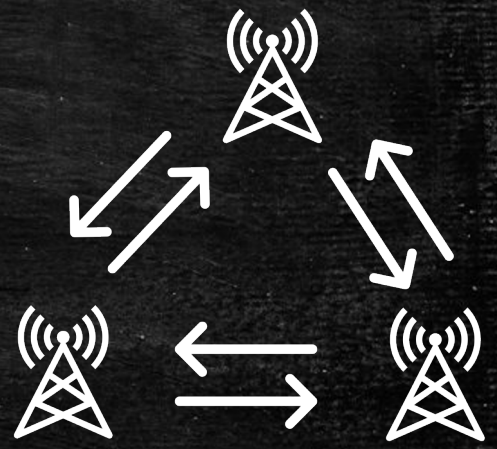
Measurement Methodology - Shout

```
3       "cmd": "measure_paths",
4       "get_samples": true,
5       "nsamps": 1024,
6       "freq": 2.45e9,
7       "txgain": 30,
8       "rxgain": 30,
9       "rate": 1e6,
10      "wampl": 0.8,
11      "freq_step": 5e4,
12      "time_step": 3,
13      "timeout": 60,
14      "client_list": ["all"]
```

allpathmeas.json

- POWDER measurements framework
- Uses JSON as a command file to tell nodes what to do

$$CF + \frac{1}{2}SR$$



Measurement Methodology – SPLAT!

Honors.lrp Below

```
5.000       ; Earth Dielectric Constant (Relative permittivity)
0.001       ; Earth Conductivity (Siemens per meter)
301.000     ; Atmospheric Bending Constant (N-Units)
2100.000    ; Frequency in MHz (20 MHz to 20 GHz)
5           ; Radio Climate
0           ; Polarization (0 = Horizontal, 1 = Vertical)
0.50        ; Fraction of Situations
0.50        ; Fraction of Time
0.01        ; Transmitter Effective Radiated Power in Watts or dBm (optional)
```

Honors.qth Below

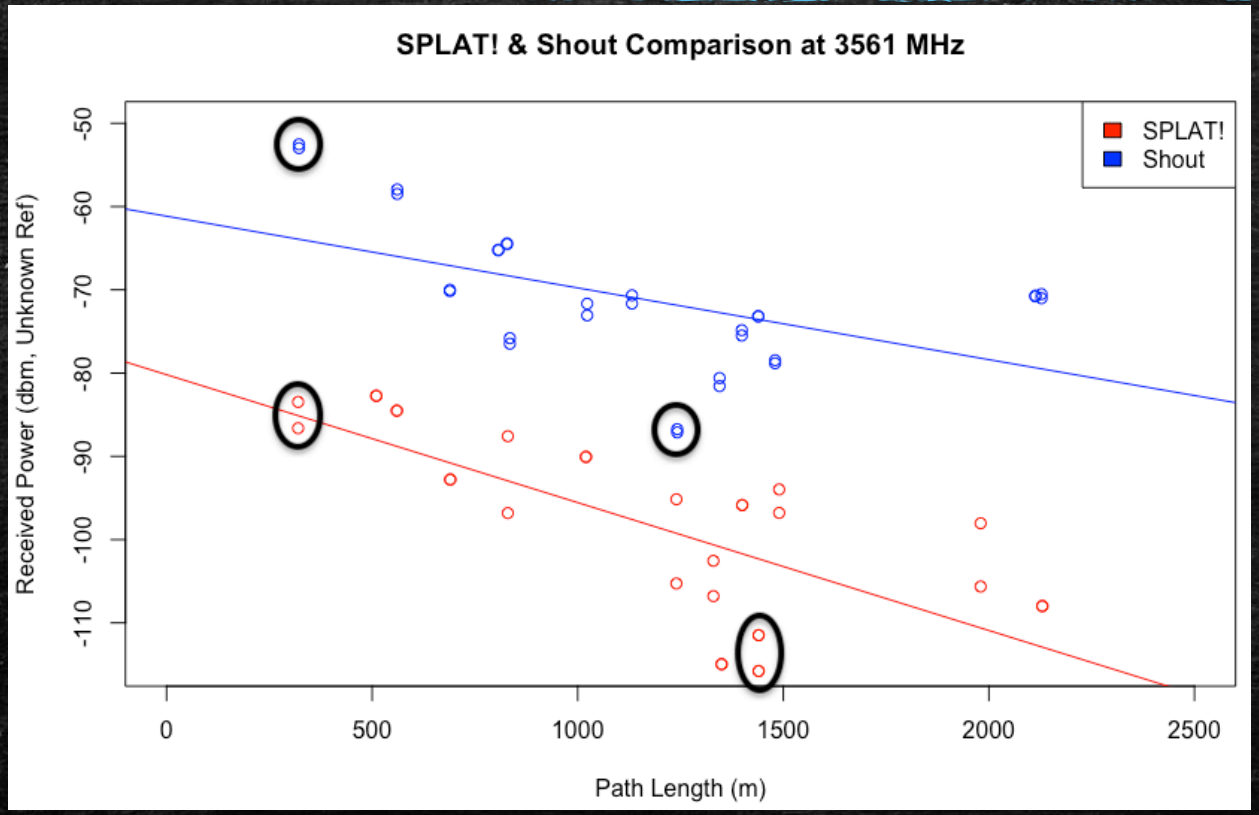
```
Honors
40.7644037
111.8369526
100
```

- Command line driven application
- Created python scripts
- Uses QTH and LRP files for each node

Measurements

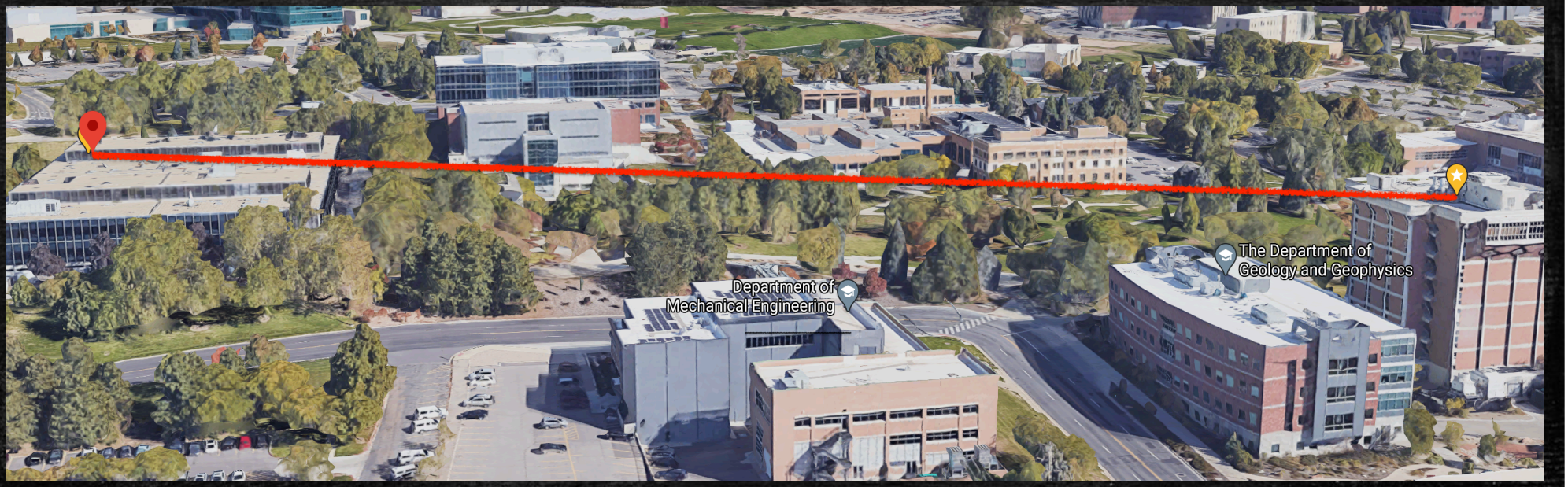
Run	Frequency (MHz)	When	Nodes
Run 1	3561	Early October	Bes, Browning, FM, Sagepoint, MEB, SMT
Run 2	2620	Early November	Bes, Browning, FM, Honors, Sagepoint, Ustar, Bookstore, EBC, Garage, Guesthouse, Humanities, Law73, Madsen, Moran, WEB
Run 3	3550	Late November	Bes, Browning, Honors, Sagepoint, SMT, Ustar, FM
Run 4	3690	Late November	Bes, Browning, Honors, Sagepoint, SMT, Ustar, FM

Results – Path Loss Exponent



- SPLAT!: -0.0154
- Shout: -0.00862
- Power decays d^v

Results – Terrain (Best Propagation)



https://www.google.com/maps

Results – Terrain (Worst Propagation)

https://www.google.com/maps

Next Steps

- **More** measurements
- Use **different** propagation models
  - CloudRF

https://cloudrf.com/

Questions?

Related Works

- Prediction mean field for CU Mountain Range
- Using CloudRF to place access points
- Studies on propagation models and where they fit best
  - ECC-33 is best results in urban environment