Optimal Sensor Placement for Spectrum Sensing

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BACKGROUND

Radio spectrum is one of the most important resources for information technology – yet is hard to monitor. Spectrum occupancy maps are a tool for spectrum situational/spatial awareness. Applications include:

- **Spectrum Monitoring** - Security, Interference Detection/Localization
- **Spectrum Sharing** - CBRS Incumbent & DoD Naval Radar Protection
- **Spectrum Enforcement** - Verification of carrier coverage & broadband mapping

RESEARCH QUESTIONS

Can we estimate occupancy over a large region quickly with only a small number (10) of sensors?

Where should the spectrum sensors be placed to maximize the radio occupancy map estimation accuracy?

METHODS AND MATERIALS

- Simulate accurate RF power maps generated using commercial Forsk Atoll Software
- Sample and threshold the RF maps to create the input and target maps, respectively
- Leverage datasets to perform sensor placement optimization
- Train models with around 40,000 parameters on NVIDIA GPUs (provided by ND's CRC)
- Measure spectrum power with RadioHound system for deployment

ACKNOWLEDGEMENTS

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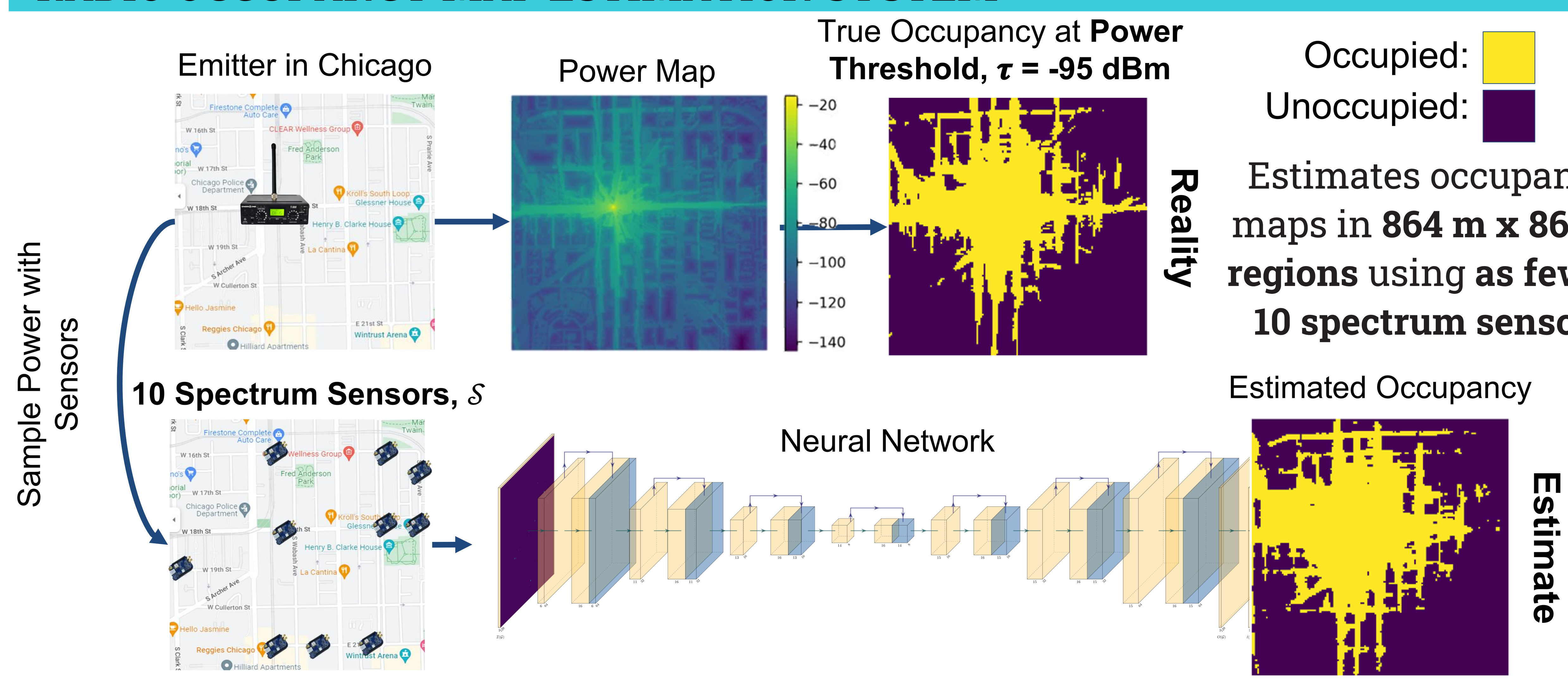
REFERENCES

[1] N. Kleber et al., "RadioHound: A pervasive sensing platform for sub-6 GHz dynamic spectrum monitoring"
[2] A. Termos and B. Hochwald, "Deep Multi-Emitter Spectrum Occupancy Mapping that is Robust to the Number of Sensors, Noise and Threshold"

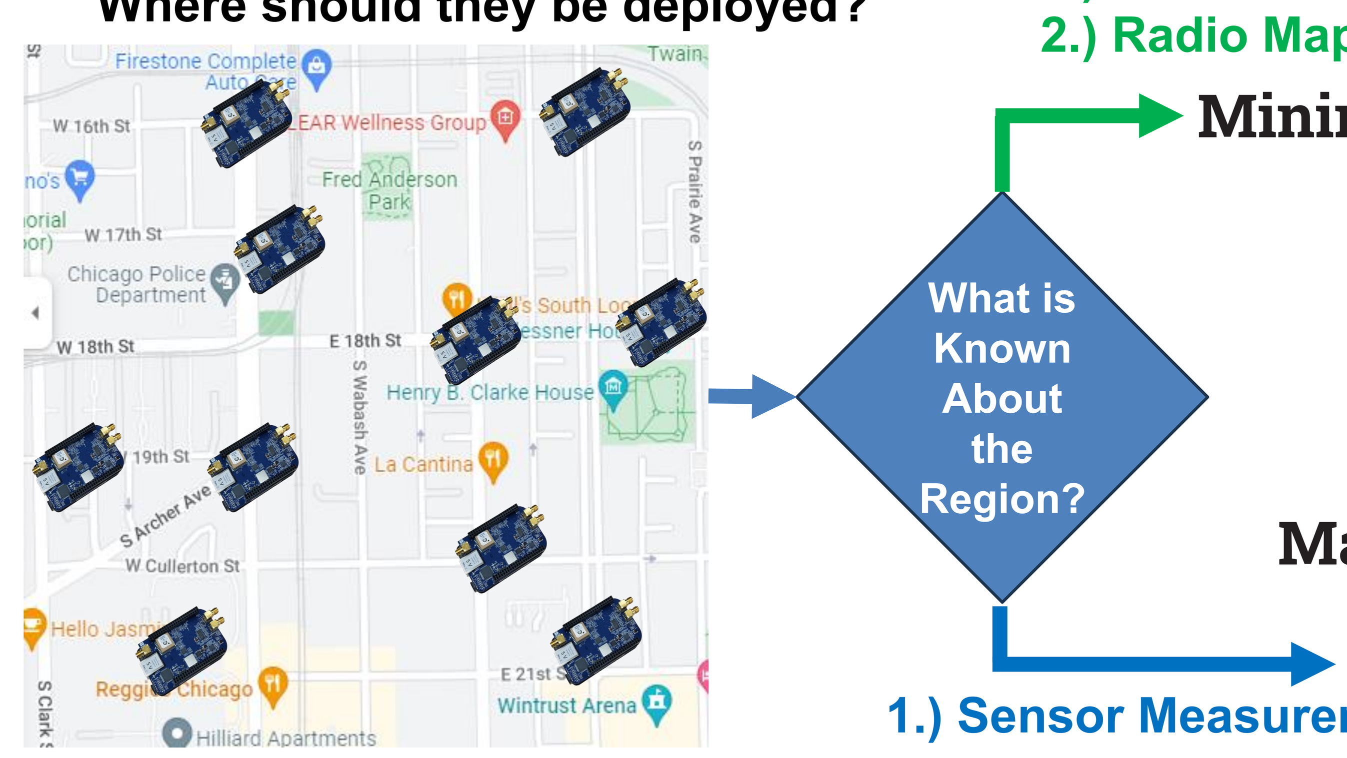
RADIO OCCUPANCY MAP ESTIMATION SYSTEM



Estimates occupancy maps in **864 m x 864 m regions** using **as few as 10 spectrum sensors**

OPTIMIZING SENSOR PLACEMENT FOR IMPROVED RADIO MAP ACCURACY

10 Spectrum Sensors for radio mapping
Where should they be deployed?



1.) Sensor Measurements Distribution
2.) Radio Map Given the Sensor Measurements Distribution

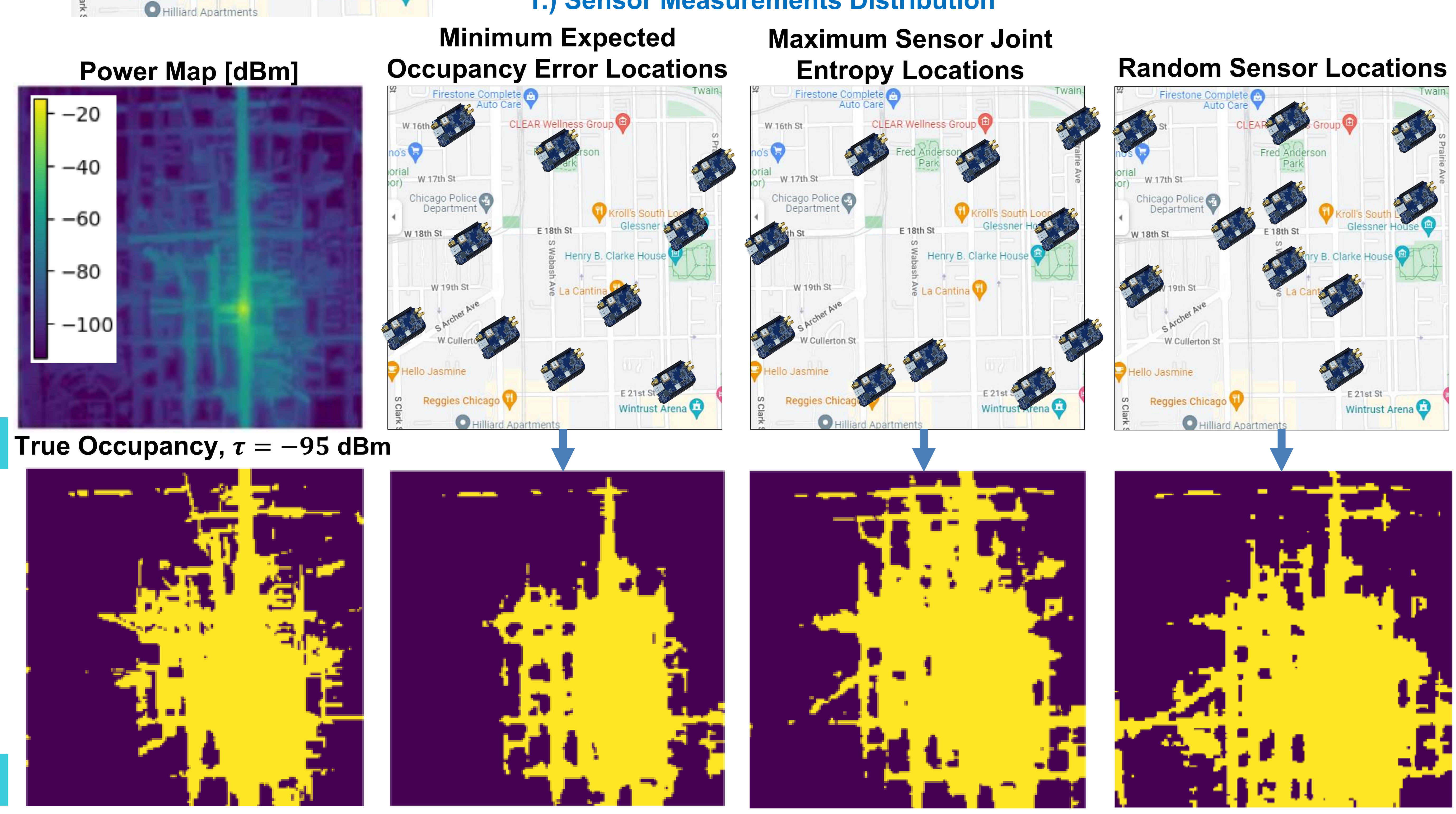
Minimum Expected Occupancy Error Optimization

$$J(\mathcal{S}) = \sum_{i=1}^{n_\mathcal{G}} E_{O_i}\left[\mathbb{1}\left(O_i \neq \hat{O}_i(\mathcal{S})\right)\right]$$

Maximum Sensor Joint Entropy Optimization

$$\mathrm{H}(\mathcal{S}) = -E_{O_\mathcal{S}}\left[\log_2\left(P_{O_\mathcal{S}}(O_\mathcal{S})\right)\right]$$

1.) Sensor Measurements Distribution



Estimation Error: 10.1% | Estimation Error: 12.3% | Estimation Error: 14.5%

KEY TAKEAWAYS:

Minimum Expected Occupancy Error Approach:

- Incorporates: 1.) Distribution of the sensor measurements, 2.) Distribution of the radio maps given the sensor measurements
- **Lowest Error**

Maximum Sensor Joint Entropy Approach:

- Only incorporates the distribution of the sensor measurements
- **Requires Less Information**