TV Whitespaces & Spectrum Databases

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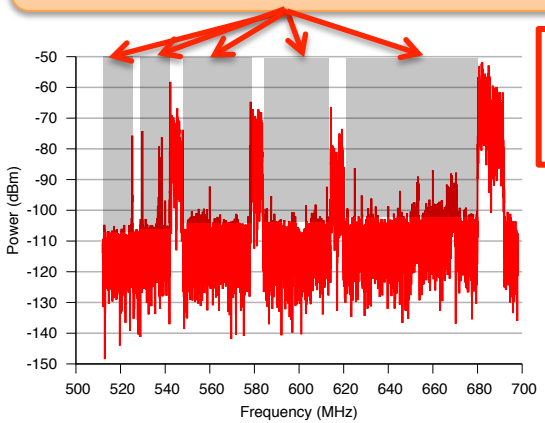
New Opportunity in TV Whitespaces

Vacant TV Channels



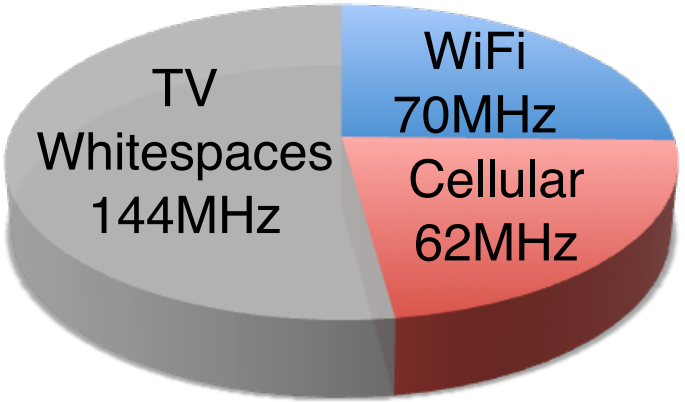
FCC OPENS TELEVISION WHITESPACES FOR UNLICENSED USE
November, 2008

Advantages of TV Whitespaces

Good Propagation Range in Lower Frequency

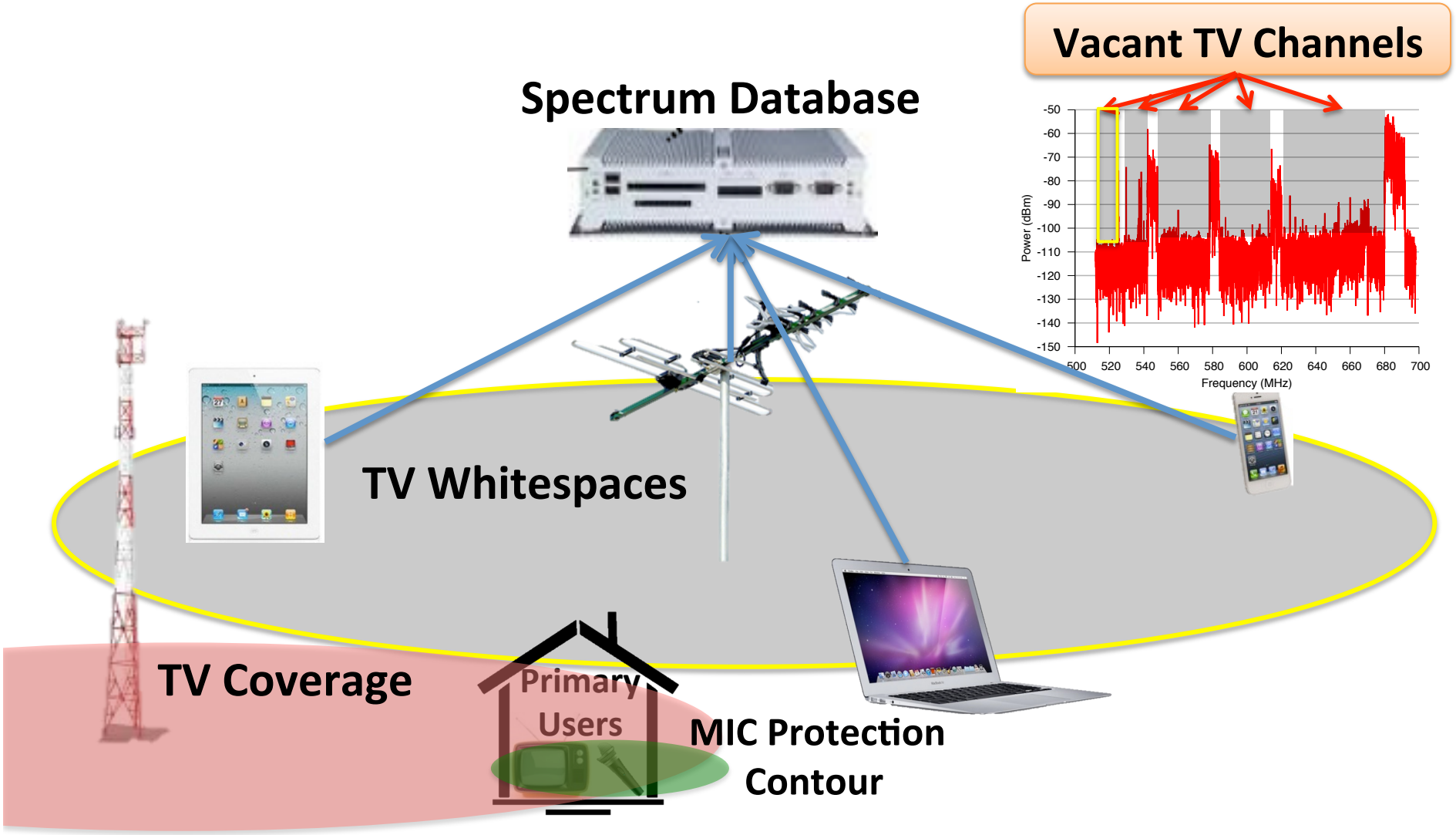
Oriental Pearl TV Tower Shanghai, China

Large Spectrum Resource after TV Broadcast Transition



Available Whitespace Spectrum at Madison, WI

Whitespace Spectrum Database



Error in Determining Whitespaces

Single Location Measurement

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Spectrum Database

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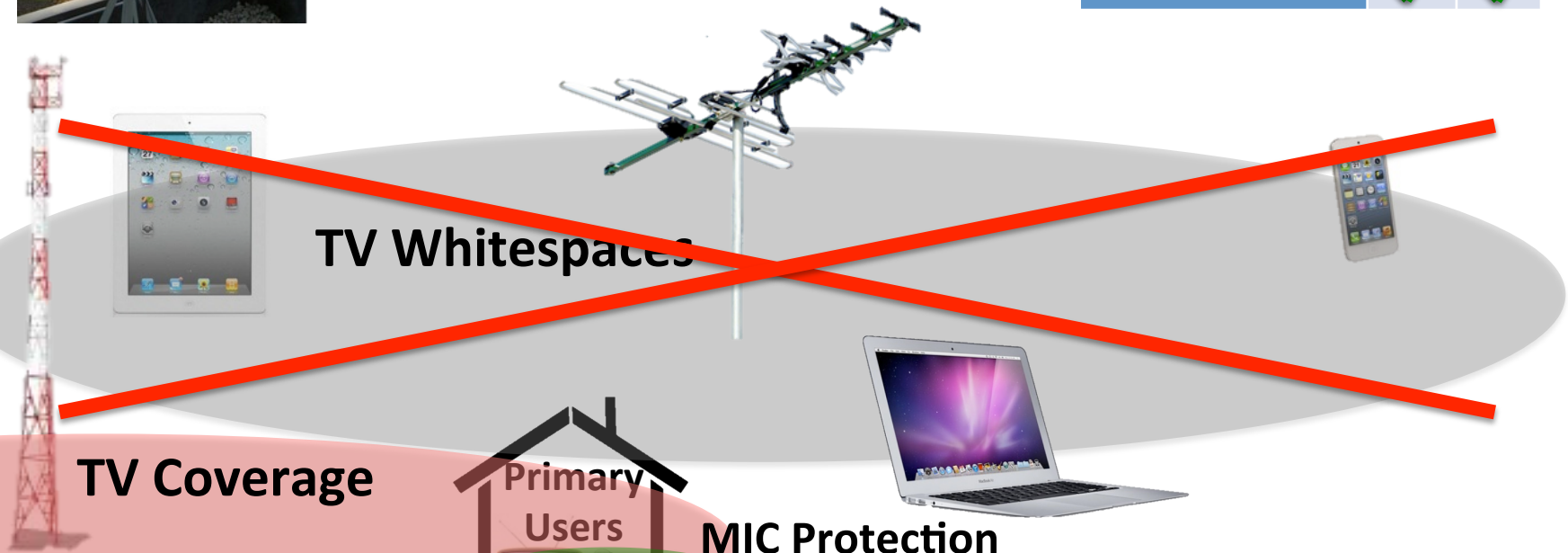
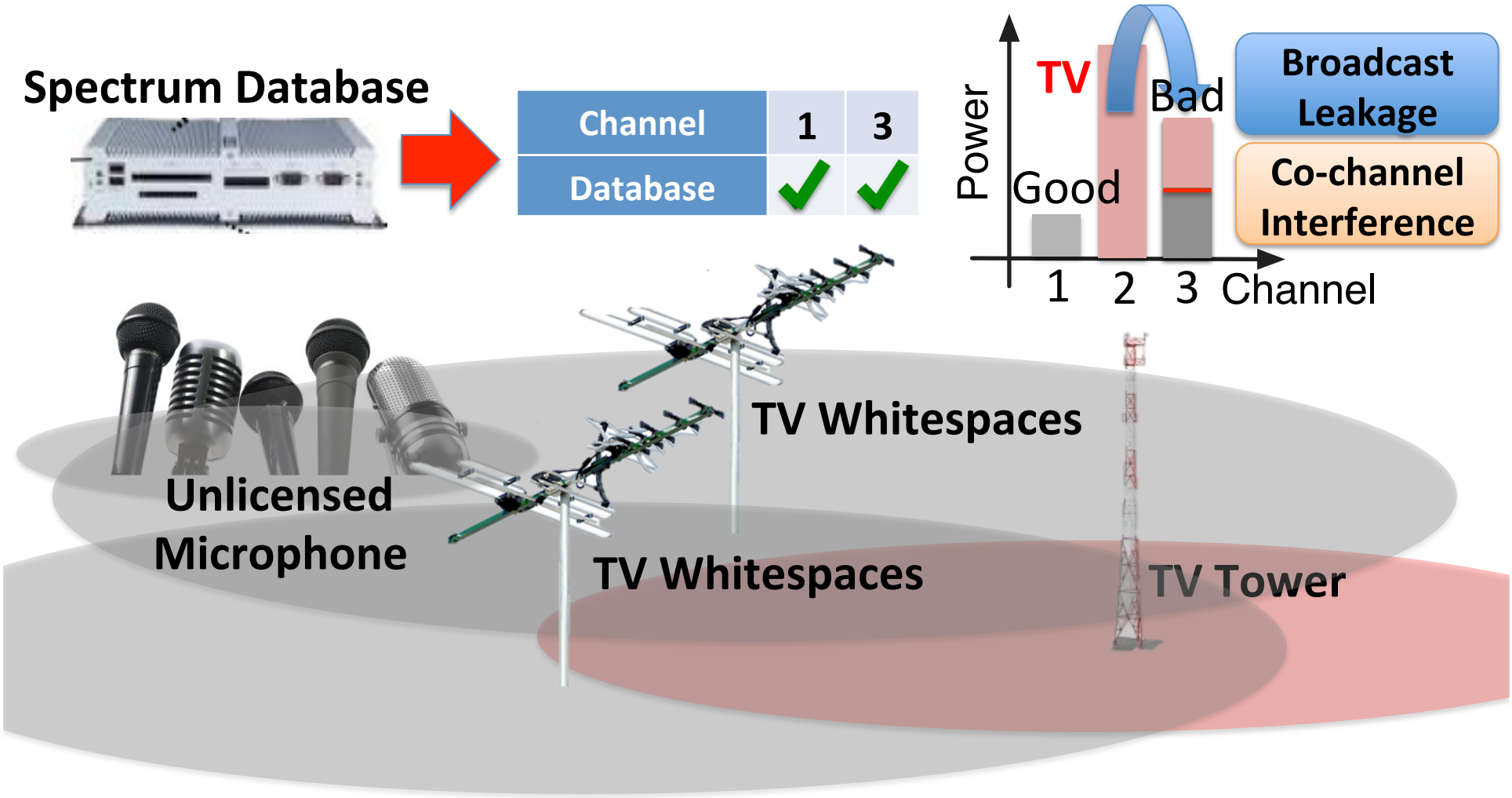
Spectrum Wastage

Channel	29	43
Database	✗	✗
Measurement	✓	✓



Unable to Predict Channel Quality



Localizing TV-band Devices

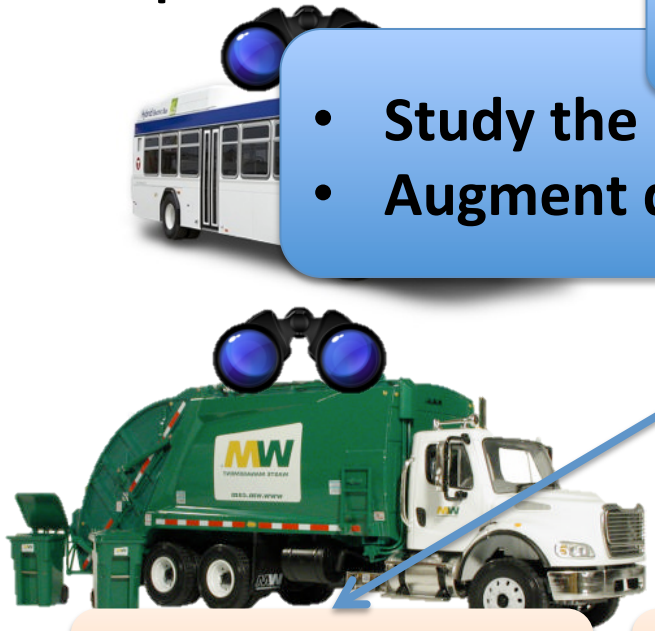
Spectrum Database

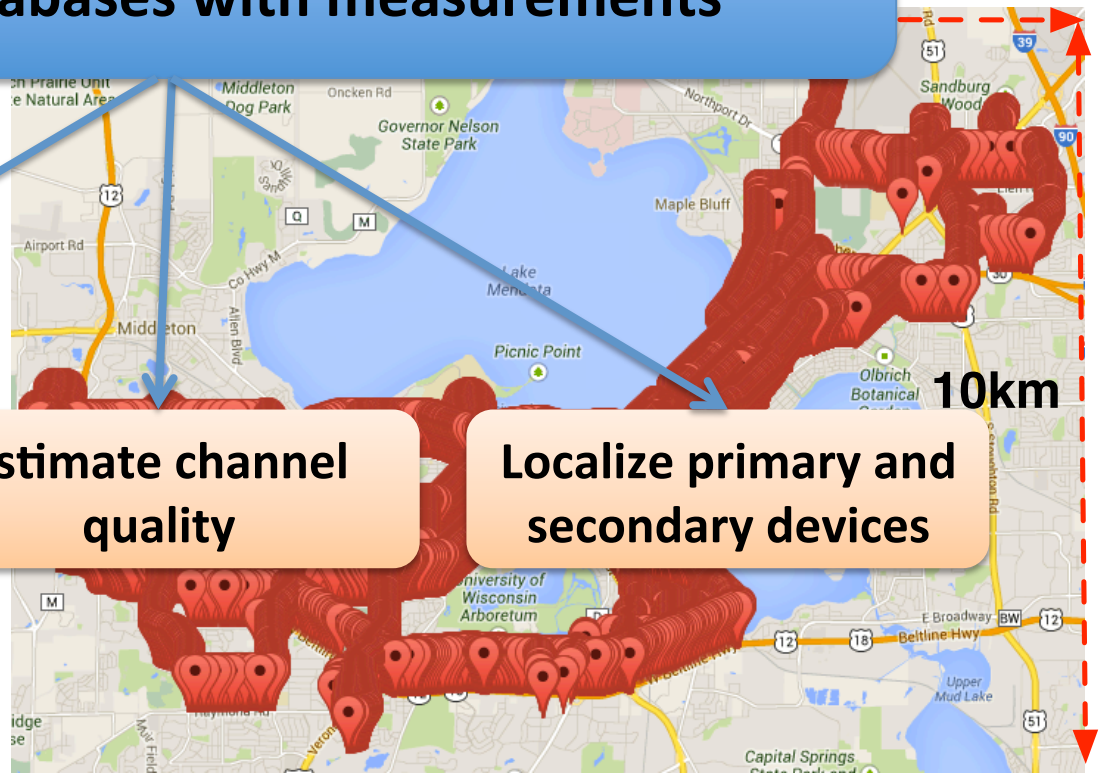
Wardriving on Public Vehicles

Spectrum Sensor

V-Scope = Vehicle + Sensor

- **Study the limitations of spectrum databases**
- **Augment databases with measurements**





Predict whitespace spectrum

Estimate channel quality

Localize primary and secondary devices

Outline

- **Database limitations**
- Opportunistic wardriving framework- V-Scope
  - Primary detection algorithm
  - Model refinement procedure
  - Broadcast leakage prediction
  - Localization algorithm
- Evaluation
- Summary

Accuracy of Commercial Databases

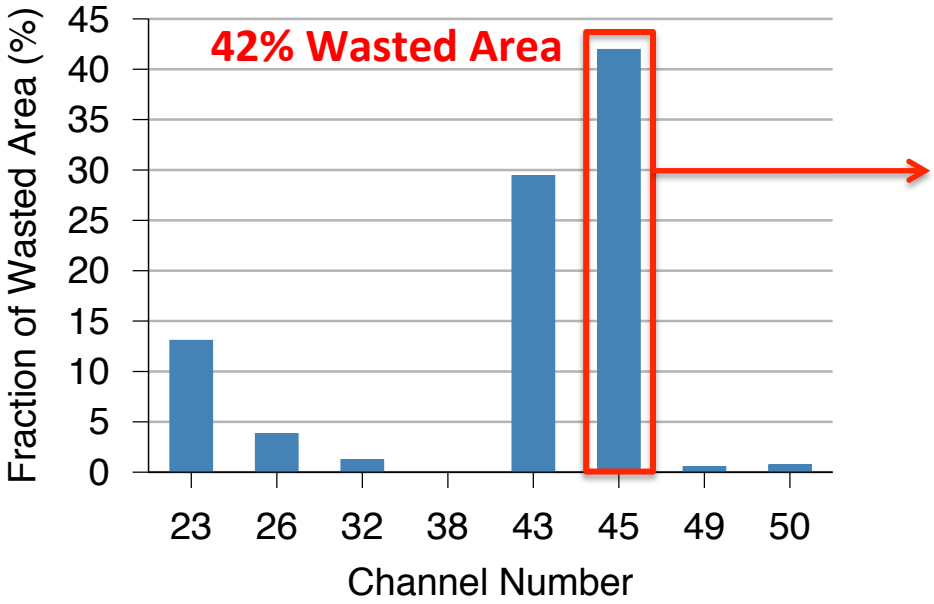
- Study a commercial-grade database from SpectrumBridge, Inc.

Device	Under Protection
TV	0.1%
Microphone	0.02%

Databases are efficient in protecting primary users

Accuracy of Commercial Databases

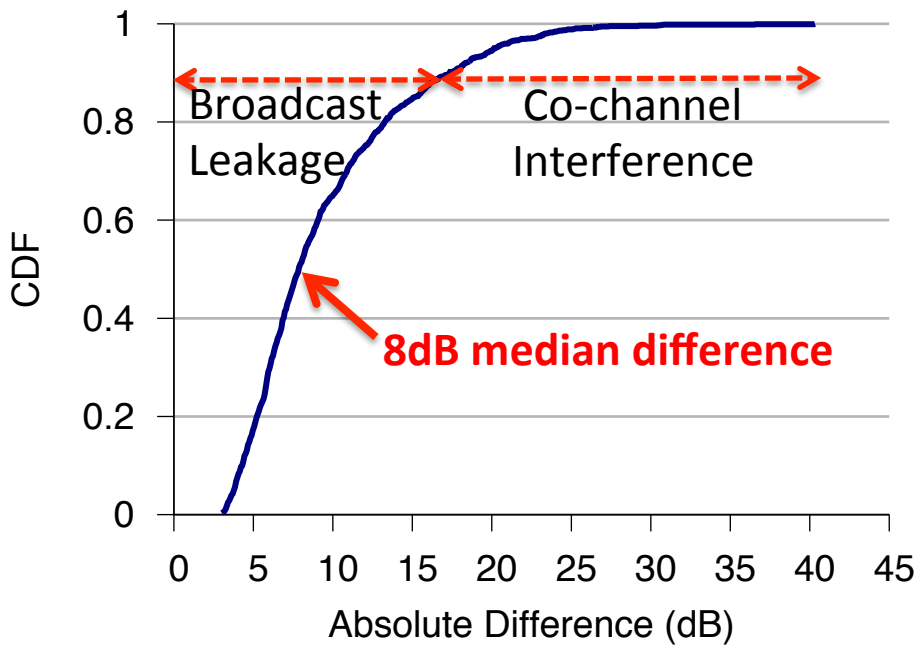
Large Waste of Whitespace Spectrum



Spectrum Waste in Protecting TV

Variation in Channel Quality

- Measure noise power in whitespace channels
- Calculate the difference between the best channel and worst channel at each location



120 Mbps Lower Data Rate

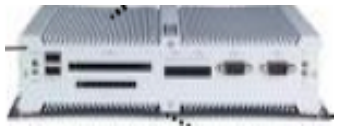
V-Scope Overview

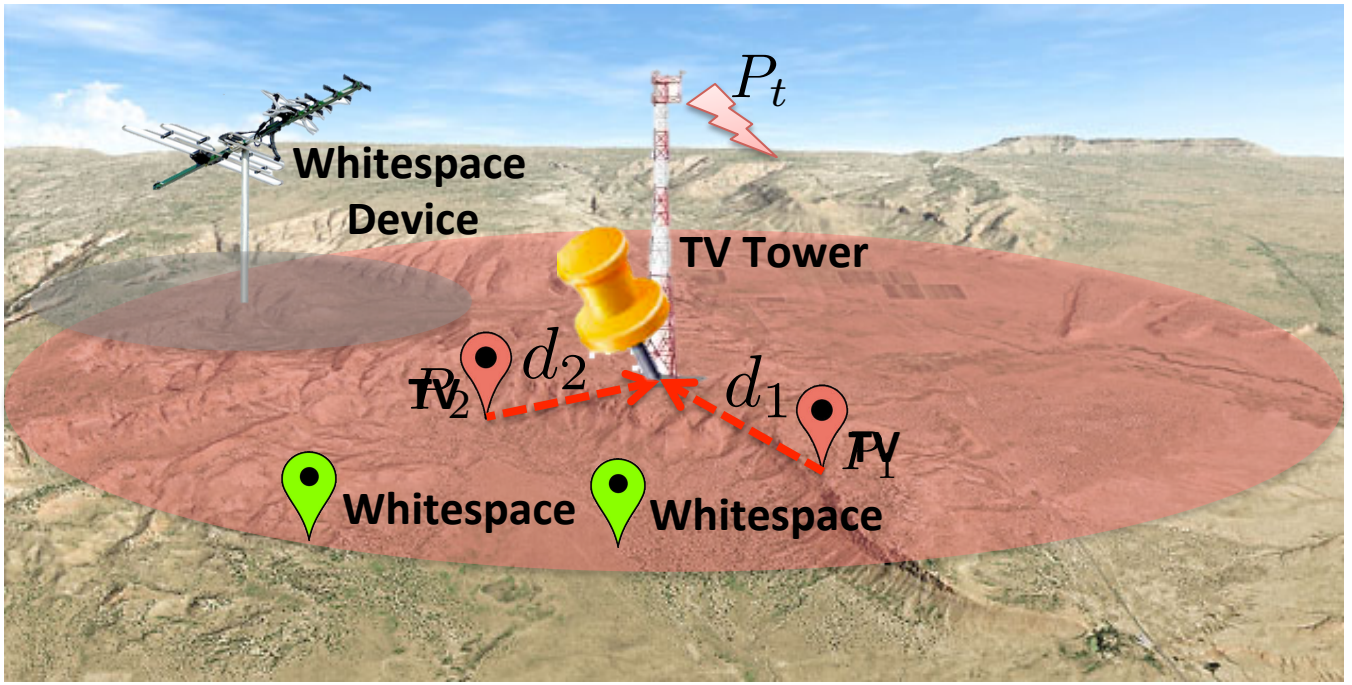
Location	Measurement
1	TV
2	Whitespace
3	Whitespace

Adjusted Parameter

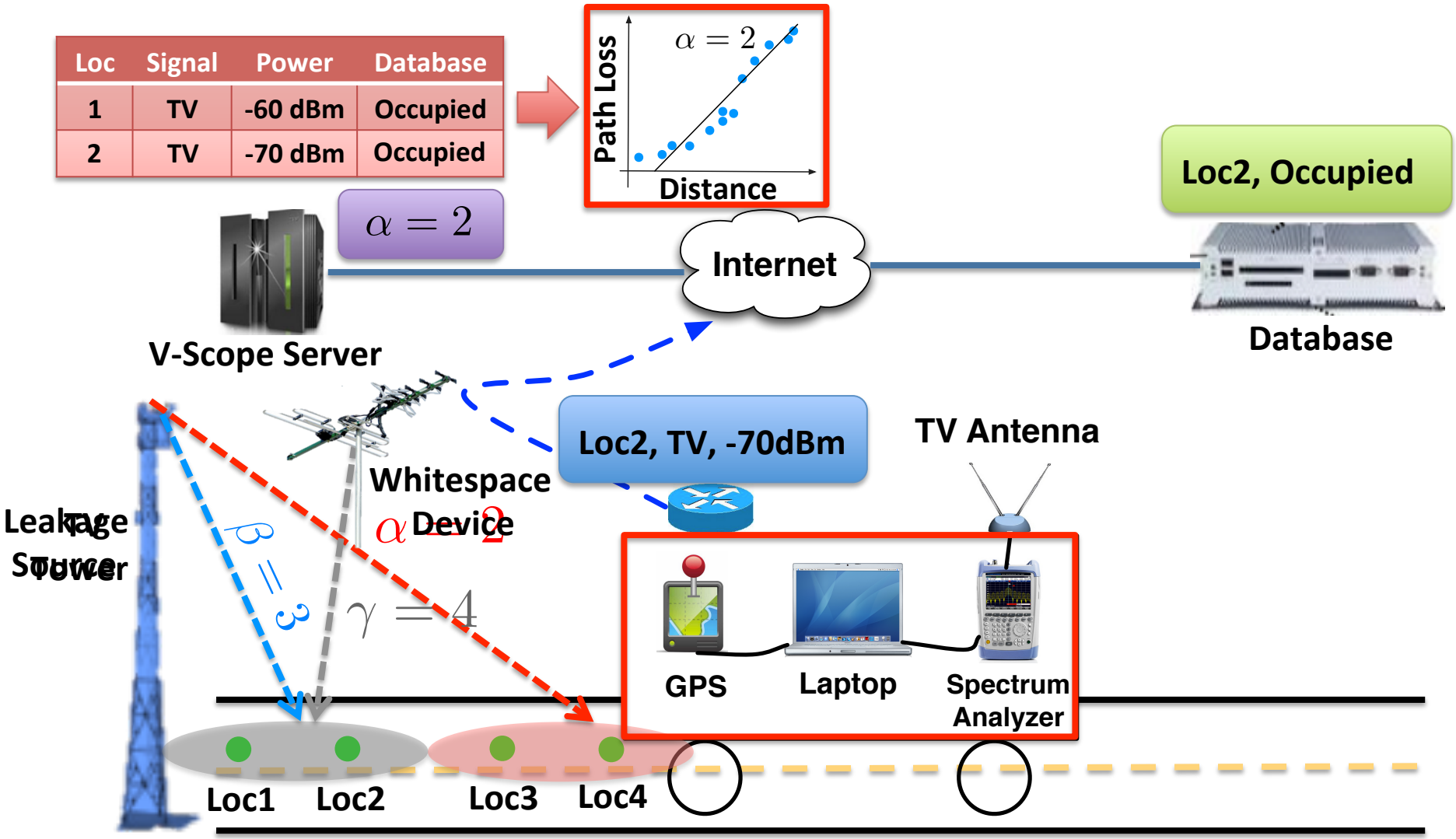
$P = \alpha \log(d)$

Database





V-Scope Architecture



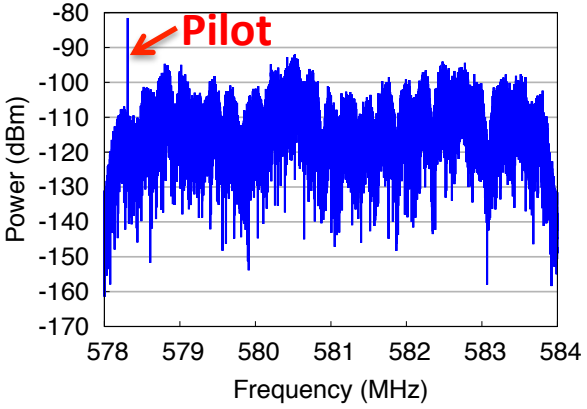
Challenge in Detecting Primary Signals

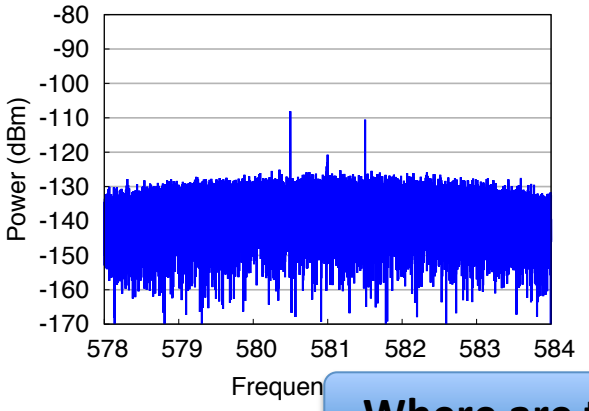
Detect primary signals based on features

Strong Signals (-60dBm)

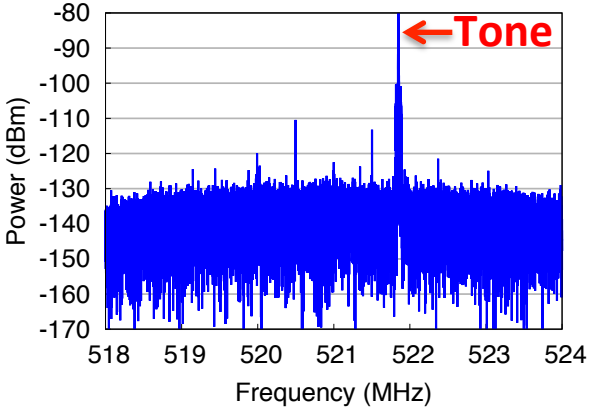
Weak Signals (-114dBm)

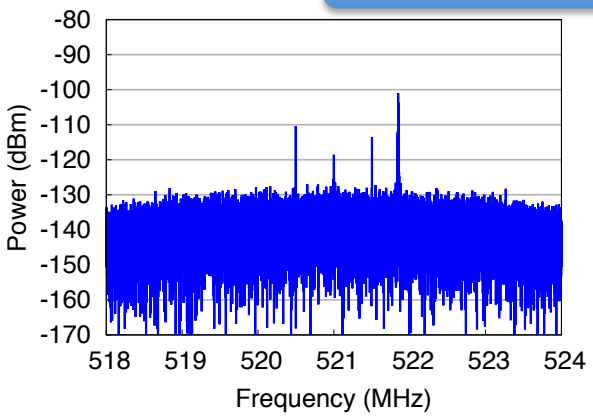
TV





MIC





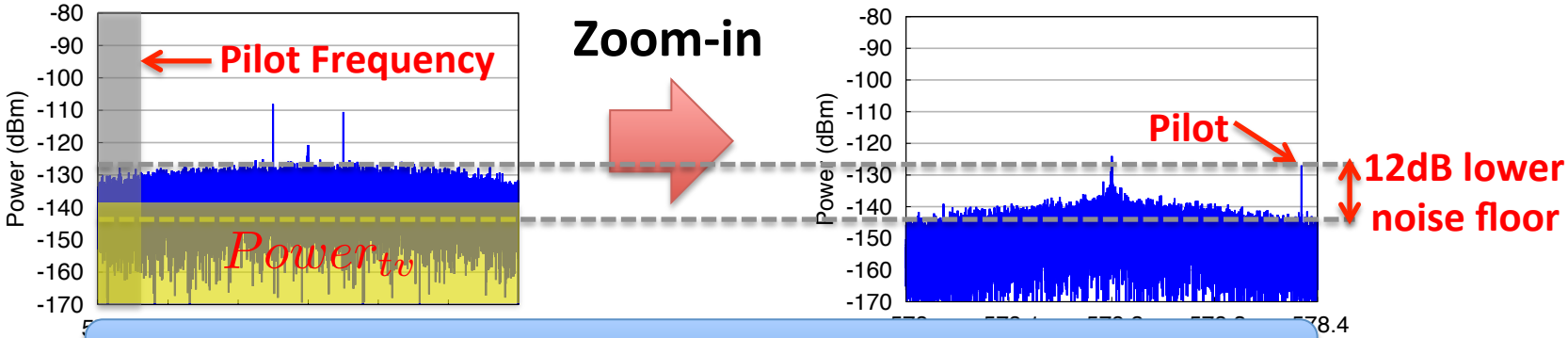
Where are the features?

32768 FFTs over 6MHz

Zoom-in Feature Detection

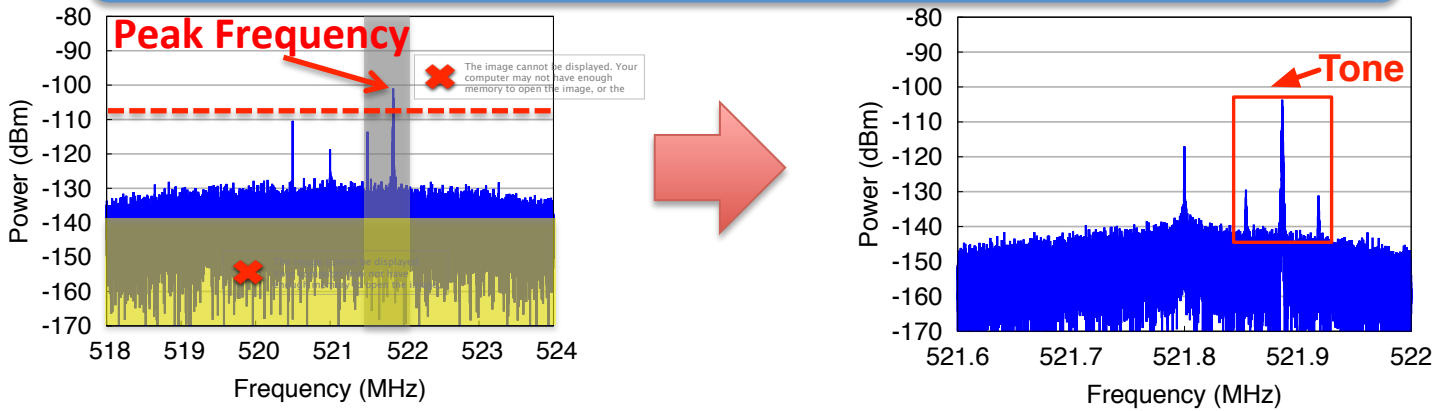
Capture at a narrower band to reduce noise floor

TV



Use feature power to estimate total power

MIC



Accuracy of Primary Detection

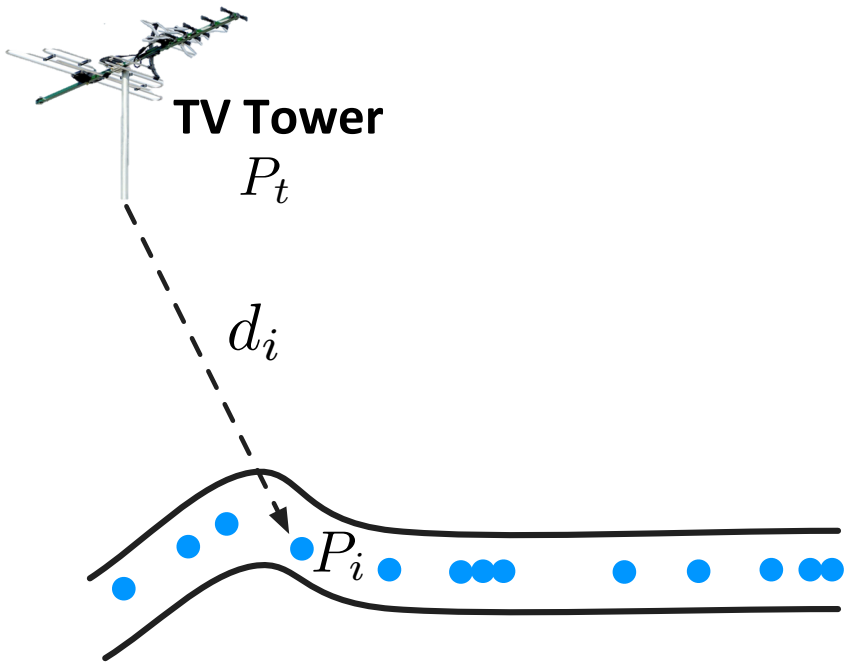
- Experiment setup
  - Collect trace in 30 UHF channels
  - Capture primary signals from -40dBm to -120dBm

Detected Groundtruth	Digital	Analog	MIC
Digital	94.9%	0.7%	4.4%
Analog	0.5%	97.4%	2.1%
MIC	1.2%	0.7%	98.1%

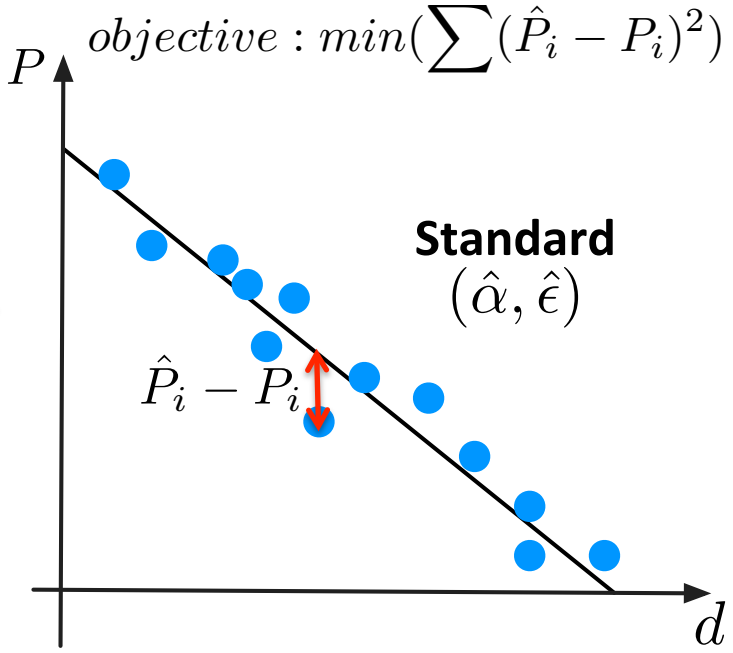
Model Refinement

Improve any propagation model by fitting its parameters with measurements

$$P = \alpha \log_{10} d + \epsilon$$

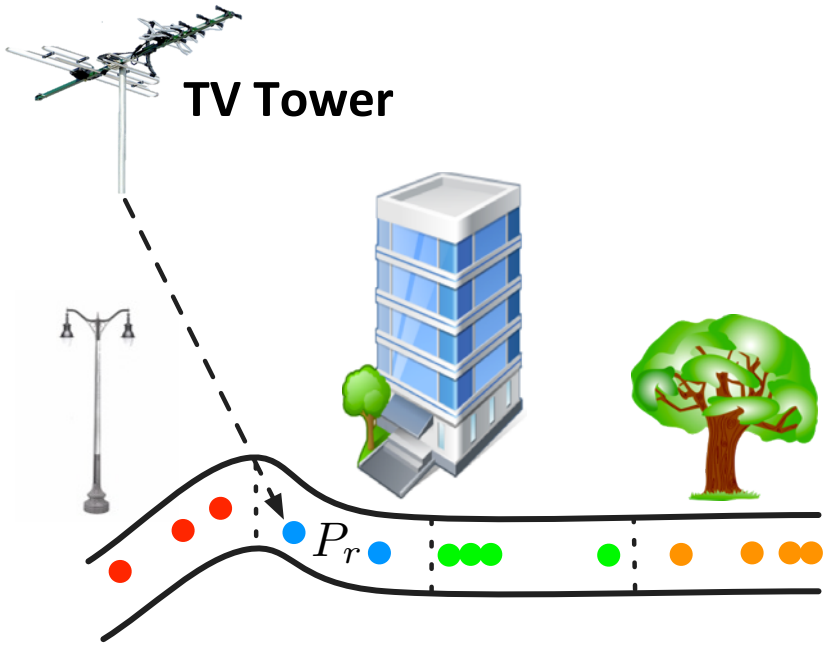


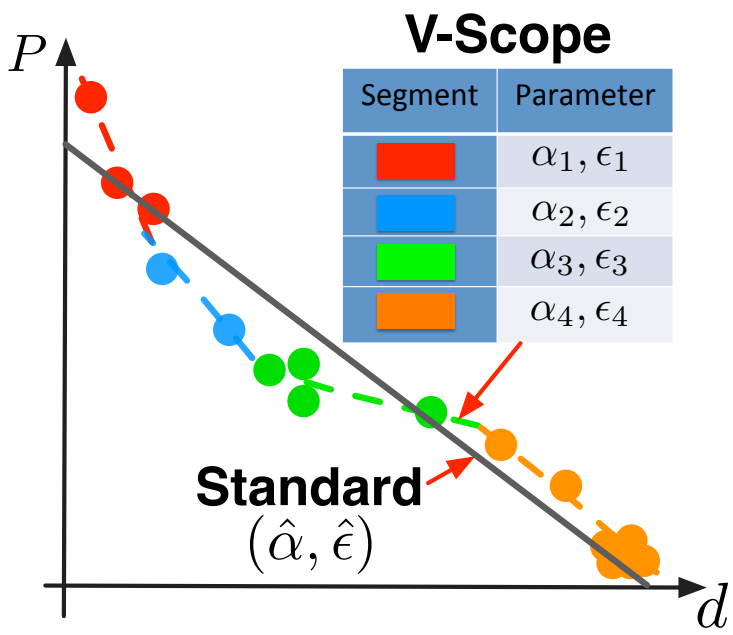
Linear Regression



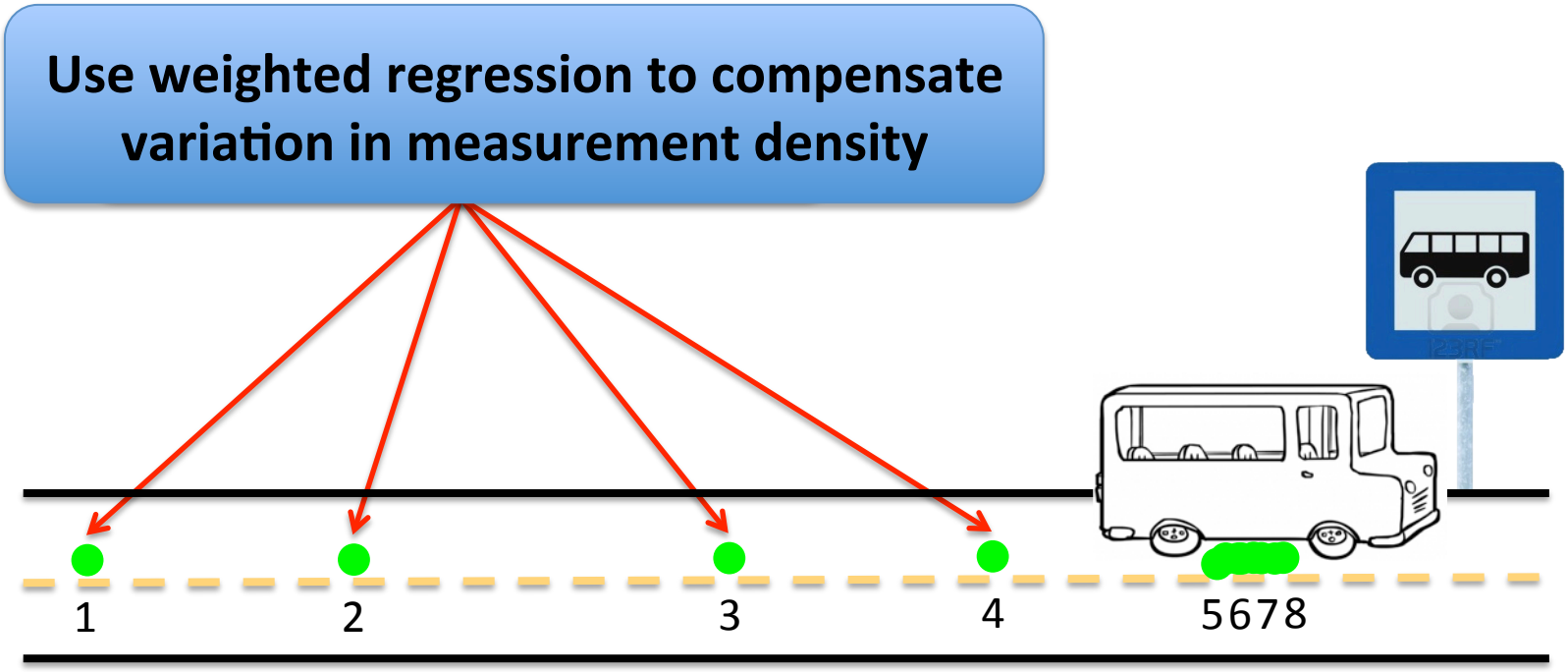
Region Specific Model

$$P = \alpha \log_{10} d + \epsilon$$



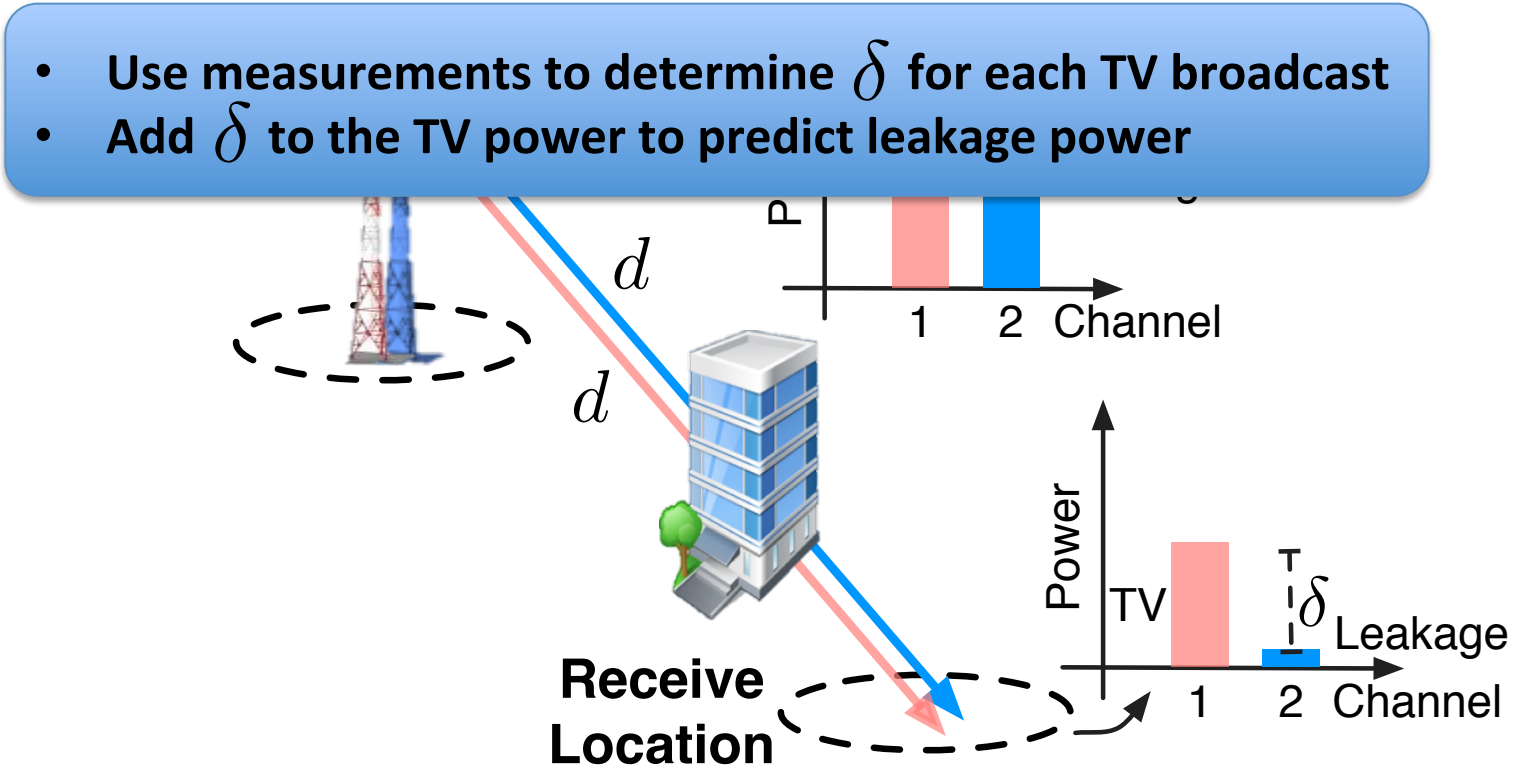


Weighted Regression Fitting



Predicting Leakage of TV Broadcast

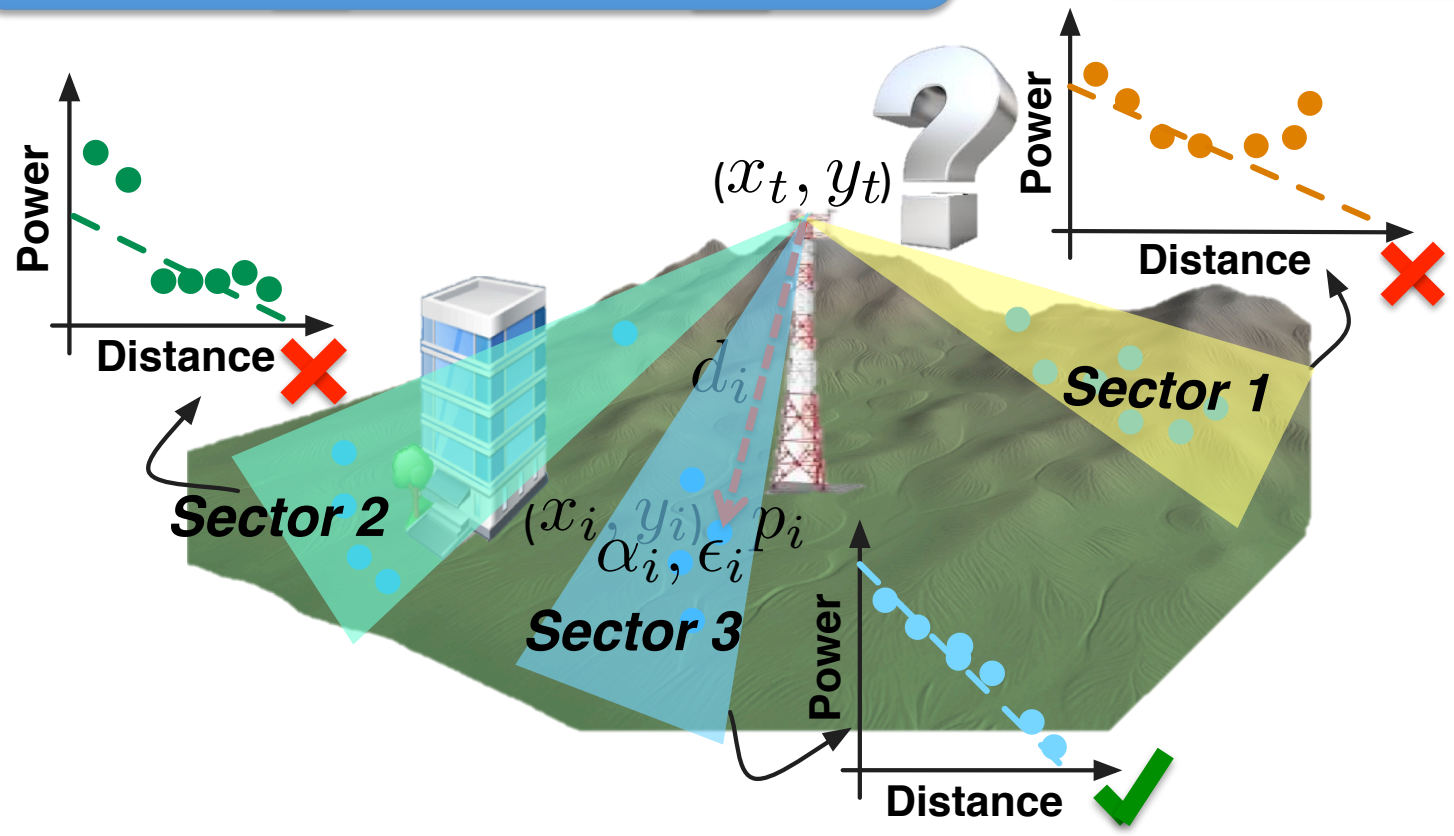
- A constant power offset between in-band signal and leakage signal at any location



Localizing TV-band Devices

- Select sectors with good linear trend
- Use a sector-specific model

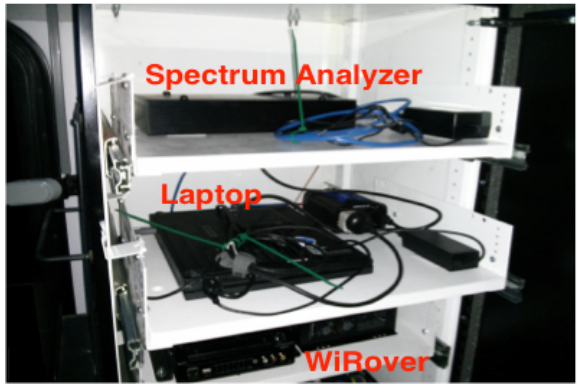
Environmental variation disturbs path loss trend



Evaluation

- Experiment setup
  - Deployed on a metro bus at Madison, WI
  - Collected over 1 million measurements around 150 square-km area

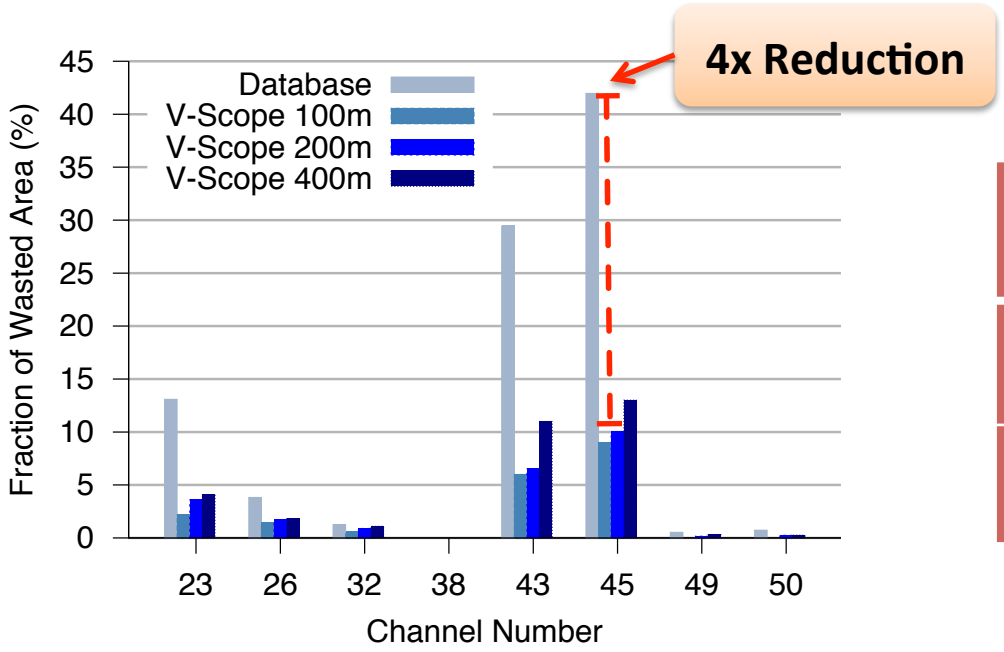
ThinkRF WSA4000



Cabinet inside bus

Predicting TV Whitespace Spectrum

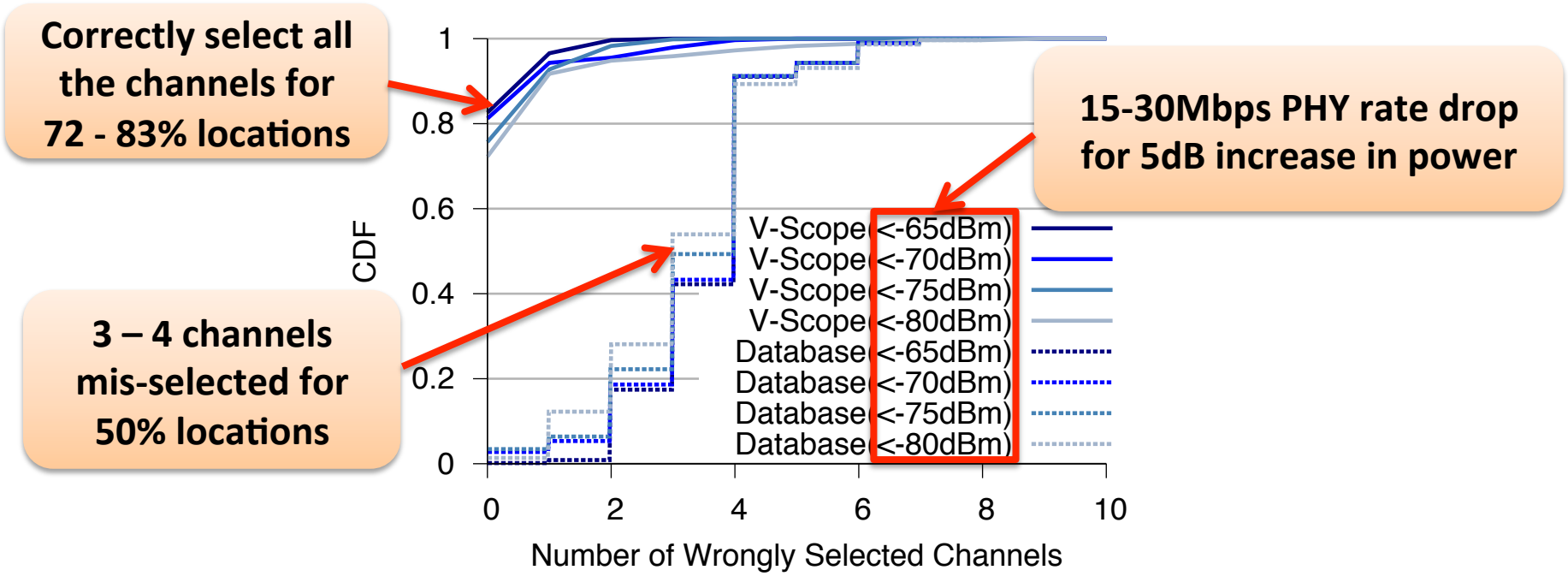
- Use 80% measurements to fit different models
- Predict TV signal strength at the rest of measurements
- Use -114dBm threshold to determine TV whitespaces



Prediction	Under Protection
Commercial Database	0.1%
V-Scope	0.037%

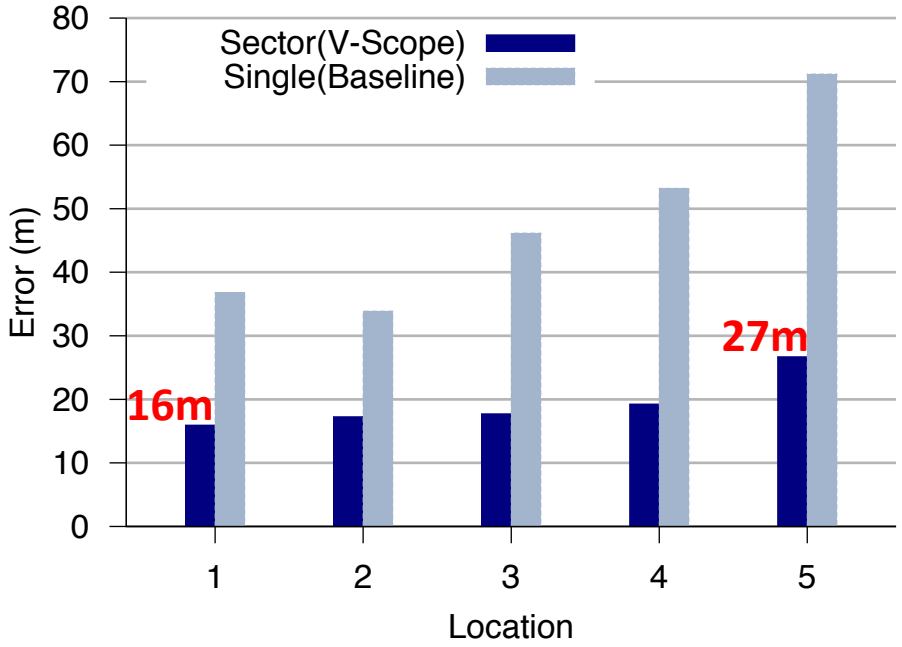
Selecting Suitable Whitespace Channels

- Sum the predicted power of unlicensed devices and broadcast leakage in each whitespace channel
- Select suitable channels with power below a threshold
- Count number of mis-selected channels at each location



Localizing Unlicensed Devices

- Collect vehicular measurements for a 100mW transmitter in 5 different buildings
- Use a GPS device to determine actual locations



Sector-based approach reduces error by 2 – 3x

Conclusion

- Deployed a system on public transit buses to collect spectrum measurements.
- Existing databases have limitations in managing TV whitespaces.
  - Cause under-utilization of whitespace spectrum
  - Unable to predict the quality of whitespace channels
  - Do not attempt to validate the location of TV-band devices
- Designed measurement-refined models to augment databases
  - Predict TV whitespace spectrum
  - Estimate the quality of whitespace channels
  - Localize primary and secondary devices

Thanks for your attention!

Questions?