Establishing the Link Between Sensor Capabilities & Spectrum Analytics Performance

Karyn Doke, Andrew Okoro, Mariya Zheleva
University at Albany, State University of New York, *{kdoke, aaokoro, mzheleva} @albany.edu*

UNIVERSITY AT ALBANY
State University of New York

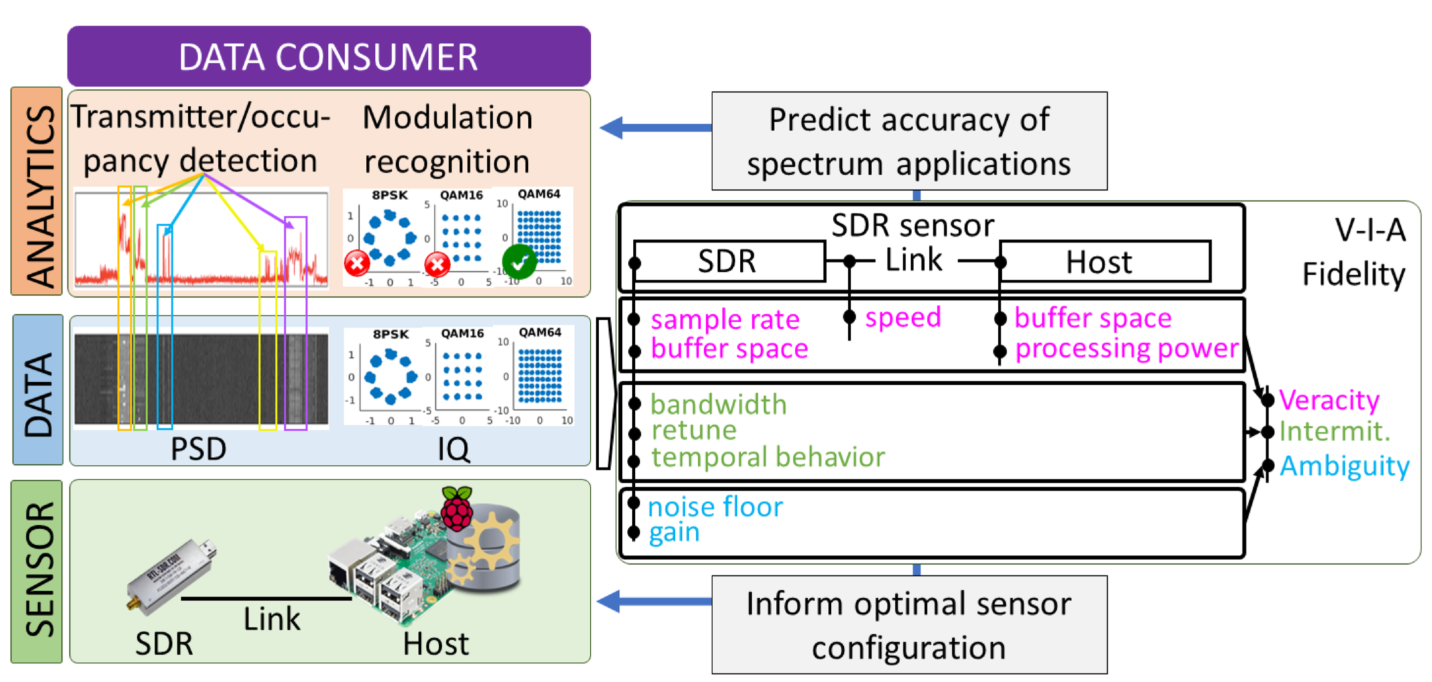
SPECTRUMX

Background

[Source: NTIA FCC Spectrum Allocation Chart]

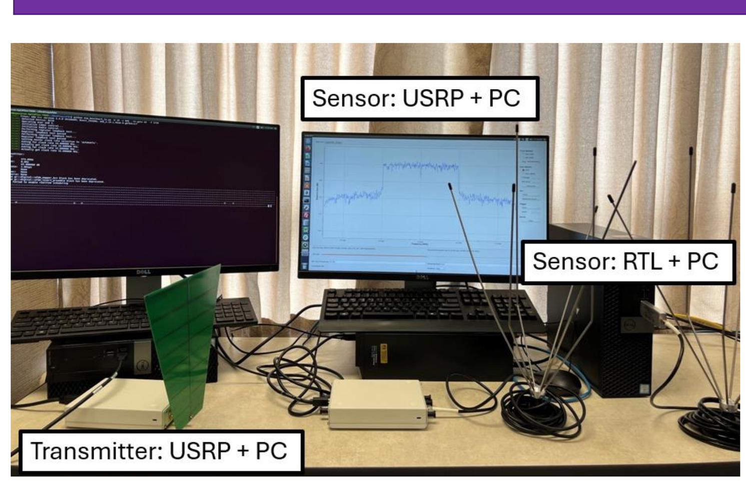
- Radio frequency spectrum is a scarce commodity.
- Spectrum assignment is full yet certain frequencies are underutilized.
- Regulators are forced to:
  - Re-allocate spectrum from existing services.
  - Develop mechanisms to share spectrum.
- Requires meaningful data collection.
- Spectrum data collection and analysis is cornerstone for future wireless networking.
- Outcomes feed into critical decisions such as determining the incumbent occupancy in geographic areas.

Problem: Sensor imperfections or configurations will affect data quality.



Solution: Develop **VIA**, a framework that quantifies spectrum data fidelity based on sensor properties and configuration.

Data Collection



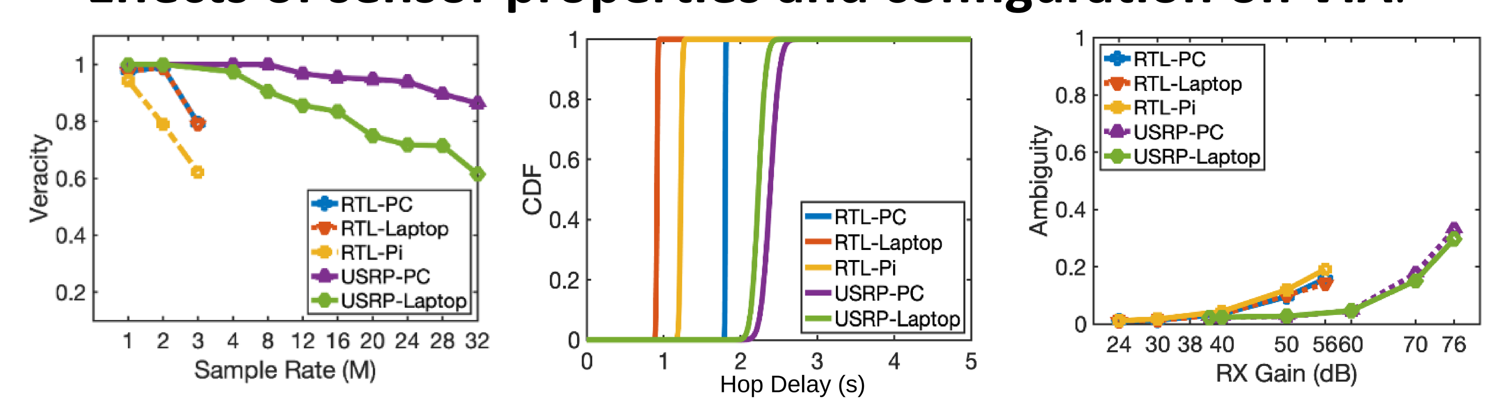
To evaluate VIA: collect and curate a large dataset of 1800 spectrum scans:
- Controlled indoor/outdoor
- Commercial FM radio/TVWS
- Focus on line of sight

Platform	SDR	SDR-HOST Link	Sample Rates (Mbps)	RX Gain (dB)
RTL-Pi	RTL2832U	USB 2.0	1,2,3	24,30,40,50,56
RTL-Laptop	RTL2832U	USB 3.0	1,2,3	24,30,40,50,56
RTL-PC	RTL2832U	USB 3.0	1,2,3	24,30,40,50,56
USRP-Laptop	USRP-B210	USB 3.0	1,2,4,8,12,16,20,24,28,32	38,40,50,60,70,76
USRP-PC	USRP-B210	USB 3.0	1,2,4,8,12,16,20,24,28,32	38,40,50,60,70,76

Methodology

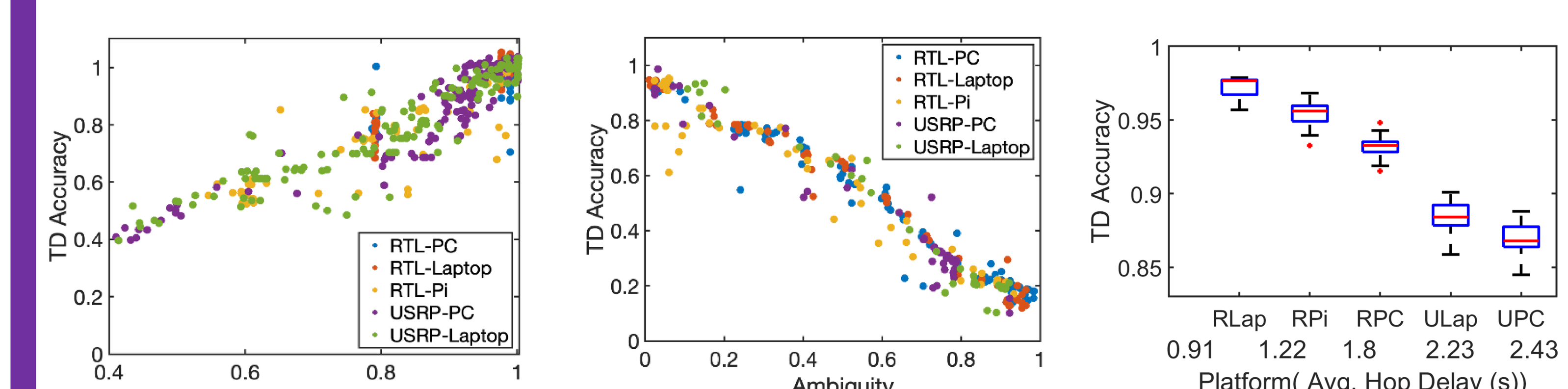
VIA takes as an input a spectrum trace and the sensor configuration, and benchmarks data quality along three vectors:
- **Veracity**: quantifies data retention in a spectrum scan.
- **Intermittency**: quantifies the effect of the temporal. persistence of sweep-based spectrum scans.
- **Ambiguity**: quantifies the likelihood that transmitter samples in a spectrum scan might be confused with noise.

Effects of sensor properties and configuration on VIA.



Left: Data veracity across the five platforms with increasing sampling rate. **Middle:** Hop delay across five platforms. **Right:** Ambiguity of the collected traces as a function of the receiver gain.

Showcasing the effects of VIA on application performance.

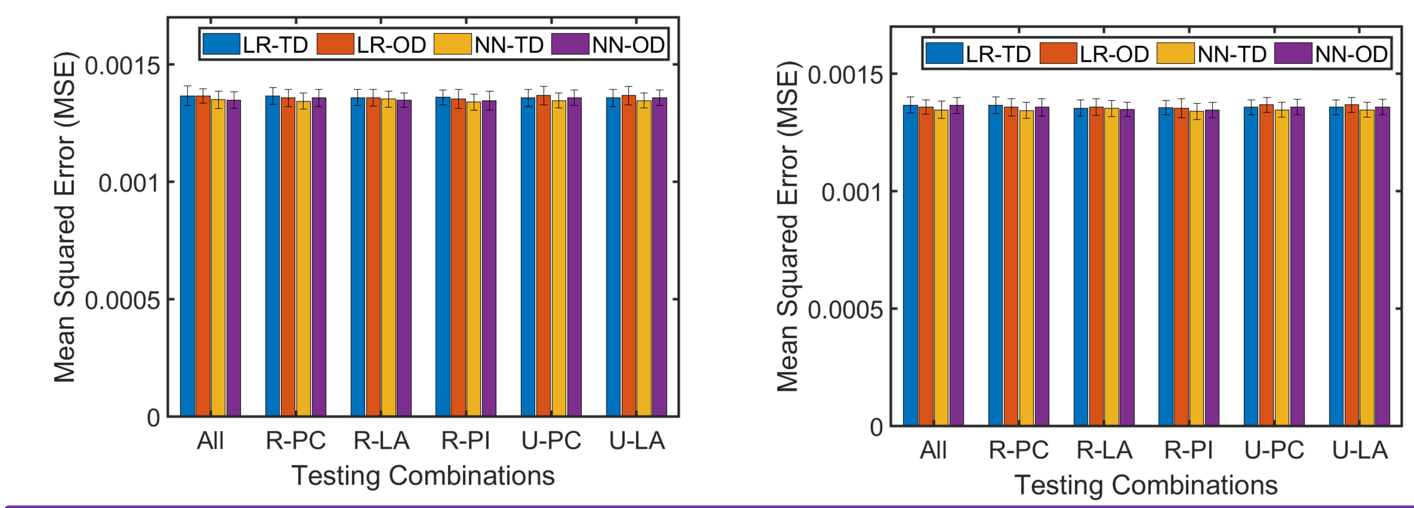


Effects of **VIA** on transmitter detection (TD) accuracy. **Left**: accuracy deteriorates as veracity decreases. **Middle**: accuracy deteriorates as ambiguity increases. **Right**: accuracy deteriorates as hop delay increases.

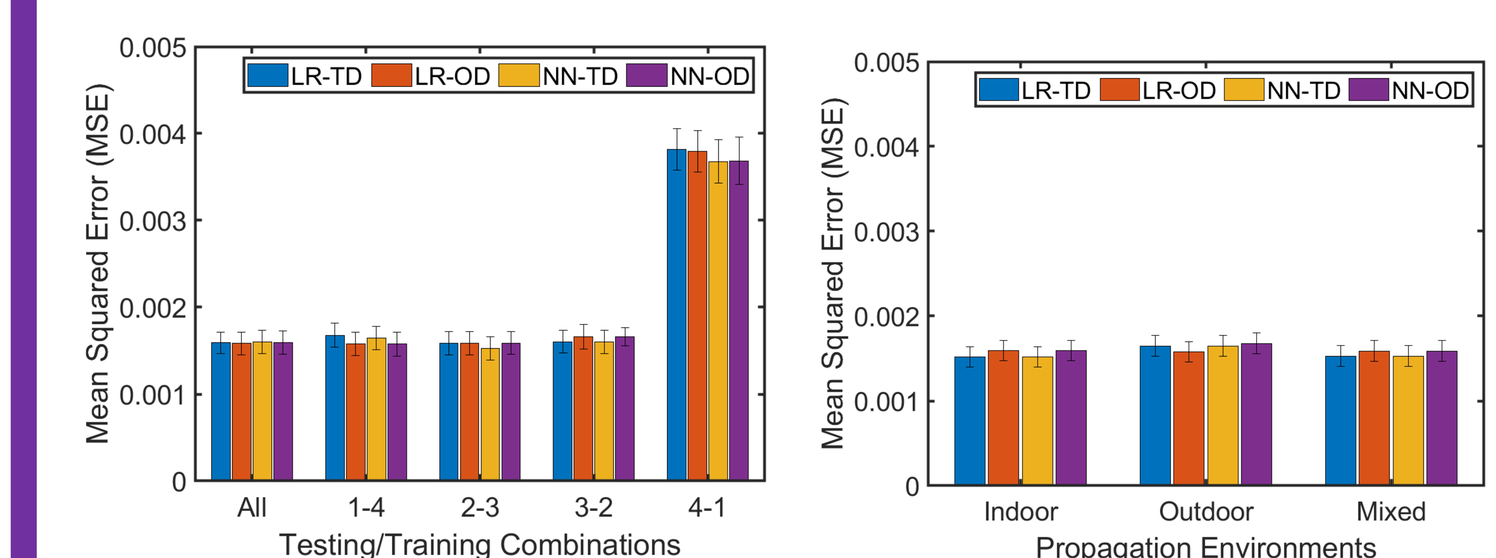
Evaluation Setup

Evaluate VIA's ability to predict application performance.
- *Prediction models* (linear regression (LR), neural network (NN)).
  - **Input**: VIA Vector
  - **Output**: accuracy target spectrum analytic task
- *Spectrum analytic task*:
  - Transmitter Detection (TD)
  - Occupancy Detection (OD)
- Report mean squared error (MSE) – common metric across both models.

Evaluation



Prediction performance for **known platforms** where training includes all platforms. Testing using **controlled traces** (left) and **real-world traces** (right). Overall low MSE across all cases.



Prediction performance for **unknown platforms** (left) and **unseen multipath environments** (right). Overall low MSE across cases for unknown and propagation environments. "4-1" combination indicates declined performance as training on RTL and testing on a mix of RTL and USRP gains bad performance.

Conclusion

- **VIA** retains high predictive performance (0.0013 MSE) for known platforms, regardless of the target sensor.
- For unknown platforms, **VIA** retains a high and consistent predictive performance (0.0013 MSE) for the first 4 combinations while the rightmost combination scores just under 0.004 MSE. As we limit the amount of training platforms, **VIA**'s performance declines.
- **VIA** retains high predictive performance (0.0013 MSE) for known (indoor/outdoor) and mixed propagation environments.

References

[1] VIA: Establishing the link between spectrum sensor capabilities and data analytics performance, K. Doke, A. Okoro, A. Zare, and M. Zheleva, IEEE INFOCOM, 2024
[2] AirVIEW: Unsupervised transmitter detection for next generation spectrum sensing, M. Zheleva, T. Larock, P. Schmitt, and P. Bogdanov. IEEE INFOCOM 2018.