Finding an Unknown Interference Source in POWDER via Time Difference of Arrival

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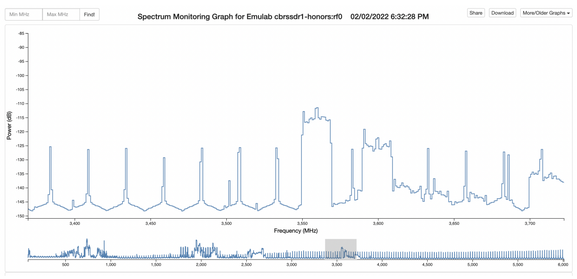
Abstract

Adaptive spectrum sharing between different systems and operators is being deployed in order to make use of the wireless spectrum more efficient. However, when spectrum is shared, it can create situations in which an operator is unable to determine the identity of an interferer transmitting an unknown signal. This is the situation which the POWDER testbed found itself in, starting in late 2021. This poster describes a tool we developed to locate an unknown signal source in the POWDER deployment area. We used cross-correlation between the signals measured at multiple time-synchronized base stations to estimate their time difference of arrival (TDOA), which we combined in a TDOA localization algorithm to locate each source. Our tool is open source and available for other researchers to use to locate interferers near their deployed network.

Problem Statement

- Unknown signal detected over CBRS band (3550-3700MHz) at multiple POWDER base stations (receivers).



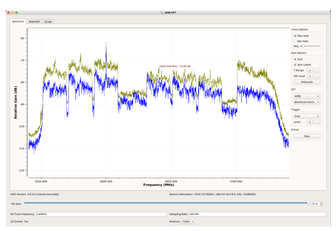
POWDER

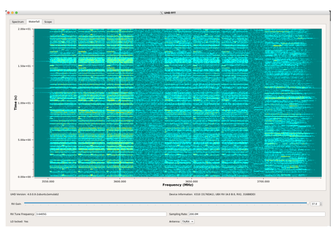
- **P**latform for **O**pen **W**ireless **D**ata-driven **E**xperimental **R**esearch
- City scale living laboratory (6 km^2)
- NSF sponsored

CBRS band

- Citizens Broadband Radio Service Band 3550 MHz to 3700 MHz
- Public available
- Governed by Federal Communications Commission (FCC)
- Deployment managed by Google spectrum access system (SAS)

Method - Data Collection





- 4 Receivers
- Center frequency at 3560, 3580, 3600, 3620, 3640, 3660 and 3680 MHz
- Sampling rate = 20 MHz
- Time duration = 10 msec (200000 samples in total)

Method - TDOA estimation

- Cross-correlation algorithm

$$r_{i,j}(k) = \sum_{n=0}^{N} X_i(n+k)X_j^*(n), \tag{1}$$

- Maximum value of the cross-correlation results indicates the Highest similarity
- Corresponding K_{ij} of the maximum correlation value is the desired TDoA estimate:

$$K_{i,j} = \underset{-M_{i,j} \le n \le M_{i,j}}{\operatorname{argmax}} \|r_{i,j}(n)\| \tag{2}$$

Method - Localization

- Mean squared error (MSE) calculation

$$MSE(Y) = \frac{1}{n} \sum_i \sum_{j<i} \{\frac{1}{c}\{\| Y - p_i \| - \| Y - p_j \|\} - K_{i,j}\}^2 \tag{3}$$

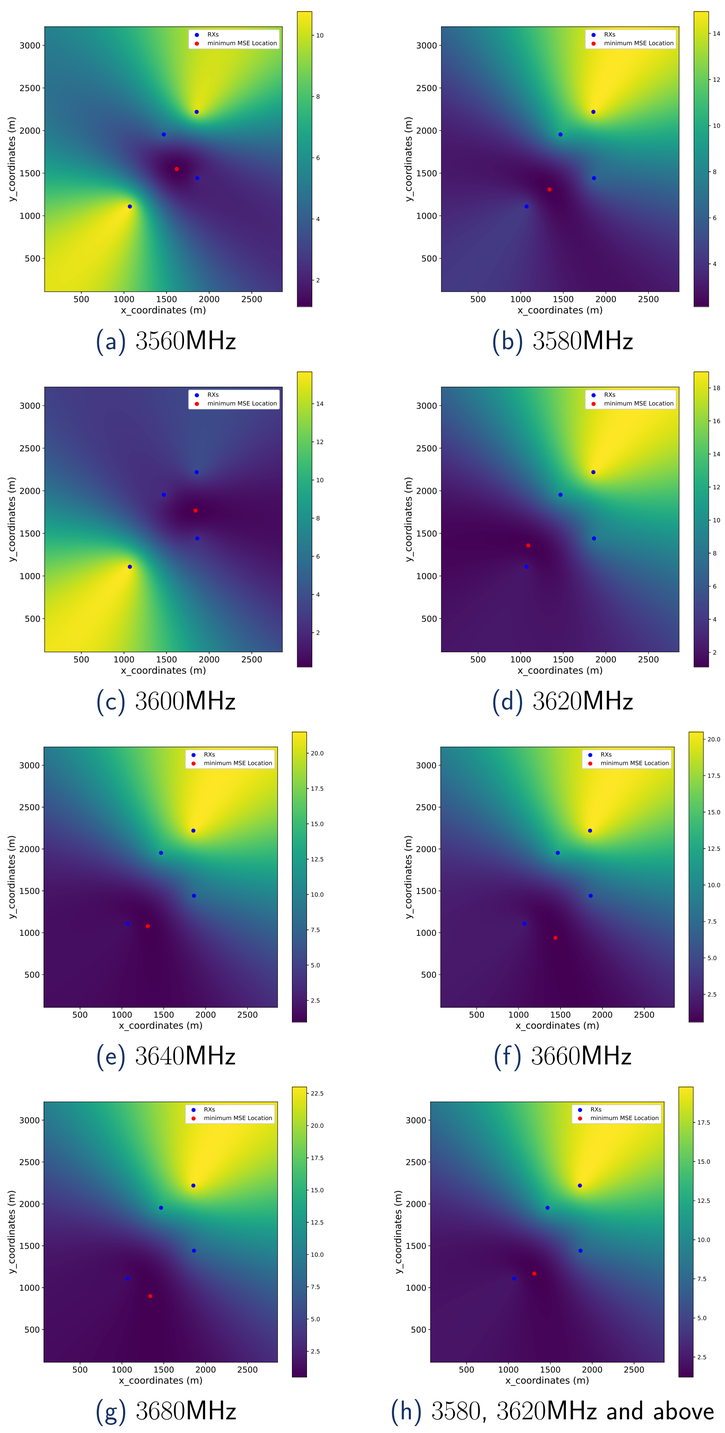
- Grid map area covers the used receivers
- Plenty of measurements are taken to average out the biased condition

$$avgMSE(Y) = \frac{1}{S} \sum_S MSE(Y) \tag{4}$$

- We regard the coordinate with the minimum value of the final MSE results, $\hat{Y}$, as the possible location of the unknown signal source

$$\hat{Y} = \underset{Y}{\operatorname{argmin}}\{avgMSE(Y)\} \tag{5}$$

Results



(a) 3560MHz (b) 3580MHz (c) 3600MHz (d) 3620MHz (e) 3640MHz (f) 3660MHz (g) 3680MHz (h) 3580, 3620MHz and above

Figure: MSE Maps for all channel center frequencies (the blue points are the receivers' locations, the red point is the coordinate with the MMSE, and the color bar indicates the value of the MSE on the map.)

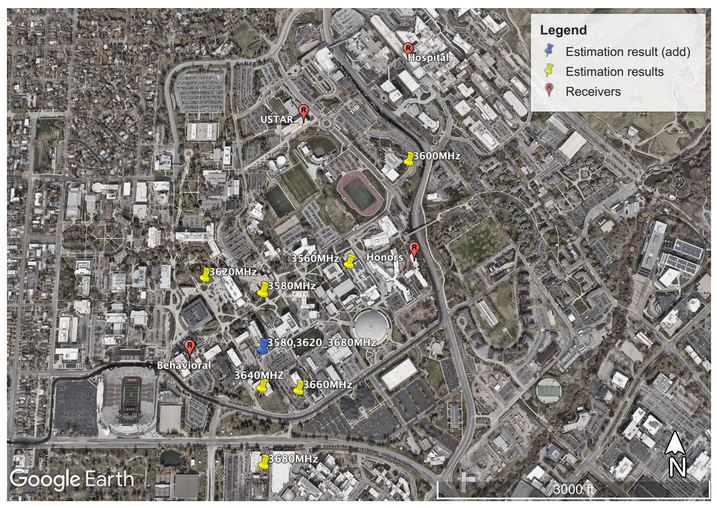
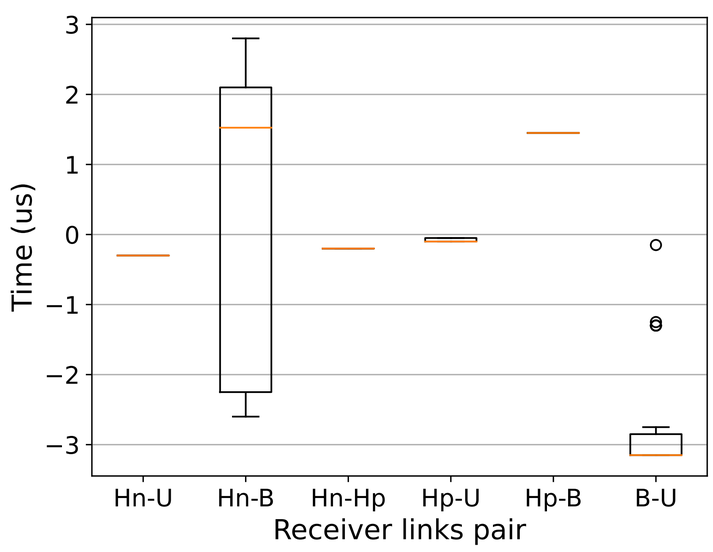


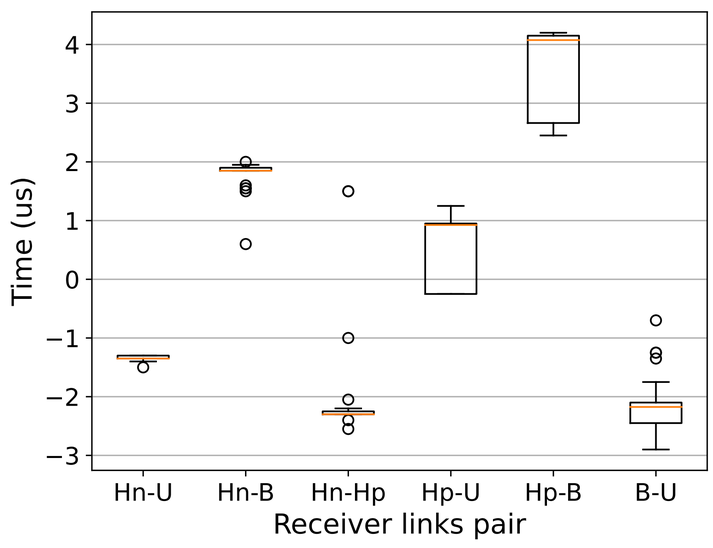
Figure: The localization results in the POWDER deployment area, with receivers (red pins), location estimates for single bands (yellow pins), estimate combining 3580, 3620, 3640, 3660, and 3680 MHz bands (blue pin).

Discussion

- 3580 MHz: MMSE = 2.52 us^2; RMSE =476 m
- 3680 MHz: MMSE = 0.51 us^2; RMSE = 214m



(a) 3580MHz



(b) 3680MHz

Figure: Box and whisker diagram of TDoA estimates for channel center frequency at 3580 and 3680MHz.

- Collecting random signals: Different part of information packet and interference cause dispersed TDoA estimation results.
- Signal attenuation and multipath propagation mislead the estimation of TDoAs.

Future Work

- Add in more mobile sensors or transceivers in wider area.
- Implement in 3D Cartesian coordinate system.
- Explore the weights for different estimation results when taking the average (TDoA estimates, MSE results for localization).

Conclusion

- Localization results
- Interference localization tool
- Localize any unknown signal source in POWDER.
- Applicable for other operators in shared spectrum scenarios.
- Open source: https://gitlab.flux.utah.edu/Chiaying/interference_source_localization

References

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[2] Neal Patwari, Joshua N Ash, Spyros Kyperountas, Alfred O Hero, Randolph L Moses and Neiyer S Correal. "Locating the nodes: cooperative localization in wireless sensor networks", *IEEE Signal processing magazine*, 22(4):54–69, 2005.

[3] Yiu-Tong Chan and KC Ho. "A simple and efficient estimator for hyperbolic location", *IEEE Transactions on signal processing*, 42(8):1905–1915, 1994.