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WINLAB | Wireless Information Network Laboratory

Effecient Time-Frequency Localization of Packet Based Radio Transmitters

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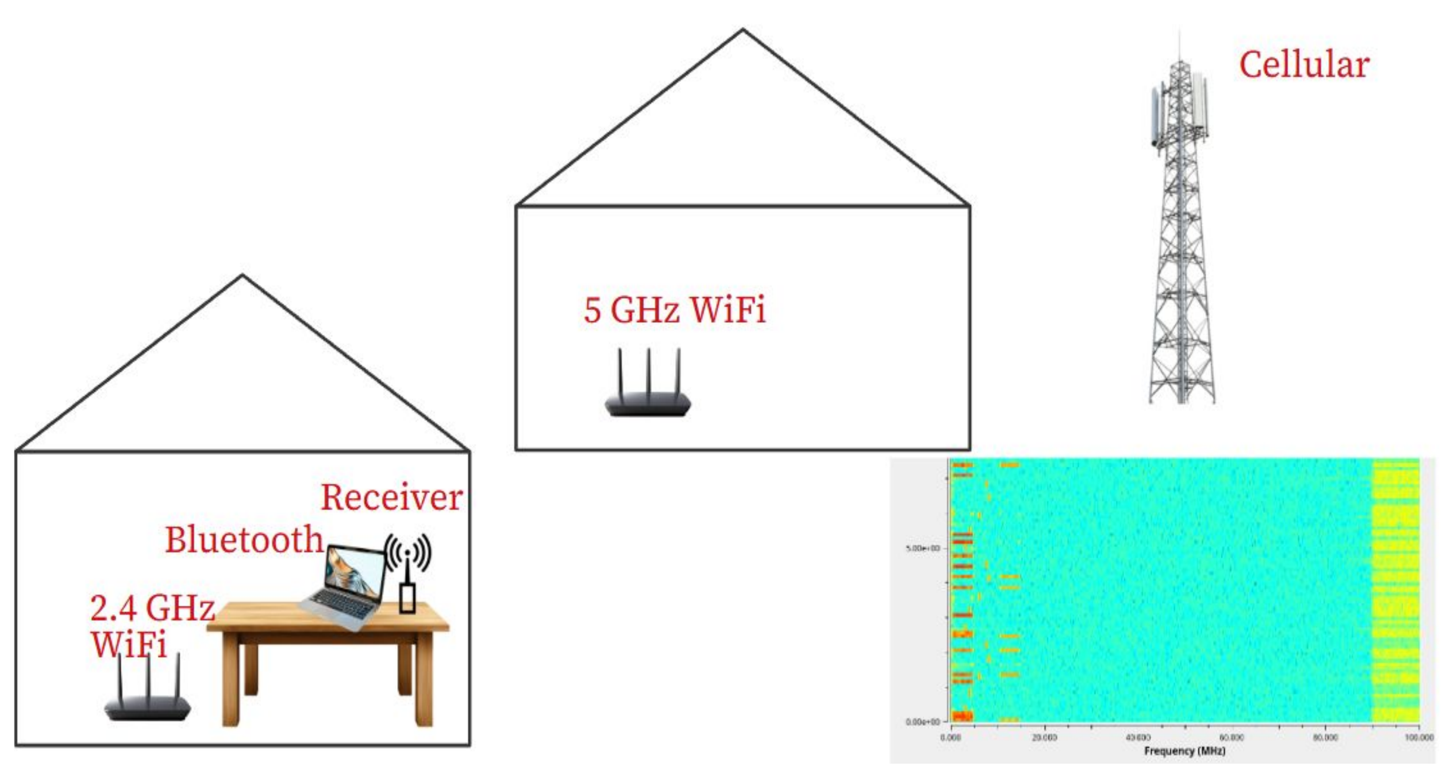
Abstract

We propose an iterative methodology for estimating time-frequency bounds on wireless communication packets in a spectrogram.

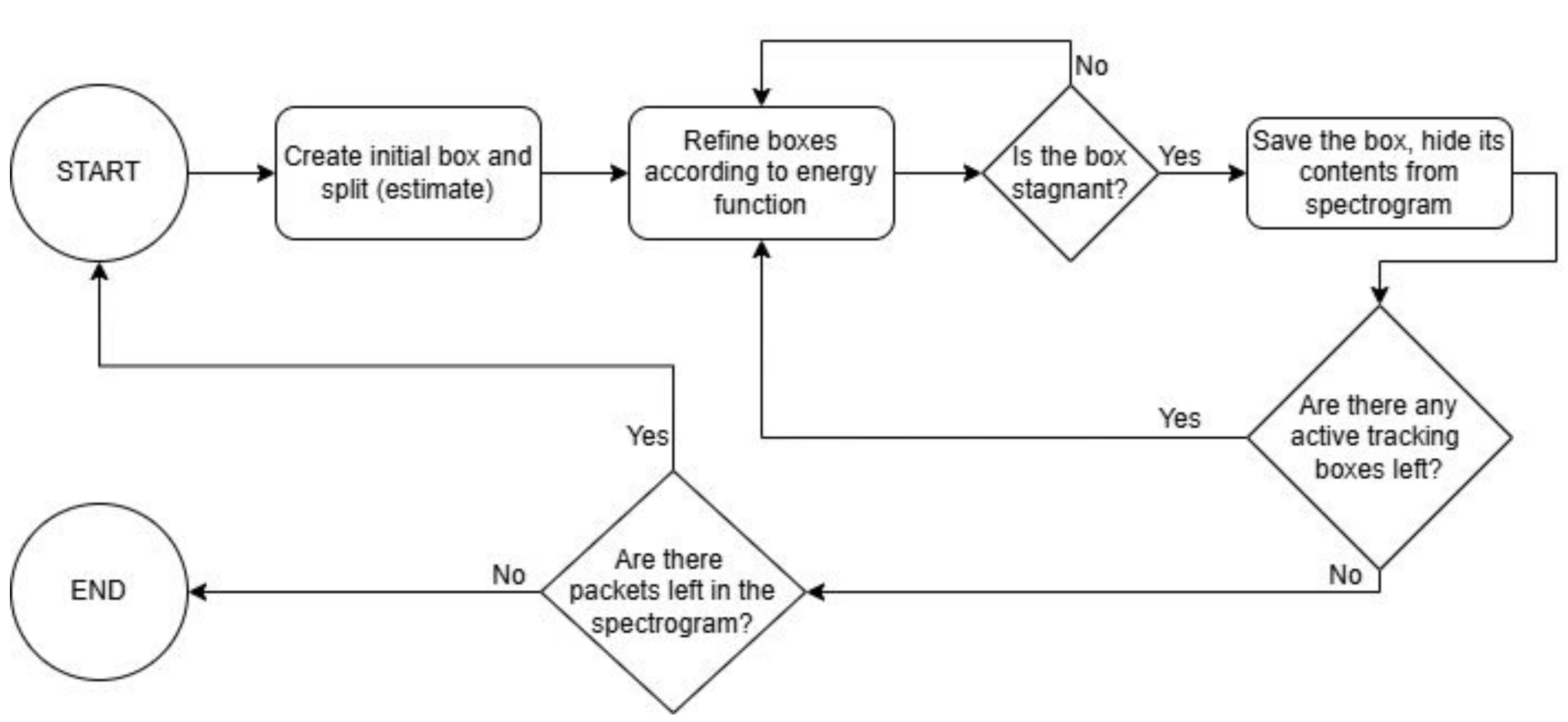
- We assume that the user has estimates for packet bandwidth and duration
- Our algorithm relies on a few parameters that can either be manually selected or estimated via a neural network
- Our algorithm proves more efficient than comparable techniques by leveraging problem-specific information

Problem Setup & Methods

One candidate scenario is shown below. We wish to localize the packets from each radio transmitter in time and frequency.



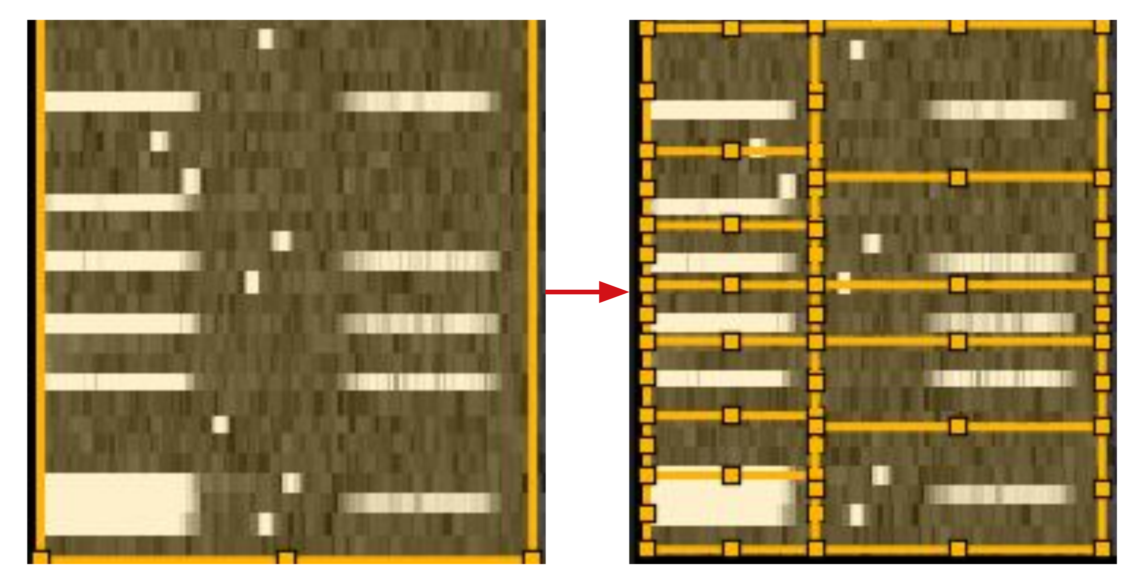
In order to do so, we repeatedly estimate and refine bounding boxes across the spectrogram until we have "good" bounds for every packet as quantified by a custom metric.



Methods, Continued

Estimate:

1. Create 1D sequences of the means in both time and frequency
2. Compute moving averages with window sizes = smallest size from the protocol
3. With moving average peaks as centers, create partitions of the original interval
4. Combine both 1D partitions to create a 2D grid partition



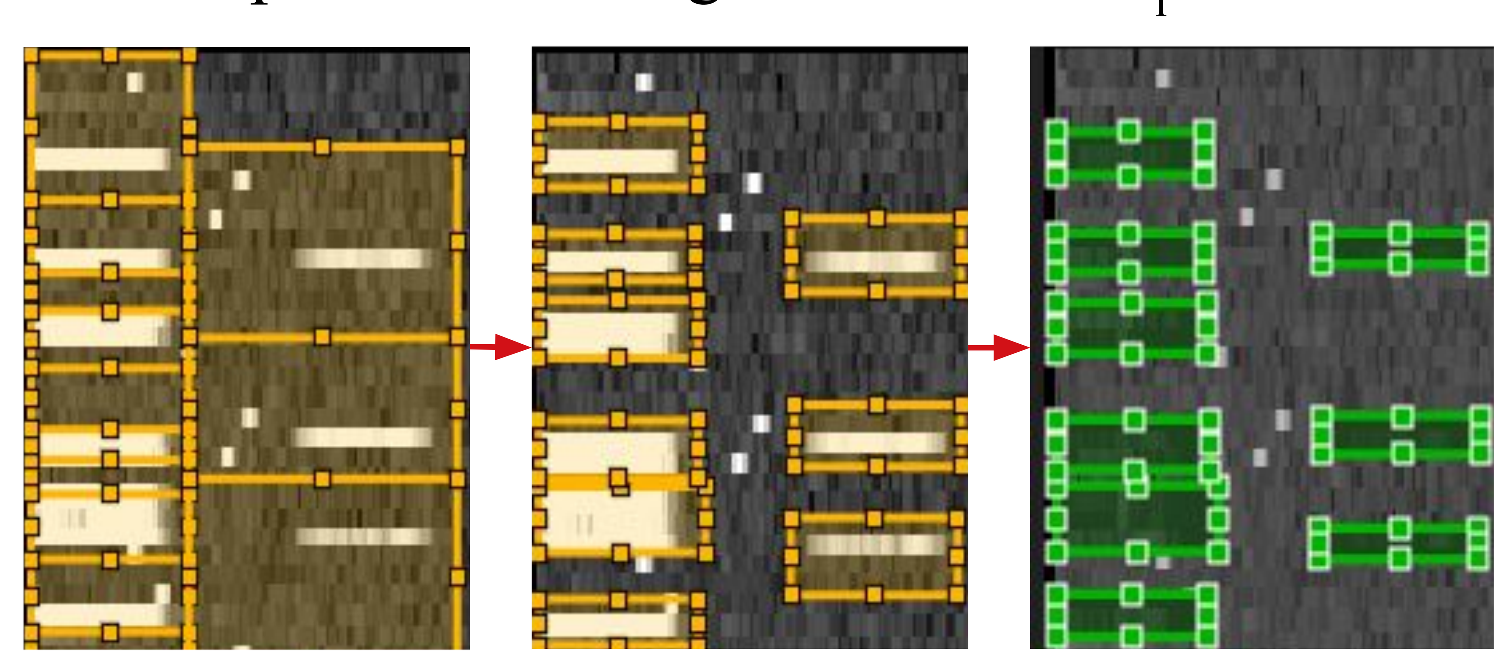
Refine:

We optimize for a metric that combines:

1. A penalty for the distance between the center of power in a box and the geometric center, denoted $F_c(\mathbf{x}_i)$
2. A penalty for the difference between the current size and the allowable size from the protocol, denoted $F_s(\mathbf{x}_i)$
3. A multiplier based on how much power in the box falls below the noise threshold estimate, denoted $G(\mathbf{x}_i)$

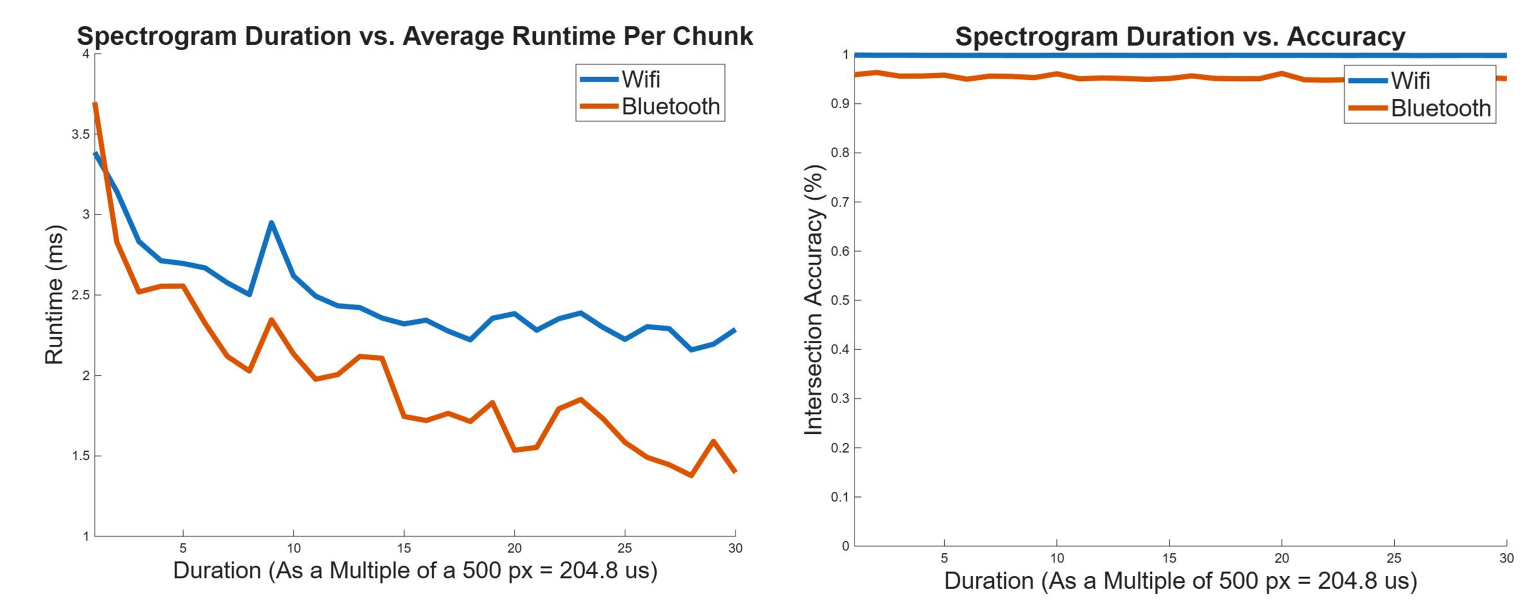
$$E(\mathbf{x}_i) = G(\mathbf{x}_i)(F_s(\mathbf{x}_i) + F_c(\mathbf{x}_i))$$

$-\nabla E$ then encodes a flow towards an optimal bounding box for each $\mathbf{x}_i$.



Conclusion & Future Work

On a dataset of 100 GNU radio simulation spectrograms with SNR $\in$ [10dB, 20dB] and size (100 px, 500 px), we benchmarked our algorithm running in MATLAB Online.



These benchmarks were performed using a static set of manually-chosen parameters. Training neural networks to estimate variable parameters as functions of physical quantities, implementing parallelization, and porting the code to C/C++ will almost certainly improve accuracy and massively improve performance.

Fast and accurate localizations can allow for the detection of various RF anomalies, such as:

- denial of service attacks
- transmissions of unknown protocols
- interference between known protocols

It is our hope that this work may advance the feasibility of real-time packet localization and improve RF anomaly detection in future wireless communication technologies.

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