Low-Complexity Detection of Signals Under Unknown Bandwidth Constraints

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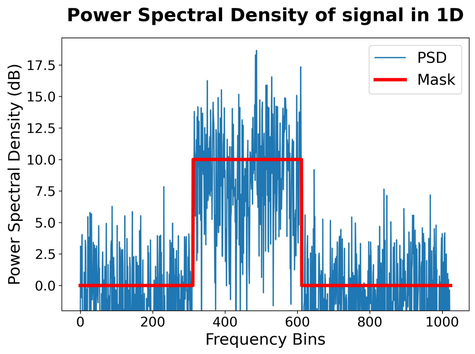
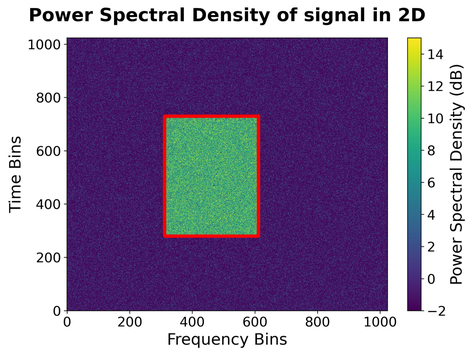
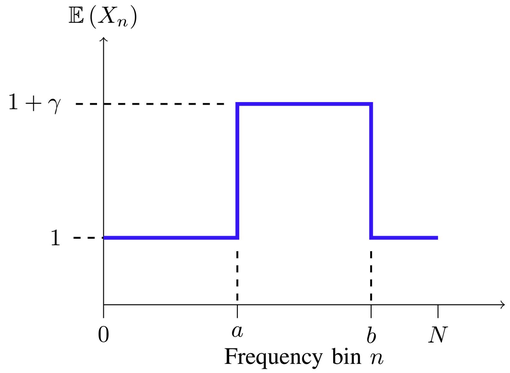
Outstanding paper award at Asilomar 2025

Background & Motivation





- **Problem:** Signal detection when frequency, bandwidth, time are unknown.
- **Applications:** Cognitive radio, adversarial comms, radar, upper mid-band coexistence.
- **Challenge:** Traditional FD-ED methods fail under unknown occupancy.



$$\mathbb{E}[X_n] = \begin{cases} 1+\gamma & \text{if } n \in S \\ 1 & \text{if } n \notin S \end{cases}$$

- Non-coherent exponentially distributed power measurements.
- Signal interval unknown.
- Detection based on GLRT metric.

Methodology & Algorithms

$$J(S,\gamma) := \log\left[\frac{p(\boldsymbol{X}|S,\gamma)}{p_0(\boldsymbol{X})}\right] \qquad J_\ell^* := \underset{\substack{S,\gamma\geq 0 \\ |S|=\ell}}{\operatorname{argmax}} J(S,\gamma)$$

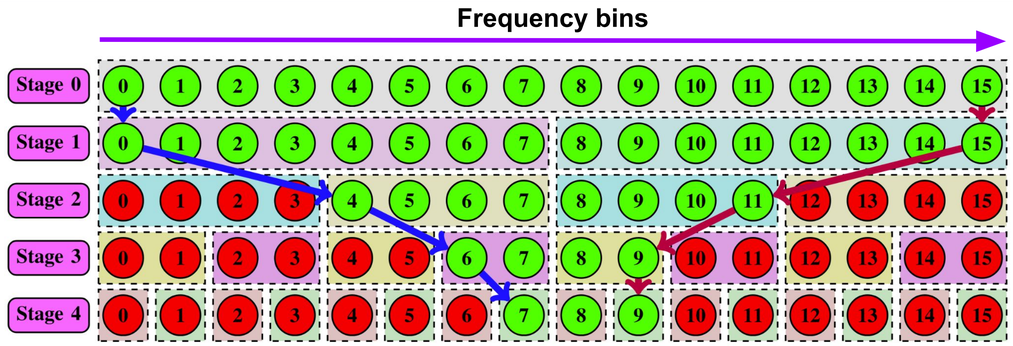
$$J(S,\gamma) = |S|\left[\overline{X}_S\left[\frac{\gamma}{1+\gamma}\right] - \log(1+\gamma)\right]$$

$$J(S) = |S|\left[\overline{X}_S^+ - 1 - \log(\overline{X}_S^+)\right]$$

$\overline{X}_S^+$ → Normalized mean power in S

$$u_\ell = \frac{1}{2\ell}F^{-1}\left(\frac{2P_{\text{FA}}}{N^2};2\ell\right)$$ Interval dependent thresholding

$$P_{\text{FA}} \leq \frac{N^2}{2}\max_{\ell=1,\ldots,N} F(2\ell u_\ell;2\ell) \qquad P_{\text{MD}} \leq 1 - F\left(\frac{2\ell u_\ell}{1+\gamma};2\ell\right)$$

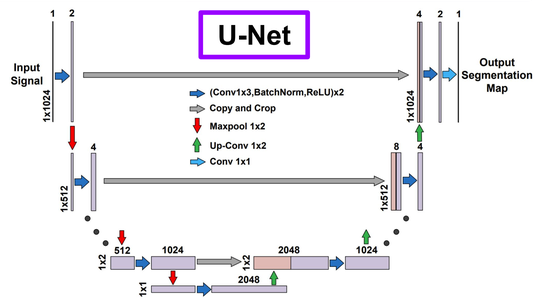


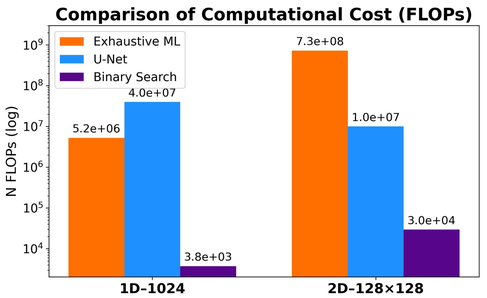
Efficiency through Dyadic Interval Search

$$\widehat{H} = \begin{cases} 1 & \text{if } \overline{X}_S \geq u_{|S|} \text{ for some } S = I_{m,i} \\ 0 & \text{if } \overline{X}_S < u_{|S|} \text{ for all } S = I_{m,i}. \end{cases} \qquad I_{m,i} = [i2^m, (i+1)2^m) \subseteq [0,1,\ldots,N)$$

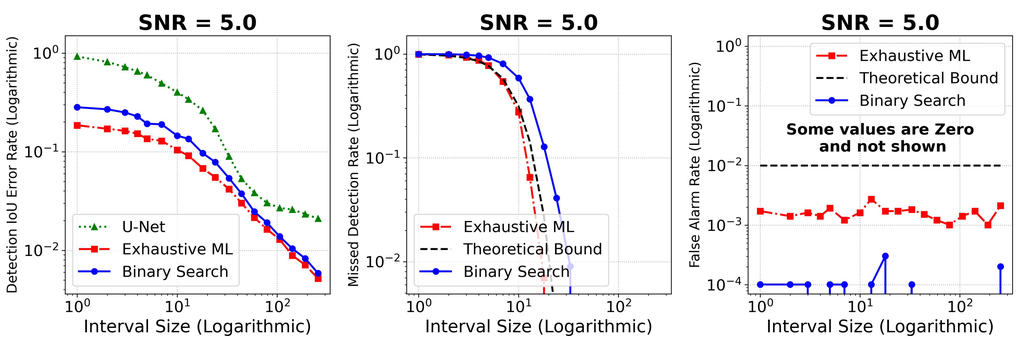
$$\widehat{S}_N^{(t)} = [\widehat{a}_N^{(t)}, \widehat{b}_N^{(t)}) \qquad \text{IoU}_N^{(t)} = \frac{|\widehat{S}_N^{(t)} \cap S_N^0|}{|\widehat{S}_N^{(t)} \cup S_N^0|} \qquad \lim_{N,t\to\infty} \text{IoU}_N^{(t)} = 1$$

Under constant SNR per bin, the interval-of-overlap converges to 1 almost surely as N goes to infinity





Results, Comparison & Takeaways



- **GLRT-based binary search = *near-optimal detection at 0.1% of computation***
- **Consistent and robust across SNRs and bandwidths**
- **Outperforms deep neural nets without training cost**
- **Ideal for real-time spectrum sensing**