Large Scale Spectrum Sensing Implementation for Cognitive Radio Systems

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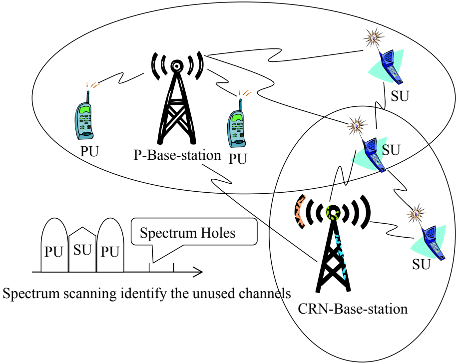
Introduction

- Dynamic spectrum access as a solution for spectrum shortage
- Mutliband spectrum sensing to identify unused frequency bands quickly and accurately
- Research focuses on developing optimal sensing algorithms, not much literature on the implementation of these algorithms



Objective

- Develop a framework that can be deployed in a grid testbed with multiple nodes such as ORBIT testbed.
- Each node is equipped with universal software radio peripheral (USRP).
- Develop spectrum sensing algorithms suitable for practical implementation.
- Implement the algorithms and study their performance.

System Model

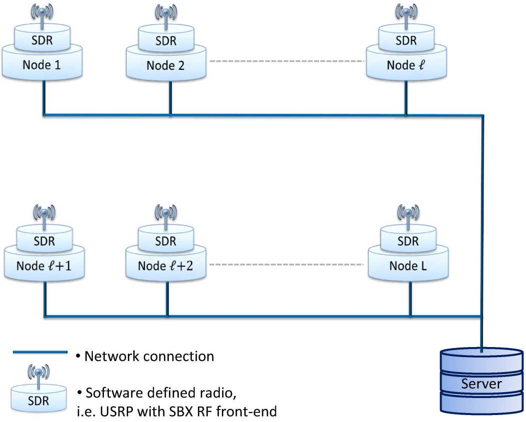
- Total number of bands $M = \lceil B_w / B_{wc} \rceil$
- Number of sensors: L

$$
\begin{aligned}
H_0^{(m)} &: y_{n_m} = w_{n_m}, \quad n_m = 1, 2, \ldots \quad , \\
H_1^{(m)} &: y_{n_m} = x_{n_m} + w_{n_m}, \quad n_m = 1, 2, \ldots \quad ,
\end{aligned}
$$

- Probability of mis-detection $P_{MD}^{(m)}$
- Probability of false-alarm in any band $P_{FA}^{(m)}$

Sensing Framework

- ORBIT measurement library (OML)$\Longrightarrow$ Collects sensing data
- Each node: USRP2/N210 and SBX daughterboard $400 - 4400 MHz$
- Use C++ along with USRP-UHD driver in each node



Multiband Time-Based Energy Detection

- A simple energy detector for each band:

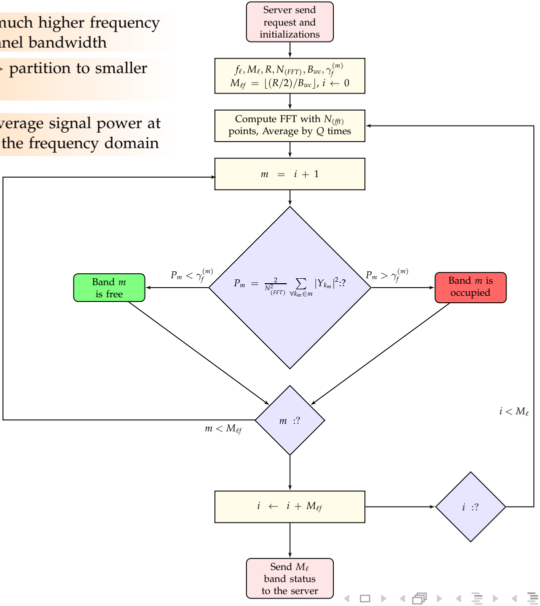
$$\frac{1}{N_m} \sum_{n_m=1}^{N_m} |y_{n_m}|^2 \underset{H_0^{(m)}}{\overset{H_1^{(m)}}{\gtrless}} \gamma_t^{(m)}$$

- Repeat for each band
- Fixed total number of samples at sensor ℓ:

$$ASN_\ell = \sum_{m=1}^{M_\ell} N_m$$

Multiband FFT Based Sensing

- Sample at much higher frequency than the channel bandwidth
- Take FFT ⇒ partition to smaller segments
- Compute average signal power at each band in the frequency domain



Multiband Sequential Sensing

- A sequential procedure can perform better than a fixed sample size procedure.
- Use a concatenation of SPRT tests accompanied by time truncation.
- Threshold bounds are characterized by the target SNR and error probabilities.

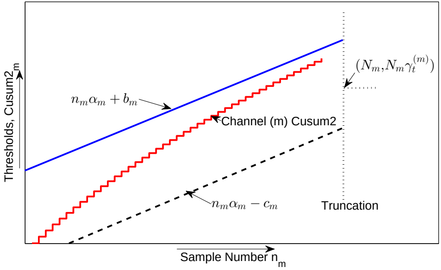
$$\frac{\prod_{j=1}^{n_m} q_1^{(m)}(y_j)}{\prod_{j=1}^{n_m} q_0^{(m)}(y_j)} \overset{H_1^{(m)}}{>} B_U^{(m)}, \text{ and } \frac{\prod_{j=1}^{n_m} q_1^{(m)}(y_j)}{\prod_{j=1}^{n_m} q_0^{(m)}(y_j)} \overset{H_0^{(m)}}{<} B_L^{(m)}$$

$$\sum_{j=1}^{n_m} |y_j|^2 \overset{H_1^{(m)}}{>} (n_m \alpha_m + b_m), \text{ and } \sum_{j=1}^{n_m} |y_j|^2 \overset{H_0^{(m)}}{<} (n_m \alpha_m - c_m)$$

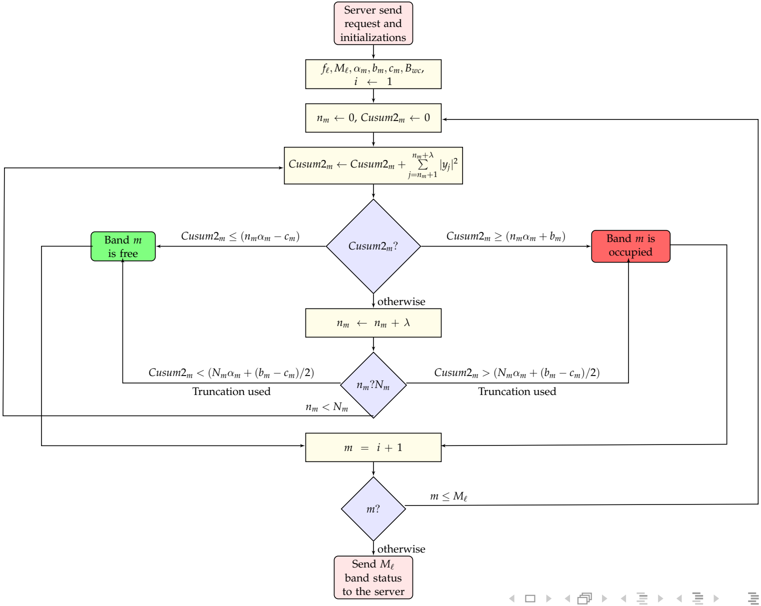
Practical Considerations

- Impose delay constraint.
- If SPRT is truncated $\Rightarrow$ use the same number of samples as energy detector.
- Sample a block of samples with size λ.

- Calculate $\gamma_t^{(m)} = \alpha_m + \frac{b_m - c_m}{2N_m}$
- Assume $P_{MD}^{(m)} = P_{FA}^{(m)}$, then $b_m = c_m$ and $\gamma_t^{(m)} = \alpha_m$
- Compute these values by averaging over thousand repetitions.



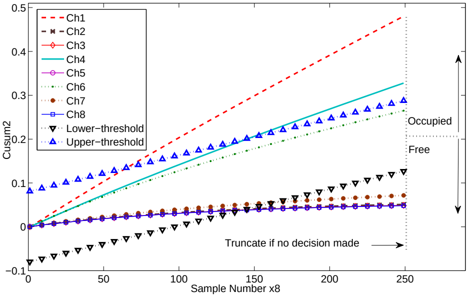
Multiband Sequential Sensing



Threshold averages

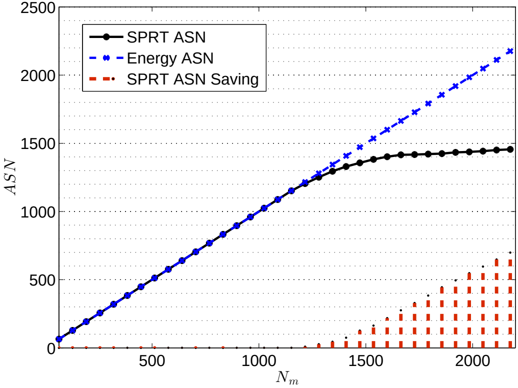
- $M_\ell = 8$, $B_{wc} = 100KHz$, $f_\ell = 500MHz$, $N_m = 2048$ and $\lambda = 8$ samples
- Inject signals with different power levels in bands $1, 4, 6$, and 7
  $\Rightarrow$ compute $Cusum2_m$ averages

- $\gamma_t^{(m)} = \alpha_m = 0.00010117$, i.e. slope of the SPRT threshold, Adjust offset values $\Rightarrow$ $b_m = c_m = 0.08$
- For FFT case, $\gamma_f^{(m)} = 0.00010375$



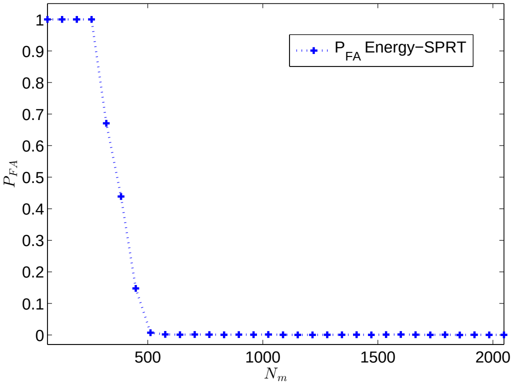
Performance, ASN

- $M_\ell = 8$, $B_{wc} = 100KHz$, $f_\ell = 510MHz$, and $\lambda = 8$ samples
- Use previously calculated thresholds



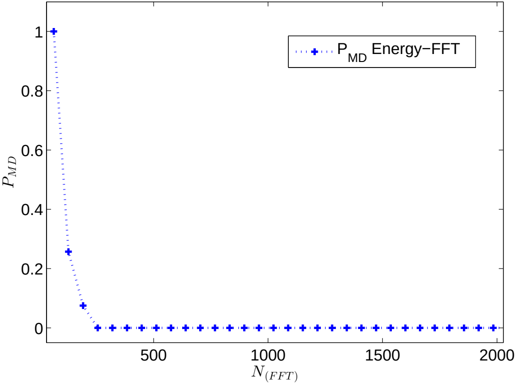
PERFORMANCE, P_{FA}

- Energy and SPRT sensing have similar performance with respect to detection errors



Performance, P_{MD}

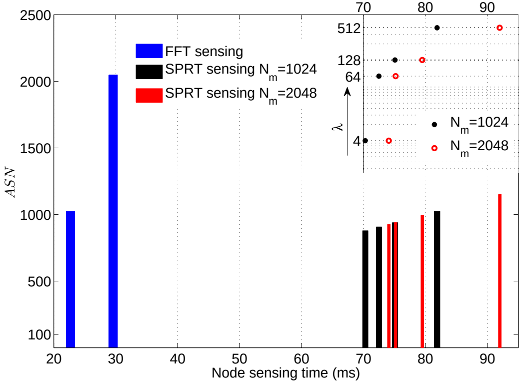
- $M_\ell = 8$, $B_{wc} = 100KHz$, $f_\ell = 510MHz$, and $Q = 8$.



Multi-Node Sensing

- $L = 8$, $M_\ell = 16$, $B_{wc} = 100KHz$, and $f_1 = 500MHz$.
- OML server collects sensing data $\Rightarrow$ repeat $\Rightarrow$ average

- SPRT uses less samples but switches band frequency more often.
- FFT based sensing covers the entire 16 bands on each node without switching the frequency.



CONCLUDING REMARKS

- We have developed a flexible sensing framework that can be used for CR research and applications.
- We have developed, implemented and evaluated performance of three sensing algorithms using our sensing framework.
- We have shown that while SPRT sensing scheme performs better in terms of number of samples, it is not always wise to use it.
- Beside performance, selecting the appropriate sensing algorithm will also depend on other factors such as: channel bandwidth, SDR sampling rate, SDR RF switching time and the number of bands.

Thank you.

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