USRP testbed for spectrum sensing of OFDM signals

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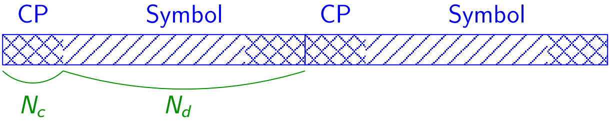
Outline

Background

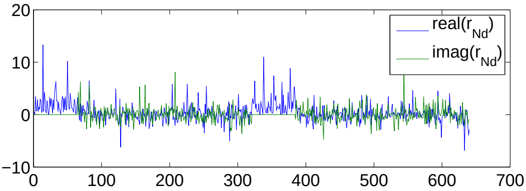
- Cognitive radio
  - opportunistic use of licensed spectrum by secondary user
  - autonomous units with adaptable radio-system parameters
  - requires ability to detect primary user activity
- Application: secondary use of TV frequencies
  - TV frequencies often underutilized
  - IEEE 802.22: rural broadband access
  - detection of primary user: spectrum sensing or (national) database
- Spectrum sensing
  - detection of primary user in licensed spectrum
  - does not require legacy channel to database
  - finer detection granularity (in time and space)
- Focus of work
  - spectrum sensing of digital TV (OFDM) signals
  - practical evaluation of sensing algorithms
  - single secondary user, idle while sensing

Feature-based signal detection

- Primary user uses OFDM signal
- FFT size: N_d, cyclic prefix: N_c

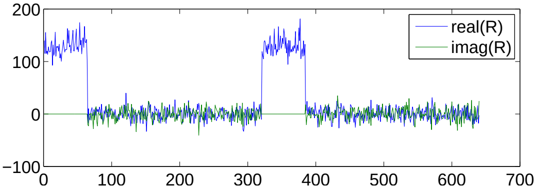


- Received signal: $x(n)$
- Define auto-correlation at distance N_d: $r_{N_d}(n) = x(n)x^*(n + N_d)$



Feature-based signal detection (cont)

- Noise suppression by averaging over K symbols:
  - $R(n) = \sum_{k=0}^{K-1} r_{N_d}(n + k(N_d + N_c)), n = 0, \ldots, N_d + N_c - 1$



- General description of sensing algorithm
  - Compute metric M based on $x(n)$, $r_{N_d}(n)$ and/or $R(n)$
  - Primary user detected if $M > t$
  - t threshold calibrated such that $P(M > t) = P_{FA}$ (false alarm probability) when primary user not present

Algorithms

- Averaging

$$M = \frac{1}{\sum_{n=0}^{K(N_d+N_c)-1} |x(n)|^2} \left| \sum_{n=0}^{N_d+N_c-1} R(n) \right|$$

- Sliding window [802.22]

$$M = \frac{1}{\sum_{n=0}^{K(N_d+N_c)-1} |x(n)|^2} \max_{\tau} \left| \sum_{n=\tau}^{\tau+N_c-1} R(n) \right|$$

- Generalized likelihood ratio test-based

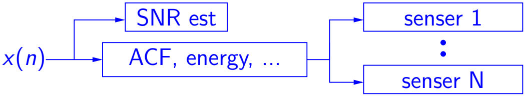
$$M = \max_{\tau} \frac{\sum_{i=0}^{N_c+N_d-1} |R(n)|^2}{\sum_{k\in S_\tau} \left| R(k) - \frac{1}{N_c} \sum_{i\in S_\tau} R(i) \right|^2 + \sum_{j\notin S_\tau} |R(j)|^2}$$

- Energy

$$M = \sum_{n=0}^{K(N_d+N_c)-1} |x(n)|^2$$

USRP implementation

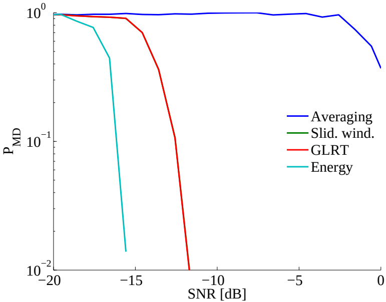
- Measurement setup
  - 1 USRP as primary user, 1 USRP as secondary user
  - secondary user is only sensing the spectrum
  - USRP 1 with RFX2400 daughterboards
  - Measurements done in university basement (weak WLAN signals present)
  - Antenna distance: ca 10 meters
- Spectrum senser data path

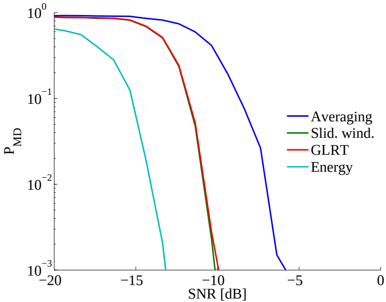


- Receiver SNR estimation
  - SNR range: -30, .. -10 dB: SNR estimation hard
  - SNR estimation algorithm
    1. Measure received P_{noise} with transmitter off
    2. Measure received P_{fs} with transmitter at full power
    3. Compute $SNR_{0dBfs} = 10 \log_{10} \frac{P_{fs} - P_{noise}}{P_{noise}}$
    4. Determine SNR at A dBfs: $SNR = SNR_{0dBfs} + A$

Measurement results

- Signal bandwidth: 6.4 MHz
- Calibration for $P_{FA} = 0.05$



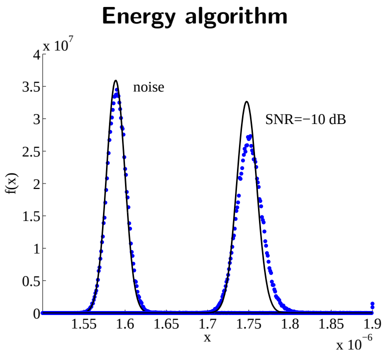


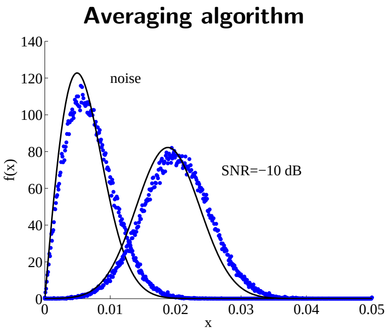
- FFT: $N_d = 2048$
- Cyclic prefix: $N_c = 64$
- Sensing time: 16.9 ms ($K = 64$)

- FFT: $N_d = 256$
- Cyclic prefix: $N_c = 64$
- Sensing time: 2.56 ms ($K = 64$)

Metric distribution

- Theoretical distribution of metrics determined for energy and averaging algorithms
- Can be used to set calculate threshold theoretically





Conclusions

- General observations
  - Sliding window and GLRT-based detectors very similar in performance
  - Averaging detector inferior
  - Energy detector superior despite being sensitive to noise estimation
  - WRAN detector similar to GLRT detector
- Future work
  - Outdoor measurements
  - Performance in presence of interference
  - Measurements with larger FFTs
  - Robustness to noise uncertainty