Energy Sensing Parameterization Criteria and Channel Availability Assessment for Cognitive Radio

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Outline

1. Motivation
2. System Description
3. Criteria
4. Assessment of Channel Availability
5. Conclusions

- MOTIVATION
- SYSTEM DESCRIPTION
- PARAMETERIZATION CRITERIA
- ASSESSMENT OF CHANNEL AVAILABILITY
- CONCLUSIONS
Cognitive Radio

- Solution to alleviate the increasing demand for radio spectrum;
- Allows unlicensed users to exploit the licensed radio spectrum.

PU – Primary User
SU – Secondary User
Motivation

๏ Study of the decision threshold parameterization of the detector energy:
 ๏ Performance Characterization (formal and validation);
 ๏ Comparison between various criteria proposed in the literature.
Most of the criteria proposed to parameterize the energy detector needs the probability of channel availability as input.
In this work we propose a characterization of the channel availability, based on the output of the Energy Detector.
Cognitive System *Single-Radio*

- Characterizing the performance of a cognitive network, wherein the secondary users perform the sensing process through an Energy Detector;

- SUs operation cycle:

  - It is assumed that only primary nodes change their behavior at the beginning of each operation cycle of the secondary nodes.
Energy-based Sensing

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Considerations:
- $w(n) \sim N(0, 1)$;
- $x(n) \sim N(\mu_s, \sigma_s^2)$.

$$\mathcal{H}_0 : x(n) = w(n) \quad n = 1, 2, \ldots, S,$$
$$\mathcal{H}_1 : x(n) = s(n) + w(n) \quad n = 1, 2, \ldots, S.$$ 

Decision $\mathcal{H}_0$ or $\mathcal{H}_1$

$$P_{FA} = Q\left(\frac{\gamma - S}{\sqrt{2S}}\right)$$

$$P_D = Q\left(\frac{\gamma - S - S\Lambda}{\sqrt{2S + 4S\Lambda}}\right)$$
Validation

Neyman – Pearson Theorem

\[ P_D = Q\left(\frac{\gamma - S - SA}{\sqrt{2S + 4SA}}\right) \]

\[ P_{FA} = Q\left(\frac{\gamma - S}{\sqrt{2S + S}}\right) \]

\[ \gamma = Q^{-1}(P_{FA}) \sqrt{2S + S} \]

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Characterization of the Network

1. Motivation

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Throughput achieved by SUs:

\[ S_{SU} = \frac{T_{D}^{SU} (1 - \tau_{PU})(1 - P_{FA})}{T_{F}^{SU}} \]

Throughput achieved by PUs:

\[ S_{PU} = \tau_{PU} P_{D} \]

Throughput achieved by PUs and SUs:

\[ S = \frac{T_{D}^{SU} (1 - \tau_{PU})(1 - P_{FA})}{T_{F}^{SU}} + \tau_{PU} P_{D} \]
Throughput validation

Probability of PUs access equal to 0.3 and 0.5
3. Criteria

- **Criterion 1**
  
  Define: \( P_I \)
  
  Calculate: \( P_D = 1 - \frac{P_I}{\tau_{PU}} \)
  
  \[
  \gamma = Q^{-1} \left( 1 - \frac{P_I}{\tau_{PU}} \right) \sqrt{2(N_S + 2\Lambda)} + N_S + \Lambda
  \]
  
  Find: \( \gamma^* \)
  
  Condition: \( N_S \geq 2W T_{SU} \)

- **Criterion 2**
  
  Maximize: \( C_2 = (1 - P_I)\tau_{SU} \)

- **Criterion 3**
  
  Maximize: \( C_3 = P_D (1 - P_{FA}) \)

- **Criterion 4**
  
  Where: \( C_4 = (1 - \tau_{PU})P_{FA} - \tau_{PU}(1 - P_D) \)

- **Criterion 5**
  
  Maximize: \( C_5 = P_D \tau_{SU} \)
Criteria Analysis

- For lower values of SNR the energy detector can not operate near the optimal point of operation;
- C2 is the criterion that provides less protection to primary nodes;
- For high values of SNR criteria C3, C4 and C5 ensure a good protection to the primary users.
Results

\[ \tau_{PU} = 0.3 \]

\[ \tau_{PU} = 0.5 \]
Channel Availability

- The SUs can access the shared channel when:
  - There are no PUs transmitting and SU observes $Y<\gamma$;
  - A PU is transmitting ante de SU observes $Y<\gamma$.

$$P_{\alpha} = (1 - P_D)H_1 + (1 - P_{FA})H_0$$
Channel Availability

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If $Y > \gamma$ then
   - $H_1$: Calculate $P_D$

IF $Y \leq \gamma$ then
   - $H_0$: Calculate $P_{FA}$

$$P_{H_1} = \frac{N_{H_1}}{N_{H_1} + N_{H_0}}$$

$$P_{H_0} = \frac{N_{H_0}}{N_{H_0} + N_{H_1}}$$

$$P_\alpha = (1 - P_D)P_{H_1} + (1 - P_{FA})P_{H_0}$$
Channel Availability

\[ P_\alpha = (1 - P_D)\mathcal{H}_1 + (1 - P_{FA})\mathcal{H}_0 \]

Parameterization threshold decision:
\[ \tau_{PU} = 0.5 \]

PD = 0.99
We have presented a parameterization criteria for the energy detector’s decision threshold according to the characteristics of the cognitive network.

Characterization of the channel availability based on the output of the energy detector weighted by the probabilities of detection or false alarm computed in real-time.
Thanks for your attention!