Distributed Cooperative Mode Identification for Cognitive Radio Applications

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Outline

• Wireless Sensor Networks
• Cognitive Radio
• Mode Identification and Spectrum Monitoring Problem
• General Distributed Scenario
• Distributed Proposed System
• Simulated and Theoretical Results
Objective

Study and develop a method useful to increase the spectrum awareness of Cognitive Radios

Wireless Sensor Network (WSN)
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- **Gather Information**: acquisition of information in a distributed way over large areas [1]
- **Communicate Information**: communication of the gathered information to a Master Sensor/Server

Open Issues [1]:

- **Sensing Problems**: related to the particular type of sensor and to the digitalization of the acquired data
- **Automatic Network Setup**: it should be possible to create a network hierarchy in an automatic and intelligent way
- **Flexible Communications**: even if a radio link brakes down it should be always possible to reach the Master Sensor/Server

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WSN: Node Model

- Antenna
- Tranceiver
- Digitalization, Communication Signal Processing, Network Intelligence
- Digitalization, Sensor Signal Processing, Sensor Intelligence

- External Sensor
Cognitive Radio

A fully cognitive radio should have the ability to do the following [2][3][8][9]:

1. **Sense** the external environment
2. **Analyze** gathered data and **classify** the internal and external status
3. **Decide** in relation to present status and by using past experience
4. **Act** in order to modify the environment or to reach precise goal and needs.
**Mode Identification and Spectrum Monitoring**

MISM is the process through which a base station or a terminal understands the radio-scene by classifying the available transmission modes and the spectrum holes in the channel. By using MISM a Cognitive Terminal should be able to:

- Recognize available modes
- Recognize spectrum holes
- Improve the efficiency of radio resources

**General Scenario**
Proposed Distributed Architecture

Wigner-Ville Time-Frequency Analysis

Feature extraction and reduction

Exchange of knowledge: A priori knowledge about the classification behavior: statistical maps of features' distribution

Classification Trees

The sources to be identified are two:

- Direct Sequence Code Division Multiple Access (WLAN)
- Frequency Hopping Code Division Multiple Access (BLUETOOTH)
Distributed Bayesian Classification

Under the hypothesis of a binary classification problem, the only presence of multiple detectors influences the classification process of each one: 

Bayesian likelyhood function: 
\[ A(y_1) = \frac{p(y_1|H_1, z_1)}{p(y_1|H_0, z_1)} \]

Bayesian distributed decision: 
\[ C_{1\text{dist}} = \begin{cases} 1 & \text{if } \frac{1}{p_1} \sum_j p(C_1|y_1, z_j)p(y_1) > \frac{1}{p_1} \sum_j p(C_2|y_1, z_j)p(y_1) \\ 0 & \text{otherwise} \end{cases} \]

Bayesian distributed threshold for sensor 1: 
\[ \theta_1 = \frac{p_1}{p_1} \sum_j p(C_1|y_1, z_j)p(y_1) - \frac{1}{p_1} \sum_j p(C_2|y_1, z_j)p(y_1) \]

The same results can be obtained for sensor 2.

The sensors have to be aware of their position in the space.

Description of the System

- Down-conversion to 30 MHz IF stage
- Sample rate: 120 Msample/s
- Wigner-Ville TF distribution: 
  \[ W(t, \omega) = \frac{1}{2\pi} \int p(t + \frac{\tau}{2}) y^*(t - \frac{\tau}{2}) e^{-j\omega \tau} d\tau \]
  - Standard deviation of the instantaneous frequency
    \[ \text{std}(\omega) = \frac{1}{T} \sum (\omega - \omega_i)^2 \]
    - Maximum time duration of the signal
      \[ T_M = \max(T(\omega)) \]
- Feature reduction method: Kahruren-Loeve
- Features statistical models: Generalized Gaussian, Asymmetric Generalized Gaussian

Important: the position of the sensor is considered known
Simulated Environment

Results (1/2)

(a) Error probability (a) and Error Rate (b) for WLAN+BLUETOOTH and Noise Classes
Results (2/2)

Error probability (a) and Error Rate (b) for WLAN+BLUETOOTH and WLAN Classes

Short Bibliography

Cognitive Radio: Terminal Model

- Antenna
- Transceiver/Radio Sensing
- Digitalization, Communication Signal Processing, Context Intelligence
Wireless Cognitive Sensor Node: Potentialities

Benefits of a Wireless Sensor Cognitive Node (WCSN):

- **Spectrum efficiency**: transmission allocation in spectrum holes
- **Security of the terminal**: an intelligent transmission of the information reduces the risk of source localization
- **Secure remote activation**: it allows a noise-like activation transmission in the spectrum holes from the Master Sensor/Server, it's possible to activate the transmissions of the nodes on-demand reducing the risk of the code interception.