Spectrum sensing issues for cognitive radios

Timo Bräysy, Janne Lehtomäki and Johanna Vartiainen
Introduction

With the rapid development of the “wireless Internet” and increasing requirements from mobile users, forthcoming wireless systems are expected to provide heterogeneous multimedia services for multiple users.

A fundamental problem in designing such a system is how to efficiently exploit and allocate limited radio resources among the users of the network.

The spectrum is one of the most critical radio resources, whose management in future wireless communication networks will be a challenging task.
Introduction: Spectrum scarcity

Opportunistic spectrum use is needed for flexible spectrum management!
Introduction: Spectrum white spaces

• The static allocation of frequencies to different systems and operators causes inefficiency!
• Periodical as well as sporadic occurrence of spectrum white spaces in several frequency bands have been reported!

Introduction: Cognitive radio research

- Ministry of transport and communications
  Press release 07.10.2009
  - ”Finland to enable field tests in Cognitive Radio”
    “Finland wants to ensure that its legislation poses no difficulties for the
development of Cognitive Radio and thus efficient use of spectrum. The Finnish legislation concerning radio spectrum will be amended accordingly during this autumn. Testing in Cognitive Radio is meant to be started in the beginning of next year.”

Definition:
A radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state;
• to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives;
• and to learn from the results obtained.
Cognitive cycle by Mitola

Orient
- Establish Priority
  - Immediate
  - Urgent
  - Normal

Plan
- Generate Alternatives
- Evaluate Alternatives
- Register to Current Time
- Allocate Resources

Learn
- Save Global States
- Prior States
- New States

Decide
- Initiate Process(es)

Act
- Send a Message
- Set Display

Observe
- Receive a Message
- Read Buttons

Outside World
- Infer on Context Hierarchy
- Pre-process
- Parse
Assumptions for FSU

• Main system assumption is that the cognitive radios are operated as secondary users (SU) of the spectrum, i.e., there is a primary user (PU) who owns (or has licensed) the spectrum and CRs must avoid interfering the PU communications.

• In order to take advantage of the opportunistic spectrum usage, the cognitive radio devices must
  1. be equipped with spectrum sensing HW and algorithms in order to locate the white spaces in the spectrum,
  2. sacrifice resources for scanning the spectrum (communication time, processing power, battery)
  3. be able to make reliable decisions about the state of the spectrum,
  4. be equipped with adjustable radio front-end HW in order to switch to the observed white space of the frequency band.

In addition, SU radio network should support the FSU operation.
Spectrum sensing studies in Cognac-project

• Fundamental spectrum sensing algorithms and their reliability.
• Protocols and decision making algorithms for applying the spectrum sensing information in opportunistic spectrum usage.
• Application of cooperative sensing in centralized as well as in decentralized network environments.
• Basic building blocks for implementing the spectrum sensing database and subsequent learning algorithms for CR devices.
• The spectrum regulatory framework is also taken into account and contributions provided to regulation.

Cognac = COGNitive And opportunistic wireless Communication networks
Spectrum sensing algorithms

Main aim is to locate the spectrum white spaces reliably in order to enable spectrum usage decision making with low enough false positive as well as false negative probabilities.

Since the primary users have strict priority to use the channel(s), highly accurate detection of the presence of the primary users by the secondary users is required.
Spectrum Sensing Based on Double Thresholding

**Aim:** To improve sensing performance by a single station.

**Approach:** The FCME and LAD ACC algorithms are used for detection.

Measurements were carried out to validate real-life performance. Combination of narrowband and wideband detection increases the detection probability (of both NB and WB signals)

Lehtomäki J., Salmenkaita S., Vartiainen J., Mäkelä J.-P., Vuotoniemi R., Juntti M.:

**Measurement studies of a Spectrum Sensing Algorithm based on Double Thresholding,**


Lehtomäki J., Vartiainen J., and Juntti M.:

**Combined wideband and narrowband signal detection for spectrum sensing,**

Cognitive radio networks with imperfect sensing

**Aim**: To analyze effects of imperfect sensing

**Approach**: State diagram based analysis of interacting primary and secondary users in case of three channels.

- False alarm probability, $P_F$
- Misdetection probability, $P_M$
- Detection probability, $P_D$

The critical $P_M$ must be minimized in real-world cognitive system

Analysis provides tools for estimating the effect of primary and secondary call and service rates.

Suliman I., J. Lehtomäki, T. Bräysy and K. Umebayashi.

**Analysis of cognitive radio networks with imperfect sensing**, in Proc of the PIMRC’09, 2009
Cognitive radio framework
Channel history database structure – Work in progress
Future plans

Implementation of LAD and basic opportunistic spectrum usage methods for WARP platforms exists.

Spectrum sensing database and spectrum occupancy decision algorithms will be added.

– Managing the database will be very challenging!

What was not included in this presentation is very important cooperative sensing issues!

Cognac project is not only about spectrum sensing: other network resources can also be managed via cognitive radio paradigm
Thank You!

Questions?