Radio Resource Management in OFDMA-CRN Considering Primary User Activity and Detection Scenario

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Outline

- Cognitive Radio Environment
- Real-time Observations & Requirement Analysis
- Learning in Cognitive Radio Networks
- Resource Allocation in Multi-carrier Systems
- Problem Formulation in OFDMA-CRN
- Simulation Results
- Conclusion & Future Works
Opportunity in 900 MHz Band

Measurements taken at Adyar, Chennai on 16th August, 2011

Fig.1. At 12:14:12 p.m.

Fig.2. At 12:24:44 p.m.

Fig.3. At 12:49:13 p.m.
Spectrum Usage in 2.4 GHz Band

On 24th August, 2011 (Adyar, Chennai)

Fig.1. At 11:30:43 a.m.

Fig.2. At 11:39:31 a.m.

Fig.3. At 11:39:51 a.m.

Fig.4. At 11:40:39 a.m.

On 24th August, 2011 (Adyar, Chennai)

Cape Town, South Africa, 12-14 December 2011
Learning in Cognitive Radio Network

- **WIRELESS ENVIRONMENT**
  - TX
  - RX

- **PARAMETERS**
- **RULES**
- **ENGINE**
  - **KNOWLEDGE**
  - **SENSORS**
  - **EXTERNAL STATE**
  - **INTERNAL STATE**
  - **RULES ENGINE**
- **WAVEFORM**
- **EXTERNAL STATE**
- **PARAMETERS**
- **OPERATIONAL FUNCTIONS**
- **RADIO COMMUNICATION CHANNELS**
- **RADIO SYSTEM**
Learning in a Broader Perspectives


Resource Allocation in Multi-carrier Base Cognitive Radio Networks

- Is situation-aware learning is enough in multi-carrier systems?
- Resource allocation
  - Sub-carrier selection
  - Power allocation
- Resource optimization
Resource Allocation in OFDMA-CRN: Problem Formulation

Objective Function:

\[
\max_{P_{g,k}} \sum_{g=1}^{G} \sum_{k=1}^{K} \alpha_g |M_g| \log_2 \left( \frac{1 + \gamma_{g,k} P_{g,k}}{K} \right) - \phi_k L(P_{g,k}) - \beta_k F(P_{g,k})
\]

Subjected to

(i) \(\sum_{g=1}^{G} \sum_{k=1}^{K} P_{g,k} I_k \leq I_{th}\)
(ii) \(P_{g,k} \geq 0, g = 1,2,...,G \quad k = 1,2,...,K\)
(iii) \(P_{g,k} P_{g',k} = 0 \quad \forall \ g' \neq g\)
(iv) \(\sum_{g=1}^{G} \alpha_g = 1\)
Optimization Methods

The overall objective defined can be assumed to be optimization of $K$ independent functions:

$$D_k(\lambda) = \sum_{g=1}^{G} \left\{ \frac{\alpha_g |M_g| \log_2 \left( 1+\gamma_{g,k} P_{g,k} \right)}{K} - \left( \sum_{n=1}^{N} \lambda_n I_k^{(n)} P_{g,k} + \phi_k L(P_{g,k}) + \beta_k F(P_{g,k}) \right) \right\}$$

Applying Karush–Kuhn–Tucker (KKT) conditions for optimal power allocation,

$$\nabla_{P_{g,k}} D_k(\lambda) = \frac{\alpha_g |M_g| \gamma_{g,k}}{K (1 + \gamma_{g,k} P_{g,k}^{*}) \log 2} - \sum_{n=1}^{N} \lambda_n I_k^{(n)} - \phi_k C_1 - \beta_k C_2 = 0$$

The KKT condition provides a basis for a closed-form solution, and $P_{g,k}^{*}$ can be derived as follows

$$P_{g,k}^{*} = \frac{\alpha_g |M_g|}{K \left[ \sum_{n=1}^{N} \lambda_n I_k + \phi_k C_1 + \beta_k C_2 \right] \log 2} - \frac{1}{\gamma_{g,k}}$$
The optimal result can be obtained as

\[
D_k^*(\lambda) = \max_g \left\{ \frac{\alpha_g |M_g| \log_2(1+\gamma_{g,k}P_{g,k})}{K} - \left( \sum_{n=1}^{N} \lambda_n I_{k} P_{g,k}^* + \phi_k L(P_{g,k}^*) + \beta_k F(P_{g,k}^*) \right) \right\}
\]

The \( \lambda \) is updated in step-size sequence given by

\[
\lambda_n^{(t+1)} = \left( \lambda_n^{(t)} - \delta(t) \left( I_{th}^{(n)} - \sum_{g=1}^{G} \sum_{k=1}^{K} P_{g,k} I_{k}^{(n)} \right) \right)^+
\]
Sub-carrier and Power Allocation (SPA) Algorithm

Start

Categorize the secondary users into different groups

Initialize ($\lambda_1, \lambda_2, \ldots, \lambda_N$)

$k=1$ (subcarrier)

Compute $P_{g,k}^*$ for all groups

Pick the group $g^*$ that gives the minimum of $D_k(\lambda)$

Assign the sub-carrier to the group $g^*$

Allocate power for the group $g^*$

Set $P_{g^*,k} = P_{g^*,k}^*$ and $P_{g,k} = 0$ for all $g \neq g^*$

Increment $k$

Is $k < K$

Yes

No

Stop
## Main Simulation Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>$N$</td>
<td>Number of primary users</td>
<td>2</td>
</tr>
<tr>
<td>$K$</td>
<td>Number of OFDM sub-carriers</td>
<td>128</td>
</tr>
<tr>
<td>$B$</td>
<td>Maximum spectrum hole</td>
<td>10MHz</td>
</tr>
<tr>
<td>$G$</td>
<td>Number of groups</td>
<td>10</td>
</tr>
<tr>
<td>$</td>
<td>M_g</td>
<td>$</td>
</tr>
</tbody>
</table>
Effects of Varying Loss Parameters

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Effects of Varying Detection Parameters

Beta (with fixed phi = 0.04)

Data rate (bps per Hertz)

C2 = 0.0
C2 = 0.2
C2 = 0.4
C2 = 0.6
C2 = 0.8
C2 = 1.0
Sum Data Rates in Two Proposed Scenarios

![Graph showing data rates in two proposed scenarios.](image-url)
Throughput Comparison

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Conclusion & Future Work

- Analysed the spectrum availability based on real-time measurements.
- Discussed the learning scenarios
- Defined the objective function and optimized it analytically.
- Developed Sub-carrier and Power Allocation (SPA) Algorithm for OFDMA-CRN.
- Analysis & simulation of the effect of both issues i.e. primary user activity and detection
- Unification of learning algorithm with sub-carrier allocation in OFDMA-CRN is our future work.
Thank You