Interference in Radio Resource Management: A Comparison of Coordinated and Uncoordinated Approaches

Philipp P. Hasselbach, Anja Klein
Communications Engineering Lab
Technische Universität Darmstadt, Germany

Dirk von Hugo, Eckard Bogenfeld
Deutsche Telekom Laboratories
Darmstadt, Germany

This work was partly funded by Deutsche Telekom AG
Motivation

- Fluctuating resource demand of the cells
  - Rush hour traffic
  - Change in user behaviour
  - Change in environment

Dynamic Resource Allocation (RA)

- Coordination in RA
  - Effect on Interference
  - Effect on Performance
Coordination in Resource Allocation

Uncoordinated:

I take SC 1.

Local Scheduling

Coordinated:

Can I take SC 1?

OK, I take SC 2

Inter-BS communication

+ : Collisions can be avoided QoS
- : Overhead? Implementation?

+ : easy implementation
- : Collisions, QoS?

ITG FG 5.2.4, 32. Treffen, 18. Februar 2010  |  Philipp P. Hasselbach, Technische Universität Darmstadt, Communications Engineering Lab
Outline

- **System Model**
  - Resource Allocation
    - Coordinated Approaches
    - Uncoordinated Approaches
  - Performance Evaluation
System Model

- OFDMA, downlink
- Adaptive modulation is used

Inter-cell interference
Data signal

Reuse distance $D$

$N_C$ cells

Transmit power of cell $i$
Required bit rate of user $k$ of cell $i$
Inter-cell interference power
Noise power
SINR of user $k$ of cell $i$
Power-Bandwidth Characteristics

- Model the interdependence of transmit power, cell bandwidth and QoS
- Contain information on user distribution, environment, inter-cell interference
- Analytic derivation available
- Measurement based derivation available, determined from standard system measurements (attenuation, SINR)
Power-Bandwidth Characteristics

Probability that a certain assignment of transmit power and cell bandwidth is sufficient with respect to user QoS requirements

\[ \Gamma = \frac{P_{tx}}{P_I + P_N} \]

- \( P_{tx} \): Transmit power
- \( P_I \): Avg. interference power
- \( P_N \): Noise power
Outline

- System Model
- **Resource Allocation**
  - Coordinated Approaches
  - Uncoordinated Approaches
- Performance Evaluation
Fractional Reuse Modes

No fractional reuse
- One area per cell
- Same bandwidth and transmit power for the whole cell

Fixed fractional reuse
- Two areas per cell
- Different bandwidths and transmit powers for the two areas possible
- Constant size of the two areas

Variable fractional reuse
- Two areas per cell
- Different bandwidths and transmit powers for the two areas possible
- Variable size of the two areas

Bandwidth allocation of inner and outer area are orthogonal
Resource Allocation Techniques

- **Uncoordinated** bandwidth allocation
  - Fixed power allocation
  - Bandwidth allocation to maximise capacity
  - Reuse one
  - Random subcarrier selection

- **Coordinated** bandwidth allocation
  - Fixed power allocation
  - Bandwidth allocation to maximise capacity
  - Reuse one
  - Coordinated subcarrier selection: adjacent cells or outer areas cannot use the same subcarriers

- Transmit power allocation
  - Fixed bandwidth allocation
  - Reuse one in no fractional reuse mode
  - **Coordinated** fixed bandwidth allocation in fractional reuse mode
  - Power allocation to maximise capacity

Coordinated bandwidth allocation: B1, B2, B3 are non overlapping sets of subcarriers
RRM Approaches

Resource allocation techniques

<table>
<thead>
<tr>
<th>Fractional reuse modes</th>
<th>Power allocation</th>
<th>Uncoordinated bandwidth allocation</th>
<th>Coordinated bandwidth allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Fractional</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Fixed Fractional</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Variable Fractional</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
### Coordination in Resource Allocation

<table>
<thead>
<tr>
<th>Power allocation</th>
<th>Uncoordinated bandwidth allocation</th>
<th>Coordinated bandwidth allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Fractional</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Fixed Fractional</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Variable Fractional</td>
<td>✔ ✔ ✔ ✔</td>
<td>✔</td>
</tr>
</tbody>
</table>
Outline

- System Model
- Resource Allocation
  - Coordinated Approaches
  - Uncoordinated Approaches
- Performance Evaluation
Simulation Scenarios

- Three hotspot scenarios
  - Number of users in hotspot cell $N_{hs}$
  - Number of users in normal cell $N_0$

- Wrap around technique
  - No boundary effects

- Performance comparison of bandwidth allocation and power allocation
  - Bandwidth allocation: no frequency reuse within frequency reuse distance, fixed transmit power
  - Power allocation: fixed frequency planning, homogeneous bandwidth allocation
## Simulation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell radius $R$</td>
<td>250 m</td>
</tr>
<tr>
<td>User distribution</td>
<td>uniform</td>
</tr>
<tr>
<td>Propagation model</td>
<td>3GPP SCM Urban Macro</td>
</tr>
<tr>
<td>Shadow fading variance</td>
<td>8 dB</td>
</tr>
<tr>
<td>Hotspot strength factor $= \frac{N_{hs}}{N_0}$</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>Total system bandwidth</td>
<td>10 MHz</td>
</tr>
<tr>
<td>Scheduling</td>
<td>Fair throughput</td>
</tr>
<tr>
<td>Data rate per user</td>
<td>100 kbit/s</td>
</tr>
<tr>
<td>Inner area size for fixed fractional reuse mode</td>
<td>30 % of total cell area</td>
</tr>
</tbody>
</table>
Performance Results Single Hotspot Scenario

- Performance gain due to coordination
- Highest performance achieved with bandwidth allocation
  - log₂-relation of capacity and power

![Graph showing performance results for Single Hotspot Scenario with different bandwidth allocation strategies.](image)
Performance Results Multi Hotspot Scenario

- Performance gain due to coordination
- Independent hotspots for bandwidth allocation
- Dependent hotspots for power allocation

![Graph showing performance results for multi hotspot scenario.](image)
Performance Results Cluster Hotspot Scenario

- Performance gain due to coordination
- Dependent hotspots for bandwidth allocation
- Independent hotspots for power allocation
Performance Comparison

Single Hotspot

Cluster Hotspot

Multi Hotspot

Number of users

Hotspot strength

No frac. Uncoord. B
Fix frac. Uncoord. B
Var frac. Uncoord. B
Var frac. TxPwr
Var frac. Coord. B