Radio Resource Management in a Coordinated Cellular Distributed Antenna System by using Particle Swarm Optimization

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Introduction

• Frequency reuse factor = 1 → Cell-edge users experience inter-cell interference. Heaped-up users experience intra-cell interference
  – Solution: Heterogeneous Networks (HetNets)
    • Apart from macrocells → picocells, femtocells, remote radio heads (ports)
• With the introduction of new access point types into the network, conventional interference mitigation techniques are not valid anymore.
• New radio resource management (RRM) approaches and algorithms must be developed to optimize the system performance.
System Model – CoMP scenario

- **Scenario:**
  - Multiple ports in a cell (7 ports/cell)
  - One RB throughout the network
  - One user served per cell
  - Inter-Cell Interference (ICI)

- **Problem formulation:**
  - Maximize the worst SINR over the network
  - Each user must have a guaranteed SINR level.
Problem Formulation

\[
SINR_m(\alpha, w) = \frac{|\sum_{l=1}^{L} \alpha_{lm} \sqrt{P_{lm} h_{lmm} w_{lm}}|^2}{\sigma_n^2 + \sum_{n=1, n \neq m}^{M} \alpha_{ln} \sqrt{P_{ln} h_{lnm} w_{ln}}}^2
\]

\(m\): user in the \(m\)-th cell

\(P_{lm}\): max. Power transmitted from the \(l\)-th port antenna in the \(m\)-th cell

\(h_{lnm}\): channel gain bw. the \(m\)-th user and the \(l\)-th port in the \(n\)-th cell

\(\alpha_{lm}\): weight (power) of the \(l\)-th port antenna in the \(m\)-th cell

\(w_{lm}\): weight (beamforming) of the \(l\)-th port antenna in the \(m\)-th cell

\[
w_{lm} \triangleq e^{-j\angle h_{lmm}}, \forall l, m
\]

Problem variables \(\in [0,1]^{LM} \times \mathbb{C}^{LM}\)

\[
\text{max} \quad \min SINR_m(\alpha) \quad \text{max} \quad \min SINR_m(\alpha)
\]

\[
\alpha \quad \text{s.t.} \quad \alpha \in \{0,1\}^{LM} \text{ for BPM} \quad \alpha \quad \text{s.t.} \quad \alpha \in [0,1]^{LM} \text{ for CPM}
\]
Ahmad, et al.* defined and solved a max-min problem by setting ports on/off (binary power management), i.e. $\alpha_{lm} \in \{0,1\}$.

Solver used for the problem is Semi-Definite Relaxation (SDR).

We propose to set the port power weight in the range (continuous power management), i.e. $\alpha_{lm} \in [0,1]$.

→ A nonlinear multimodal optimization problem over $\mathbb{R}^{LM}$

We use particle swarm optimization (PSO) to solve the problem.

Particle Swarm Optimization (PSO)

- A stochastic evolutionary optimization algorithm

```
Initialize population
Do
for i=1 to population size
for d=1 to dimension size
    pick random numbers, \( r_l, r_g \sim U(0, 1) \)
    update particle's velocity:
    \[ v_{i,d} \leftarrow wv_{i,d} + c_{lr}(p_{i,d} - x_{i,d}) + c_{gr}(g_{i,d} - x_{i,d}) \]
    update particle's position: \( x_i \leftarrow x_i + v_i \)
    if \( f(x_i) > f(p_i) \) do
        update particle's best known position: \( p_i \leftarrow x_i \)
        if \( f(p_i) > f(g) \) do
            update the population best known position: \( g \leftarrow p_i \)
Until stopping criterion is satisfied
```
Complexity Analysis

• Exhaustive search $\sim O(2^{LM})$ (BPM only)

• PSO $\sim O(SLM)$ per iteration $\times N$
  
  – L: # of ports per cell
  – M: # of cells
  – S: population size
  – N: # of iterations done in PSO

<table>
<thead>
<tr>
<th></th>
<th>BPM</th>
<th>CPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 cells</td>
<td>53</td>
<td>21</td>
</tr>
<tr>
<td>7 cells</td>
<td>97</td>
<td>27</td>
</tr>
</tbody>
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Performance Evaluation

• 2-cell & 7-cell clusters with L=7 ports in each cell
• Remote radio heads (ports) located uniformly at a distance of 2/3 of the circumradius.
• 1 RB throughout the network
• At most 1 UE can use this RB in a cell.
Two cell cluster

Fig. 2: Largest minimum SINR achieved by binary power management and continuous power management for a two-cell cluster.
Two cell cluster

Fig. 3: Average transmit power per port achieved by binary power management and continuous power management for a two-cell cluster.
Fig. 4: Largest minimum SINR achieved by binary power management and continuous power management for a seven-cell cluster.
Seven cell cluster

![Graph showing average transmit power per port vs. maximum power level](image)

Fig. 5: Average transmit power per port achieved by binary power management and continuous power management for a seven-cell cluster.
Conclusion

• Instead of employing a single BS per cell, antennas (ports) and transmitted power are distributed to increase the coverage and throughput.
• Two transmission schemes: BPM & CPM
• CPM outperforms BPM especially in interference-limited region.
• For larger network, CPM performs better than BPM under practically meaningful conditions.
• Complexity of CPM is lower than that of BPM.
Thank You