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

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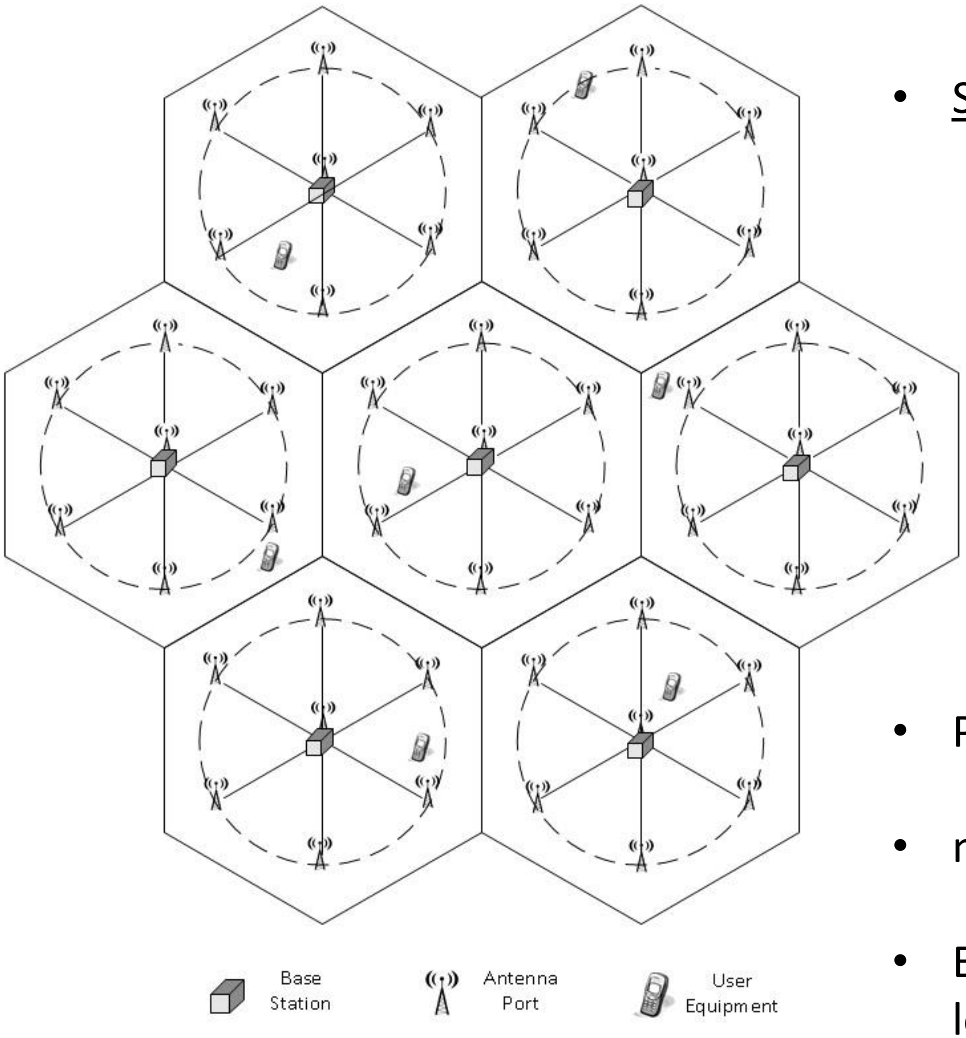
Introduction

- 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



- <u>Scenario:</u>
  - 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

$$SINR_m(\propto, \boldsymbol{w}) = \frac{\left|\sum_{l=1}^{L} \propto_{lm} \sqrt{P_{lm}} h_{lmm} w_{lm}\right|^2}{{\sigma_n}^2 + \sum_{n=1,n\neq m}^{M} \left|\propto_{ln} \sqrt{P_{ln}} h_{lnm} w_{ln}\right|^2}$$

m: user in the *m*-th cell

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

$\boldsymbol{h_{lmn}}$: channel gain bw. the m-th user and the *l*-th port in the n-th cell

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

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

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

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

$$\begin{array}{ll} \underset{\propto}{max} & \min SINR_m(\propto) \\ s.t. & \propto \in \{0,1\}^{LM} \; for\ BPM \end{array}$$

$$\begin{array}{ll} \underset{\propto}{max} & \min SINR_m(\propto) \\ s.t. & \propto \in [0,1]^{LM} \; for\ CPM \end{array}$$

Previous Work and Motivation

- 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.

* T. Ahmad, R. H. Gohary, H. Yanikomeroglu, S. Al-Ahmadi, and G. Boudreau, "Coordinated port selection and beam steering optimization in a multi-cell distributed antenna system using semidefinite relaxation," *IEEE Trans. Wireless Commun.*, vol. 11, no. 5, pp. 1861-1871, May 2012

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:
$$v_{i,d} \longleftarrow wv_{i,d} + c_l r_l (p_{i,d} - x_{i,d}) + c_g r_g (g_{i,d} - x_{i,d})$$
update particle's position: $\mathrm{x}_i \longleftarrow \mathrm{x}_i + \mathrm{v}_i$
if $f(\mathrm{x}_i) > f(\mathrm{p}_i)$ *do*
update particle's best known position: $\mathrm{p}_i \longleftarrow \mathrm{x}_i$
if $f(\mathrm{p}_i) > f(\mathrm{g})$ *do*
update the population best known position: $\mathrm{g} \longleftarrow \mathrm{p}_i$
Until stopping criterion is satisfied

Complexity Analysis

- Exhaustive search ~ $O(2^{LM})$ (BPM only)
- PSO ~ O(SLM) per iteration * N
  - L: # of ports per cell
  - M: # of cells
  - S: population size
  - N: # of iterations done in PSO

	BPM	CPM
2 cells	53	21
7 cells	97	27

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

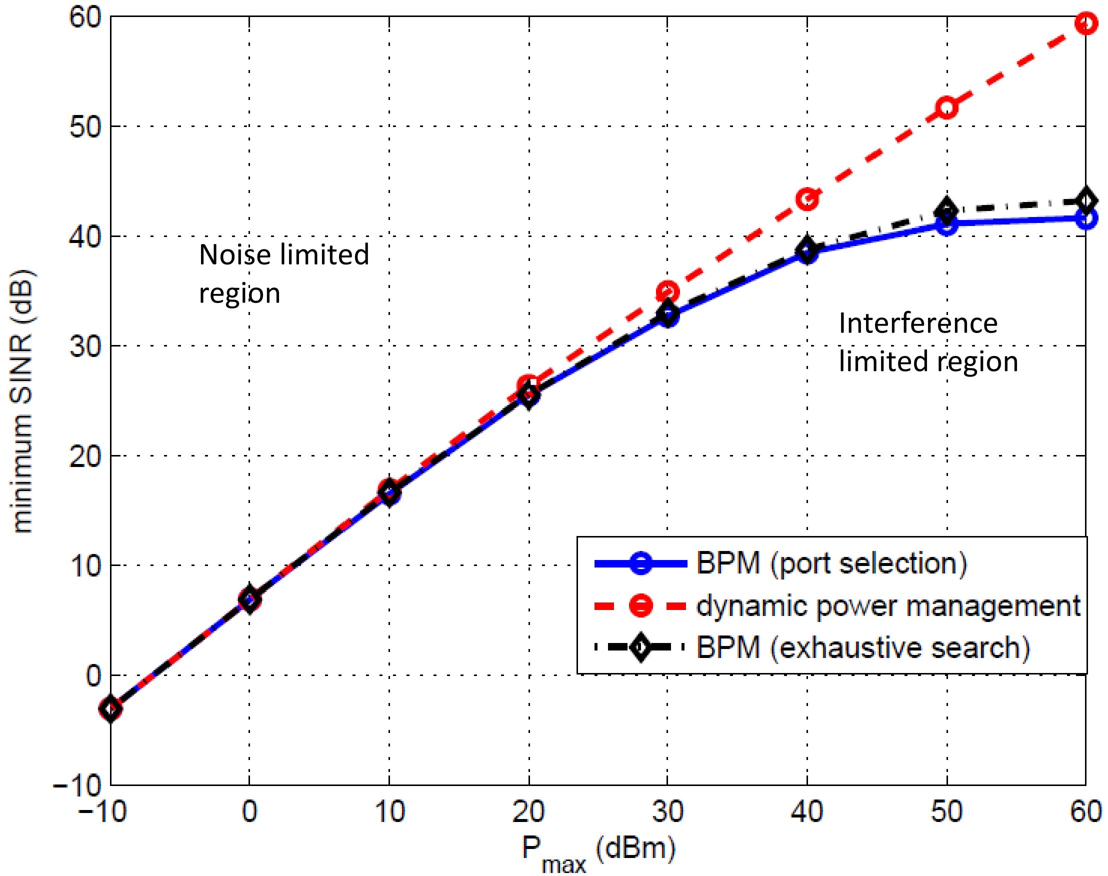


Fig. 2: Largest minimum SINR achieved by binary power management and continuous power management for a two-cell cluster.

Two cell cluster

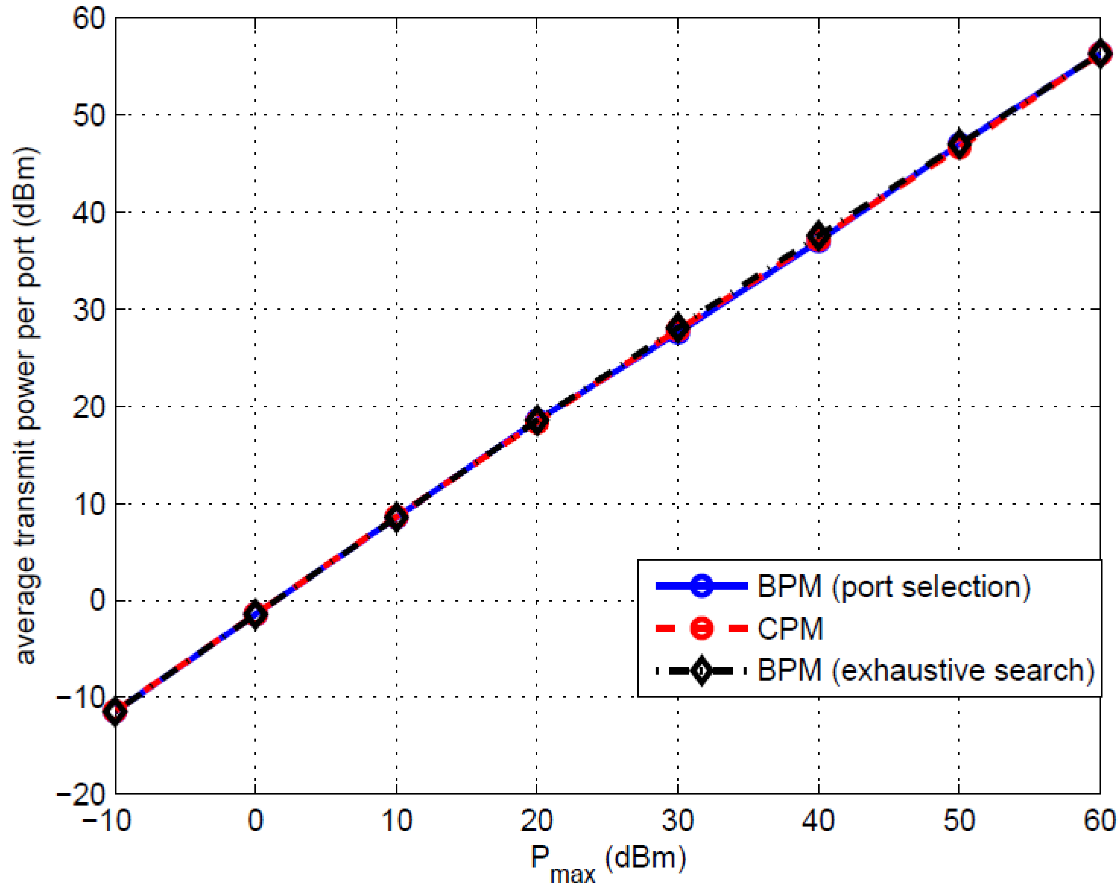


Fig. 3: Average transmit power per port achieved by binary power management and continuous power management for a two-cell cluster.

Seven cell cluster

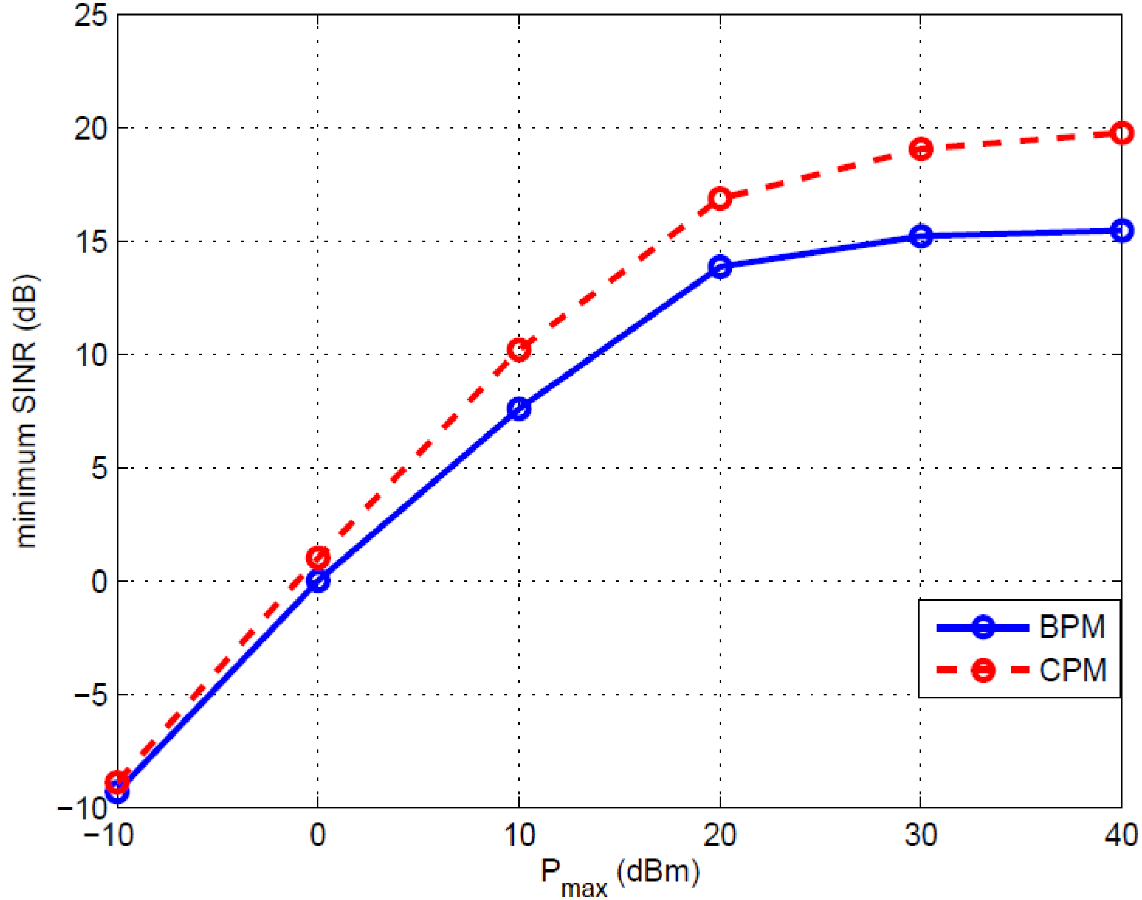


Fig. 4: Largest minimum SINR achieved by binary power management and continuous power management for a seven-cell cluster.

Seven cell cluster

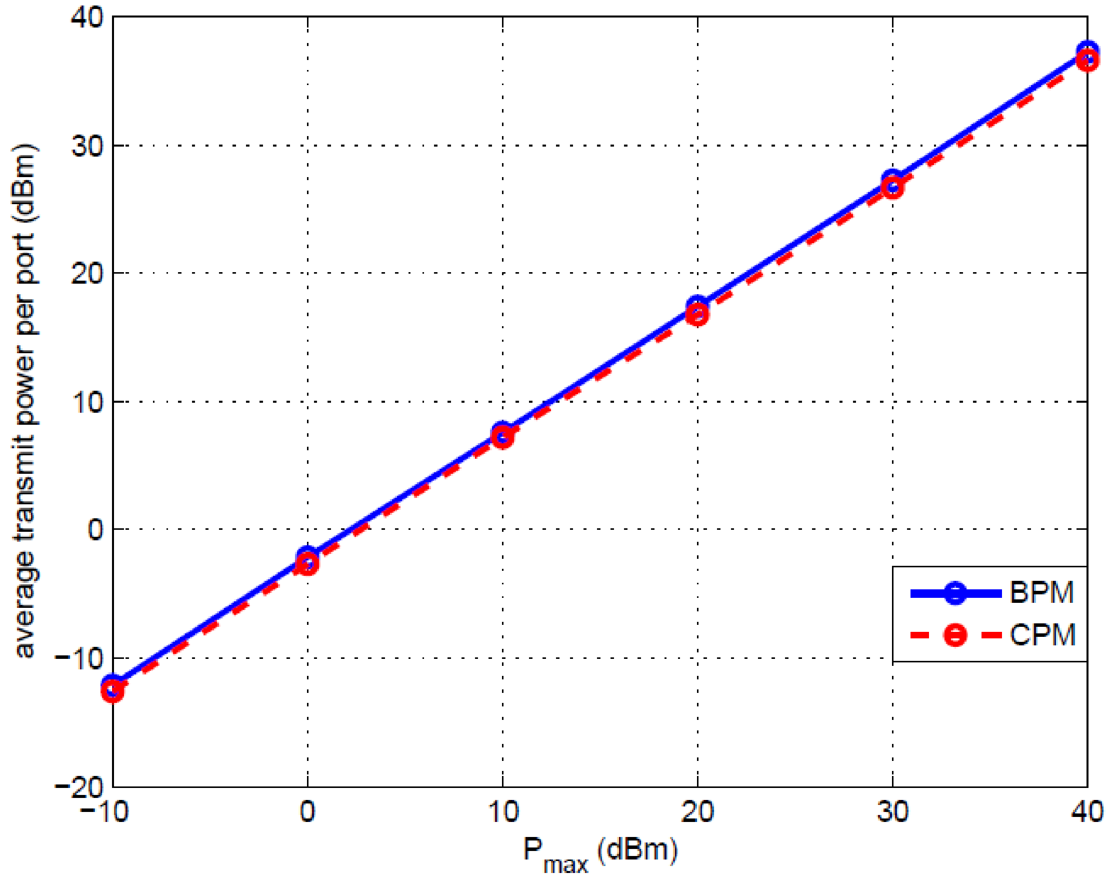


Fig. 5: Average transmit power per port achieved by binary power management and continuous power management for a seven-cell cluster.

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 expecially 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