Cooperative Scheduling, Precoding, and Optimized Power Allocation for LTE-Advanced CoMP Systems

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Agenda

- Introduction
- System Description
- Scheduling and Precoding Algorithm
- Power Allocation Algorithms
- Performance Evaluation
- Summary and Conclusion

Introduction

- The bandwidth is becoming a more scarce resource.
- The capacity of wireless cellular networks is mainly restricted by interference.
- Scheduling can definitely play an essential role in utilizing the available bandwidth.
- Increasing demand on power consumption reduction with the aim of improving the energy efficiency.
- Careful power allocation (PA) plays an important role in wireless networks performance.

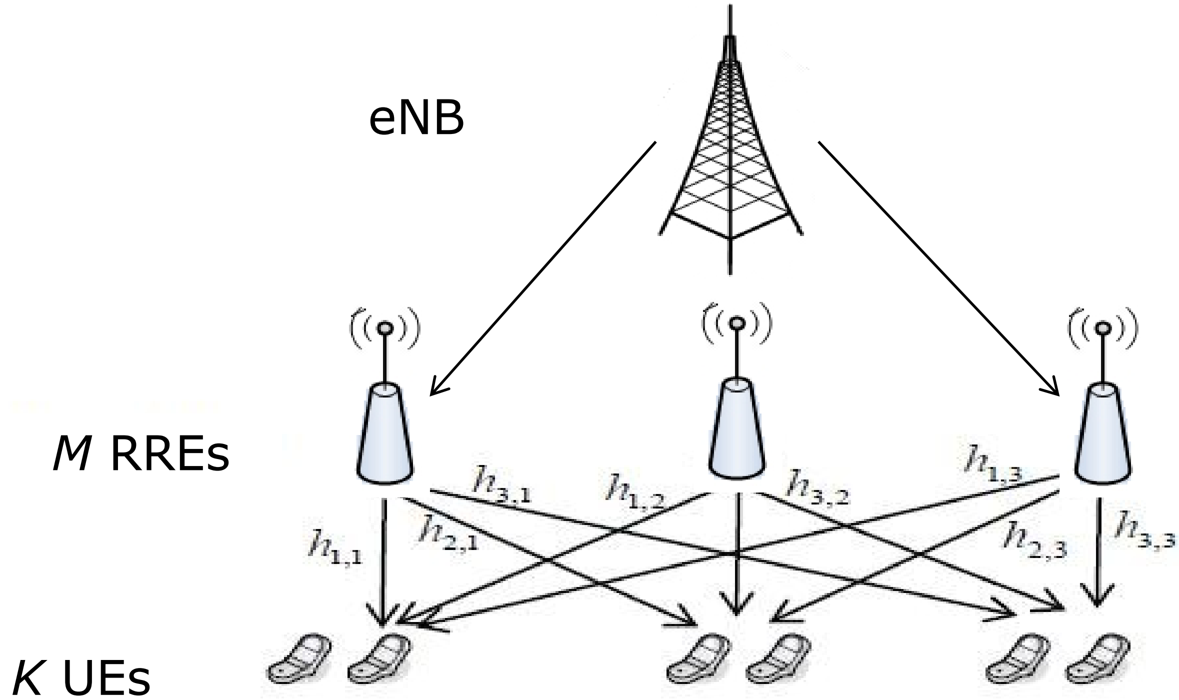
We present Scheduling, Precoding and PA algorithms based on the Signal-to-Leakage-plus-Noise-Ratio (SLNR) for CoMP systems.

Introduction

- CoMP is a technology introduced for LTE-A to meet the requirements of IMT-Advanced
- The main objectives of CoMP are:
  - To mitigate the interference
  - Provide high spectral efficiency over the entire cell area
  - Increase the overall throughput and the cell-edge throughput.

In CoMP Systems, two approaches are often considered (CS and JP)

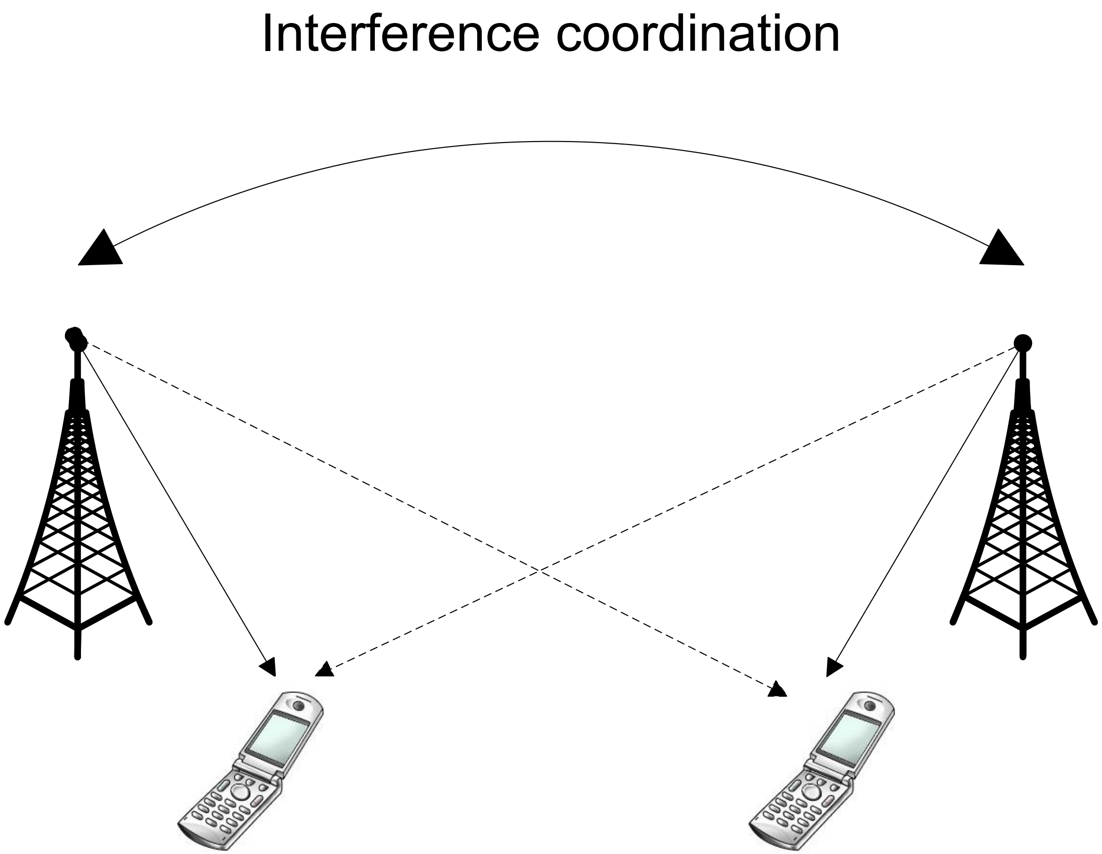
System Description



- *N* RBs are available in the system.
- Both CS and JP CoMP systems are considered.

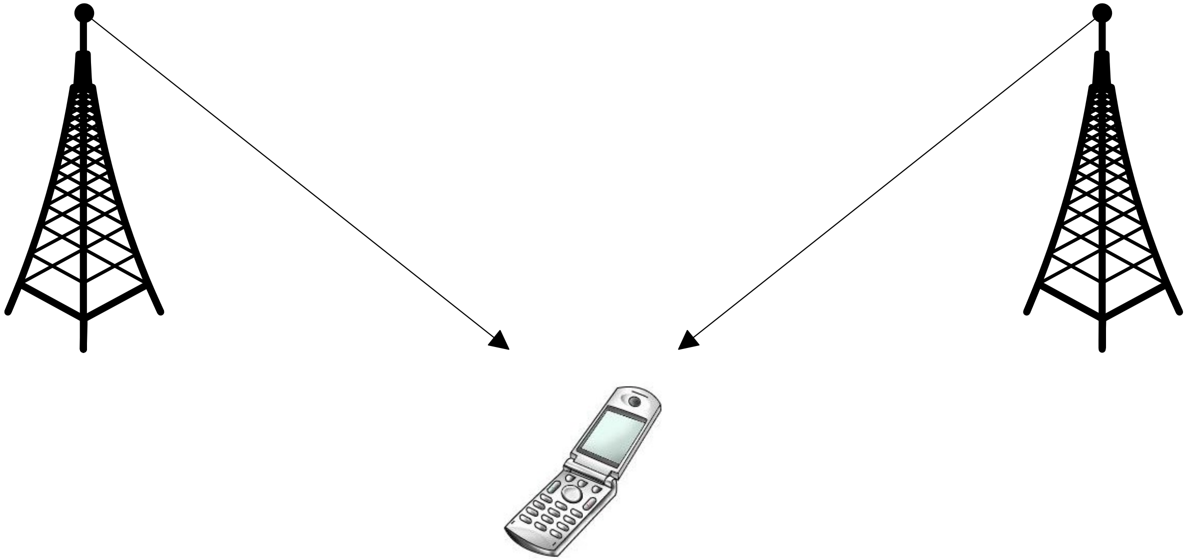
Coordinated Scheduling (CS)

- The transmission to a single scheduled UE is performed by a unique transmission point



Joint Processing (JP)

- The data is simultaneously transmitted from multiple transmission points to each UE.



System Description

- The presented schemes depend on SLNR.
- What is the SLNR β_k ?
  - SLNR is the ratio between the power intended to a UE and the power leaked towards other UEs.

$$\beta_k = \frac{P_n \left|\underline{\mathbf{h}}_k \underline{\mathbf{w}}_k\right|^2}{\sum_{k' \neq k}^{K} P_n \left|\underline{\mathbf{h}}_{k'} \underline{\mathbf{w}}_k\right|^2 + |\eta_k|^2}$$

Signal power received by *k*th UE

Signal power leaked towards other UEs

- The structure of the weighting vectors will differ between CS and JP cases.

System Description

- What is the effect of using the SLNR metric instead of the SINR metric?
  - Complexity reduction.
  - Decoupling between interference sources.

- Weighting vectors determine which RRE(s) should serve each UE.

- The weighting vector will be set in order to maximize the SLNR.

System Description

- Coordinated Scheduling (CS) scheme:
  - The weighting vector will be a vector with all elements equal to zero except only one element will be unity.
- Joint Processing (JP) scheme:
  - In this case, the weighting vector is not as simple as in the CS scheme. The weighting vector has been found previously within the context of MIMO systems with precoding using SLNR.
  - $\underline{\boldsymbol{h}}_{\boldsymbol{k}}$ is the $1 \times M$ complex channel vector of the links between the *k*th UE and all *M* RREs of the CoMP cell
  - $\widehat{\mathbf{H}}_k = \left[\underline{\boldsymbol{h}}_{\mathbf{1}}\underline{\boldsymbol{h}}_{\mathbf{2}} \cdots \underline{\boldsymbol{h}}_{\boldsymbol{k}-\mathbf{1}}\underline{\boldsymbol{h}}_{\boldsymbol{k}+\mathbf{1}} \cdots \underline{\boldsymbol{h}}_{\boldsymbol{K}}\right]^T$
  - Previous result from MIMO literature

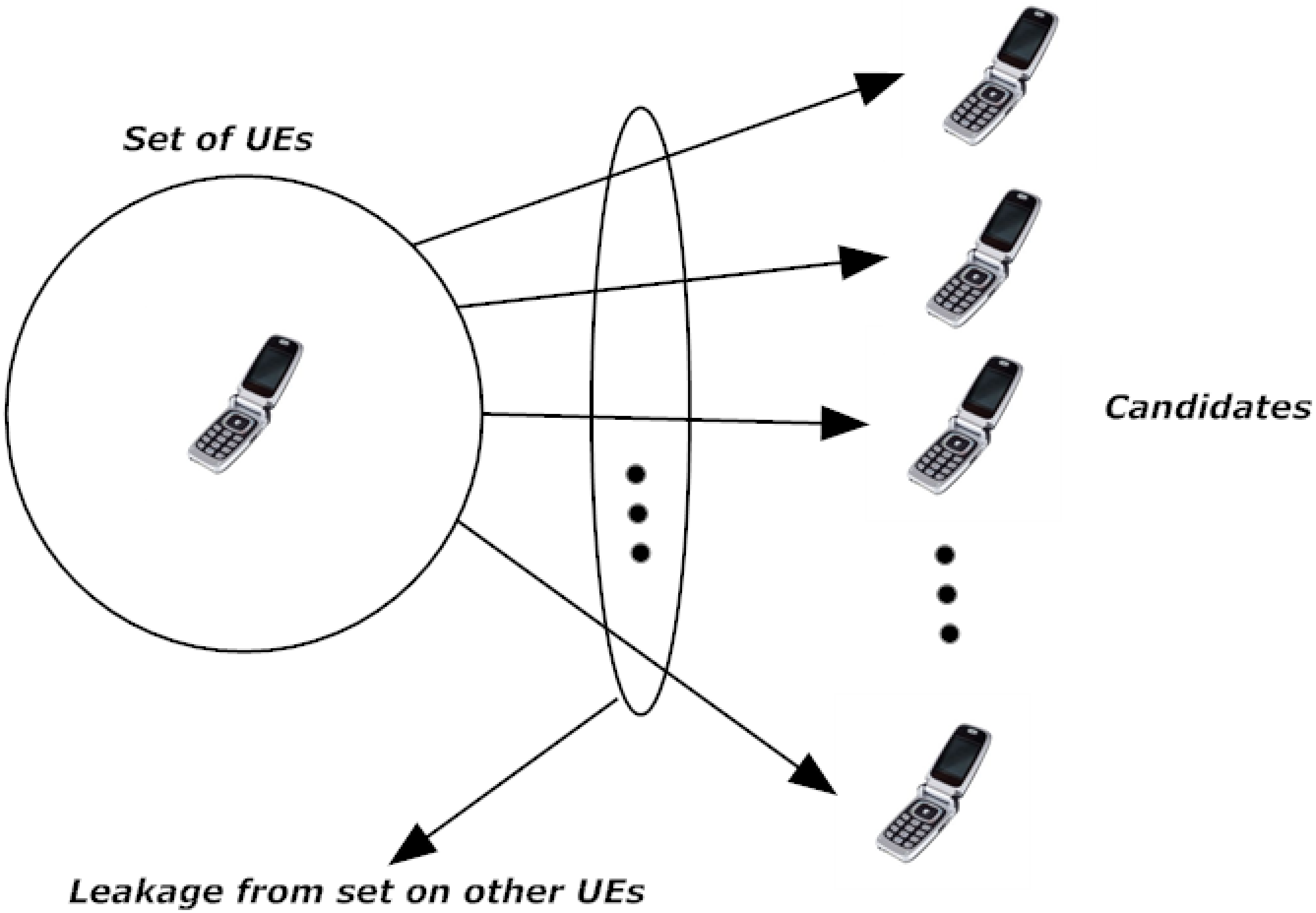
$$\underline{\boldsymbol{w}}_{\boldsymbol{k}} = \max \text{eig.vec.}\left(\left({\eta_k}^2\, \mathrm{I}_\mathrm{M} + \widehat{\mathrm{H}}_\mathrm{k}^{*}\widehat{\mathrm{H}}_\mathrm{k}\right)^{-1} \underline{\boldsymbol{h}}_{\boldsymbol{k}}^{\,*}\underline{\boldsymbol{h}}_{\boldsymbol{k}}\right)$$

Scheduling and Precoding Algorithm

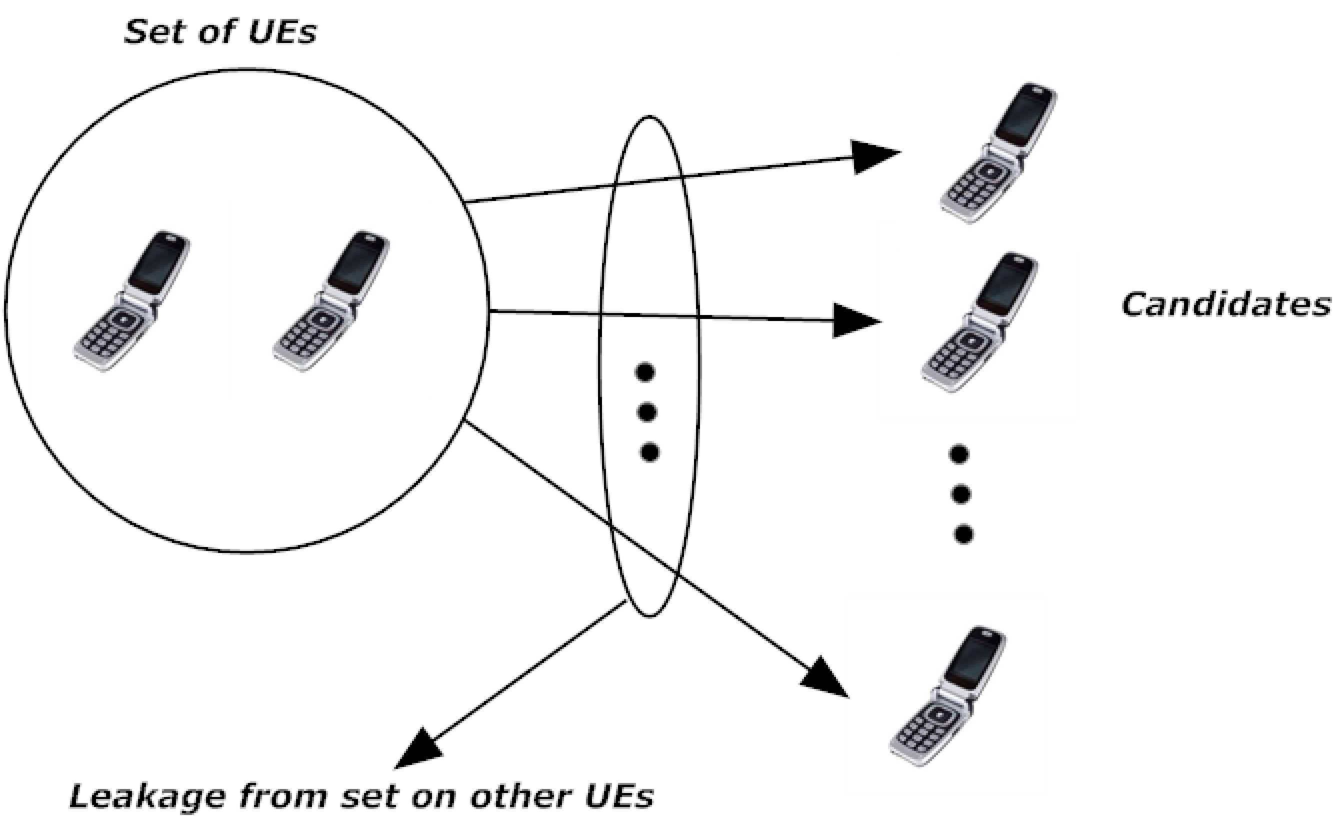
- The aim of allocating resources in a CoMP system is to maximize the throughput.
- Our proposed strategies' objective is maximizing the throughput per RB.
- This objective directly leads to maximizing the overall throughput.
- For each RB, a set of UEs will be selected by means of scheduling with their downlink data transmitted over the same RB.

The Proposed strategies select the UEs that can efficiently share the same RB without degrading the overall throughput.

Scheduling and Precoding Algorithm



Scheduling and Precoding Algorithm



Scheduling and Precoding Algorithm

- The following steps will be repeated for every available RB:

  1. Choose the UE with the maximum SLNR and set to be the first item in the set.

  $$k' = \text{argmax}_k(\beta_k)$$

  2. $\mathcal{S}_n$ is the set of UEs sharing the *n*th RB

  3. Compute the leakage value

  $$L_{\mathcal{S}_n,k'} = \sum_{k \in \mathcal{S}_n} \left| \underline{\mathbf{h}}_{k'} \underline{\mathbf{w}}_k \right|^2$$

  4. Add the UE with the least amount of leakage.

  5. Repeat steps 2-3 until the stopping condition is satisfied

  6. Details are in our WCNC'12 paper "Resource Allocation Strategies Based on the Signal- to-Leakage-plus-Noise Ratio in LTE-A CoMP Systems"

Power Allocation Algorithms

- Objective is minimizing the overall power consumption while maximizing the overall data rate.
  - Optimal Power Allocation (OPA)
  - Power Allocation Per RRE (PAR)
  - Iterative Power Allocation Per RB (IPA)
- The three problems are convex and have been solved using Newton with logarithmic barrier penalty method.

OPA Algorithm

- Objective is to maximize SLNR values for all network UEs with applying two constraints (per-RRE, per-RB).

$$\max_{P_{k,n}} \sum_{n=1}^{N} \sum_{k \in \mathcal{S}_n} \frac{P_{k,n} \left| \underline{\boldsymbol{h}}_{\boldsymbol{k}} \, \underline{\boldsymbol{w}}_{\boldsymbol{k}} \right|^2}{\sum_{k' \in \mathcal{S}_n, k' \neq k} P_{k,n} \left| \underline{\boldsymbol{h}}_{\boldsymbol{k'}} \, \underline{\boldsymbol{w}}_{\boldsymbol{k}} \right|^2 + \eta_k{}^2}$$

$$\text{subject to} \sum_{k \in \mathcal{S}_n} P_{k,n} \leq \rho_n \quad \forall\, n \in \{1, 2, \ldots, N\},$$

$$\text{and} \sum_{k \in \mathcal{K}_m} \sum_{n \in \mathcal{N}_k} P_{k,n} \leq P \quad \forall\, m \in \{1, 2, \ldots, M\},$$

- Where $\mathcal{S}_n$ is the set of UEs sharing the *n*th RB, ρ_n is the total power per the nth RB,$\mathcal{N}_{k,m}$ is the set of RBs allocated to the *k*th UE and served by the *m*th RRE, and $\mathcal{K}_m$is the set of UEs served by the *m*th RRE.

- Highly coupled optimization problem, complicated and intractable for a large system.

PAR Algorithm

- Objective is to maximize SLNR values for all UEs served by a specific RRE with applying one constraint (per-RRE).

$$\max_{P_{k,n}} \sum_{k \in \mathcal{K}_m} \sum_{n \in \mathcal{N}_k} \frac{P_{k,n} \left| \underline{\boldsymbol{h}}_{\boldsymbol{k}} \, \underline{\boldsymbol{w}}_{\boldsymbol{k}} \right|^2}{\sum_{k' \in \mathcal{S}_n, k' \neq k} P_{k,n} \left| \underline{\boldsymbol{h}}_{\boldsymbol{k'}} \, \underline{\boldsymbol{w}}_{\boldsymbol{k}} \right|^2 + \eta_k{}^2}$$

$$\text{subject to} \sum_{k \in \mathcal{K}_m} \sum_{n \in \mathcal{N}_k} P_{k,n} \leq P$$

- Solved for each RRE independently.
- Decoupled version and less complex than OPA.

IPA Algorithm

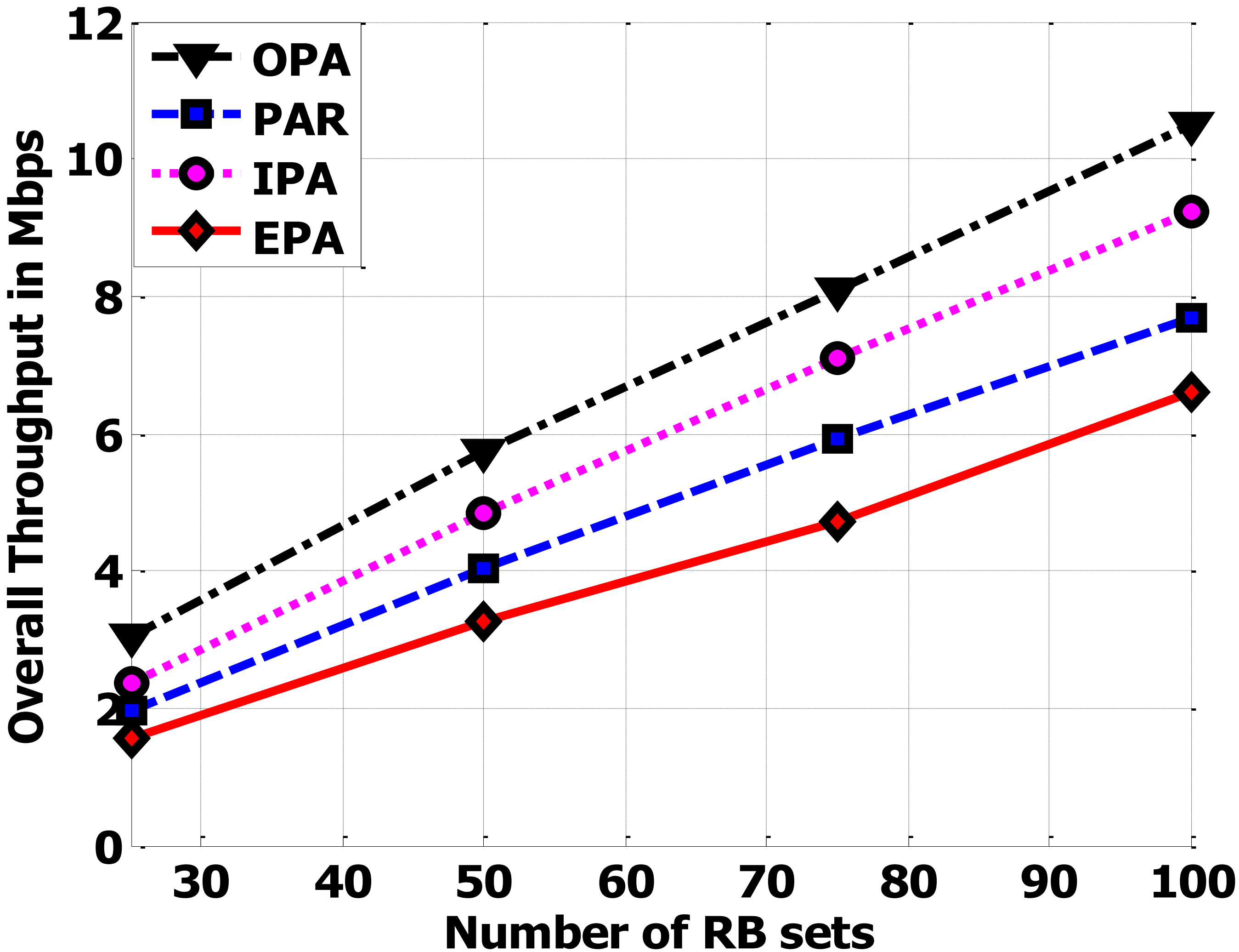
- Objective is to maximize SLNR values for all UEs served over specific RB with applying one constraint (per-RB).

$$\max_{P_{k,n}, k \in \mathcal{S}_n} \sum_{k \in \mathcal{S}_n} \frac{P_{k,n} \left| \underline{\boldsymbol{h}}_{\boldsymbol{k}}\, \underline{\boldsymbol{w}}_{\boldsymbol{k}} \right|^2}{\sum_{k' \in \mathcal{S}_n, k' \neq k} P_{k,n} \left| \underline{\boldsymbol{h}}_{\boldsymbol{k'}}\, \underline{\boldsymbol{w}}_{\boldsymbol{k}} \right|^2 + \eta_k{}^2}$$

$$\text{subject to} \sum_{k \in \mathcal{S}_n} P_{k,n} \leq \rho_n$$

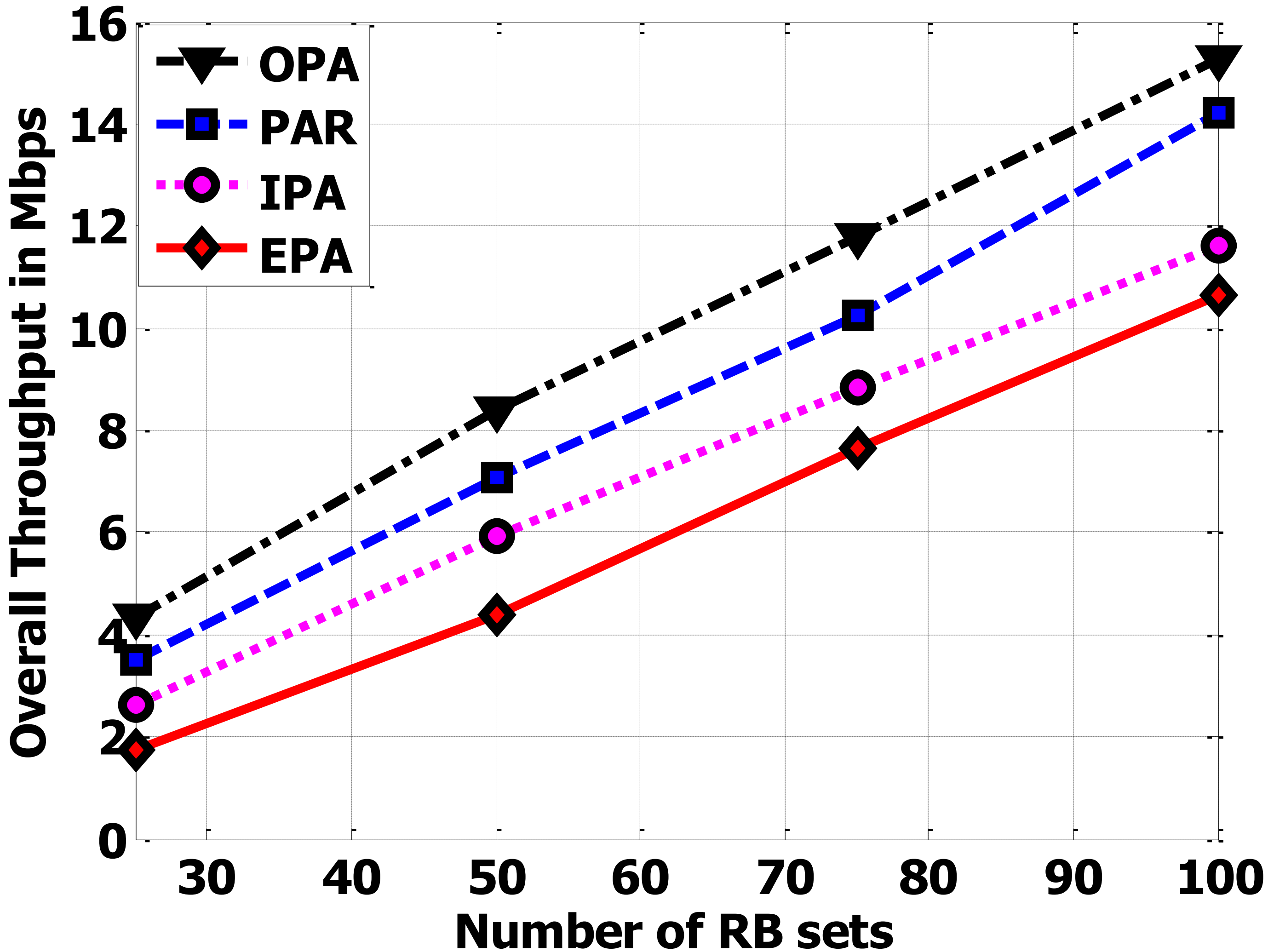
- Iterative method. Solved for each RB independently.
- Initial allocation assuming uniform power allocation from each RRE to its served UE's. Can result in unfeasible solution. Normalize, calculate new value of ρ_n and continue.
- Decoupled version and so less complex than OPA.

Performance Results



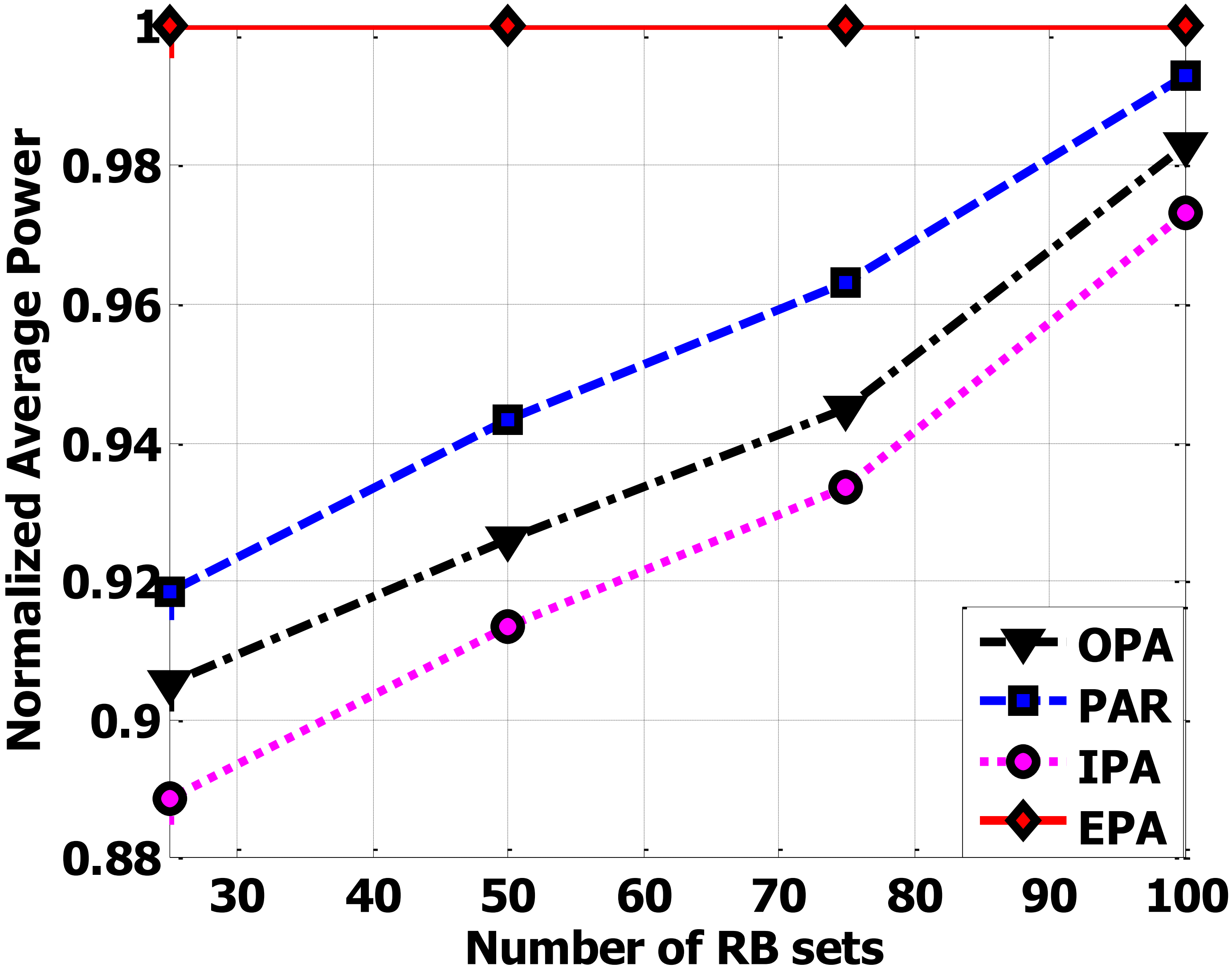
CS-CoMP

Performance Results

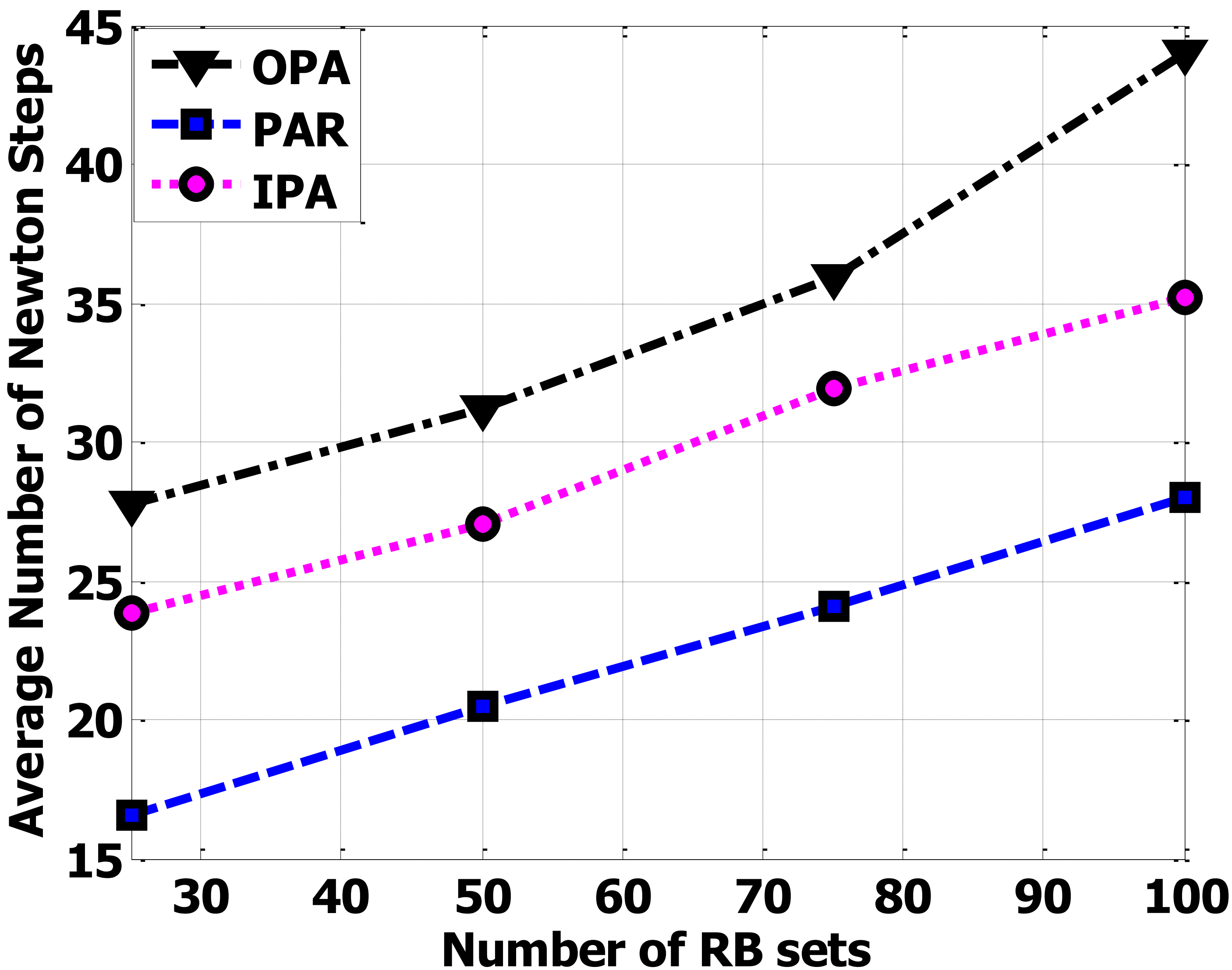


JP-CoMP

Performance Results



Performance Results



Summary and Conclusion

- We present scheduling and power allocation algorithms based on the SLNR metric.
- We tackle the power allocation problem using three different schemes (OPA, PAR, and IPA).
- The proposed power allocation algorithms achieves high throughput gains as well as reduction of the overall power consumption.

Questions?

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