Resource Allocation in SDMA/OFDMA Systems

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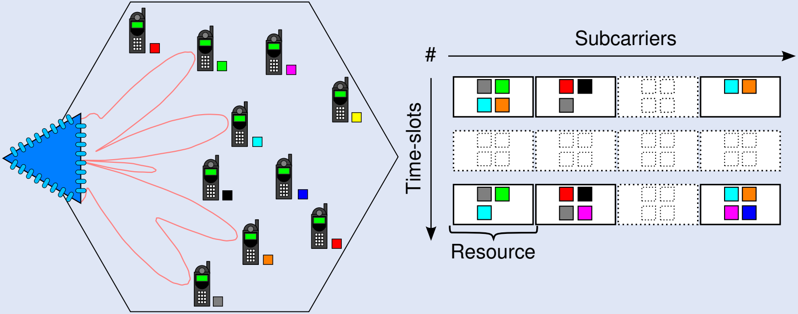
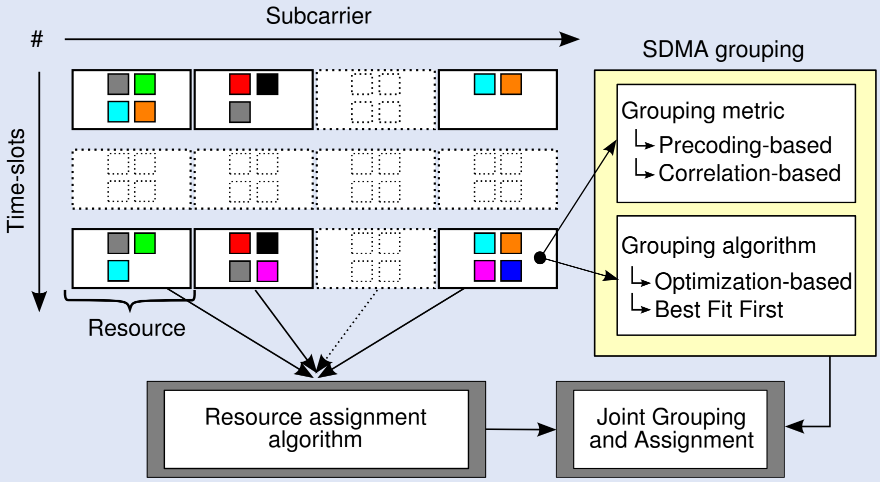
Problem overview



Some questions

- How to efficiently build Space Division Multiple Access (SDMA) groups?
- How to allocate SDMA groups onto radio resources to achieve high capacity and acceptable fairness?

Outline


Subcarrier
#
Time-slots
Resource
SDMA grouping
Grouping metric
Precoding-based
Correlation-based
Grouping algorithm
Optimization-based
Best Fit First
Resource assignment algorithm
Joint Grouping and Assignment

Common elements: grouping metric and grouping algorithm

- SDMA grouping problem
  - ➥ Often Non-deterministic Polynomial time Hard (NP-H), i.e., it has exponential complexity
  - ➥ Asks for efficient suboptimal solutions
- Grouping metric $\xi(\mathcal{G})$: measures the spatial compatibility among the spatial users/channels in the SDMA group $\mathcal{G}$
- Grouping algorithm: builds a suboptimal SDMA based on $\xi(\mathcal{G})$ with acceptable performance/complexity trade-off

Two categories: precoding- and correlation-based SDMA grouping

- Precoding-based metric ➨ $\xi(\mathcal{G})$ depends on precoding vectors
  - Ex.: channel capacity or successive projections
  - High complexity
  - Good performance
- Correlation-based metric ➨ $\xi(\mathcal{G})$ does not depend on precoding
  - Ex.: spatial correlation and channel attenuations
  - Usually lower complexity
  - “Slightly” worse performance

SDMA grouping: Regularized Correlation-Based Algorithm (RCBA)

- Grouping metric is a function of the spatial correlation and channel attenuations
- SDMA group is obtained by solving a convex optimization problem to find the group of G channels least spatially correlated

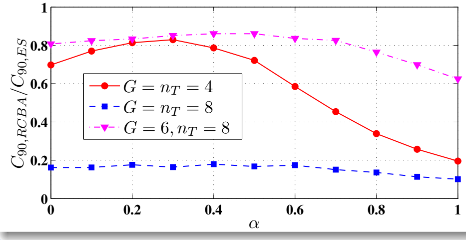
$\mathcal{G}$ is obtained from the G largest components of $\mathbf{x}^\star$

$$\begin{cases} \mathbf{x}^\star = \arg\min_{\mathbf{x}} \left\{ \frac{(1-\alpha)}{\|\mathbf{R}\|_F} \mathbf{x}^T \mathbf{R} \mathbf{x} + \frac{\alpha}{\|\mathbf{q}\|_1} \mathbf{q}^T \mathbf{x} \right\} \\ \text{s.t.: } \|\mathbf{x}\|_1 = G, \\ \quad x_c = 1,\ c \in \{1, \dots, K\}, \\ \quad x_j \in [0, 1],\ j = 1, \dots, K \end{cases}$$

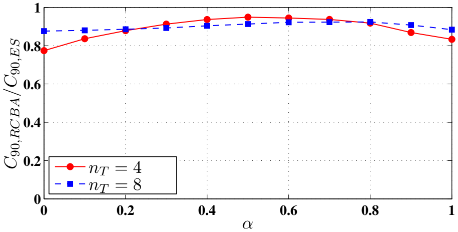
$\alpha \in [0, 1]$: control parameter

10% outage capacity of RCBA normalized to the 10% outage capacity of an Exhaustive Search (ES)

RCBA with fixed group size



RCBA with initial $G = n_T$ and SRA

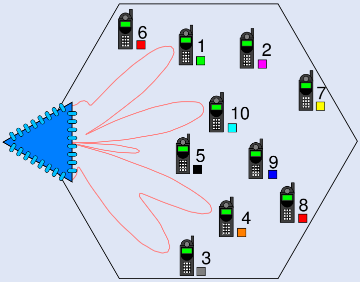


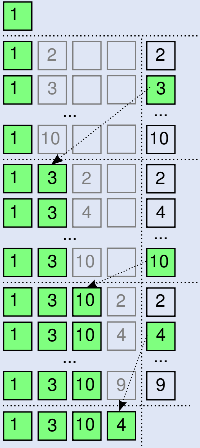
- Considers Zero-Forcing beamforming
- C_{90} corresponds to the 10% outage capacity
- Exhaustive Search (ES) considers group capacity as grouping metric

Successive Removal Algorithm (SRA)

1) Remove the most correlated user / channel from the SDMA group
2) Compute group capacity
3) Keep the group with highest capacity

SDMA grouping: Best Fit First (BFF)





1. Select an initial user / channel
2. Test the remaining users / channels for spatial compatibility using $\xi(\mathcal{G})$
3. Add the most compatible user / channel to the SDMA group
4. Repeat the previous steps until the stop condition is fullfilled

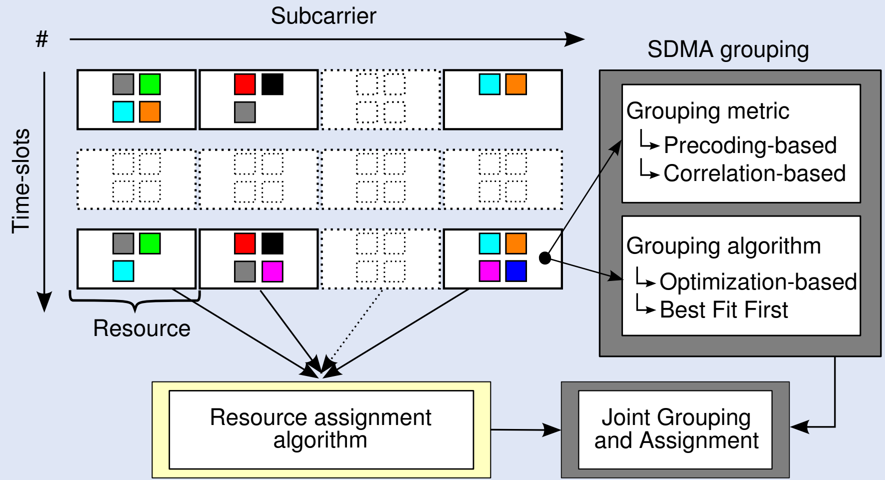
SDMA grouping: Greedy Regularized Correlation-Based Algorithm (GRCBA)

- Grouping metric is a function of the spatial correlation and channel attenuations
- Grouping algorithm based on the BFF algorithm

1) Set the best SDMA group $\mathcal{G} = \{c\}$ and $\mathcal{G}' = \mathcal{G}$
2) While $\operatorname{card}\{\mathcal{G}\} \leq G \leq n_T$

   Set $\mathcal{G} = \underset{\mathcal{G}\cup\{c'\}}{\arg\min} \left\{ \frac{(1-\alpha)}{\|\mathbf{R}\|_F} \sum_j [\mathbf{R}]_{jc'} + \frac{\alpha}{\|\mathbf{q}\|_1} [\mathbf{q}]_{c'} \right\}$, with $c' \in \{1,\ldots,K\} \setminus \mathcal{G}$, and $j \in \mathcal{G}$.

Outline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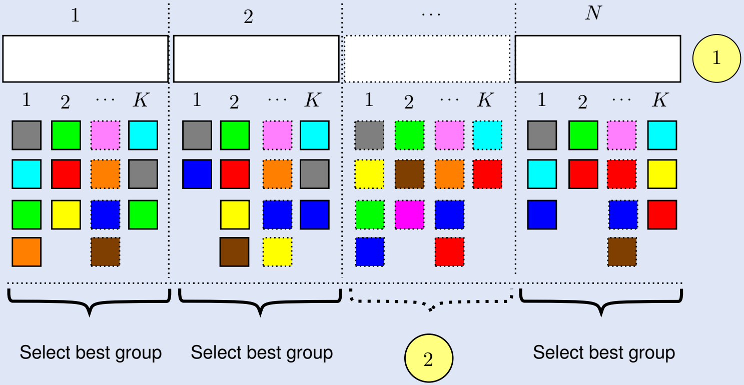
Some resource allocation alternatives

- Assuming K users / channels, N frequency resources
  - ➥ Too large number of possible SDMA groups: $\sum_{g=1}^{G} \binom{K}{g}, \; G \leq n_T$
- Assuming a BFF algorithm
  - ➥ There are K initial users / channels
  - ➥ At most K distinct candidate groups on each of N resources

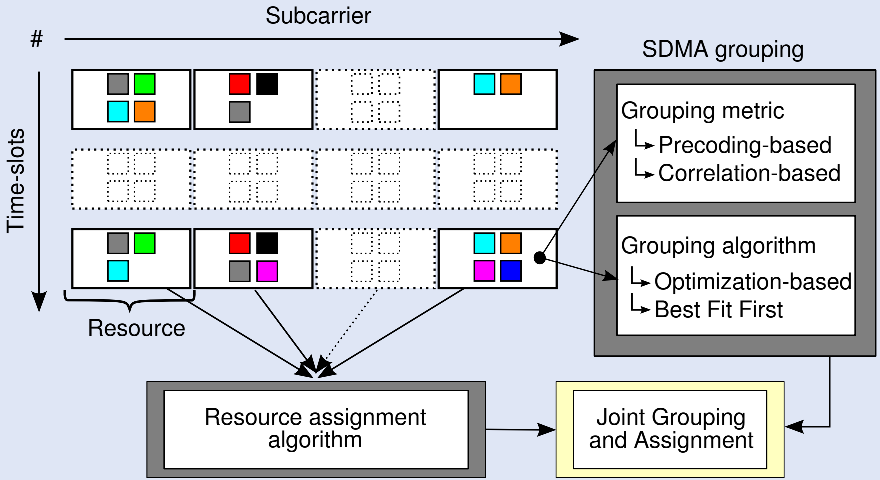
- Two alternatives:
  - Group and Assign (G&A)
    - Group users into $K' \leq KN$ candidate SDMA groups
    - Assign N of them to the resources
  - Jointly Group and Assign (J-G&A)
    - Jointly group and assign N SDMA groups on the resources

Group & Assign (G&A) resource allocation algorithm



$$w(\mathcal{G}_{mn}) = \begin{cases} \max\{q_k\}, k \in \mathcal{G}_{mn}, & \text{Round Robin (RR)} \\ C(\mathcal{G}_{mn}) \sum_k \frac{r_k}{\bar{r}_k}, k \in \mathcal{G}_{mn}, & \text{Weighted Capacity (WC)} \\ C(\mathcal{G}_{mn}), & \text{Maximum Capacity (MC)} \end{cases}$$

Outline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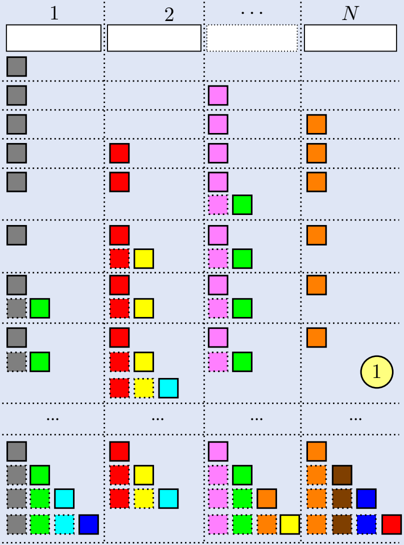
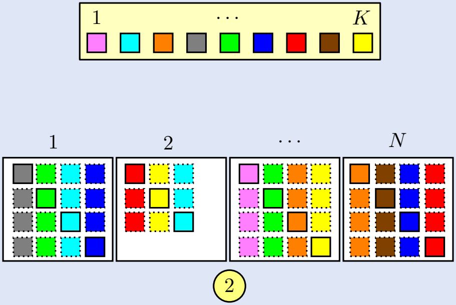
Jointly Group & Assign (J-G&A) resource allocation algorithm



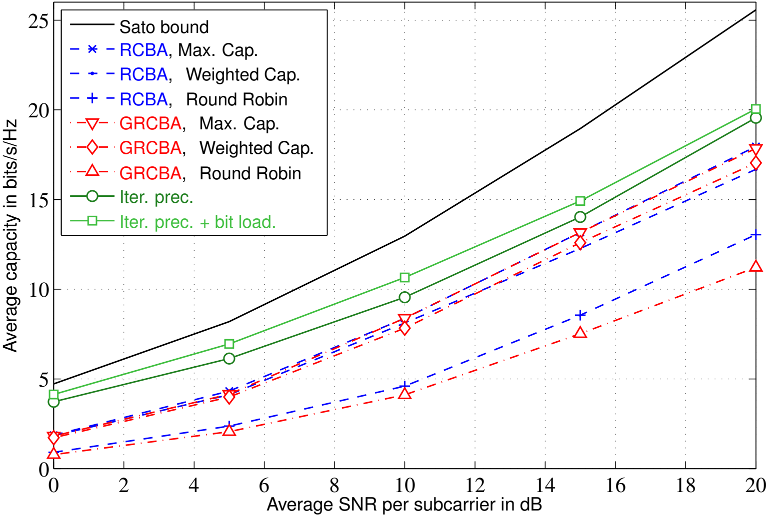


Iterative precoding and
power loading [Boche and Schubert, 2005] +
iterative bit loading

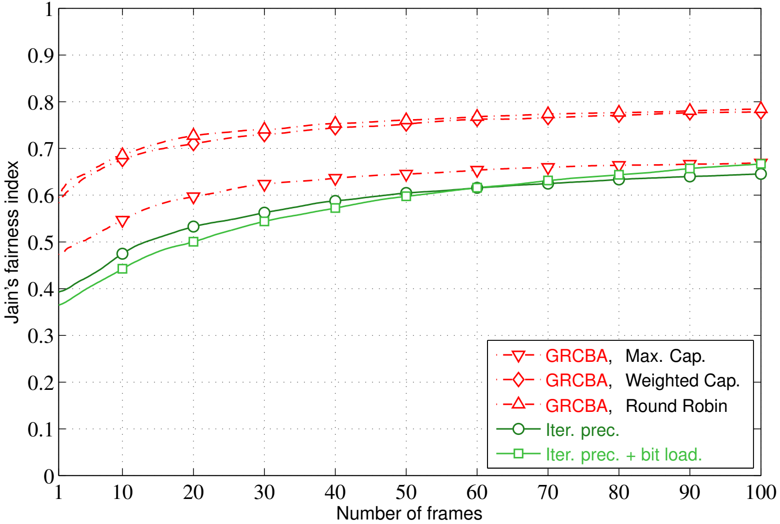
Simulation parameters

Parameter	Value
System	
System bandwidth	0.9375 MHz around 5GHz
# of subcarriers	96 in chunks of 12 subcarriers
# of tx antennas	4 omni elements separated by half wavelength
Channel model	Winner Phase I, Urban Macro
Frame duration	1 ms divided into 4 time-slots
# of single-antenna users	16
User speed	10 km/h
G&A resource allocation	
Subcarrier power allocation	Equal power allocation
Precoding scheme	Zero-Forcing
Weighting schemes	RR, WC, and MC
Capacity calculations	Per frame
Weight calculations	Per time-slot
J-G&A resource allocation	
Subcarrier power allocation	MaxMin SINR [Boche and Schubert, 2005]
Precoding scheme	UL/DL MVDR [Boche and Schubert, 2005]
Bit loading criteria	Least power

Average system capacity for different resource allocation algorithms



Fairness among users for an average SNR of 10 dB



Summary

- The dimensions (K, N) and nature (NP-H) of the resource allocation problem
  - Makes it unpractical to be solved in an optimum way
- Different suboptimal alternatives can be followed
  - Group and Assign
  - Jointly Group and Assign
- Different trade-offs have to be considered
  - Complexity versus efficiency
  - Capacity versus fairness

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