

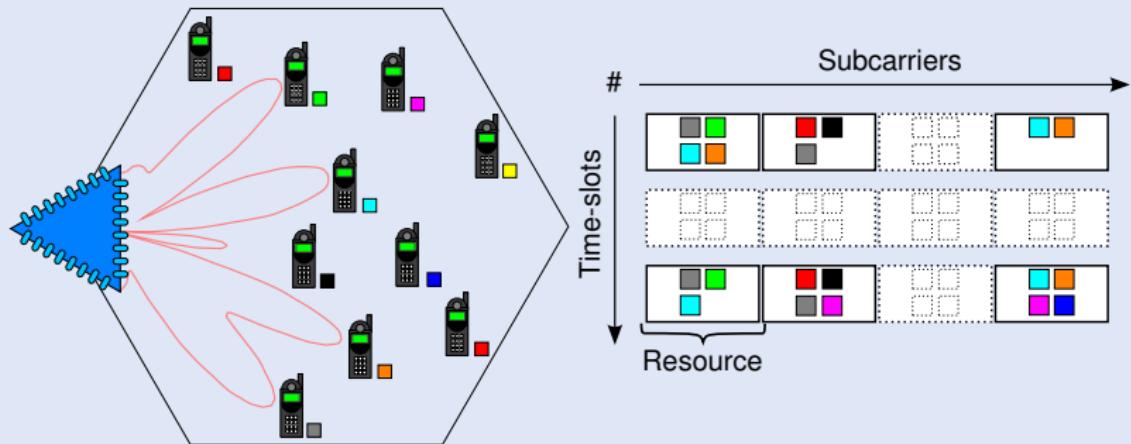
Resource Allocation in SDMA/OFDMA Systems

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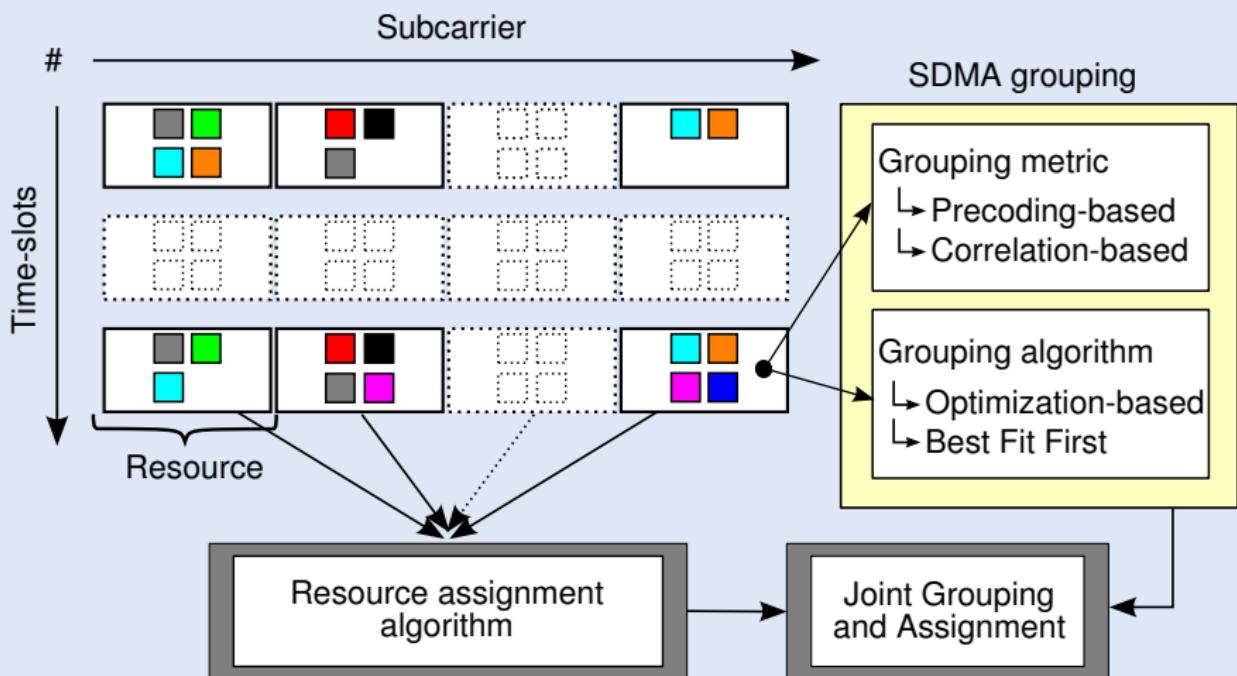
Problem overview



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



- 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



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

- 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

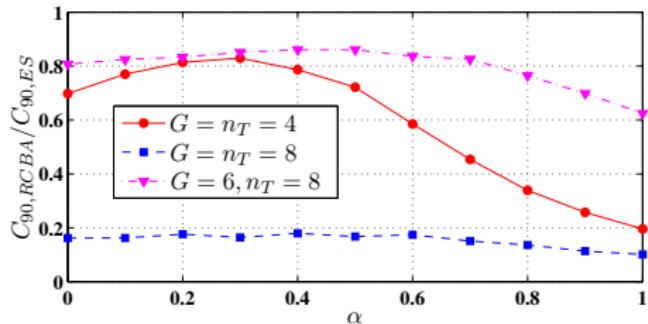
\mathcal{G} is obtained from
the G largest
components of \mathbf{x}^*

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

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

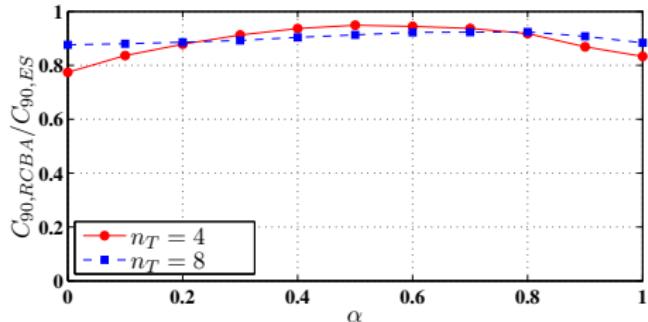


RCBA with fixed group size



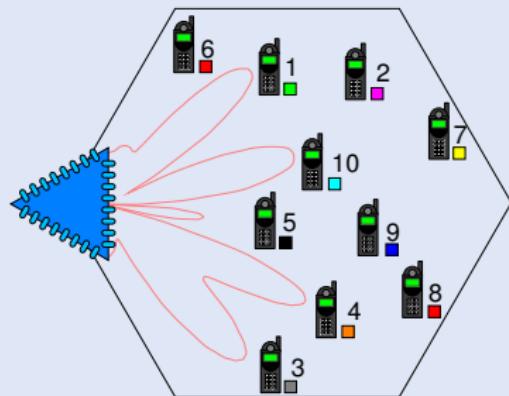
- Considers Zero-Forcing beamforming
- C_{90} corresponds to the 10% outage capacity
- Exhaustive Search (ES) considers group capacity as grouping metric

RCBA with initial $G = n_T$ and SRA



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



1										
1	2								2	
1	3								3	
1	10								10	
1	3	2							2	
1	3	4							4	
1	3	10							10	
1	3	10	2						2	
1	3	10	4						4	
1	3	10	9						9	
1	3	10	4						4	

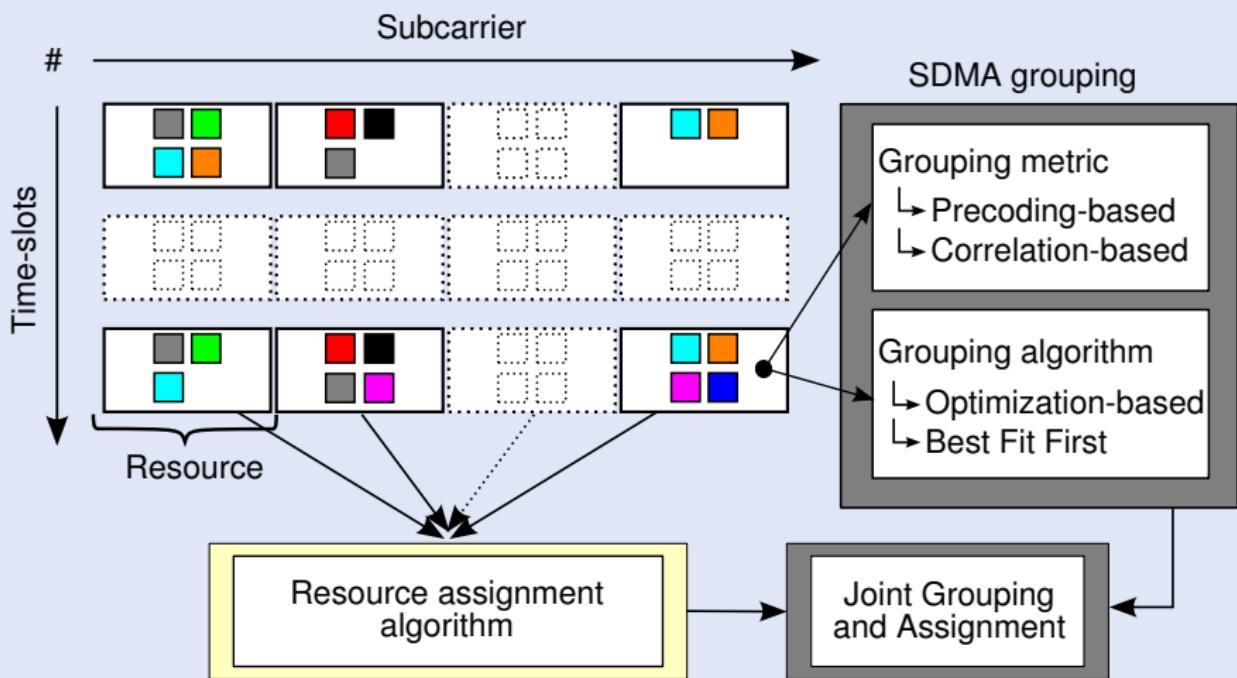
- ① Select an initial user / channel
- ② Test the remaining users / channels for spatial compatibility using $\xi(\mathcal{G})$
- ③ Add the most compatible user / channel to the SDMA group
- ④ Repeat the previous steps until the stop condition is fulfilled

- 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 $\text{card } \{\mathcal{G}\} \leq G \leq n_T$

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

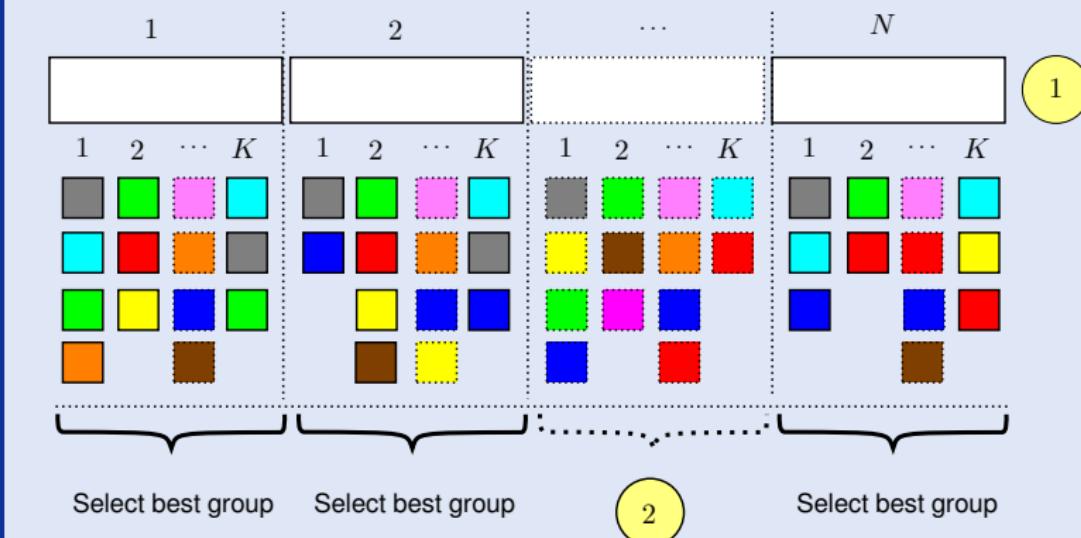
Outline





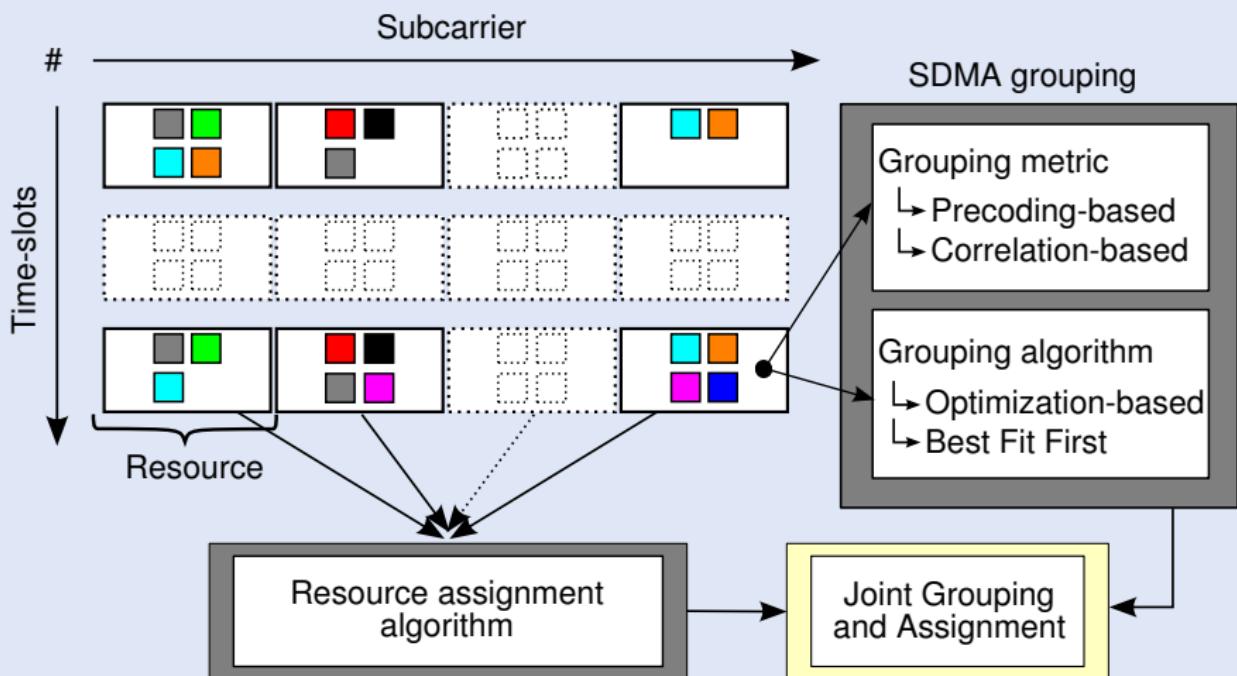
Some resource allocation alternatives

- 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



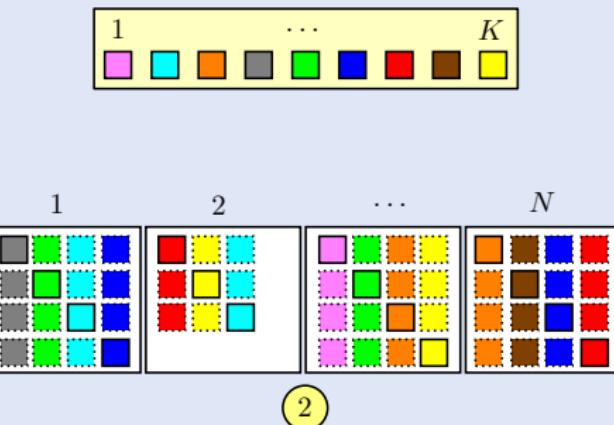
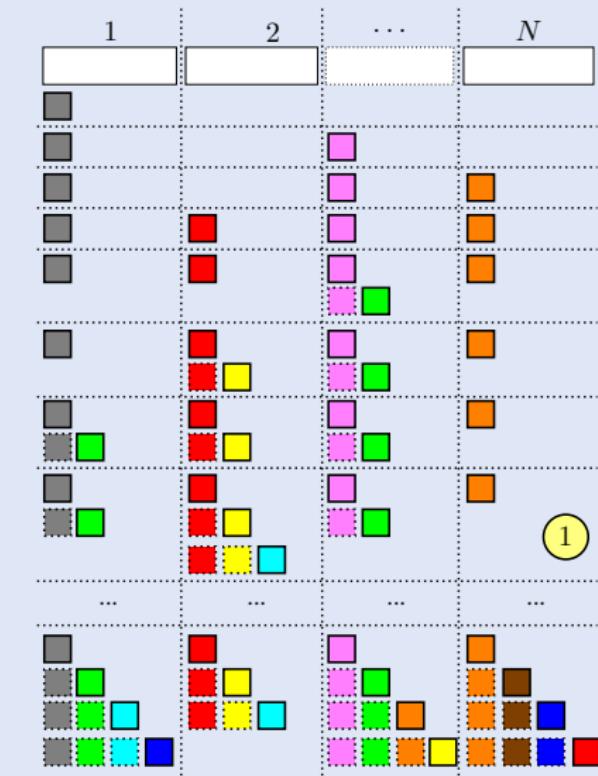
$$w(\mathcal{G}_{mn}) = \begin{cases} \max \{q_k\}, k \in \mathcal{G}_{mn}, & \text{Round Robin (RR)} \\ C(\mathcal{G}_{mn}) \sum_k \frac{r_k}{\bar{r}_k}, k \in \mathcal{G}_{mn}, & \text{Weighted Capacity (WC)} \\ C(\mathcal{G}_{mn}), & \text{Maximum Capacity (MC)} \end{cases}$$

Outline





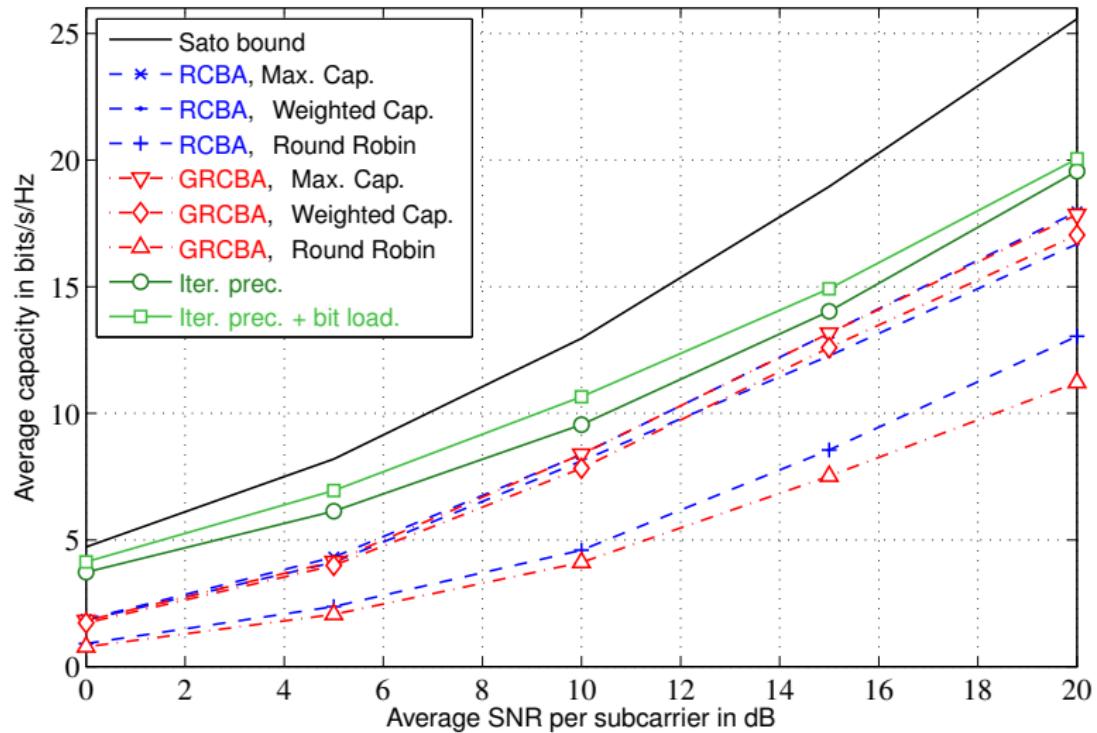
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Iterative precoding and
power loading [Boche and Schubert, 2005] +
iterative bit loading

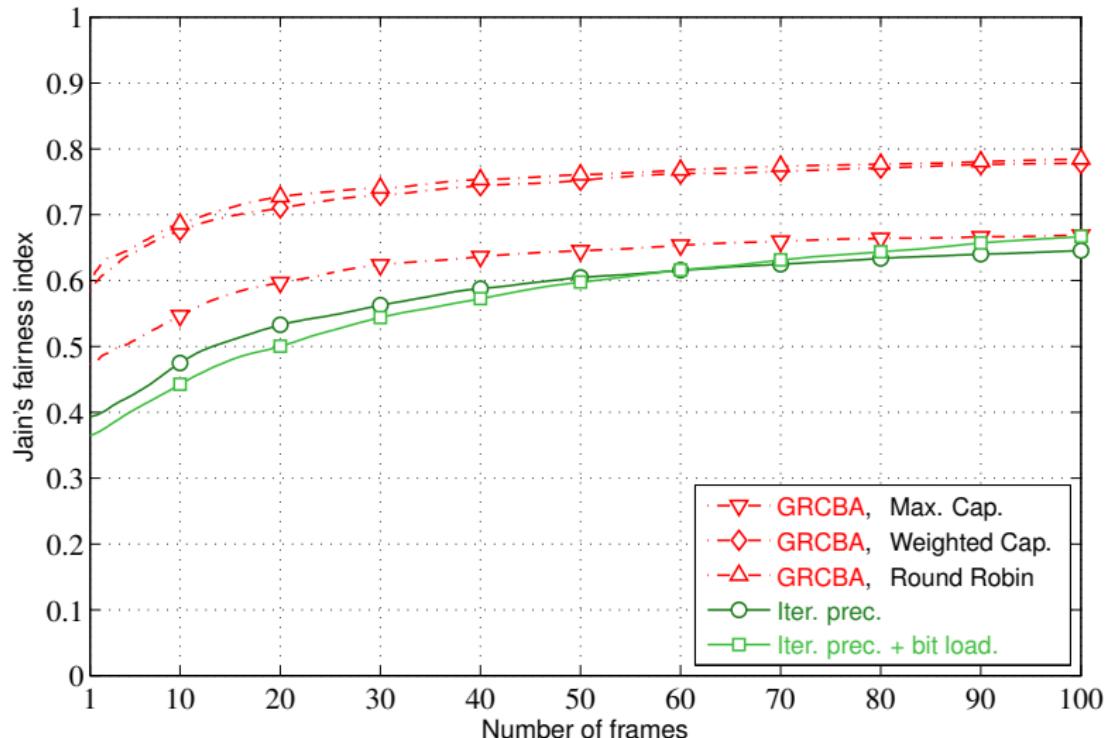


Parameter	Value
System	
System bandwidth	0.9375 MHz around 5GHz
# of subcarriers	96 in chunks of 12 subcarriers
# of tx antennas	4 omni elements separated by half wavelength
Channel model	Winner Phase I, Urban Macro
Frame duration	1 ms divided into 4 time-slots
# of single-antenna users	16
User speed	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



Fairness among users for
an average SNR of 10 dB

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- 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

Literature

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