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A Fast and Fair Algorithm for Distributed Subcarrier Allocation Using Coalitions and the Nash Bargaining Solution

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Outline

- Introduction
- Scheduling algorithm
- Results
- Conclusions

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Introduction

✓ The problem:

- *subcarrier allocation in a downlink, wireless LTE OFDMA channel*

✓ The goal:

- *harvest Multiuser Diversity benefits in a distributed way*

✓ How:

- *using Game Theory (Coalition Formation & Bargaining)*

✓ The result:

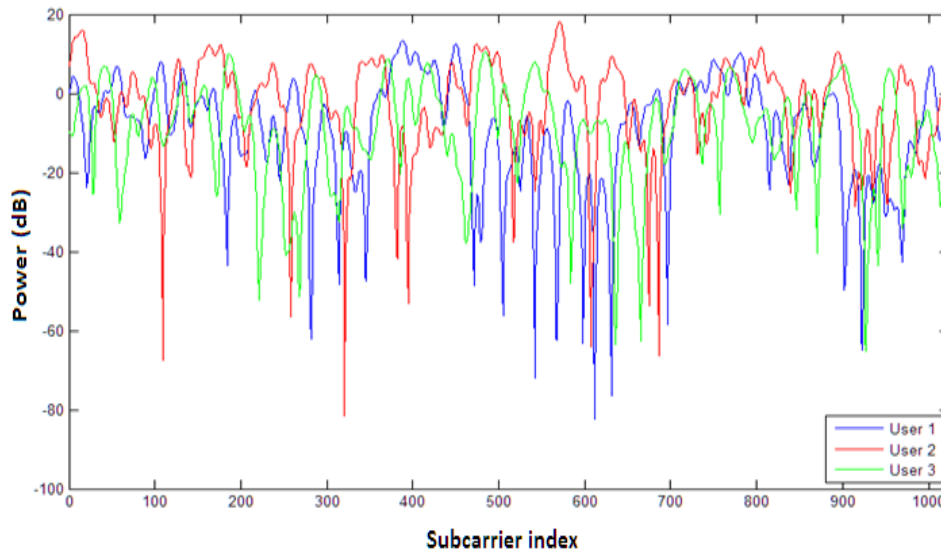
- *a distributed, fair & efficient scheduler*





Multiuser Diversity

- As the wireless channel fluctuates (both in *time* and *frequency*):
 - some users may experience *high channel gain*
 - some other experience *bad channel quality*



Therefore:

- ✓ there is probably *always* a user with high channel quality
- ✓ with more users, *higher probability*
- ✓ *smart scheduling* exploits this probability
- ✓ Overall *throughput is increased*





System Model

- ✓ Downlink, **single antenna SCM LTE channel**
- ✓ Single **Base Station**, with wireless nodes scattered around within a **150m radius**
- ✓ Propagation model: **SCM Urban Macro**
- ✓ Our metrics:
 - *theoretical **rate** (Shannon capacity)*
 - ***fairness** (using Jain's Fairness index)*
 - ***overheads** (i.e. scheduler-specific overheads only)*
- ✓ We **compare** against the **Proportional Fair** scheduler





Scheduling - 1

✓ Overview:

- i. first, users are **randomly partitioned** into coalitions
- ii. then, each coalition is **randomly assigned** a number of **subcarrier groups**
- iii. for each partition, **Nash Bargaining** takes place within each coalition
- iv. finally, the partition that **maximizes sum rate** is selected

✓ Key points:

- all coalitions are **equal in size** (except when there are not “enough” users)
- each **coalition** gets the **same number of subcarrier groups**
- each coalition **member** gets the **same number** of subcarrier groups





Scheduling - 2

✓ Nash Bargaining Solution (NBS):

- *cooperative solution*
- *maximises operating points **simultaneously** for all participants*
 - *works by maximizing the product of the utilities (or pay-off) of the participants:*

$$NBS = \arg \max \left(\prod_1^K (\text{payoff} - \text{disagreement}) \right)$$

- *guarantees a **minimum** pay-off (or disagreement point) for everyone*

✓ Important: we set **disagreement point = 0**

✓ Out utility function is **rate**: $R_{k,s} = \frac{W}{S} \times \log_2(1 + SNR \times \|H_{k,s}\|^2), \text{bits} / s$

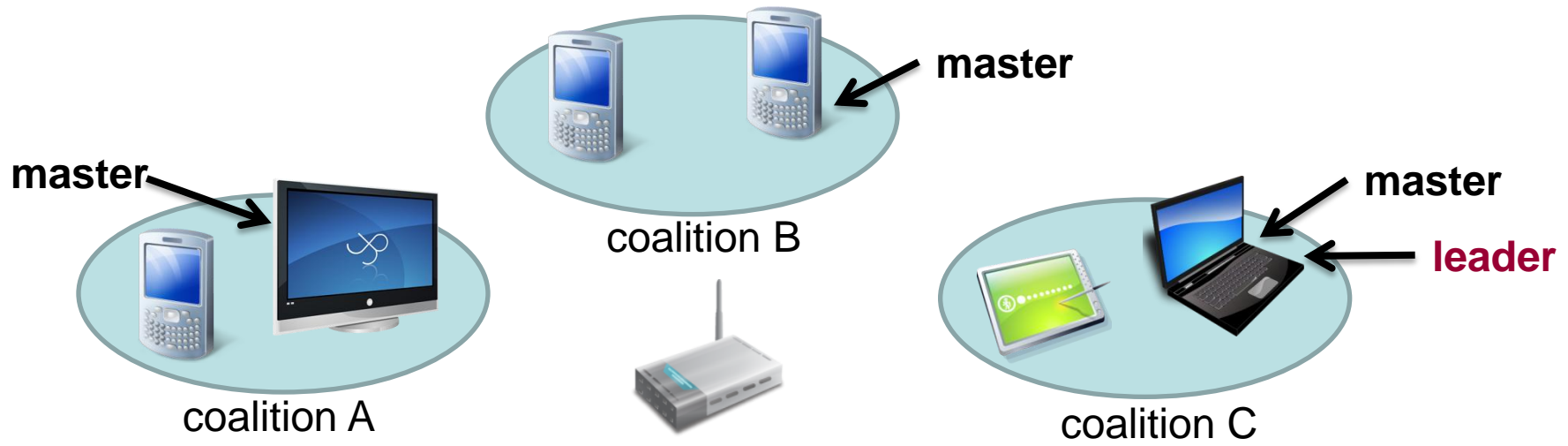




Protocol

✓ Key points:

- ✓ Each coalition has a **master** device (chosen at random)
- ✓ There is also a **leader** device (randomly chosen)
- ✓ **Beaconing** is used for coordination





Efficiency Enhancements

✓ Subcarrier **grouping**

- *makes scheduler lightweight & faster*

✓ **Equal number** of subcarriers per user

- *guarantees proportional fairness & makes scheduler faster.*

✓ **Permutations** sampling

- *not all user - subcarrier group permutations are tested*

✓ **Partitions** sampling

- *not all partitions of users into coalitions are tested*

✓ **Realizations** step

- *i.e. allocation process repeated less often*





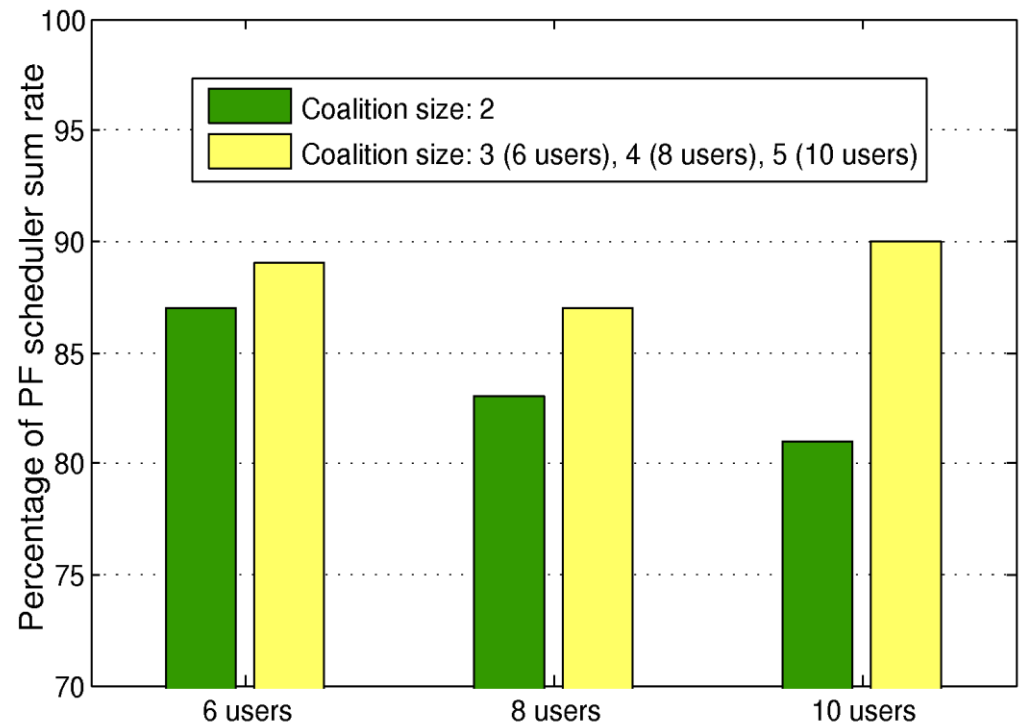
Results 1 - the effect of coalition size

✓ Sum rate:

- compared against Proportional Fair scheduler
- ranges from 70% to 108% of the PF sum rate

✓ Coalition size:

- larger coalitions increase rate
- but increase complexity

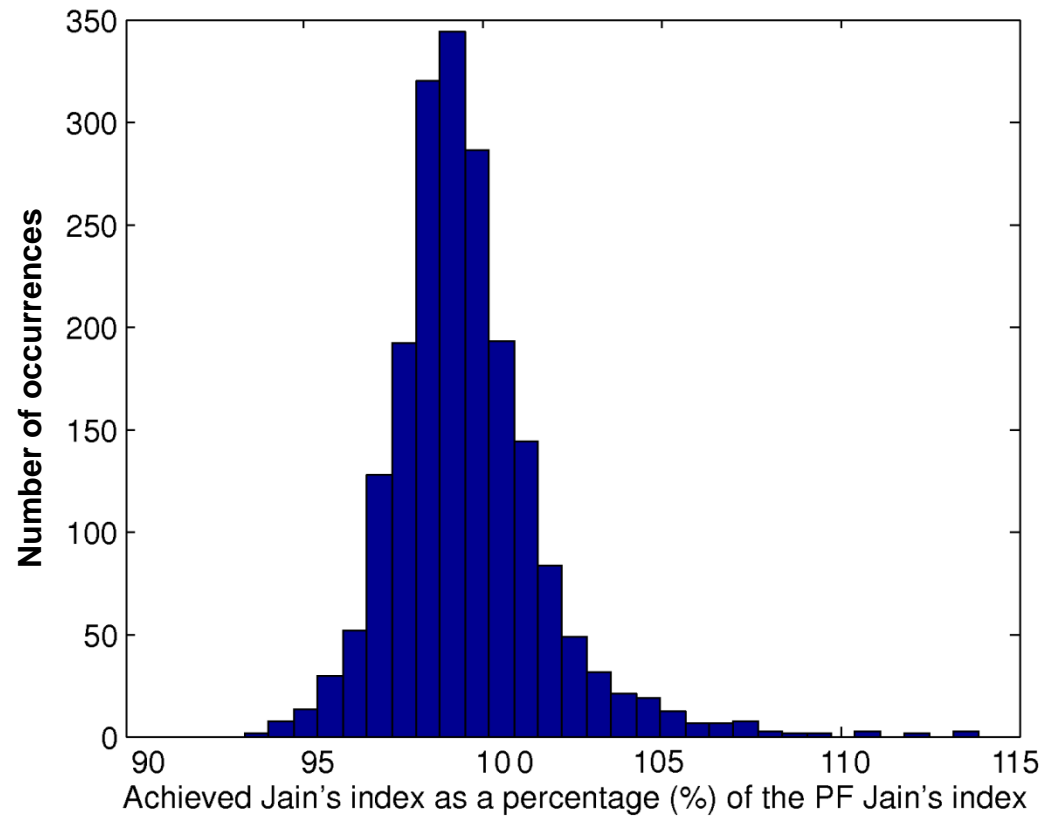




Results 2 - fairness

✓ Fairness:

- compared against the Proportional Fair scheduler, using Jain's Fairness Index
- fairness achieved is almost **identical to PF**





Results 3 - efficiency improvements

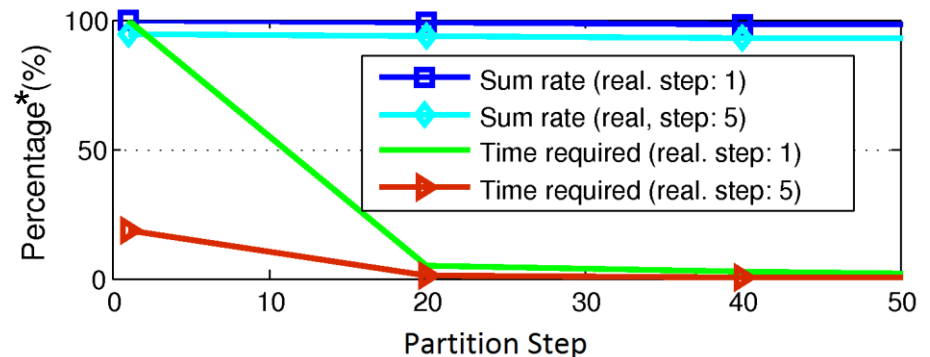
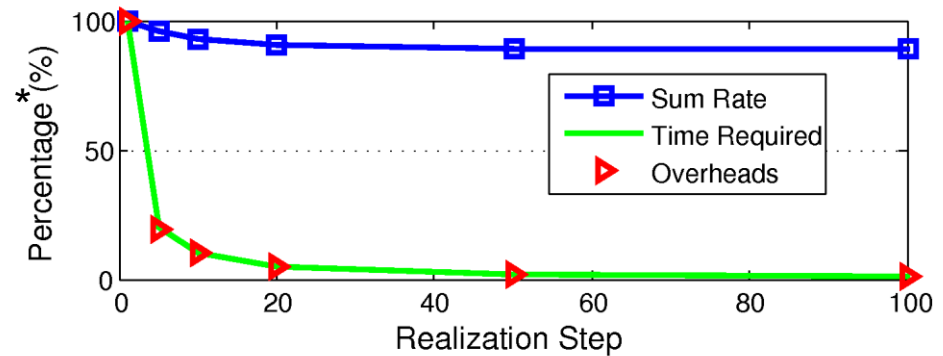
✓ Realization step:

- *overheads reduced*
- *scheduler gets faster*
- *rate only slightly reduced*
- *fairness is the same*

✓ Partition step:

- *similar benefits*
- *rate marginally affected*
- *fairness is the same*

✓ permutation step: similar benefits



* = % of the respective, original values before applying efficiency improvements

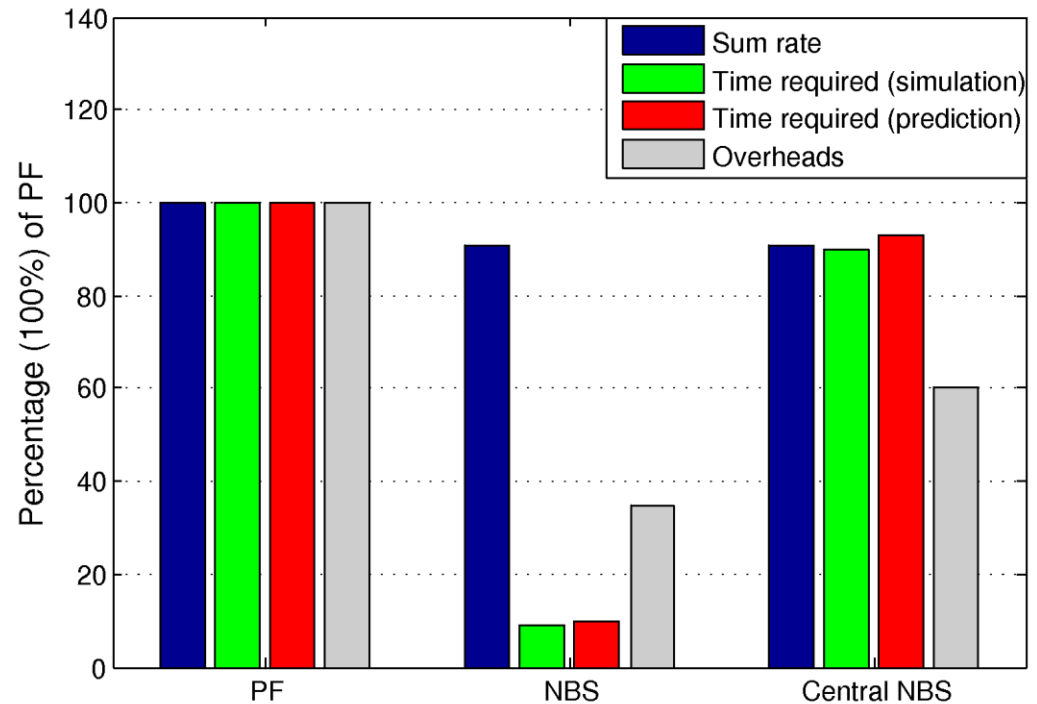




Results 4 - Overview

✓ Comparison with:

- **Proportional Fair scheduler**
- **the centralized * version of the NBS scheduler presented in our paper**



* = exactly the same scheduler, apart from the centralized coordination. Only overheads and required time change when compared to the distributed version



Conclusions

- ✓ Very **fast** scheduler
- ✓ Reduced **overheads**
- ✓ **Sum rate** comparable to Proportional Fair scheduler
- ✓ **Fairness** almost identical to Proportional Fair
- ✓ **Larger coalitions** offer more rate but induce complexity





- INTRODUCTION
- THE SCHEDULER
- RESULTS
- CONCLUSIONS

Questions?

Thank you!

