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

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SAN FRANCISCO
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Outline

- ❑ Introduction
- ❑ Scheduling algorithm
- ❑ Results
- ❑ Conclusions

Introduction

✓ **The problem:**

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

✓ **The goal:**

- *harvest Multiuser Diversity benefits in a distributed way*

✓ ***How:***

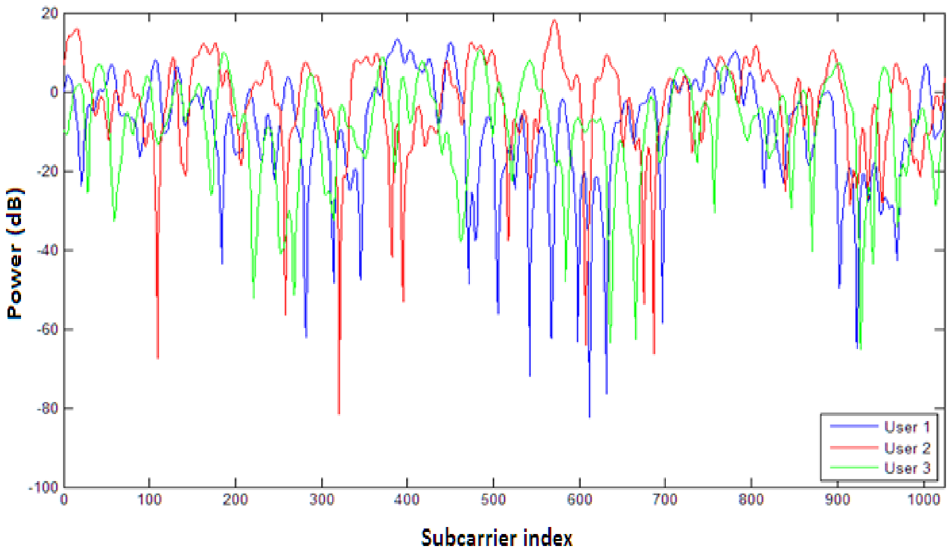
- *using Game Theory (Coalition Formation & Bargaining)*

✓ ***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:*

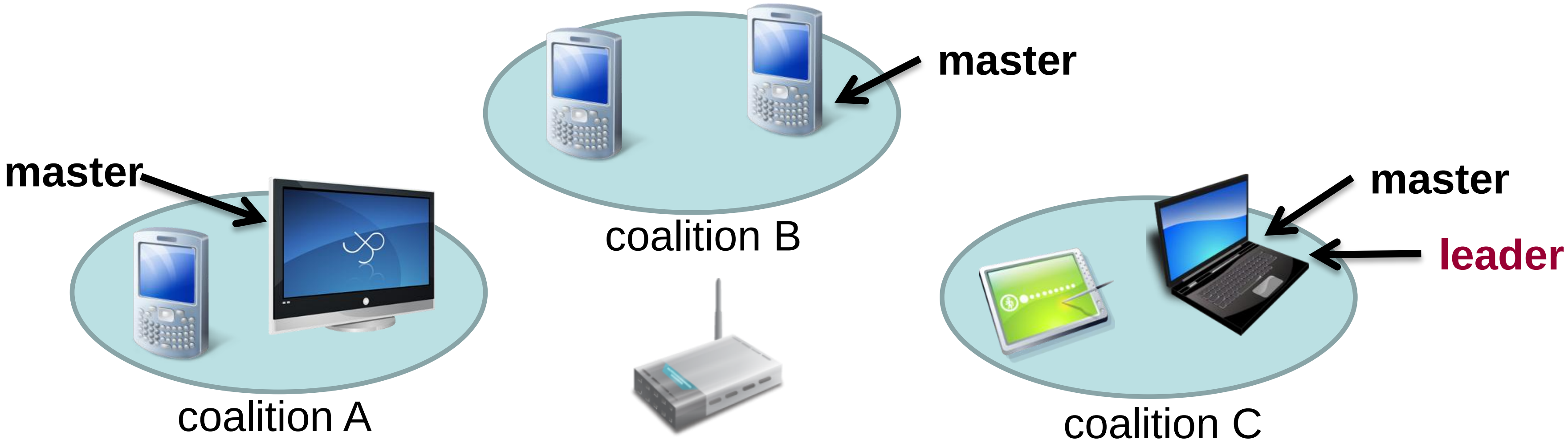
$$NBS = \arg\max\left(\prod_{1}^{K}(payoff - disagreement)\right)$$

  - *guarantees a* ***minimum*** *pay-off (or disagreement point) for everyone*
- Important: we set ***disagreement point = 0***
- Out utility function is ***rate*** : $R_{k,s} = \frac{W}{S} \times \log_2(1 + SNR \times \|H_{k,s}\|^2), bits/s$

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*

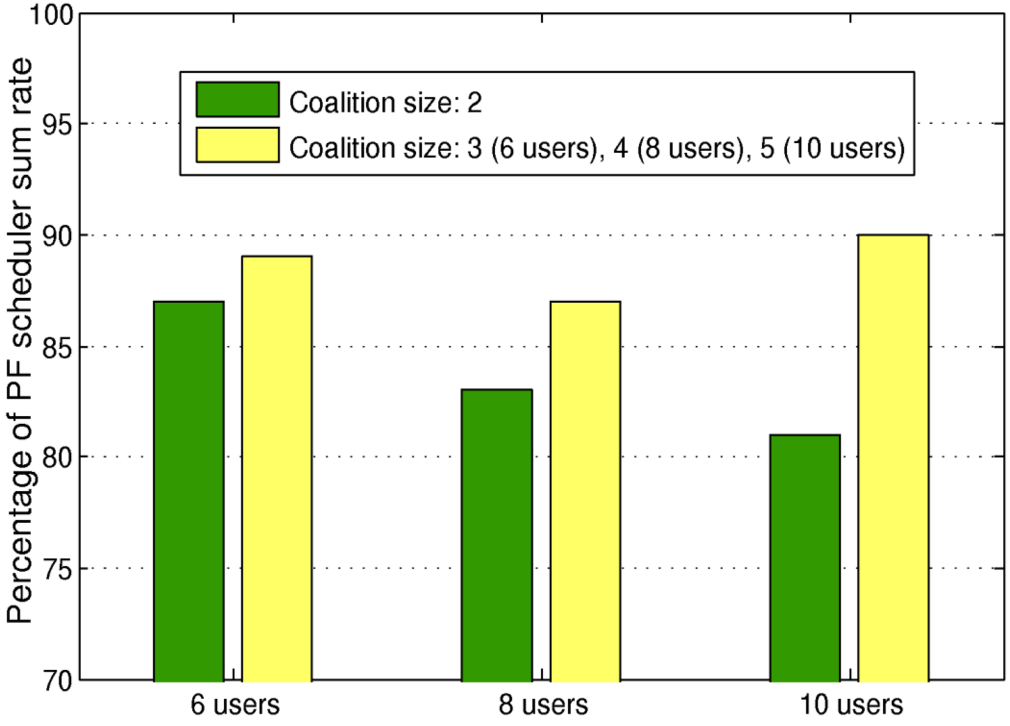
Results 1 - the effect of coalition size

✓ **Sum rate:**

- *compared against* <u>*Proportional Fair*</u> *scheduler*
- *ranges from 70% to 108% of the PF sum rate*

✓ **Coalition size**:

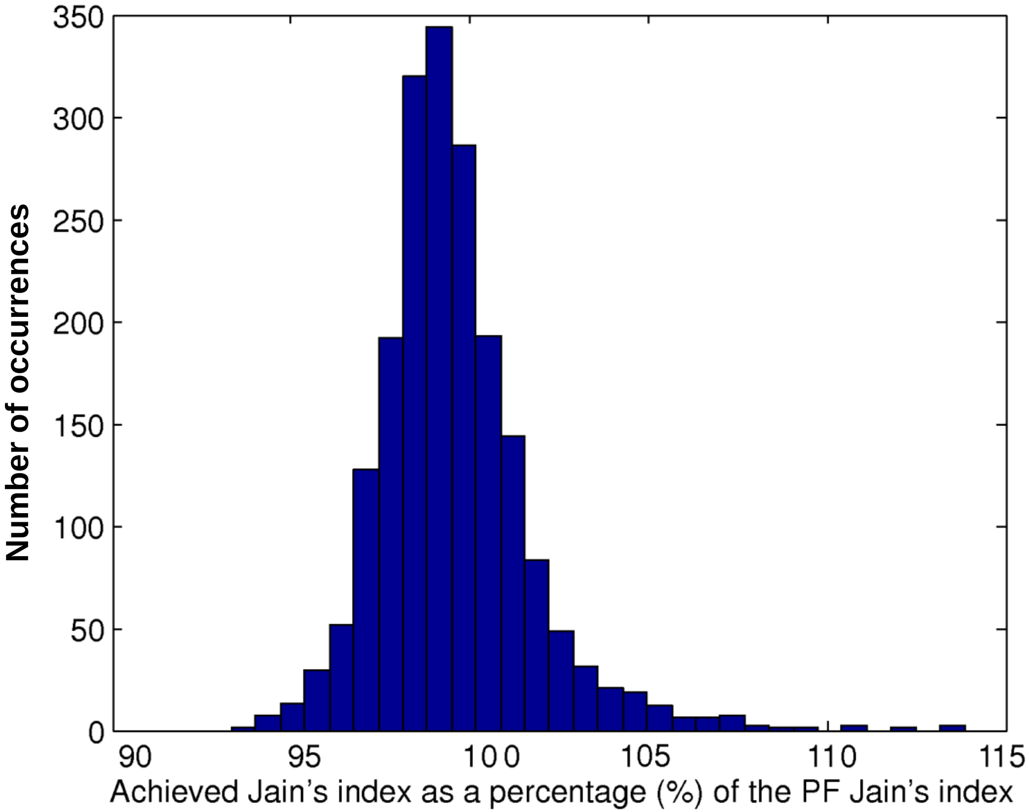
- *larger coalitions increase rate*
- *but increase complexity*



Results 2 - fairness

✓ **Fairness**:

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



Results 3 - efficiency improvements

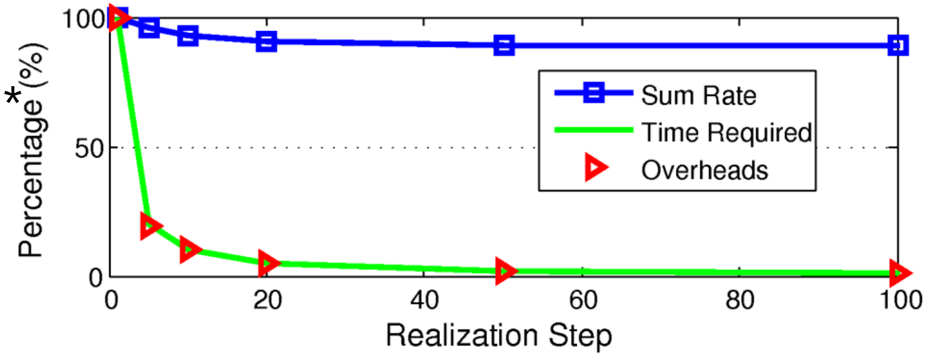
✓ **Realization step**:

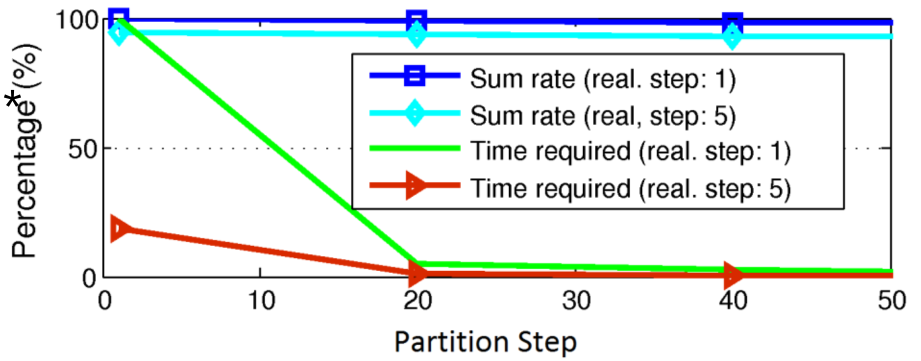
- *overheads reduced*
- *scheduler gets faster*
- *rate only slightly reduced*
- *fairness is the same*

✓ **Partition step**:

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

✓ ***permutation step:*** *similar benefits*



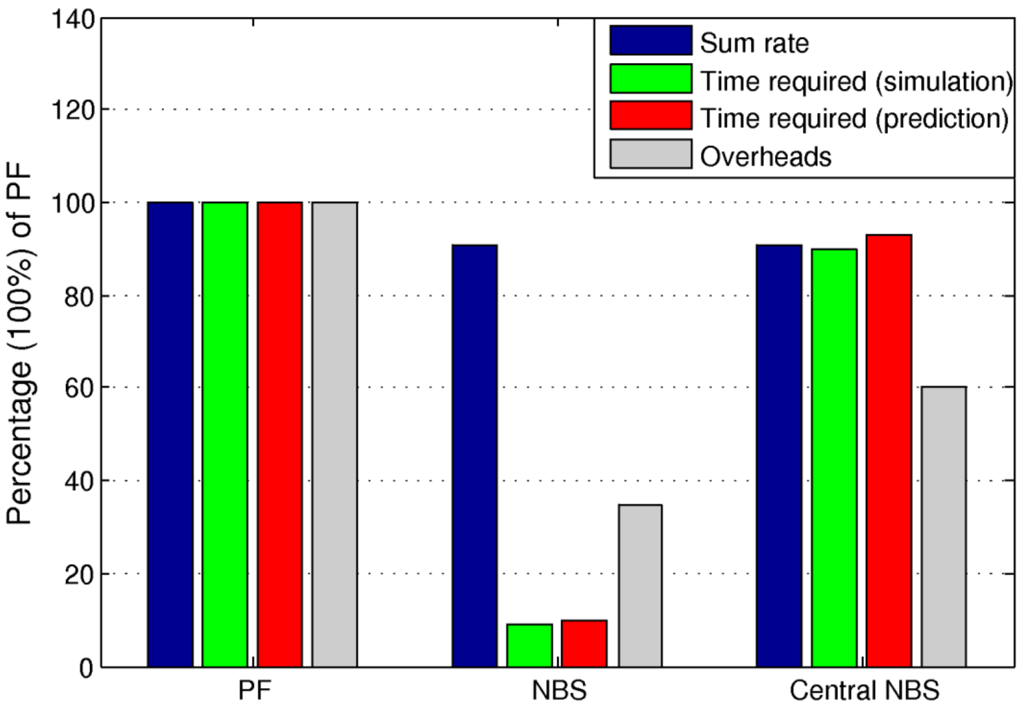


***** = % of the respective, original values before applying efficiency improvements***

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

Questions?

Thank you!