4G LTE CoMP, Coordinated Multipoint

4th Semester Institute Project

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Overview

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- Motivation
- Background
- System Model
- Simulation
- Evaluation
- Conclusions
- References

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Motivation

- Due to the network densification plans, interference will substantially increase. Interference management will play an important role in future networks
- Mainly cell edge users suffer from interference
- Goal is to improve performance via interference management schemes - such as CoMP
- CoMP is a broad category of cooperation in the network with the aim of enhancing user performance

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Overview on research

- Papers on LTE-A, Joint Transmission, Beamforming and CoMP in general
- Reference: MATLAB-based down- link physical-layer simulator for LTE (Mehlführer, C., 2009)
    - MATLAB-based downlink physical-layer simulator for LTE
    - Covering Multi-Cell Multi-User simulation scenarios → most realistic

Scheduling

- Assignment of resource blocks (RB) to each user
- i.e. Round Robin (timeslots divided equally between users)
- Dynamic scheduling: mapping RBs to users based on different criteria

Background

Channel model

- Signal-to-interference-plus-noise ratio → Description of the channel

$$\frac{P_j * (h_j * w_j)^2}{\sum (h_i * w_i)^2 * P_i + (\sigma_N)^2}$$

  - P_j - Power of signal
  - h_j - Channel
  - w - Precoding matrix
  - p_i - Power of interference
  - $sigma_N$ - Noise
- Used to determine signal quality
- Block-fading channel to reduce complexity

Background

User feedback (CSI)

- Channel Quality Indicator
- Determines modulation
  - Transfer block size (TBS)
  - Resource blocks for users
- Depends on SINR
- CSI includes CQI, PMI, RI. CQI depends on SINR, PMI and RI depends on beamforming

Background - CoMP

Overview

- LTE Advanced: major enhancement of the LTE standard
- CoMP: Coordinate MultiPoint operation
  - Refers to wide range of interference management techniques
  - Dynamic coordination or transmission and reception with multiple geographically separated eNBs (base stations)
  - Goal: enhancing overall system performance, more effective use of resources, improved end user service quality (especially at the cell edges)

Major categories

Joint Processing (JP)

- Joint Transmission (JT)
- Dynamic Point Selection (DPS)
  - With muting
  - Without muting

Coordinated Scheduling (CS) / Coordinated Beamforming (CB)

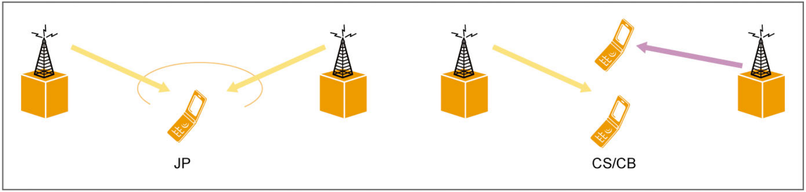


Figure 4. Principle of CoMP.

Coordinated Scheduling (CS)

- Data available at one node
- Transfered packets do not overlap in time

Dynamic Point Selection (DPS)

- Data usually available at several nodes
- User decides per packet which base station is best

Content

System Model

Assumptions

- Geographical Location of UE is known
- UE does not move so no Doppler effect, studying slow fading
- CQI, PMI, RI are randomly generated
  - PMI depends on generated CQI
- Fixed number of UEs in a simulation
- Mean values of the Rayleigh distribution (provided from 3GPP)
- Basestations are created in a hexagonal layout

System Model

Programming

- Classes providing main functionality: Central Unit, Base Station, User Entity, Channel
- Classes providing background data and auxiliary functions: TBS, Helpers, Params, Precoding Matrix (PMI)

CQI and Spectral Efficiency

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	308	0.6016
4	QPSK	449	0.8770
5	QPSK	602	1.1758
6	16QAM	378	1.4766
7	16QAM	490	1.9141
8	16QAM	616	2.4063
9	64QAM	466	2.7305
10	64QAM	666	3.9023
11	64QAM	772	4.5234
12	64QAM	873	5.1152
13	256QAM	R1	S1
14	256QAM	R2	S2
15	256QAM	R3	S3

System Model

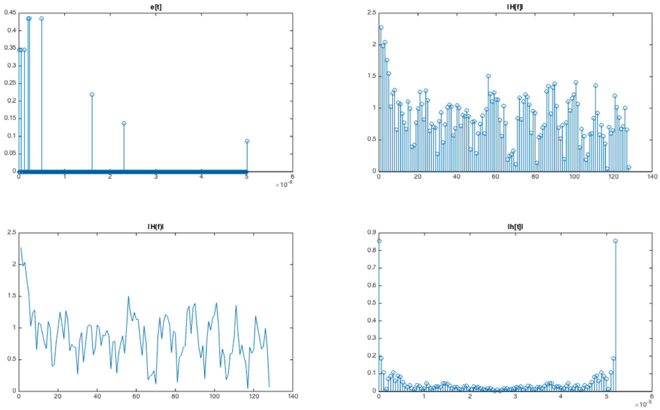
Classes providing main functionality

- Central Unit
  - Coordinates all base stations
- Base Station
  - Matches subcarriers to connected users, calculates modulation
- User Entity
  - Returns feedback to each base station
- Channel
  - Certain frequency and amount of subcarriers
  - Friis equation for calculation of path loss
  - Model - Rayleigh channel

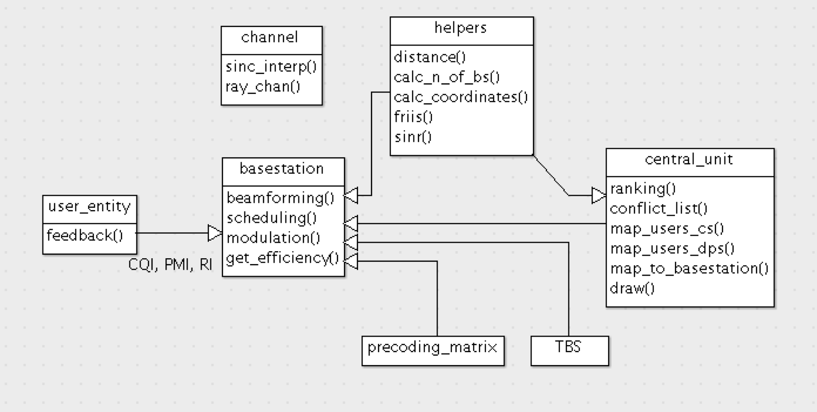
Slow versus Fast Fading

- Slow Fading
  - Coherence time of the channel is large relative to the delay requirement of the application
  - Amplitude and Phase Change imposed by the channel can be considered roughly constant
- Fast Fading
  - Coherence time of the channel is short relative to the delay requirement of the application
  - Amplitude and Phase Change imposed by the channel varies considerably over the period of use
- Block Fading chosen for simplicity

Rayleigh Channel Simulation



Class Overview

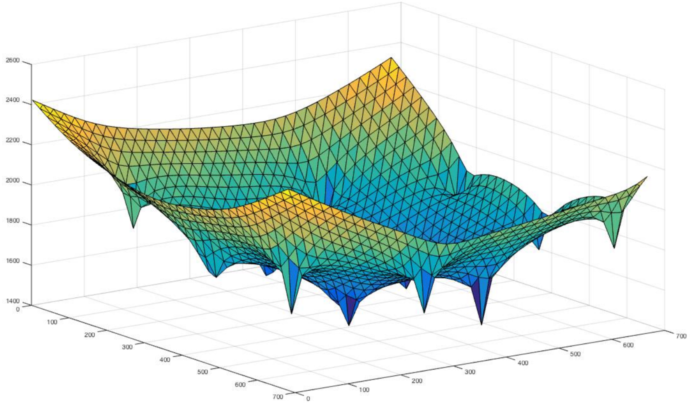


Friis Equation

$$P_r = P_t + G_t + G_r + 20log_{10}(\frac{\lambda}{4\pi R})$$

- G - Antenna Gains
- P - Received/Transmitted Power
- λ - Wavelength
- R - Distance between Antennas
- Units in dB

SINR Profile



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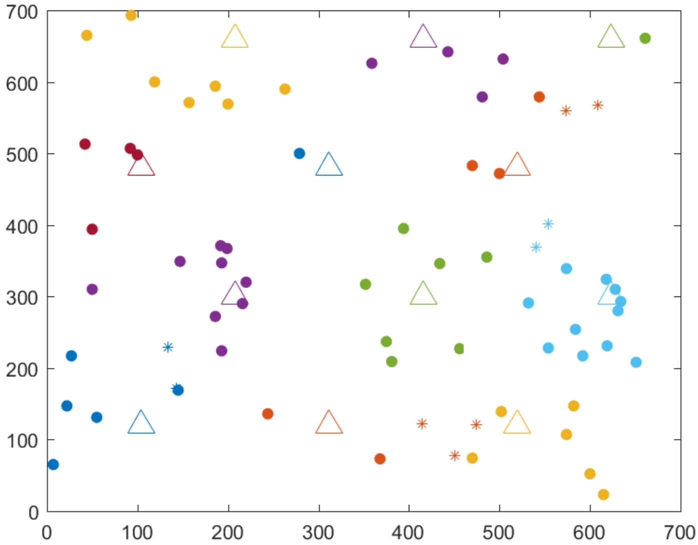
Simulation

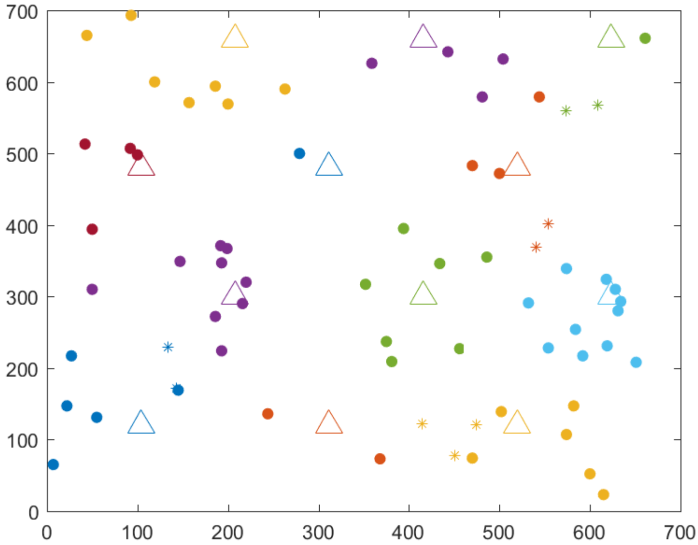
Main characteristics

- Flexibility
- Modularity
- Simulation Process
  - Initialization
  - Simulation Cycle
    - mapping of users to basestations
    - assignment of resource blocks to users
    - calculation of the best modulation and coding scheme

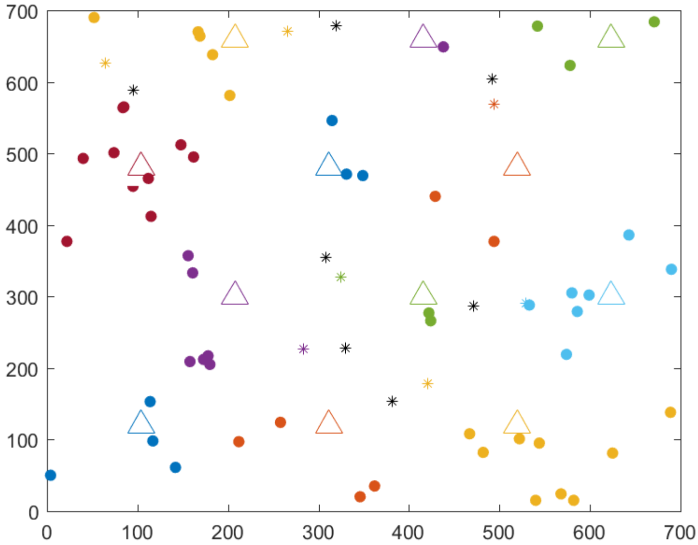
Simulation DPS I



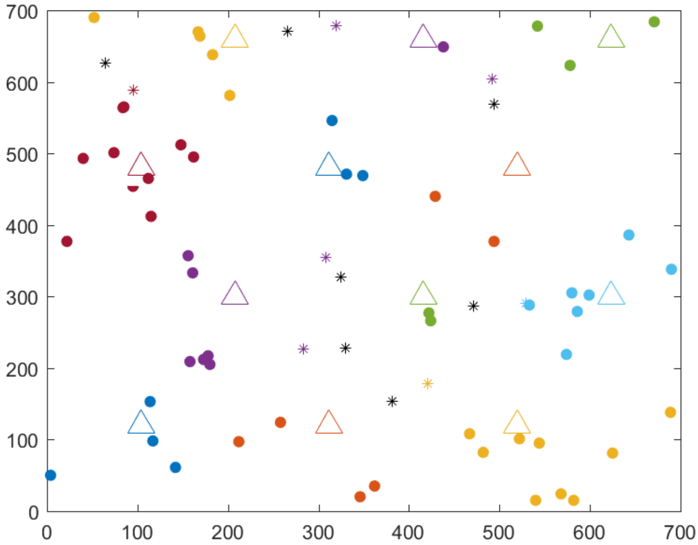
Simulation DPS II



Simulation CS I



Simulation CS II



Content

Evaluation

- 5000 Simulation Cycles
- 70 User Entities, 12 Basestations

	without CoMp	DPS	CS
users in conflict	19.65%	19.78%	19.67%
unassigned users	0%	0%	10.5%
average backhaul[bit/s]	78081	90791	77317
additional backhaul	+0%	+16.28%	-0.98%

Evaluation

Advantages

- Less interference at cell edges, thus better SINR performance.
- Utilization of different subcarriers inside conflict zones avoids interference

Disadvantages

- Complexity of algorithms
- Infeasibility with restricted backhauls
- Bigger signaling overhead between users and base stations
- More frequent communication with the CU –> bigger backhaul needed

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Summary

- Main functionalities for a LTE-Advanced simulator implemented
  - Implementation of **Coordinated Scheduling** and **Dynamic Point Selection**
  - Comparison with system behaviour without CoMP
- Advantages of CoMP mainly for users at cell edges
  - Profitability vs backhaul/signaling trade-offs should be evaluated on a case-by-case basis
  - Possible solution: activating Coordinated Multipoint only as a certain conflict density in the simulated environment is reached

Summary

Project goals reached

- Analysis of behaviour of frequency flat, slow fading channels
- Differences between SISO and MIMO channel models and their implications
- Criteria for estabishling a state of conflict between different user entities
- Choice of channel modulation based upon generated feedback
- Allocating users to base stations according to selected CoMP scheme

Learning goals reached

Programming

- **Object-oriented programming** on MATLAB
- Graphical representation of simulation results
- Working with parameter files/external files (e.g. precoding matrix) and already existing MATLAB libraries
- Making model abstractions while maintaining accuracy

Summary

Learning goals reached

Soft skills

- Collection of preliminary informations through approach to English language scientific literature
- Teamwork: weekly meetings and frequent contacts with the project supervisors
  - Task division in the team according to current needs and time availability
- Debugging and version control on GitHub
- LaTeXbasics for the final presentation

Future work

What comes next?

- Implementation of other CoMP schemes, e.g. coordinated beamforming and joint transmission
- Different channel models (e.g. *fast fading* channels)
- Optimization of CoMP techniques
  - Different allocation of implementation stages between CU and BS
  - Other scheduling patterns (currently implemented: Round Robin)
- Implementation of different environment setups and parameters

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References

- Mehlführer, C. et al, 2009. Simulating The Long Term Evolution Physical Layer. Proc. 17th European Signal Processing Conference (EUSIPCO 2009), [online]
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Thank you for your attention!