4G LTE CoMP, Coordinated Multipoint

4th Semester Institute Project

Leonhard Hetz Philipp Braun Carmine Bianco Alissa Wenzel Matthis Dirksen

Institute for Theoretical Information Technology
Prof. Dr. Rudolf Mathar
RWTH Aachen University

July 21, 2016

Overview

Content

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

Overview

Content

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

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

Overview

Content

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

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

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

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

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)

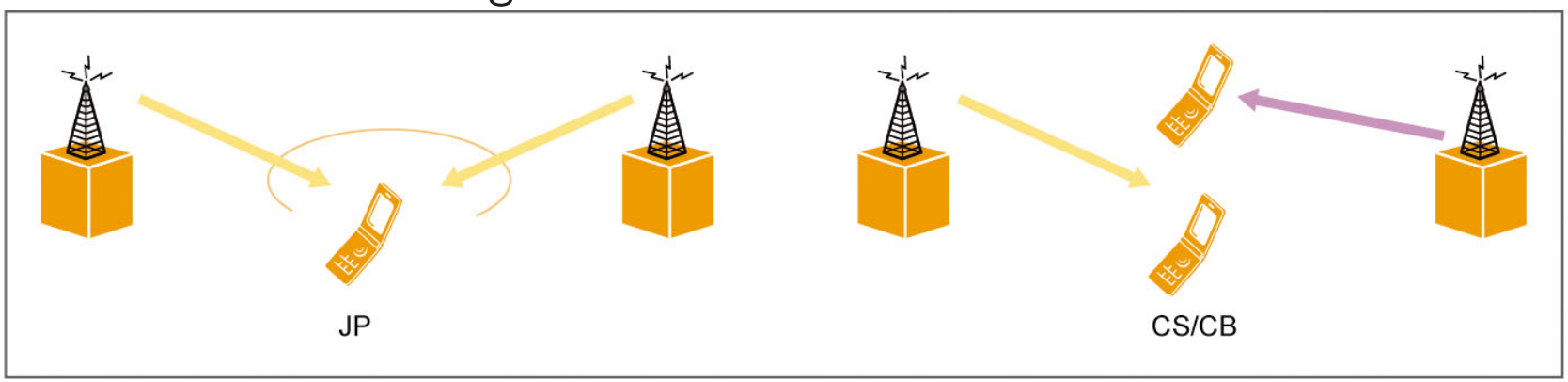
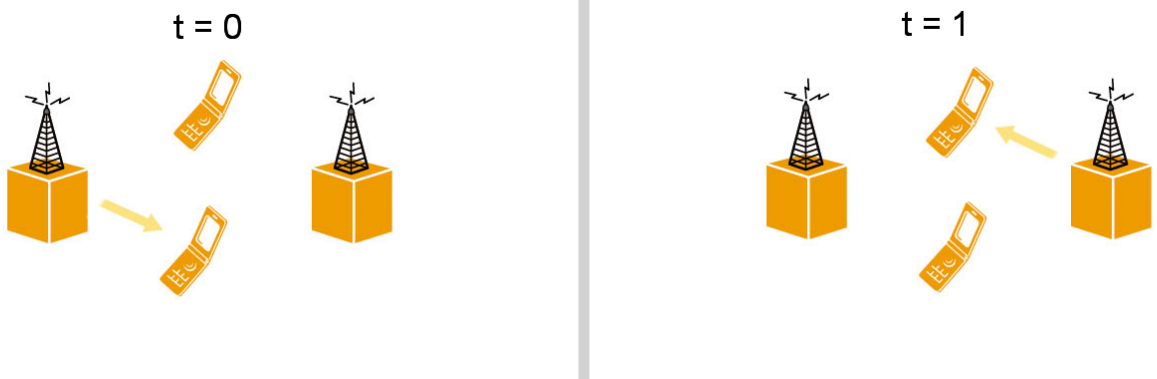


Figure 4. Principle of CoMP.

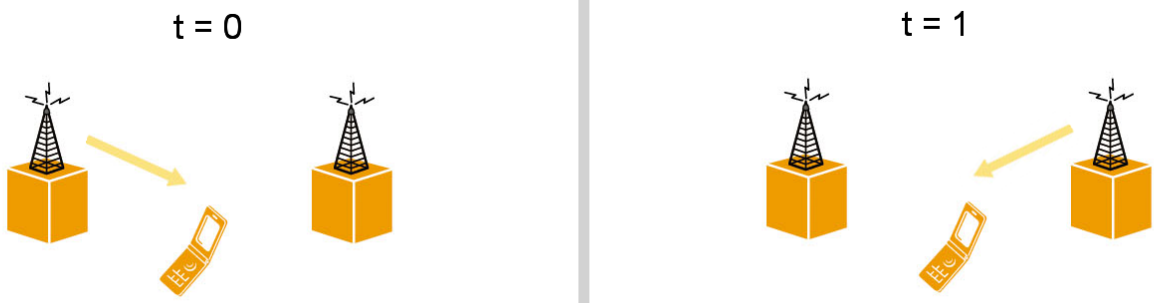
Coordinated Scheduling (CS)

- 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

- Overview
- Background
- ***System Model***
- Simulation
- Evaluation
- Conclusions
- References

Assumptions

- The geographical location of UE is shown
- UE does not move so no Doppler effect, studying slow fading
- CQI, PMI, RI are randomly generated
- Fixed number of UEs in a simulation
- Multipath channel used from 3GPP Ped/A
- Base stations are always in a hexagonal layout

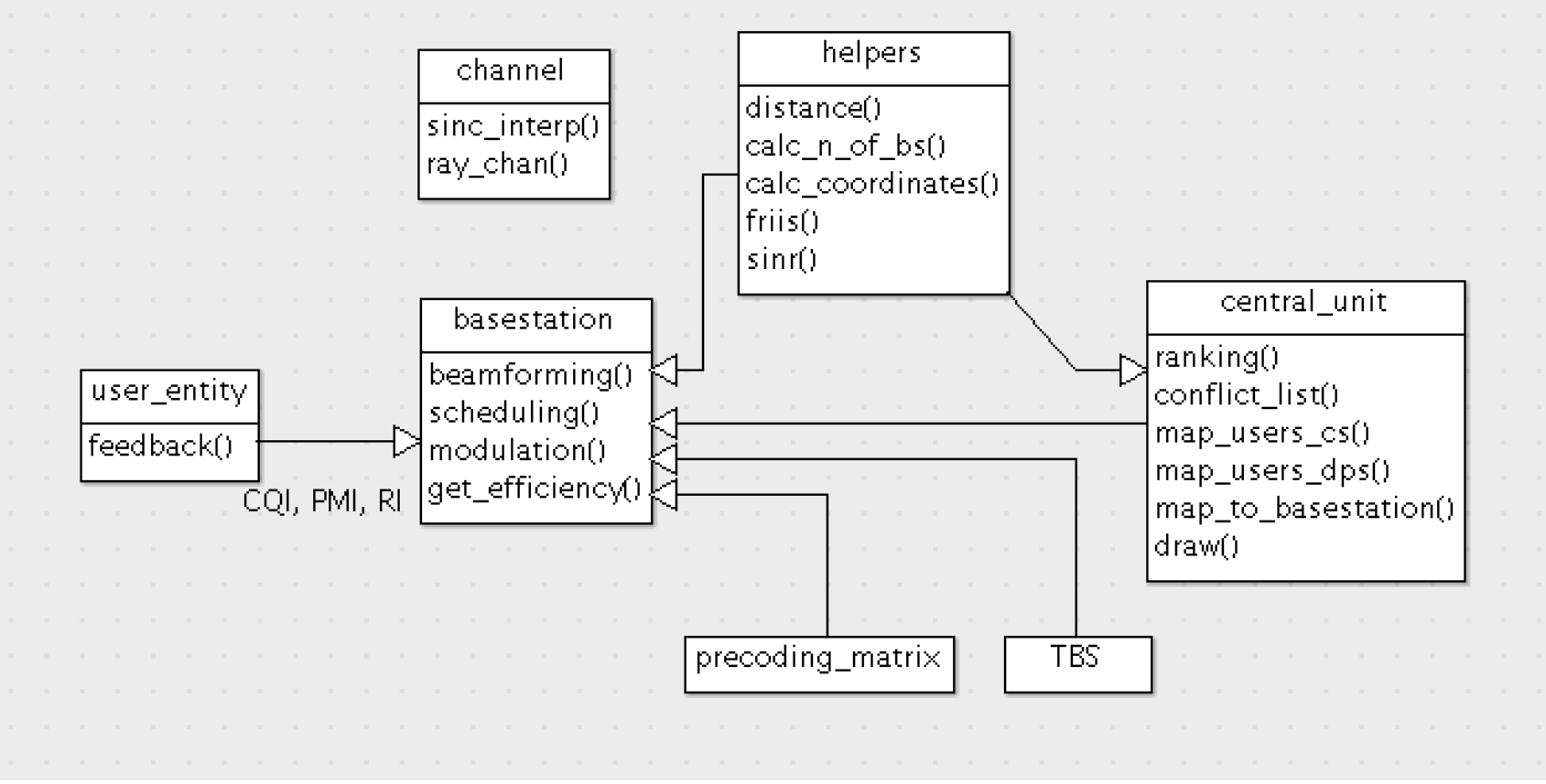
Programming

- Classes providing main functionality: central unit, base station, user entity, channel
- Classes providing background data and auxiliary functions: TBS, helpers, params, precoding matrix

Classes providing main functionality

- Central Unit: coordinates all base stations
  - one CU per simulation
- Base Station: matches subcarriers to connected users, assigns modulation and coding scheme, linked to CU via backhaul links
- User Entity: returns feedback to the base station
- Channel: has a certain frequency and amount of subcarriers
  - Frequency flat channel - using Friis equation for path loss
  - Frequency selective channel - Rayleigh channel

Overview of the classes



Overview

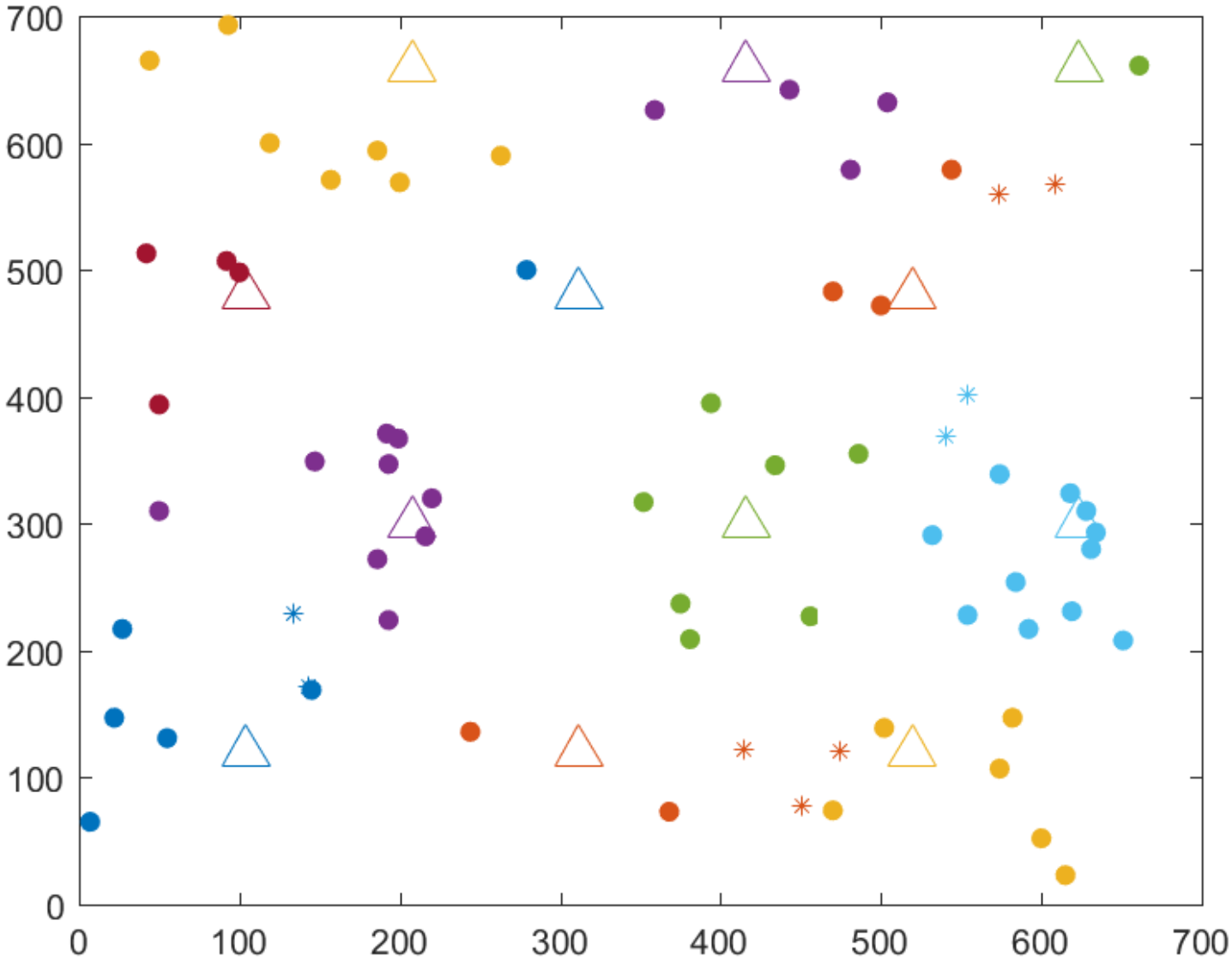
Content

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

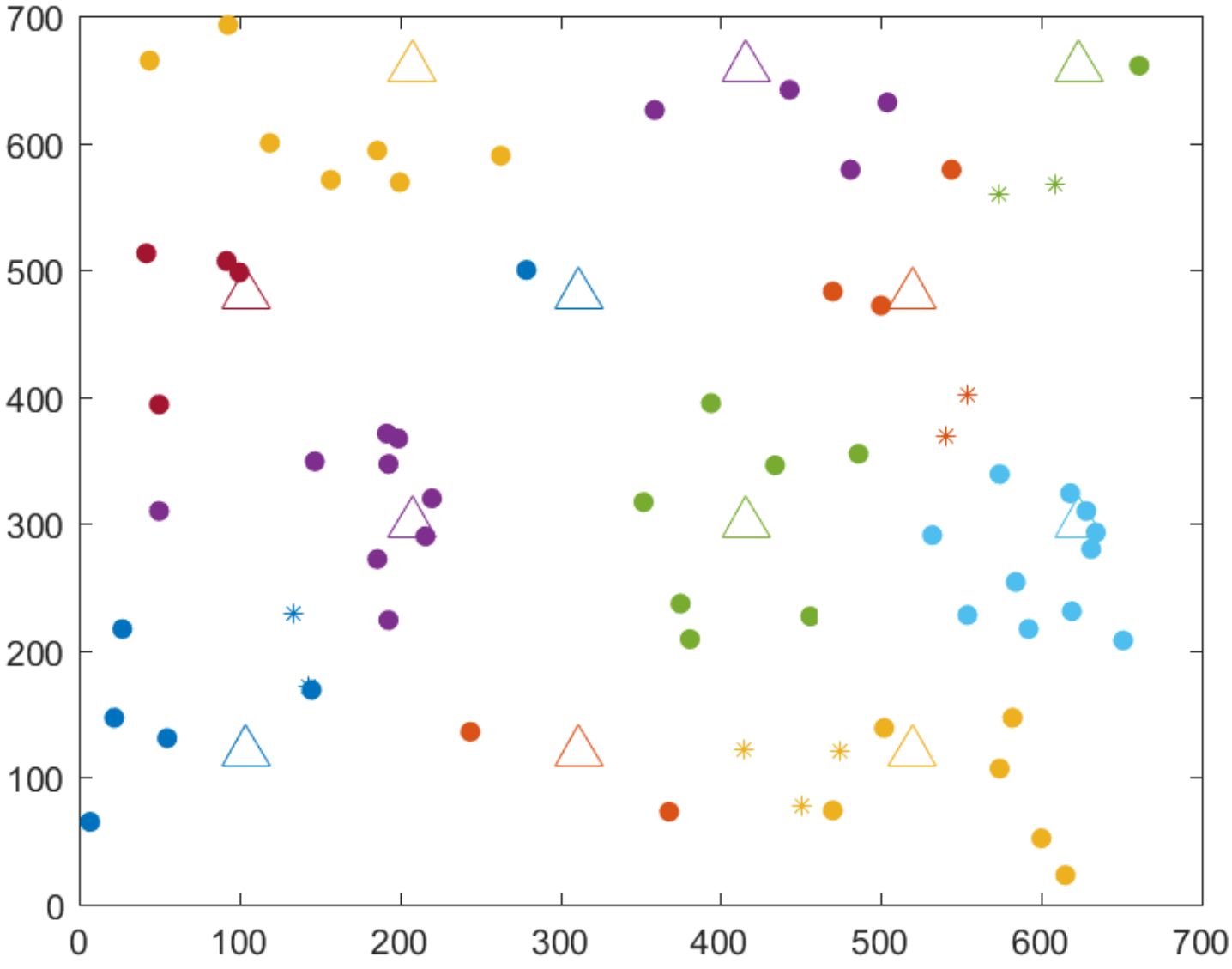
Main characteristics

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

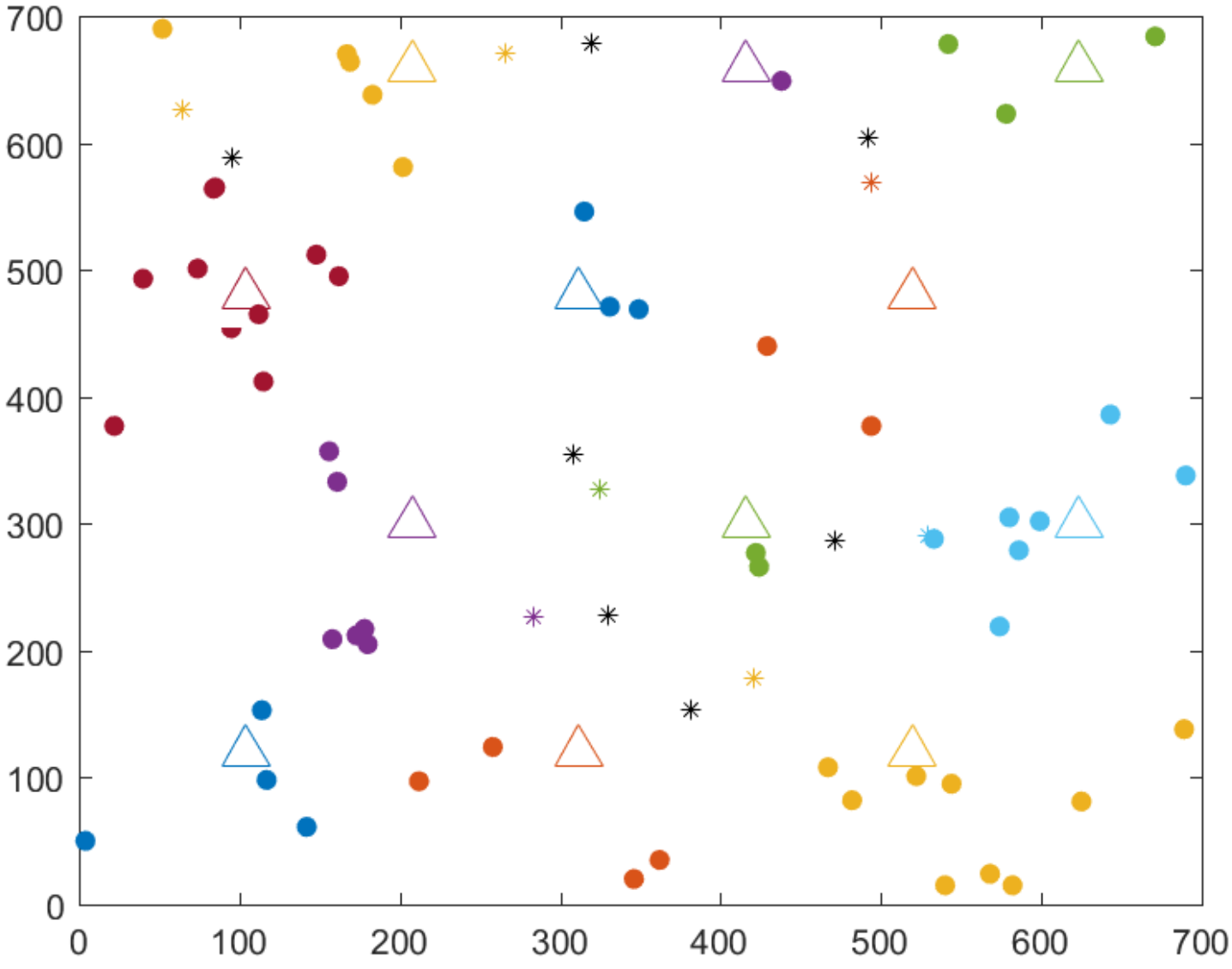
Simulation DPS I



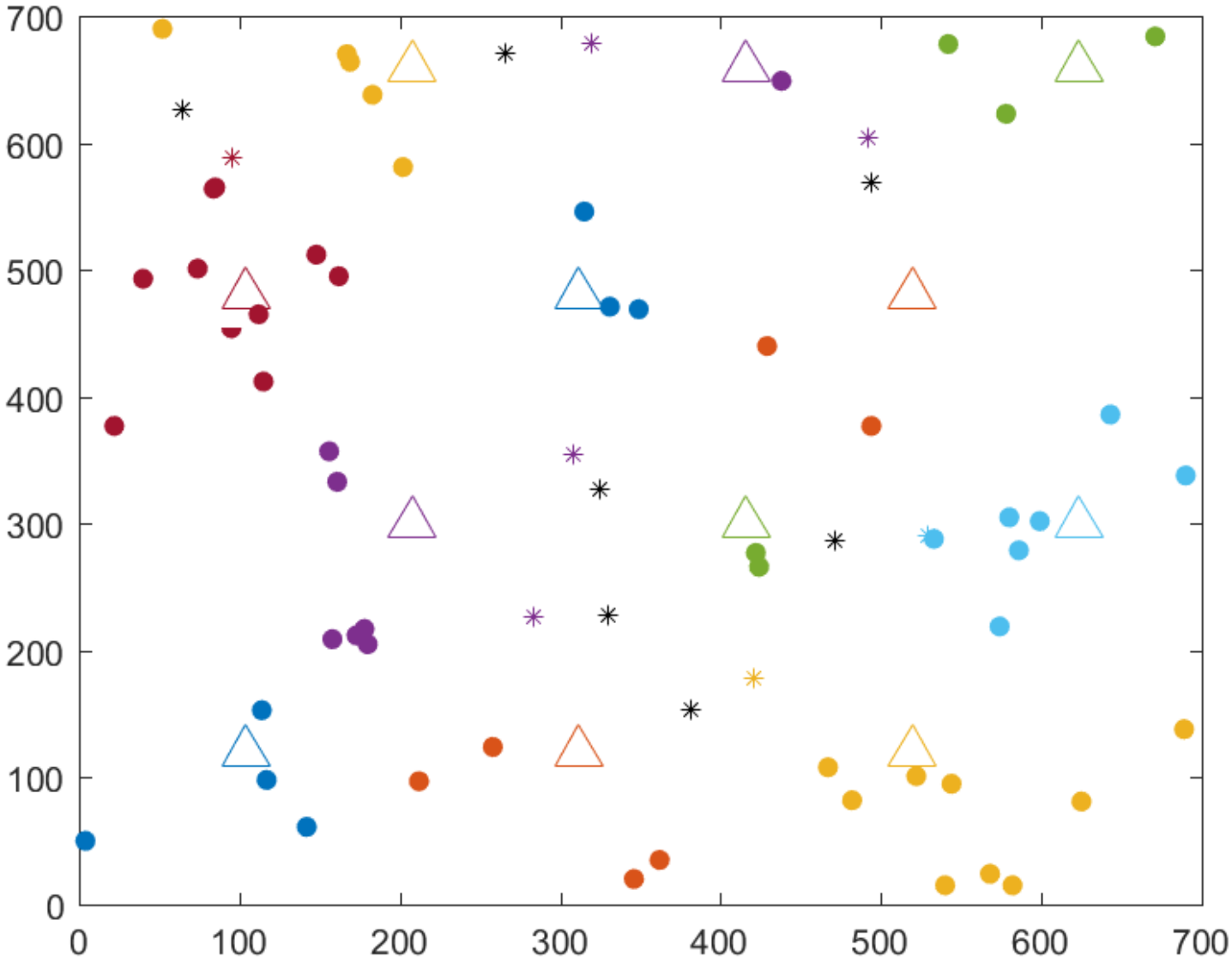
Simulation DPS II



Simulation CS I



Simulation CS II



Overview

Content

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

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

Overview

Content

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

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

Summary

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

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

Overview

Content

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

References

- Mehlführer, C. et al, 2009. Simulating The Long Term Evolution Physical Layer. Proc. 17th European Signal Processing Conference (EUSIPCO 2009), [online]
- Davydov, A. et al, 2013. Evaluation of Joint Transmission CoMP in C-RAN based LTE-A HetNets with Large Coordination Areas. Globecom 2013 Workshop.
- Hong, M. et al, 2012. Joint Base Station Clustering and Beamformer Design for Partial Coordinated Transmission in Heterogeneous Networks.
- Sawahashi, M. et al, 2010. Coordinated Multipoint Transmission/Reception Techniques For LTE-Advanced.

Thank you for your attention!