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Vodafone Chair Mobile Communications Systems, Prof. Dr.-Ing. G. Fettweis

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CoMP as a Key Technology for IMT-Advanced - Field Trial Results reveal Gains and Challenges

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Outline

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- Motivation / Overview
- Challenges
- Recent Field Trial Results
- Outlook and Conclusions

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Motivation

Potential Gains of Uplink CoMP

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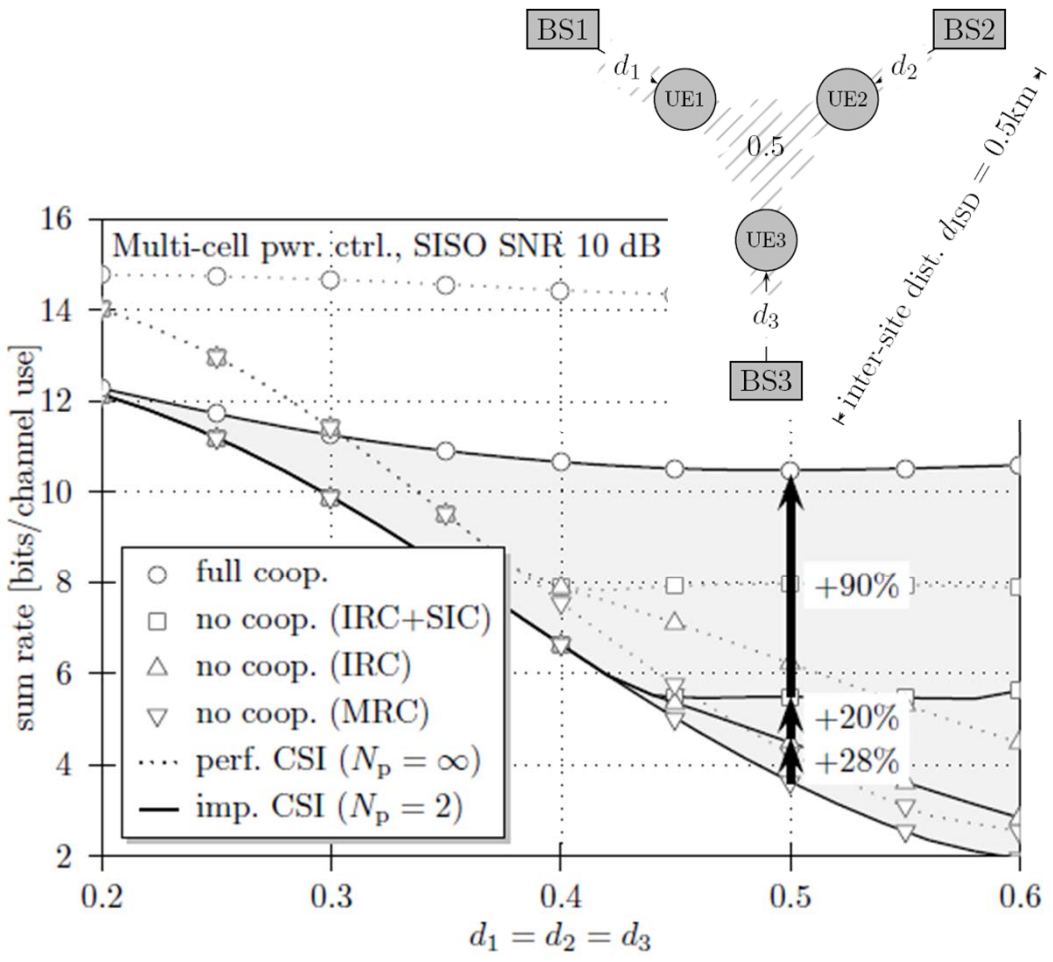
Observation of Small 3-by-3 Scenarios



Key Findings

- Strongest gain in scenarios of strong, symmetrical interference (cell-edge)
- Strongly improved fairness
- Weak interference links cannot be estimated well and hence also not exploited
- 90% performance gain at the cell-edge thinkable
- Gains also through
  - IRC
  - Local SIC

Motivation

Potential Gains of Downlink CoMP

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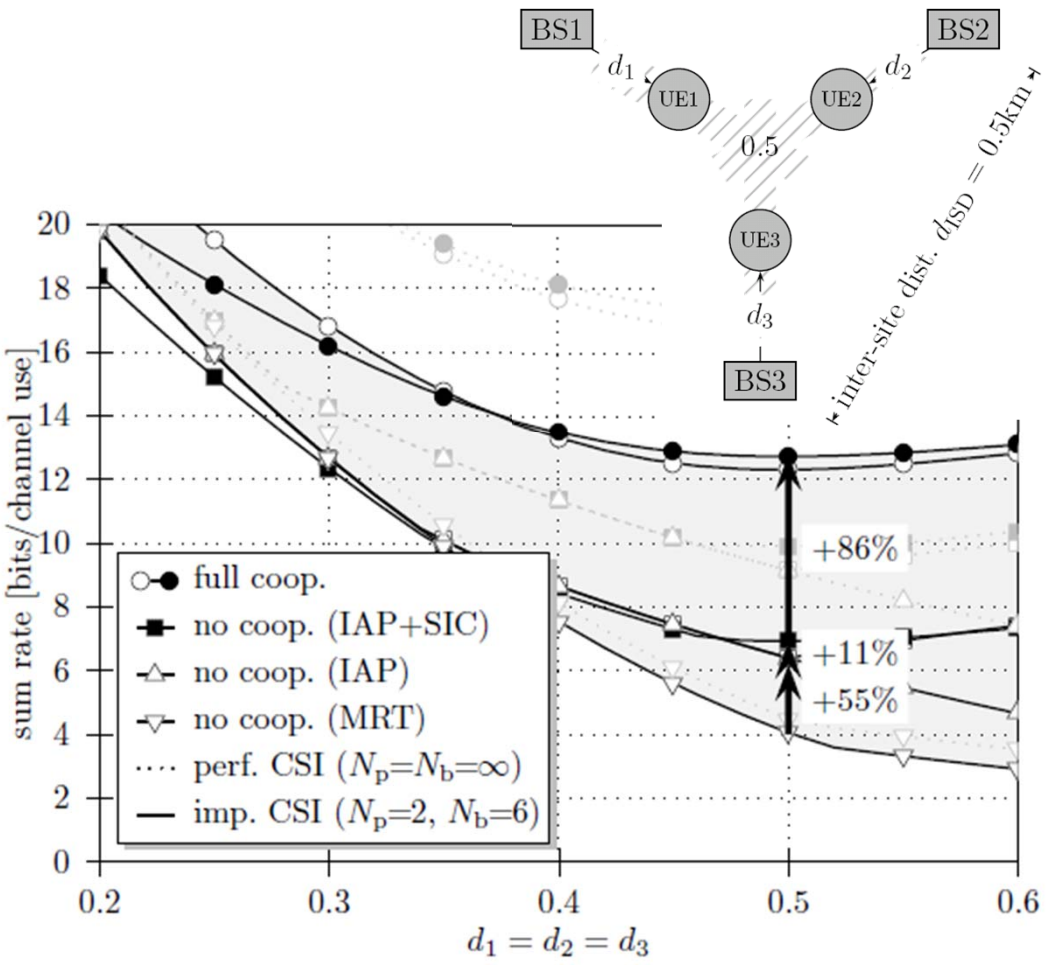
Observation of Small 3-by-3 Scenarios

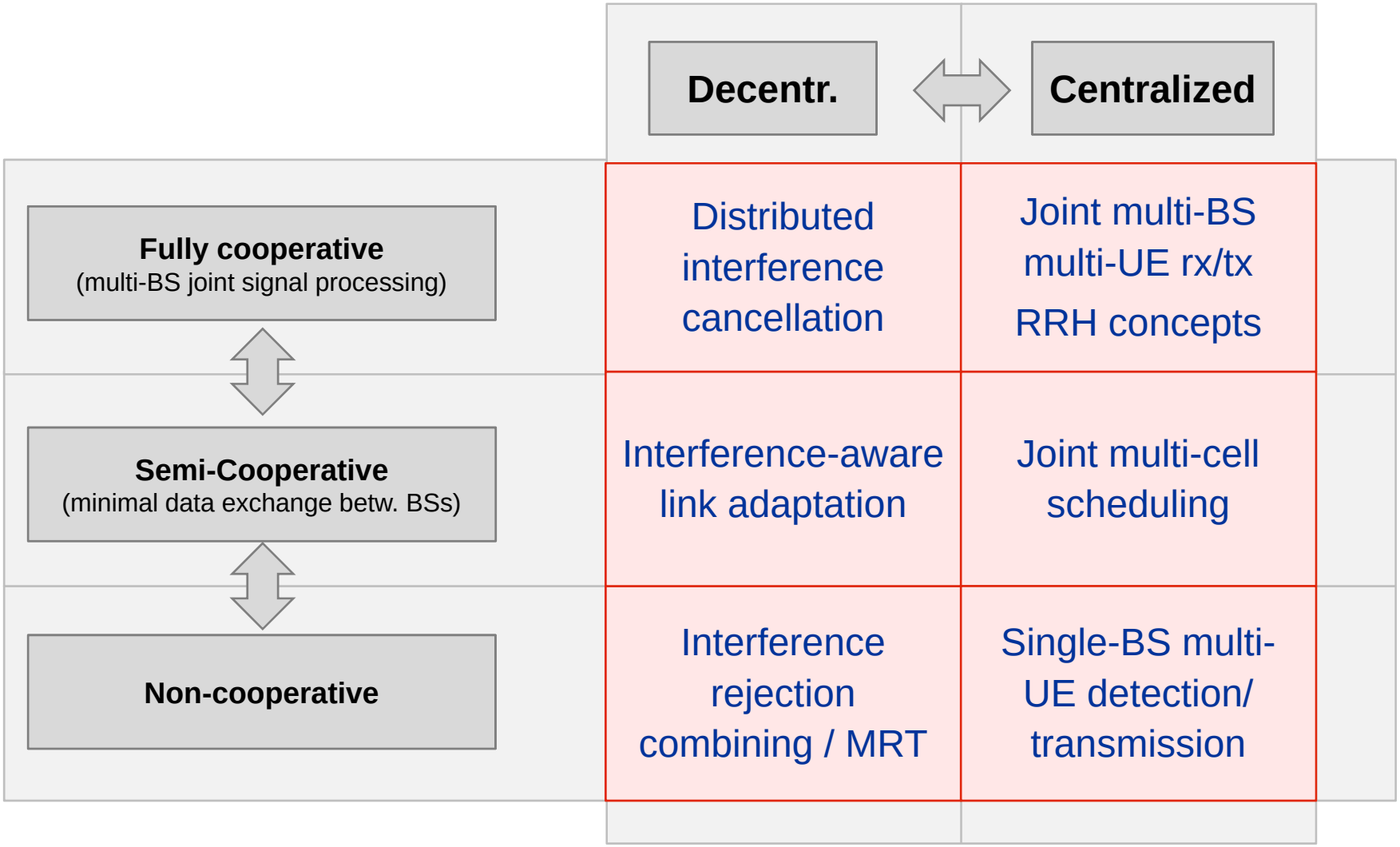


Key Findings

- Again strongest gain at the cell-edge
- Strongly improved fairness
- DPC only superior to linear precoding in cases of strong interference, otherwise links to weak to estimate well
- 86% performance gain at the cell-edge thinkable
- Only marginal gain through local multi-UE transmission with DPC

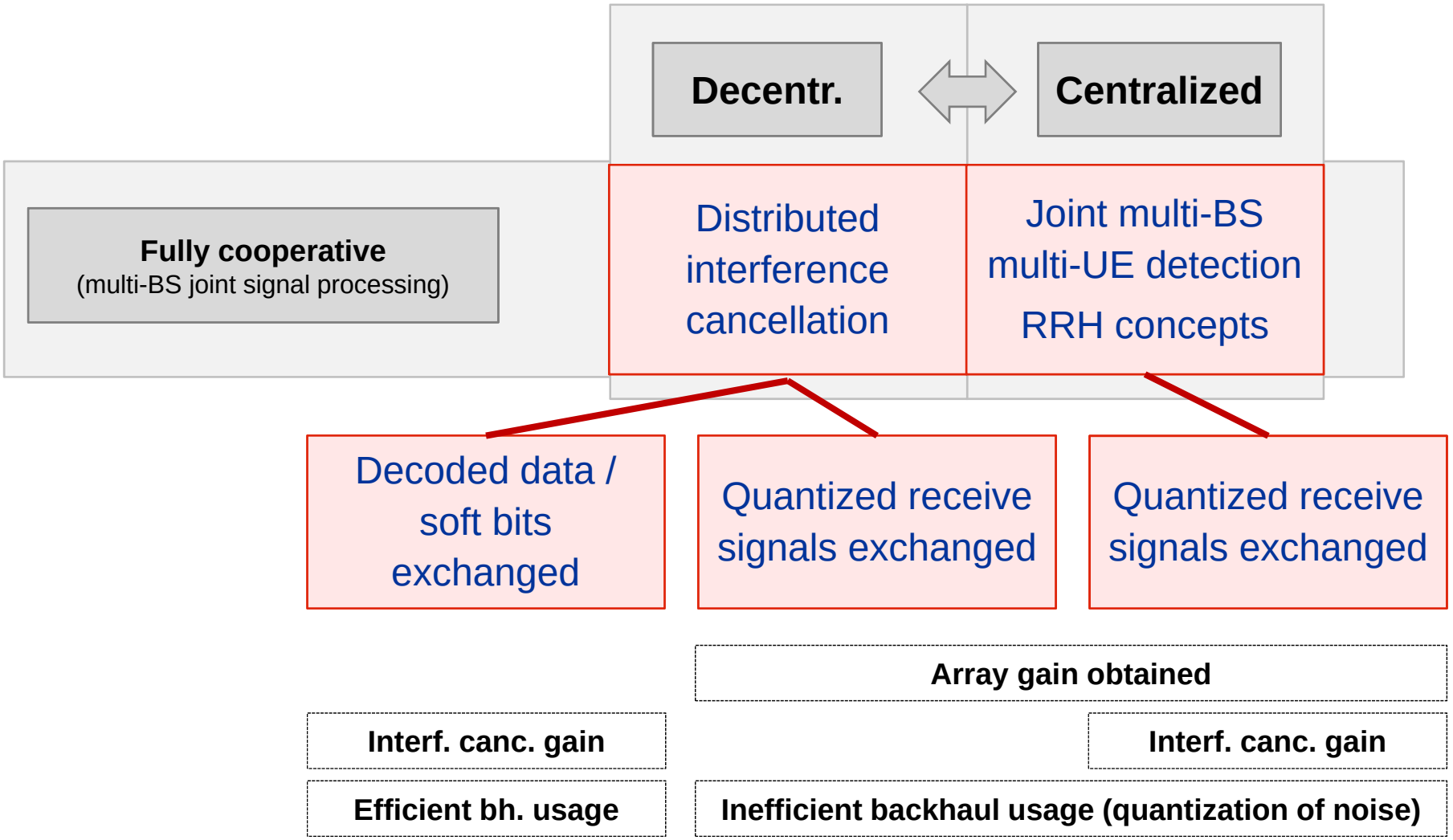
Overview

Different Types of CoMP



Overview

Centralized vs. Decentralized Joint Signal Processing in UL



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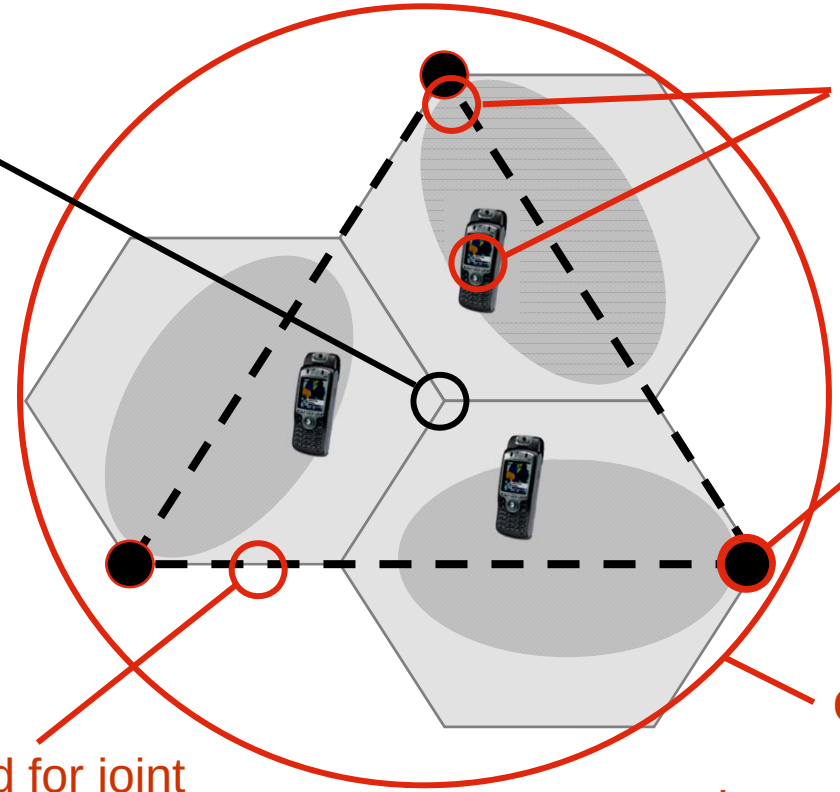
Challenges

Key CoMP Challenges Identified

- The following challenges have to be addressed to enable efficient CoMP:



Channel estimation (for DL CoMP: CSI feedback to eNB side)

Pilot and CSI feedback overhead

Synchronization in **time / frequency**

Scheduling / Link Adaptation

Clustering

Backhaul required for joint signal processing and signalling

Impact of uplink CoMP on higher protocol layers

Challenges
Clustering

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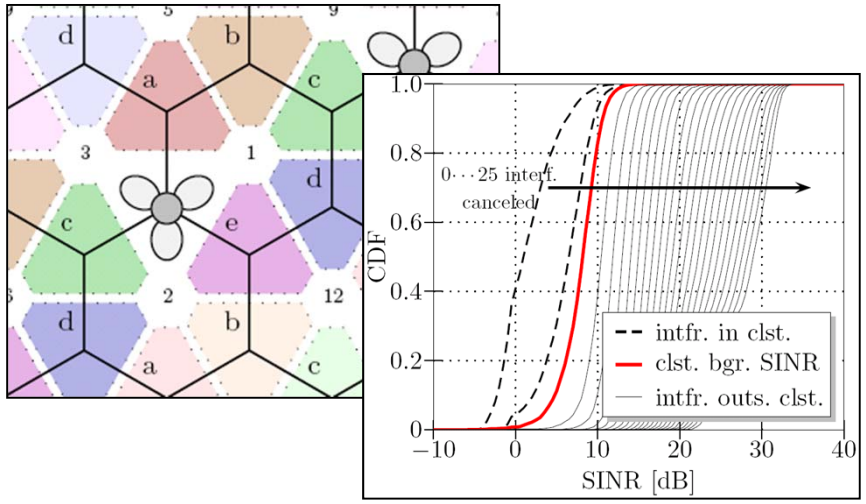
• How to extract small CoMP scenarios from a large cellular network?

Static Clustering

• Pre-definition of clusters (via ray-tracing or measurements), possibly with resource partitioning



⊕ Poss. oblivious to UEs, min. signaling

⊖ Requires manual clustering

Dynamic Clustering

• Possibly usage of pre-defined hierarchy of eNBs that may cooperate and clusters units (CU)

• Exchange among eNBs of neighbor relation tables (NRT) provided by UEs

• Clustering decisions performed by CUs and based on NRTs and/or UE location information

⊕ Reuses SON-ANR functionality

⊖ Requires more signalling

Challenges
Synchronization in Time

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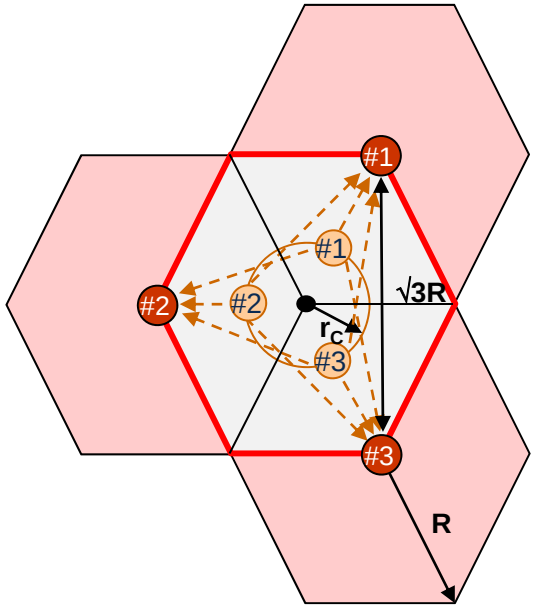
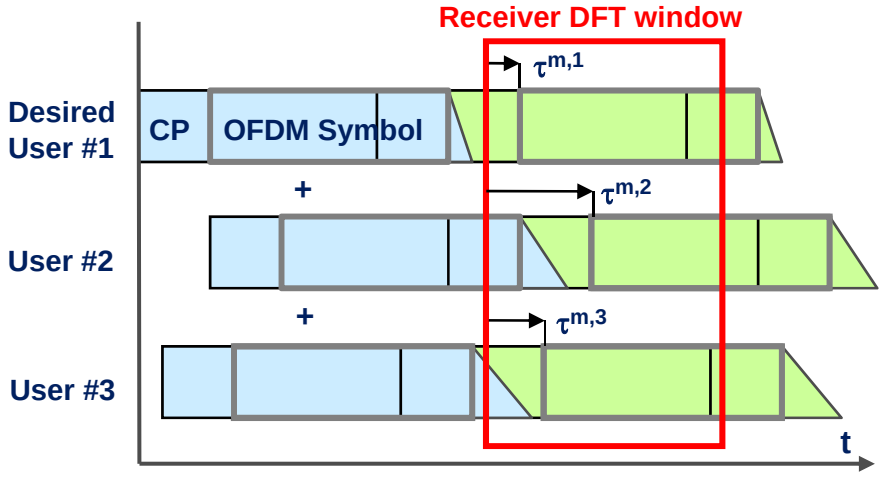
Synchronization in Time

- In a CoMP setup, each UE can only be synchronized to one eNB
- Asymmetric signal propagation delays hence lead to
  - Inter-symbol interference
  - Inter-carrier interference
- We have to consider
  - Multi-cell timing advance
  - Compensation techniques for impairments





Challenges
Synchronization in Frequency

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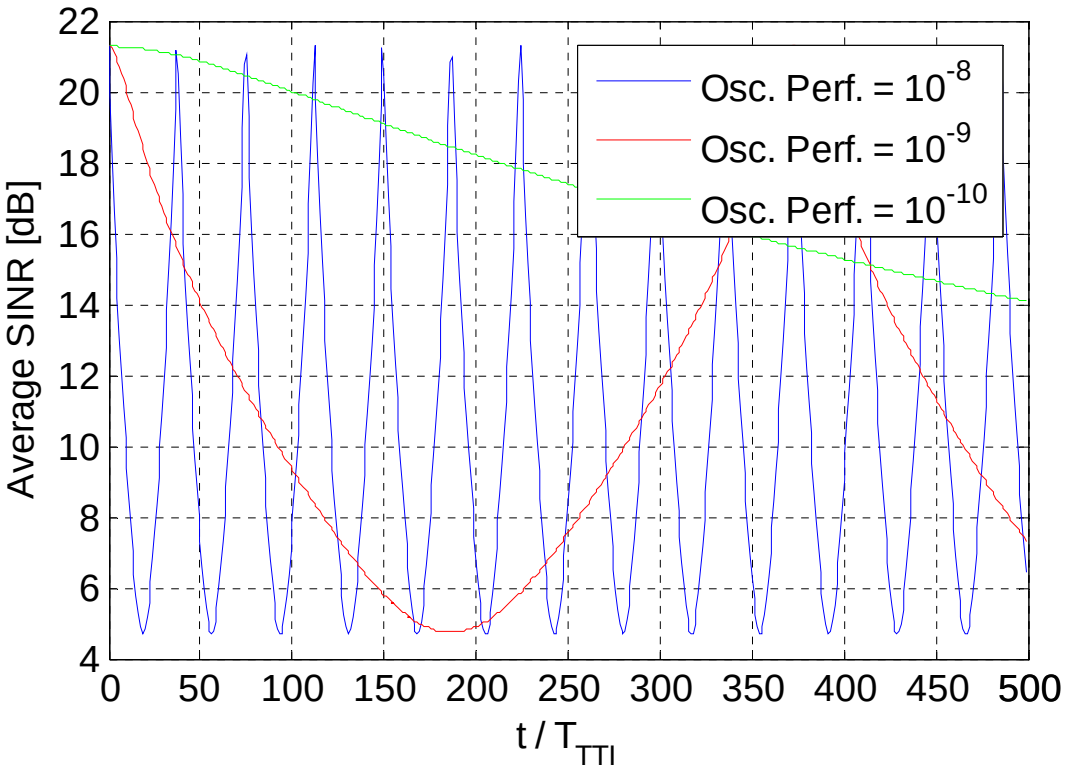
Synchronization in Frequency

• On one hand, all entities in a CoMP setup have to be synchronized in frequency to avoid ICI (legacy sync usable)

• For downlink CoMP, cooperating BSs need to have accurately synchronized LOs

• This is possible with expensive reference normals and, e.g., GPS synchronization
→ alternatives needed

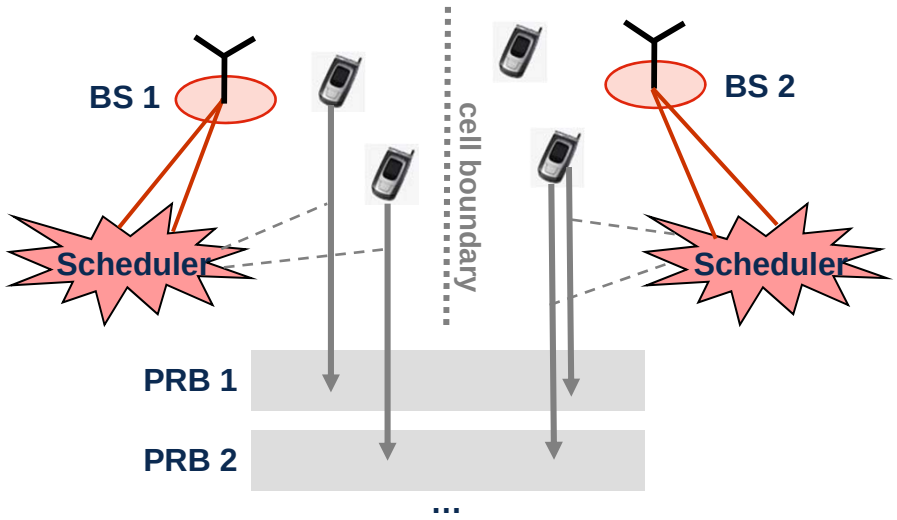
- Setup: Downlink, 2 BSs with 2 antennas each, 2 UEs with 1 antenna each



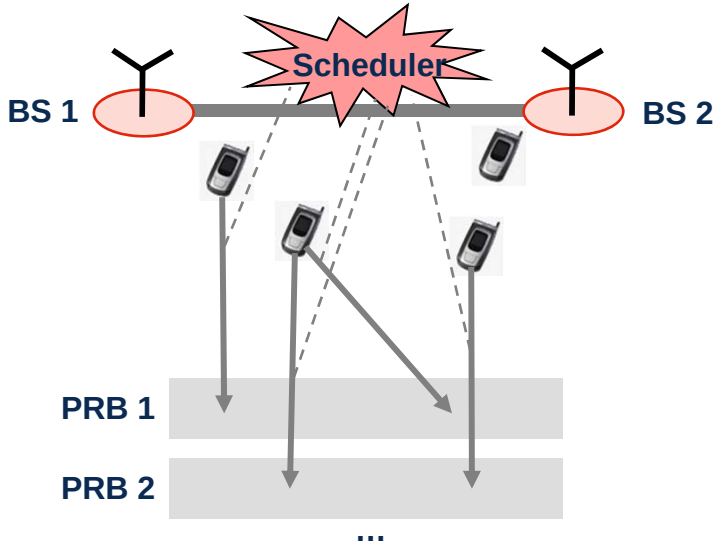
- Major performance degradation, especially if large CSI feedback delay

Challenges
Scheduling

Traditional Scheduling:



Cooperative Scheduling:



Intelligent resource allocation is essential to extract CoMP gains in network!

User requirements:

- Rate
- Max. latency
- Quality of Service

Challenges:

- User grouping
- Choice of CoMP strategy
- Link adaptation
- Power control

Issues:

- Backhaul for signalling
- Latency
- Complexity

Challenges
Backhaul

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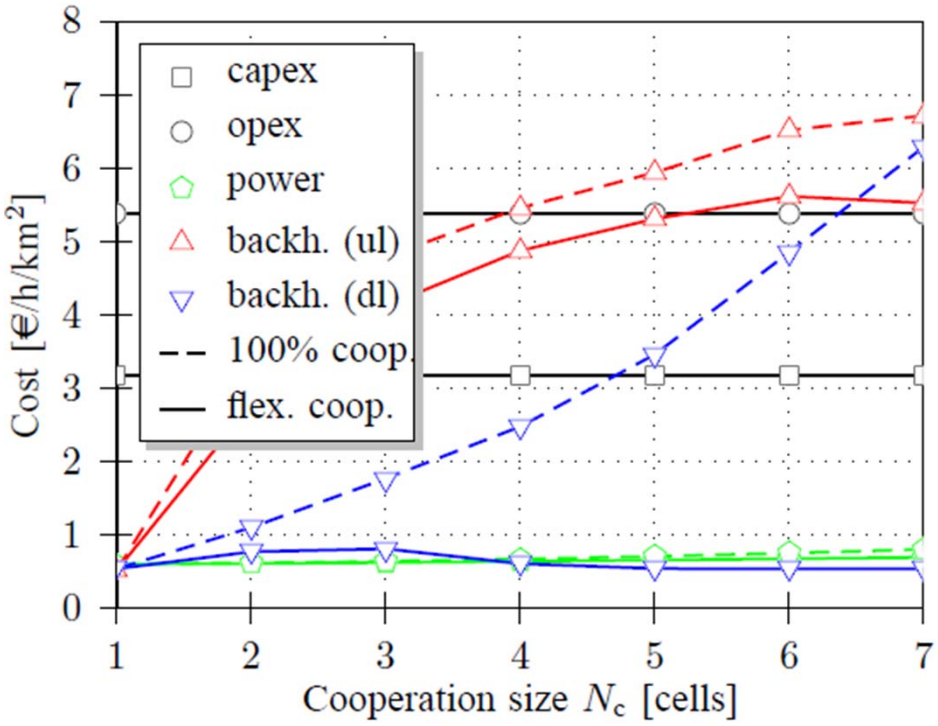
Backhaul Requirements

- Uplink
  - Exchange of quantized signals or preprocessed signals (linear in cooperation size)
  - Forwarding of data to network
- Downlink
  - Distribution of channel knowledge between base stations (quadratic in cooperation size)
  - Distribution of user data (quadratic in cooperation size)

Potential Backhaul Costs



- Smart- and backhaul-aware usage of CoMP necessary

Challenges

Pilot and CSI Feedback Overhead

Pilots required

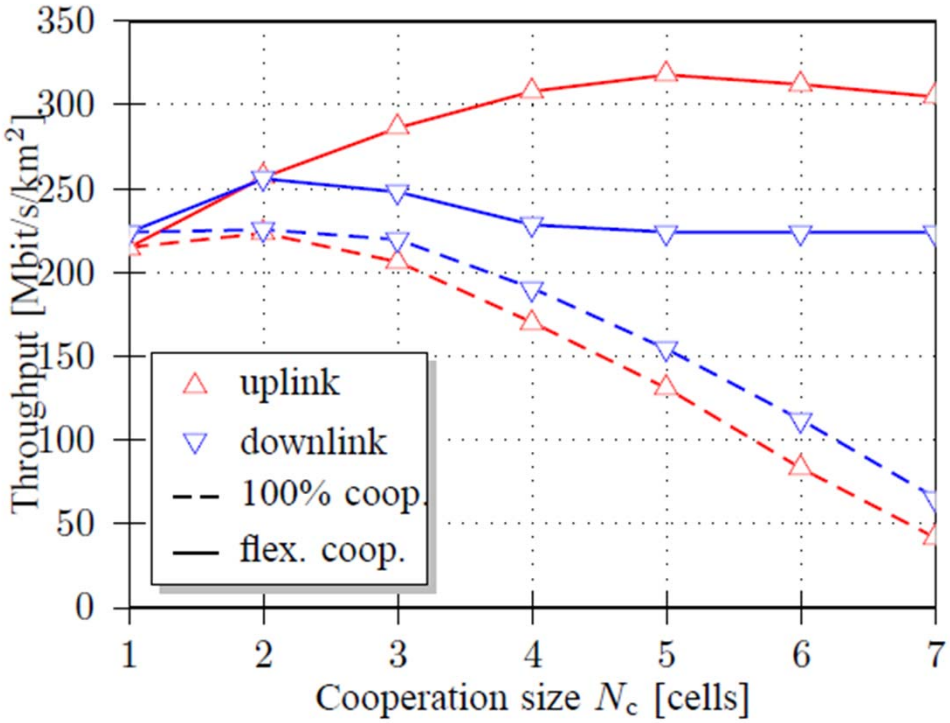
- In uplink CoMP, the pilot overhead increases linearly in the cooperation size

- In downlink CoMP, the pilot overhead increases linearly in the number of BS antennas + linearly in the coooperation size

→ pilots needed for channel estimation and CSI feedback
→ precoded pilots needed for data decoding

Simulation Results

- ISD 500m, imp. CSI (LTE Rel. 8)



- Flexible pilot schemes required

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Recent Uplink Field Trial Results

Outdoor Measurement Setup

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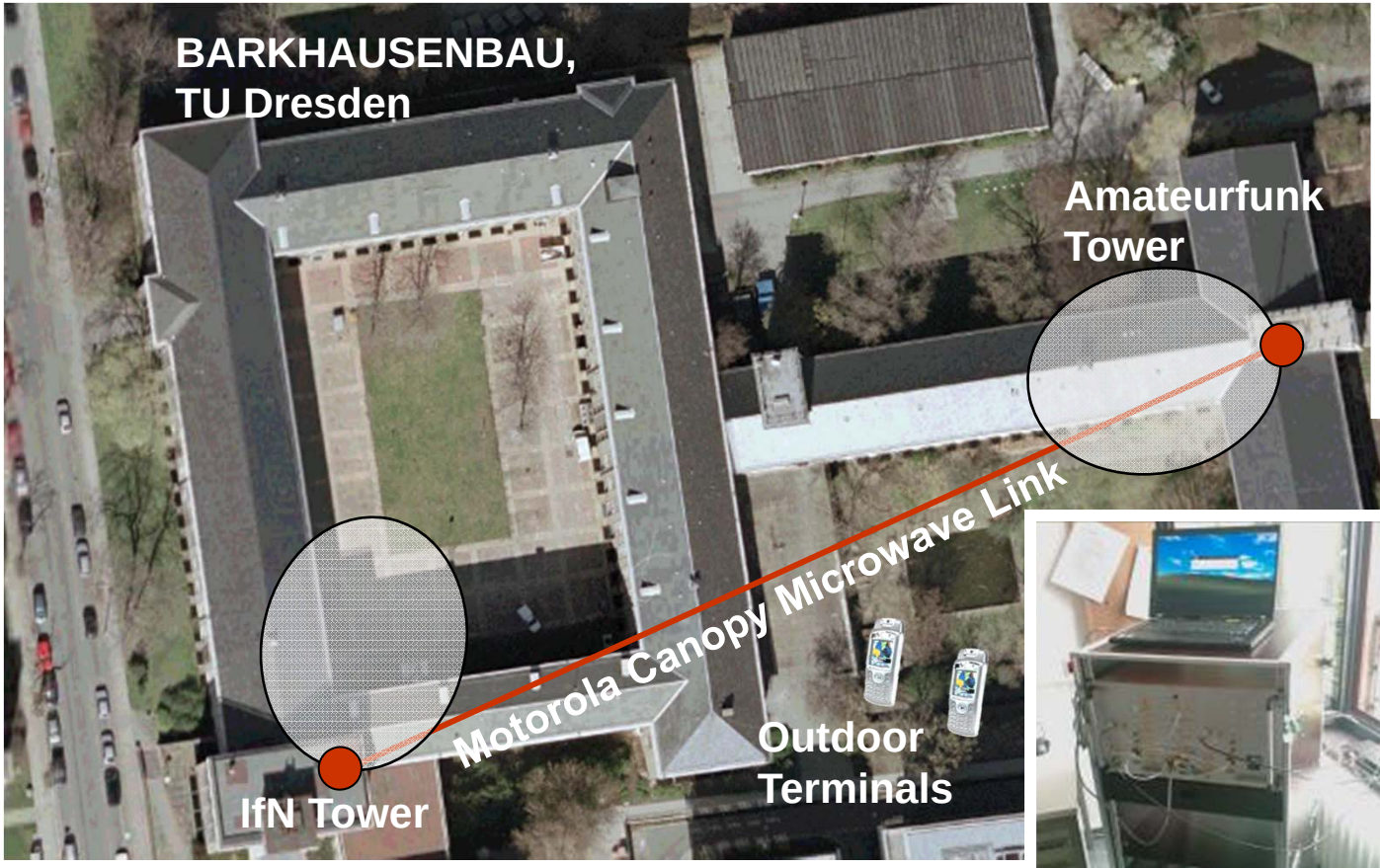
- Two base stations deployed on university rooftop

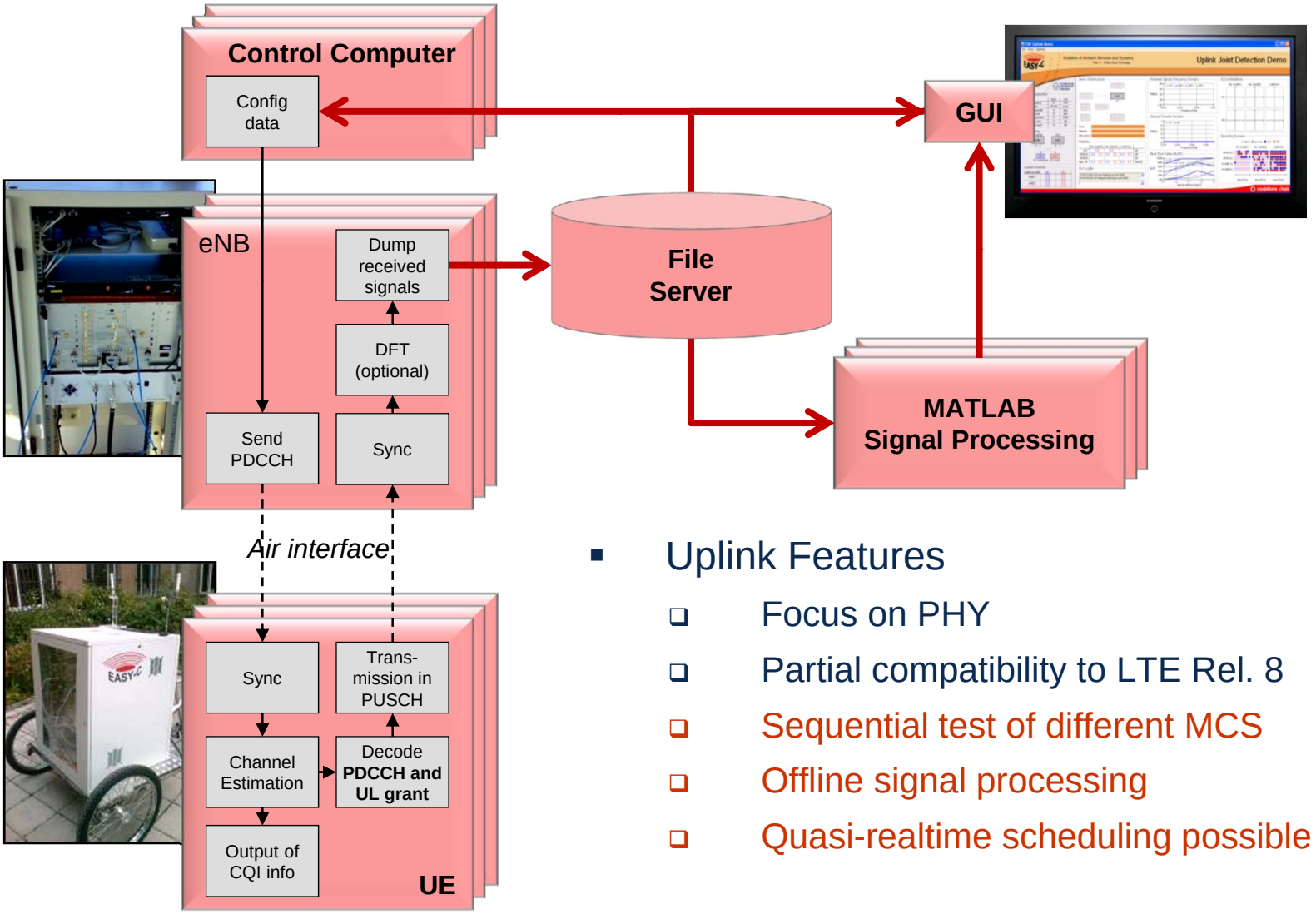


X-Pol Antenna from KATHREIN and Motorola Canopy Link

Mobile Lab Test Terminal

Recent Uplink Field Trial Results

Dresden Test Platform Uplink Setup



- Uplink Features
  - Focus on PHY
  - Partial compatibility to LTE Rel. 8
  - Sequential test of different MCS
  - Offline signal processing
  - Quasi-realtime scheduling possible

Recent Uplink Field Trial Results

Measurement Results

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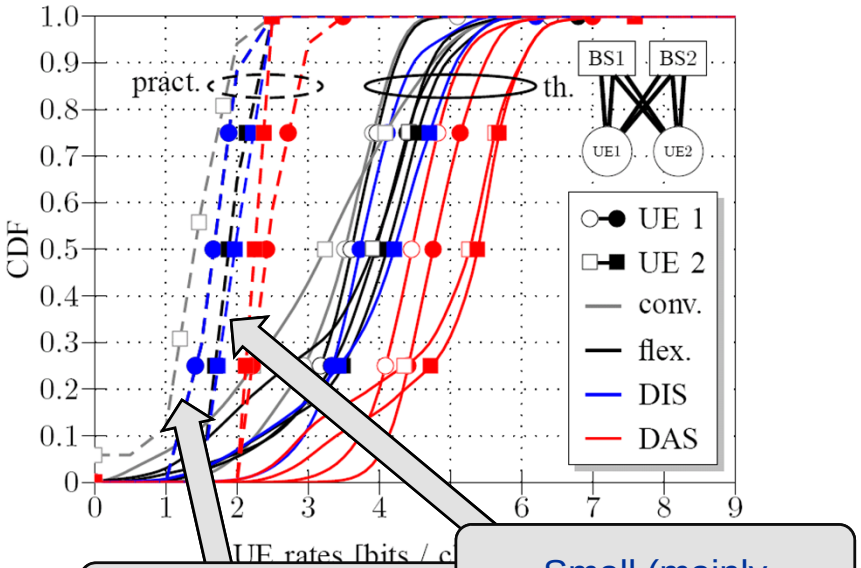
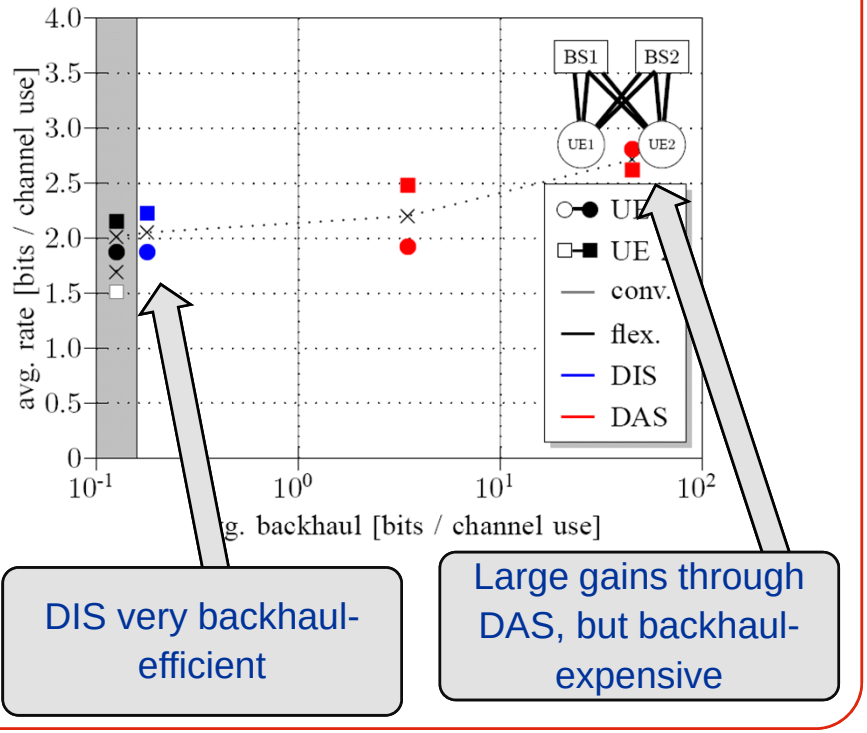
Performance vs. Backhaul in a CoMP Scenario with 2 UEs and 2 eNBs

Performance



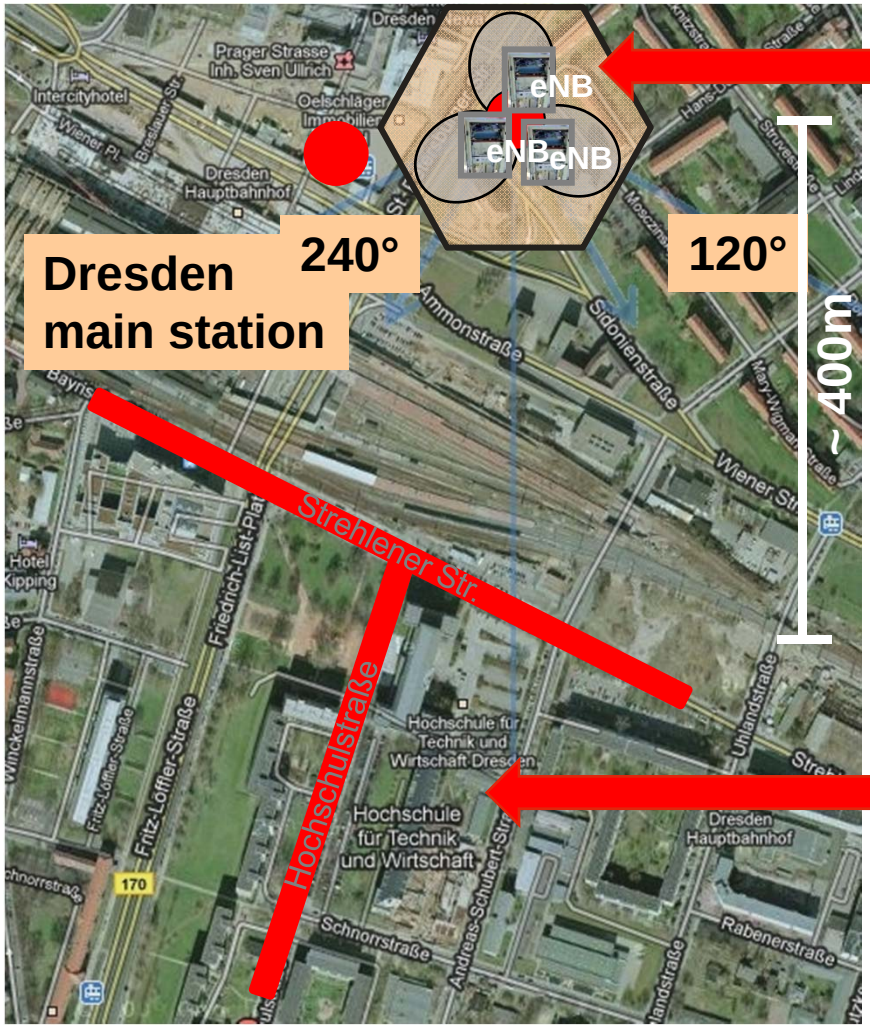
Backhaul Required



- Overall rate gain CoMP vs. LTE Rel. 8 on the order of **75%**
- DIS is a low-backhaul alternative improving outage

Recent Downlink Field Trial Results

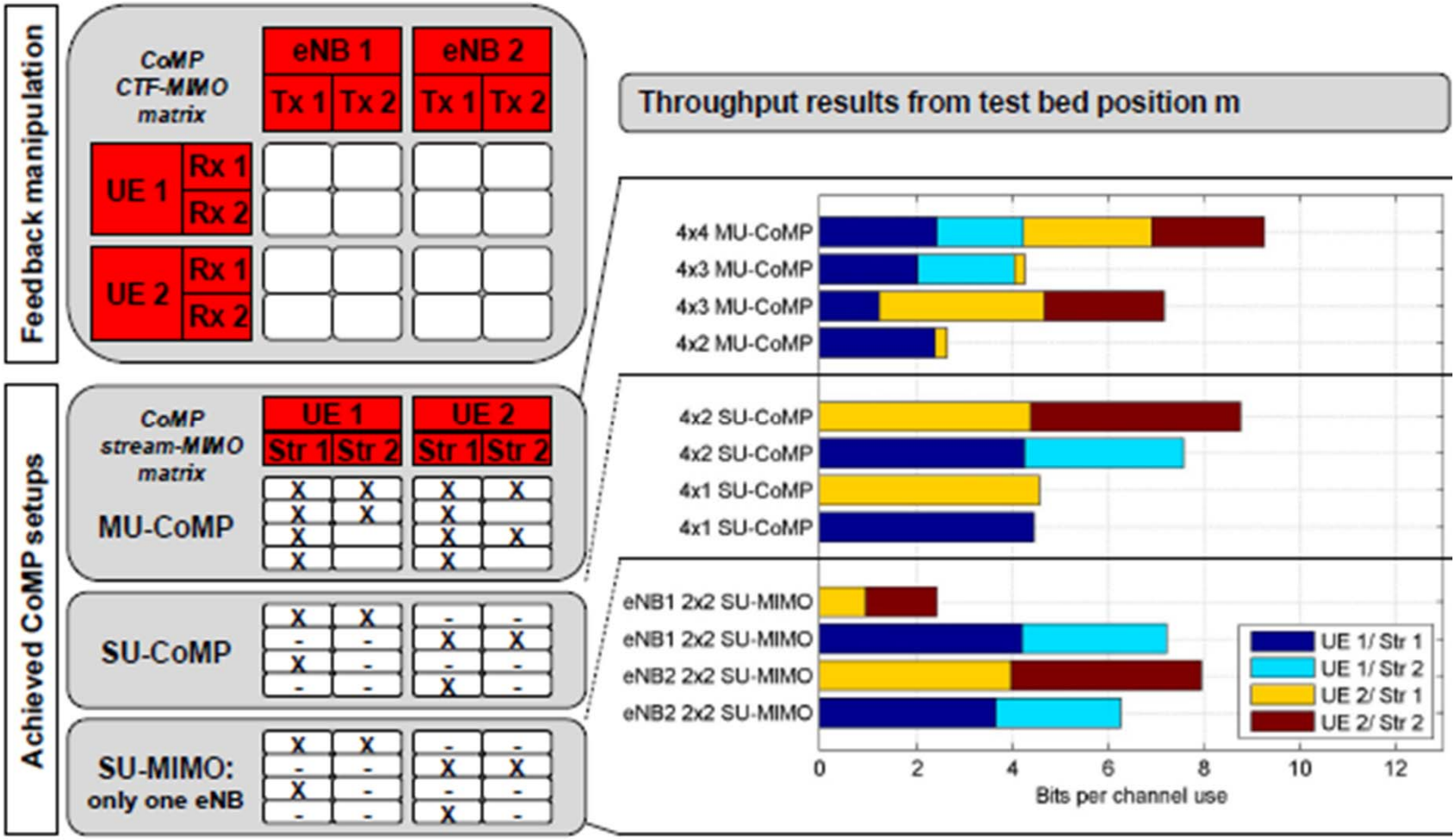
Outdoor Measurement Setup



- Location of EASY-C public workshop, April 2010 (first DL 3x3 CoMP demo)
- Location of current measurement campaign (3 co-located base stations, two terminals)

Recent Downlink Field Trial Results

Measurement Results



- Substantial gains visible at the cell-edge
- Challenge of link adaptation and adaptive CoMP

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Outlook

Open Research Questions

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- Self-organizing interference management in heterogeneous systems
  - Avoiding interference (e.g. 3D beamforming) vs. allowing interference
  - Ad-hoc CoMP (after transmission has taken place)
- What is the optimal PHY in the context of CoMP?

Conclusions

- CoMP promises substantial capacity and fairness gains
- Some CoMP concepts appear to be usable at an early point in time in LTE-A

- Remaining challenges:
  - Clustering → align with SON research
  - Synchronization
    - In frequency → solvable with expensive oscillators (alternatives needed)
    - In time → limits scenarios where CoMP can be performed
  - Scheduling / ad-hoc CoMP → vast research still needed
  - Backhaul → key lies in efficient and adaptive signal compression
  - Channel estimation → LTE Rel. 8 pilots usable, but improvements possible
  - Pilot overhead → Will most likely limit CoMP to no more than 3 cells, flexible pilots needed

Thank you for your attention!