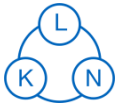

Technische Universität München
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Prof. Dr.-Ing. J. Eberspächer

VDE/ITG Fachgruppe 5.2.4 Workshop Darmstadt 2010
Interference Management and Cooperation Strategies in Communication Networks

Interference Management: From Autonomous to Closely Coordinated Approaches

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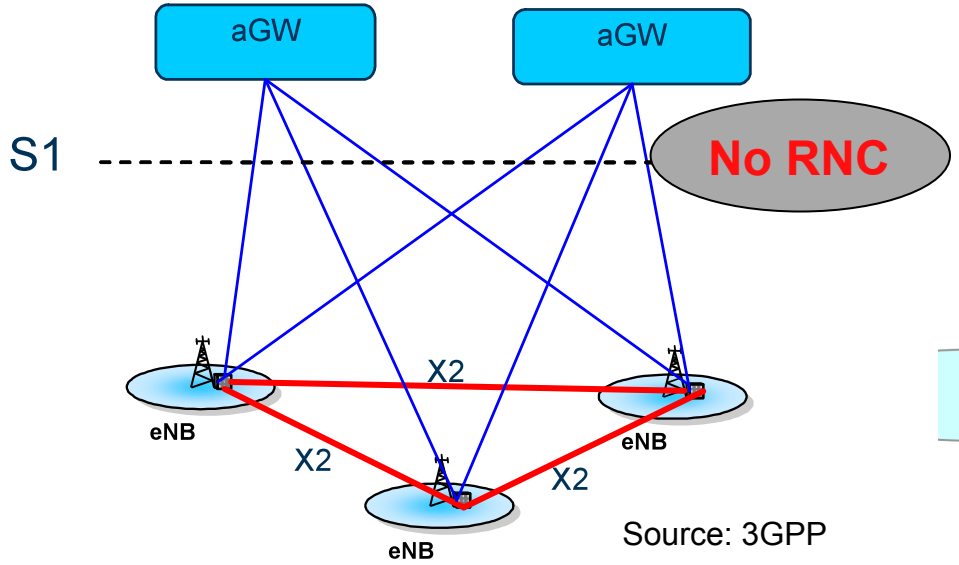
Trend from Decentralization to close Coordination

LTE Release 8

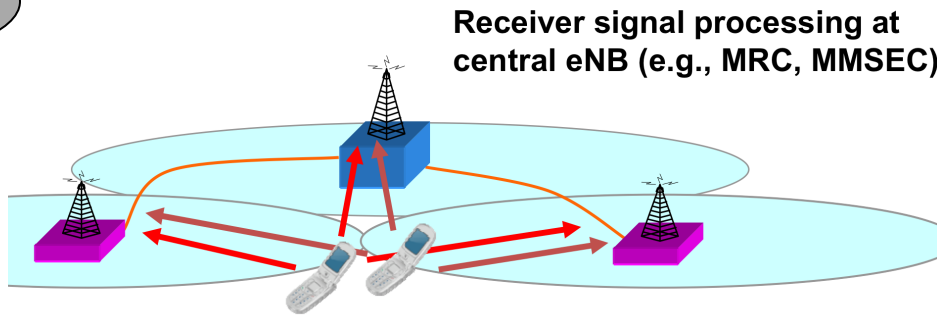
- IM usually means Interference Coordination by reuse restrictions
- Decentralized organization:
  - no central control (RNC)
  - loose coupling between eNBs
  - only some indicators (HI, OI, RNTP) defined



Source: 3GPP

LTE-Advanced Release 10

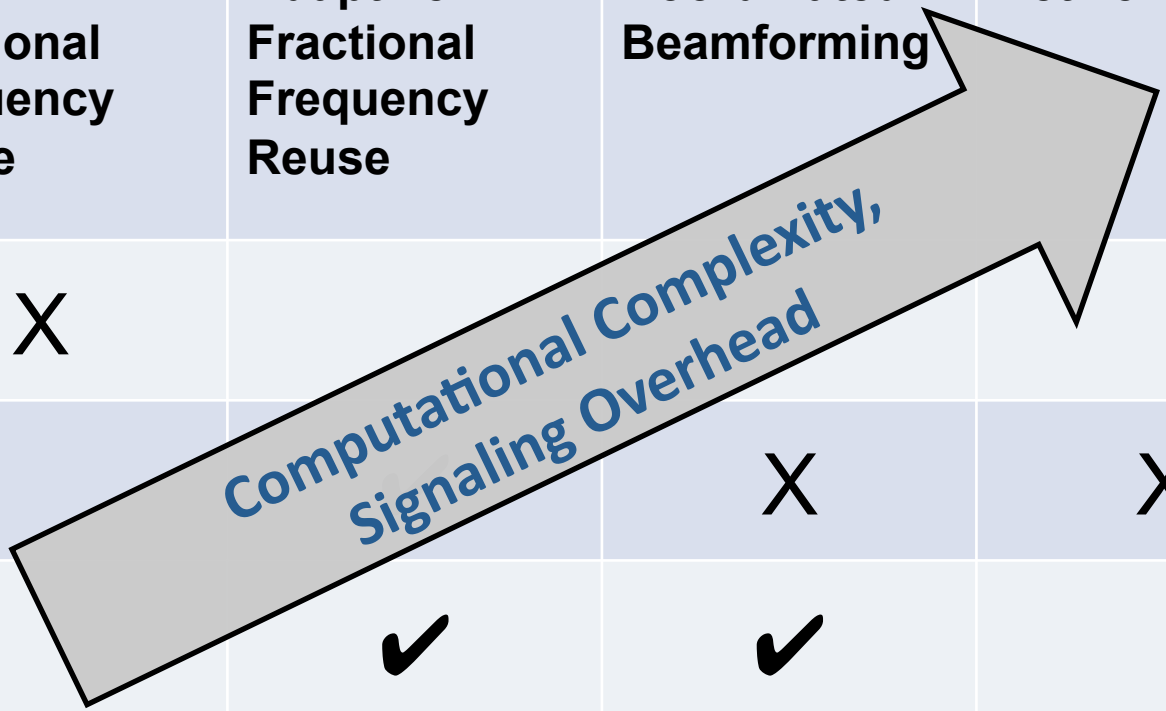
- Coordinated Multipoint (CoMP) discussed as aggressive IM technique
- Coordinated scheduling/beamforming
- Joint processing in Uplink/Downlink
- Very tight coupling between eNBs:
  - high backhaul signaling bandwidths
  - very tight delay requirements



Source: 3GPP

Classification of Interference Management Schemes

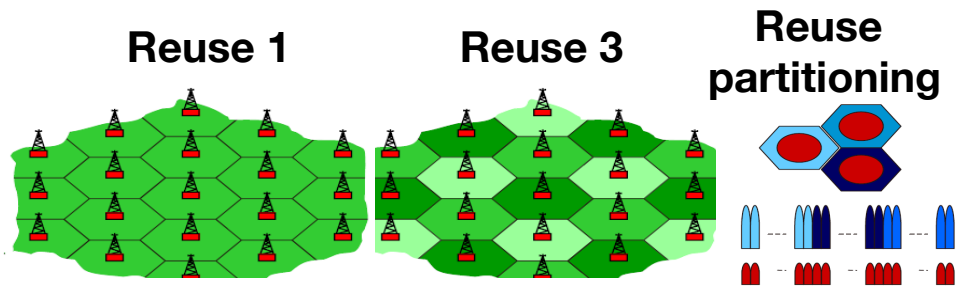
Interference Management (IM)				
Inter Cell Interference Coordination (ICIC)				
Reuse Coordination			CoMP	
	Fixed Fractional Frequency Reuse	**Adaptive Fractional Frequency Reuse**	**Coordinated Beamforming**	**Network MIMO**
Centralized schemes	X			
Decentralized schemes			X	X
Autonomous schemes		✔	✔	



Adaptive Reuse Coordination

Adaptive Reuse Coordination:

- Trade-off between spectrum reuse and interference avoidance
- Previous schemes mostly static



Source: Ericsson Research

Desirable properties:

- Dynamic scheme:
  - adapts to load situations
  - can handle uneven load distributions
  - should be stable (convergence)
- Decentralized scheme
  - no central Radio Network Controller (RNC)
  - base stations should self-organize
  - can use signaling via X2 interface
  - optionally: autonomous operation

Use cases:

- Reuse Coordination in Femtocell deployments, especially Femto-to-Femto interference coordination
- Here: Results for Reuse Coordination between eNBs in cellular systems

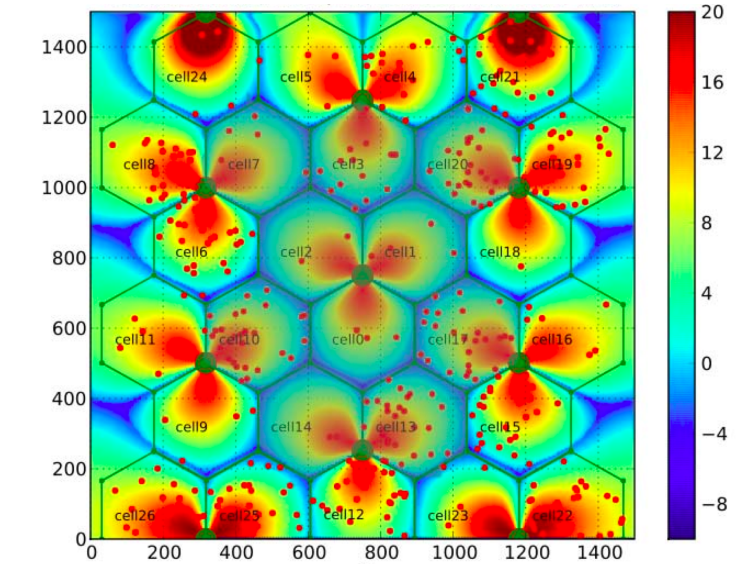
Reuse Coordination example: LTE uplink

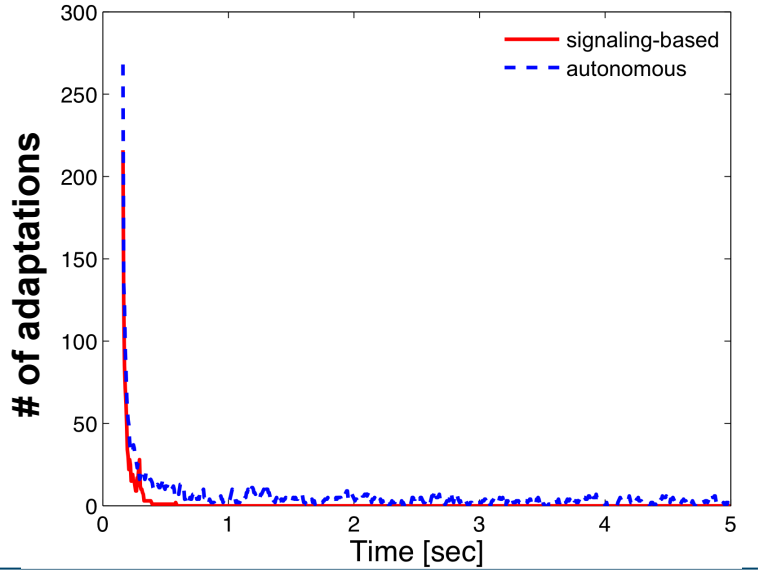
Approach:

- Each eNB chooses “best” resource subset based on local interference situation
- Base station only uses resource subset:
  - avoids interference on other resources
  - fast scheduling of users within subset possible
- Iterative process adapts to:
  - changes induced by other cells
  - changing resource demand per cell

Here:

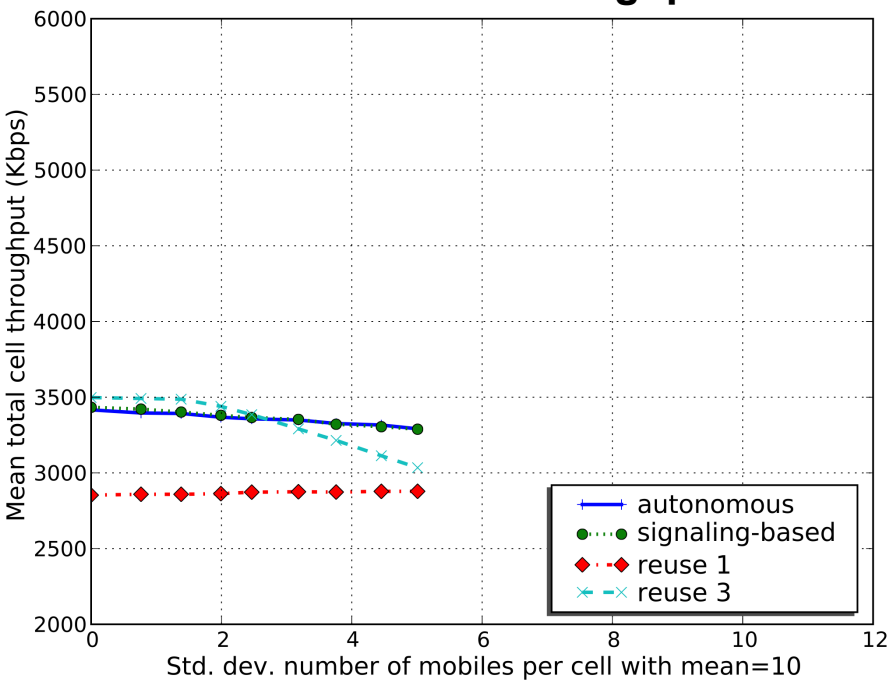
- Two schemes for the uplink:
  - autonomous operation
  - inter-cell signaling of HI indicators
- Convergence motivated by existence of Nash Equilibrium (for signaling-based approach)
- Focus on scenarios with unevenly loaded cells

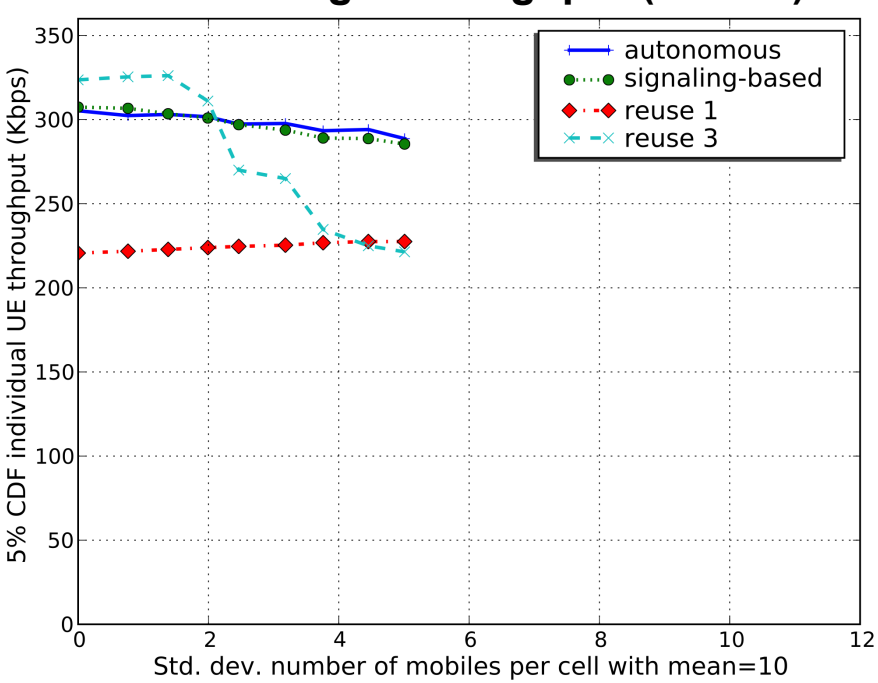




“Performance of Decentralized Interference Coordination in the LTE Uplink” J. Ellenbeck, H. Al-Shatri and C. Hartmann VTC-Fall, September 2009

Performance Evaluation (avg. 10 users/cell)





- Resource utilization: 28% of PRBs (on average)

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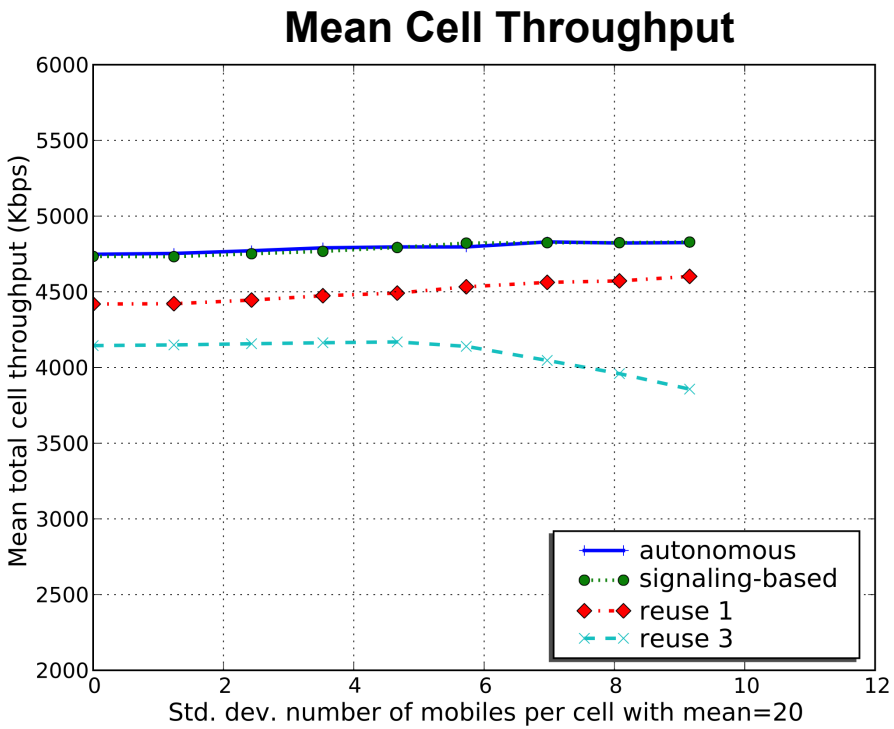
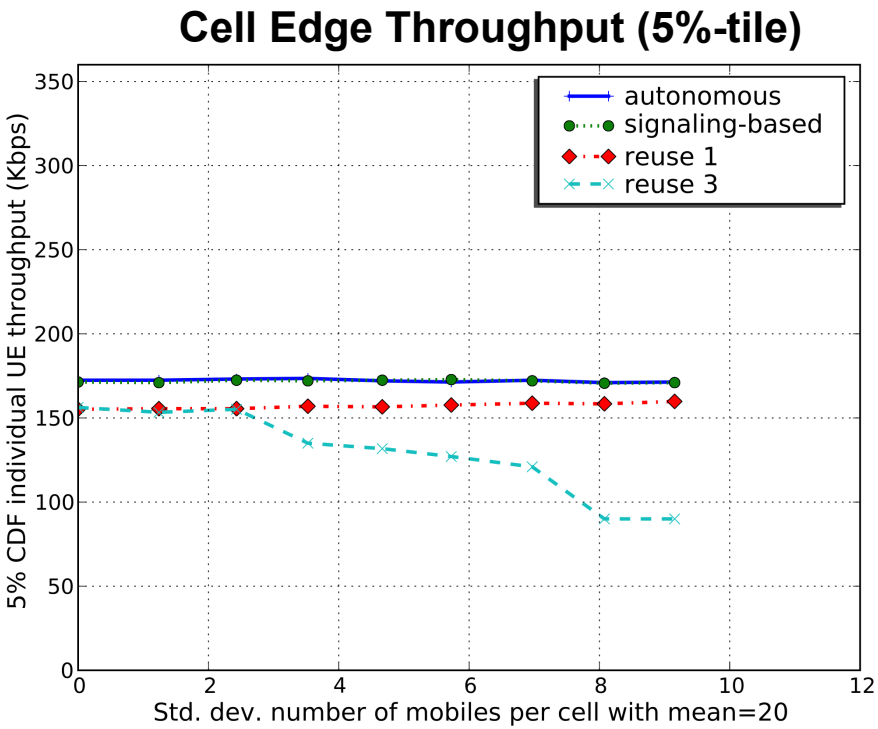
- Dynamic schemes cope well with uneven load situation
- Quality of coordination at approx. 1/3 resource utilization almost as good as reuse 3

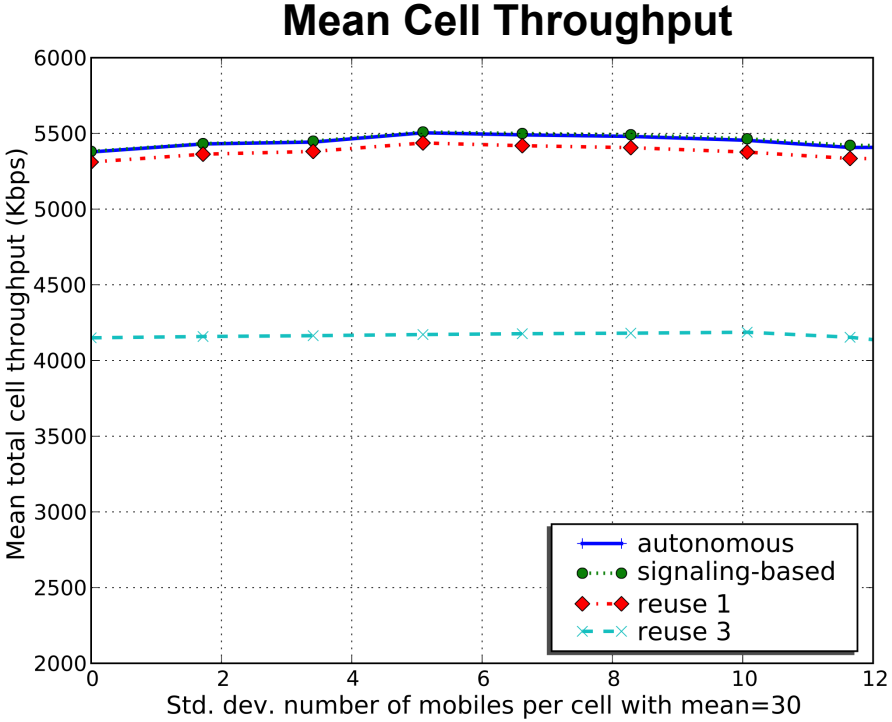
Performance Evaluation (avg. 20 users/cell)

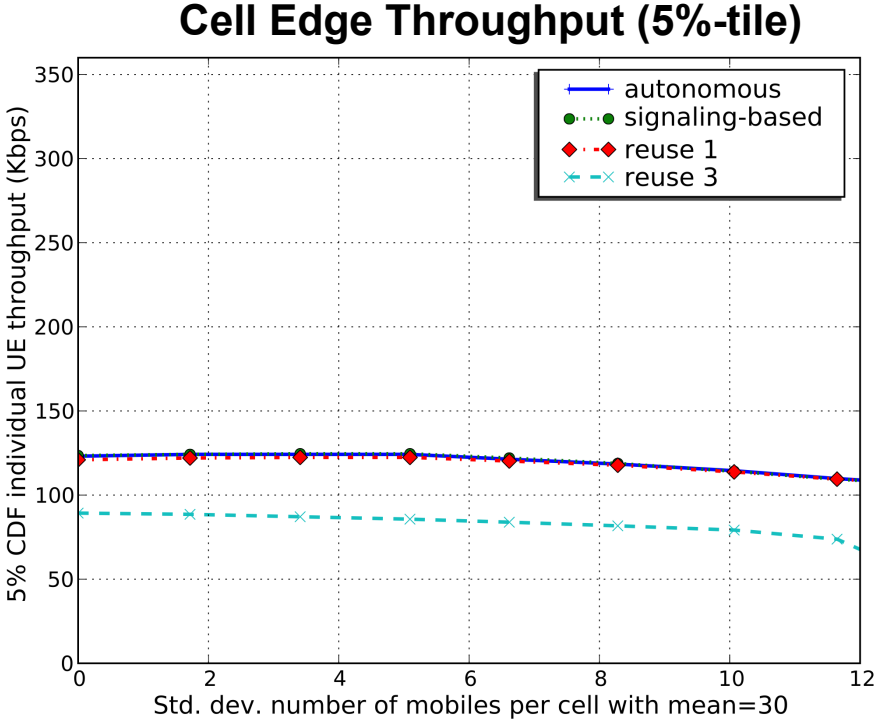




- Resource utilization: 56% of PRBs (on average)
- Dynamic schemes stable as reuse 1 and reuse 3 switch positions

Performance Evaluation (avg. 30 users/cell)





- Resource utilization: 83% of PRBs (on average)

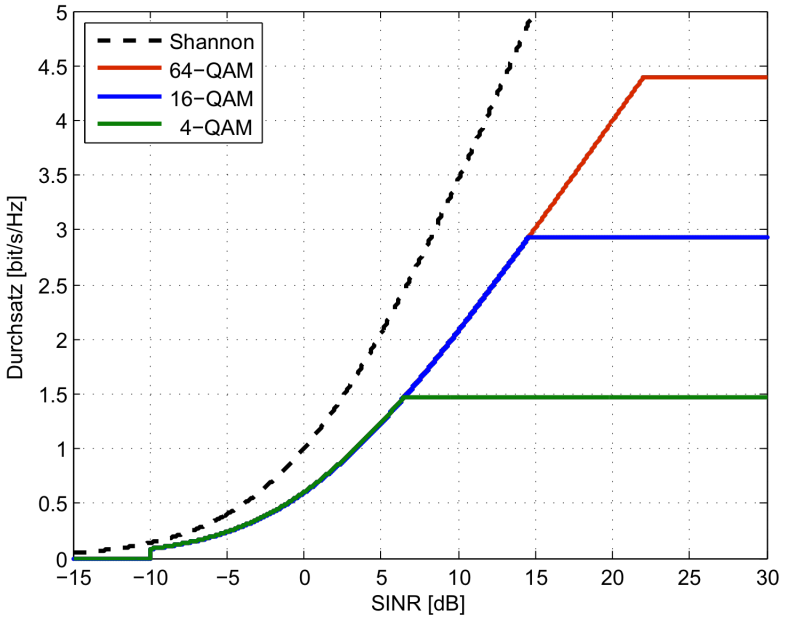
- Very limited room for interference avoidance
- Only slight improvement over reuse 1 remains

Limitations of Reuse Coordination

- Modern systems close to capacity:
  - Adaptive Modulation and Coding
  - Turbo Codes
  - Hybrid ARQ retransmissions
  - multiple Rx antennas

$$C = \frac{1}{R} \cdot \log_2 \left(1 + \frac{S}{N + I(R)}\right)$$

DL Performance Model from 3GPP TR 36.942



Spectral efficiency C [bits/s/Hz]

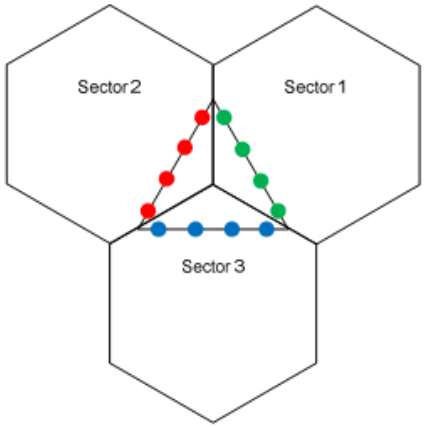
- decreases linearly with higher frequency reuse factors (R >= 1)
- reuse factor 1/R might offset gains from higher capacity due to lower interference I(R)

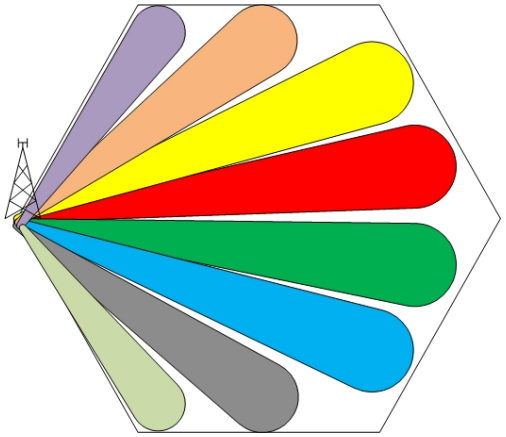
➔ Avoid reuse vs. interference trade-off by using other domains for coordination, e.g. **coordination in the spatial domain**

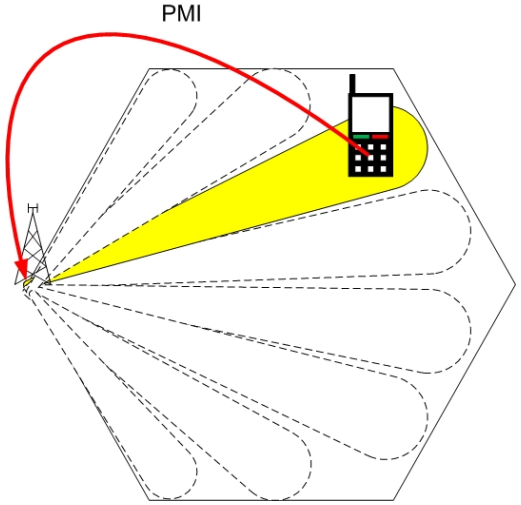
Beamforming promises to lower interference

- **Beamforming**
  - directional transmission towards a desired user via multiple antennas
  - increases received signal strength, **decreases ICI**

- **Codebook based beamforming**
  - Uniform Linear Array (ULA) with 4 Antennas
  - 8 possible beam patterns, chosen from the LTE precoding codebook specified in 3GPP TS 36.211 V 8.7.0
  - Mobile station (MS) reports the most suitable Precoding Matrix Index (PMI) to the BS





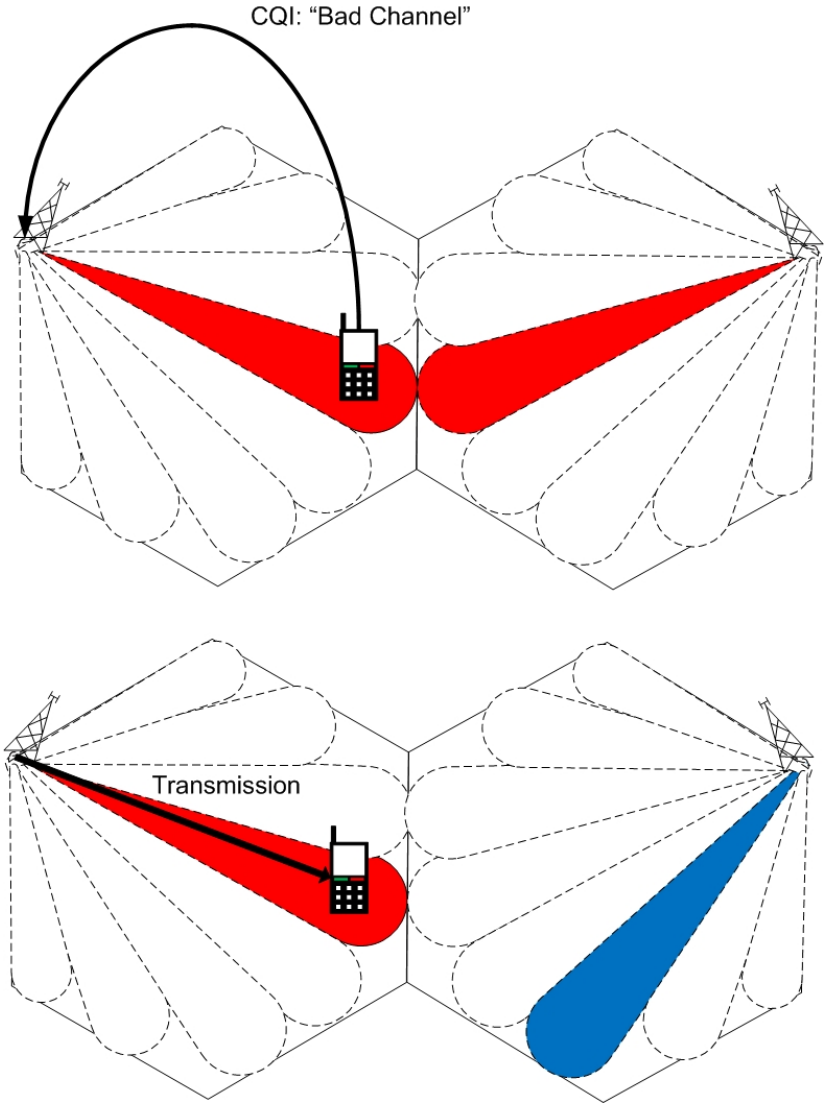


Beamforming should be coordinated among cells

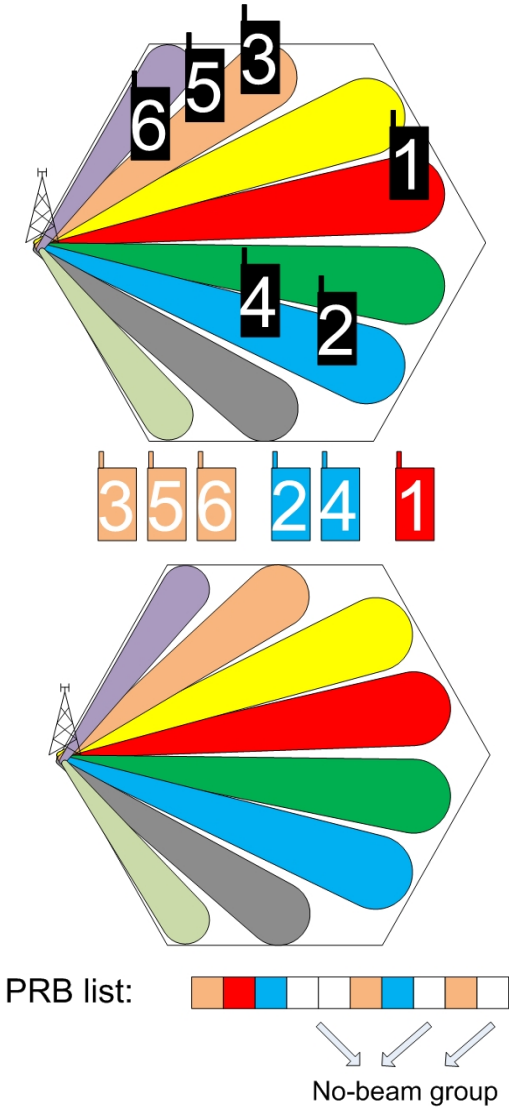
- In general, beamforming lowers interference emitted to other cells
- If beams “collide”, no SINR gain is realized
- Beamforming together with multi-user scheduling leads to highly fluctuating interference levels “flash-light effect”
  - ➔ deteriorates performance of link adaptation

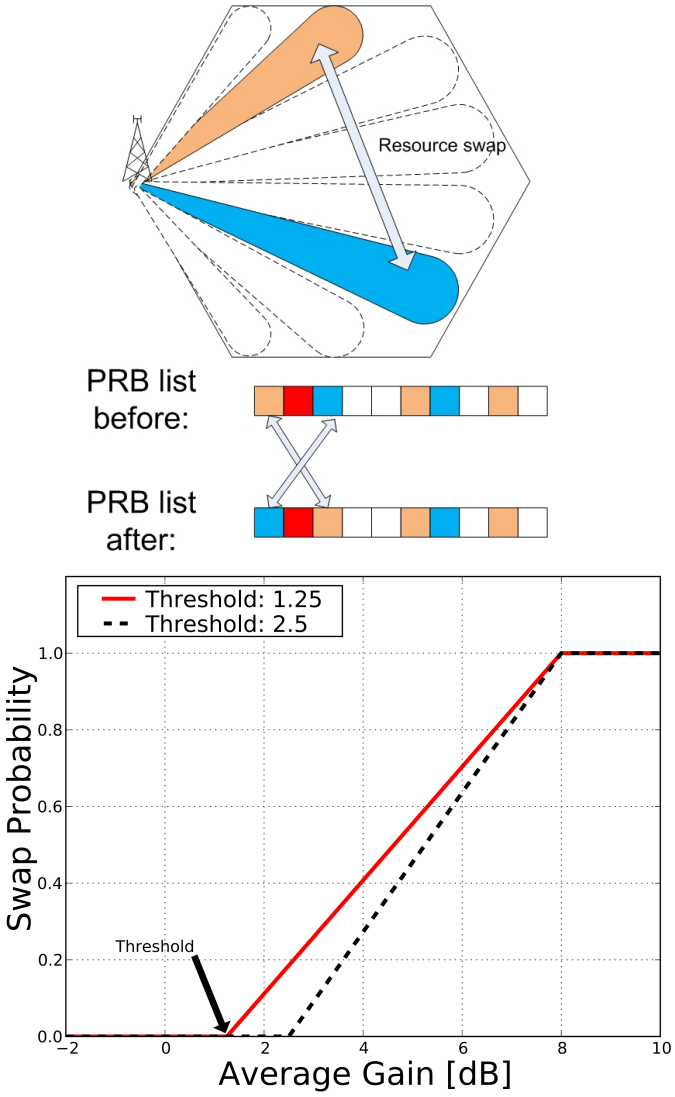
Coordinated beamforming thus promises:

- to increase average SINR by avoiding collisions
- increase performance due to better link adaptation

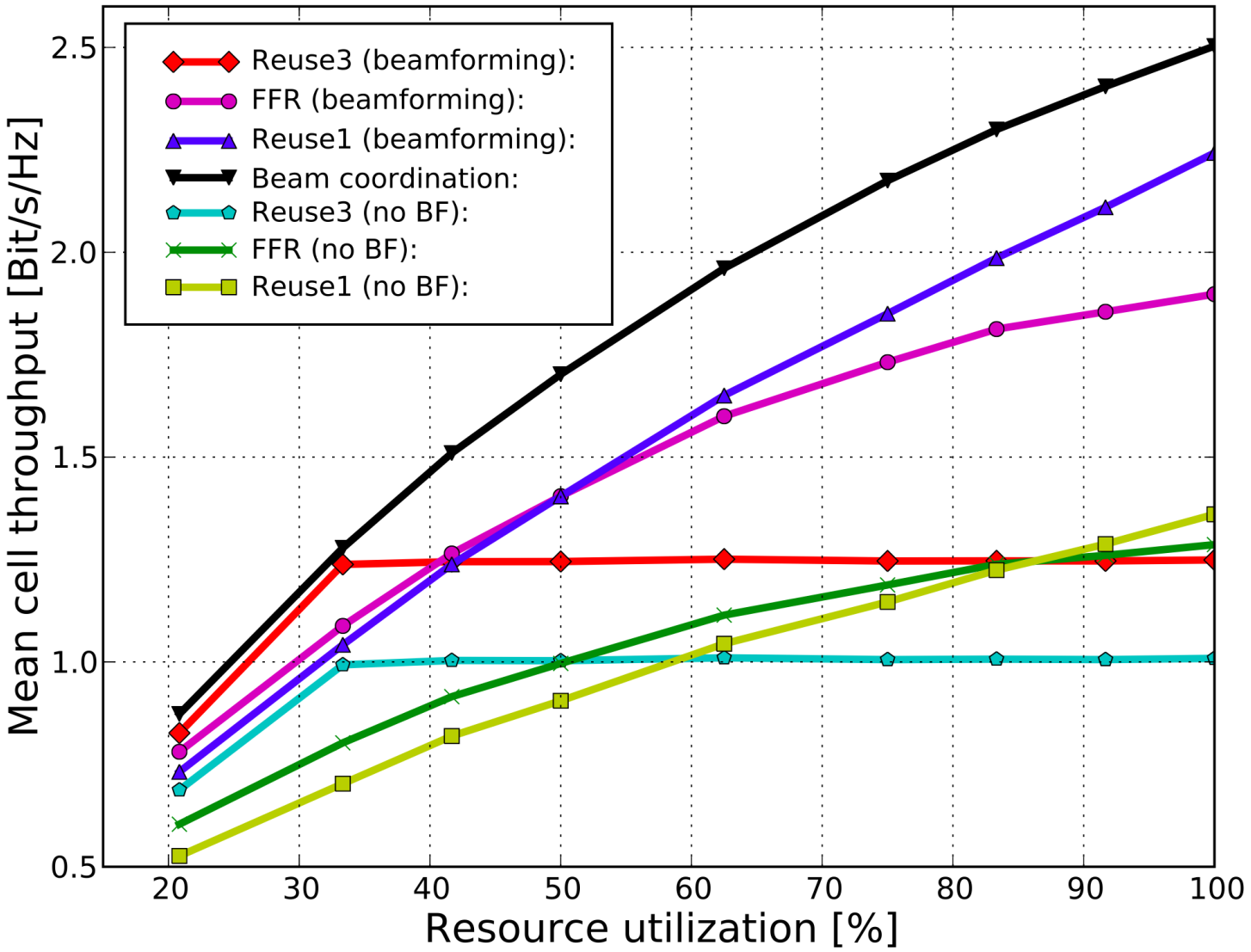


Adaptively allocating resources to beam groups

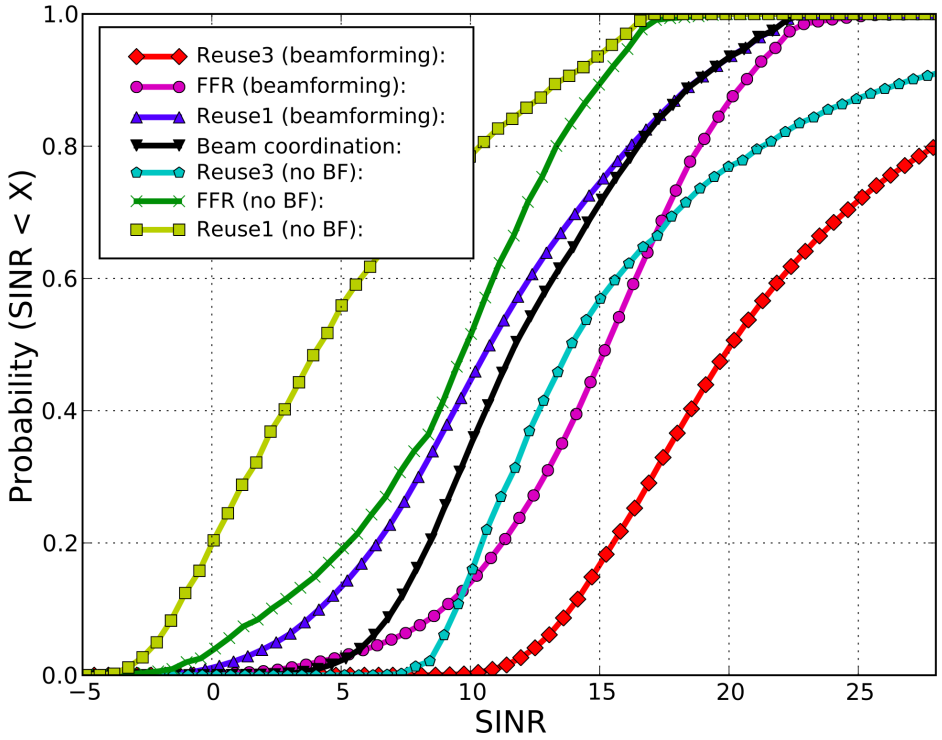


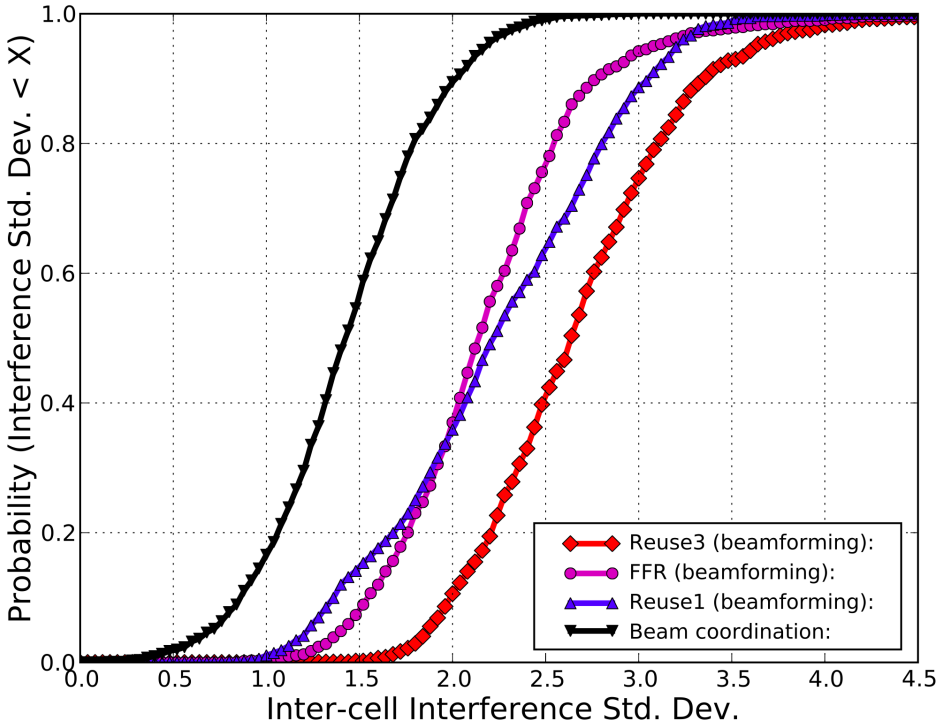


Beam coordination outperforms other schemes...



…due to higher and more predictable SINR





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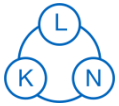
"Autonomous Beam Coordination For the Downlink of an IMT-Advanced Cellular System"
J. Ellenbeck, M. Hammoud, B. Lazarov, and C. Hartmann
European Wireless, April 2010

Outlook: Coordinated Multi Point Transmission

- Main technical improvement discussed for LTE-Advanced (decision in March 2010)
- “Interference Management on Steroids”
- Extends high-throughput coverage, improvements especially for the cell-edge
- Downlink:
  - Dynamic coordination of multiple geographically separated base stations
  - Possible schemes:
    - coordinated scheduling and/or beamforming
    - joint processing/transmission (“Network MIMO”)

Source: 3GPP

- Uplink:
  - Reception of uplink transmission from a mobile at multiple base stations
  - Scheduling decisions can be coordinated



Thank You