Interference Coordination in OFDMA Networks

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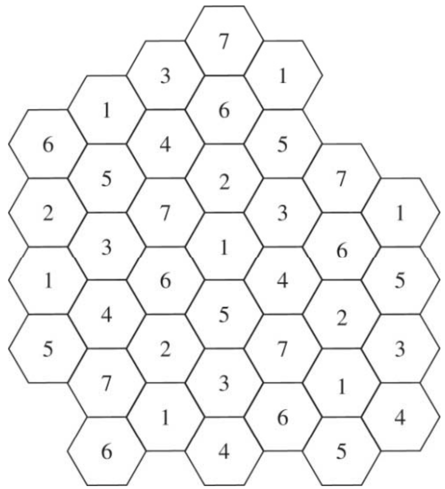
Overview

- Interference Coordination in Cellular Networks
  - Overview
  - Fractional Frequency Reuse
  - Coordinated Beamforming
  - Joint processing/transmission

- Uplink Soft FFR in 802.16

Traditional Interference Management in Cellular Systems



- Narrowband (eg. GSM)
  - Inter-cell interference made negligible at the price of poor frequency reuse
- Wideband (eg. CDMA, OFDM)
  - Universal frequency reuse but system is interference-limited.

Interference Management in OFDMA Networks

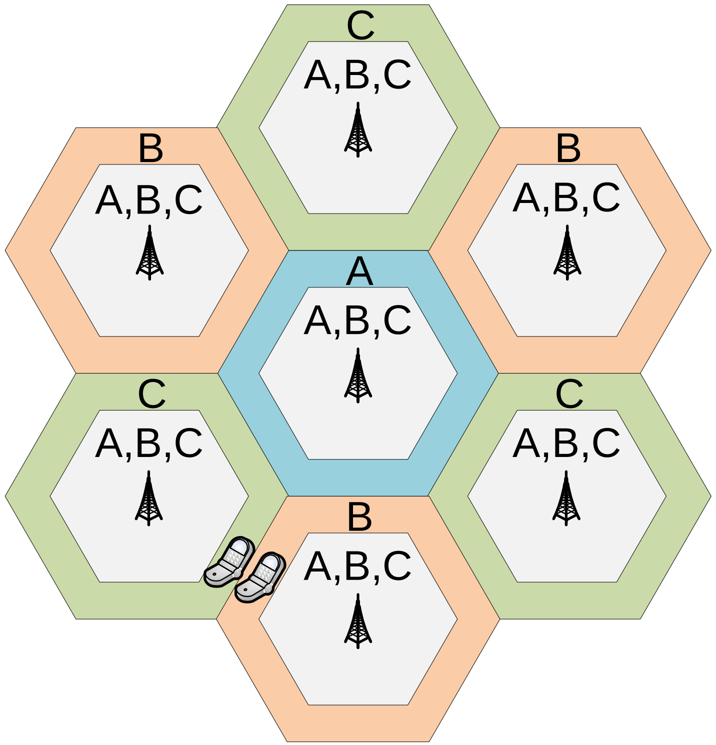
- Inter-Cell Interference Avoidance
  - Resource Partitioning
  - Fractional Frequency Reuse (FFR)
  - Static/Adaptive

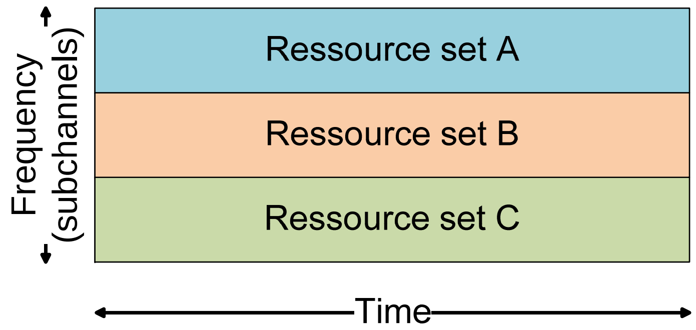
- Coordinated Beamforming
  - Static/Adaptive

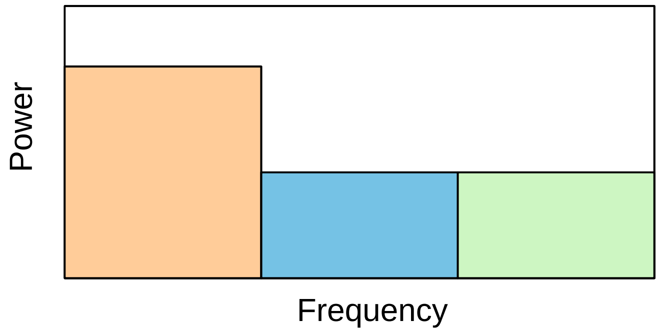
- Network MIMO and Interference Alignment

- Characteristics
  - Centralized and decentralized approaches
  - Static and adaptive approaches
  - Usage of interface between base stations

Fractional Frequency Reuse







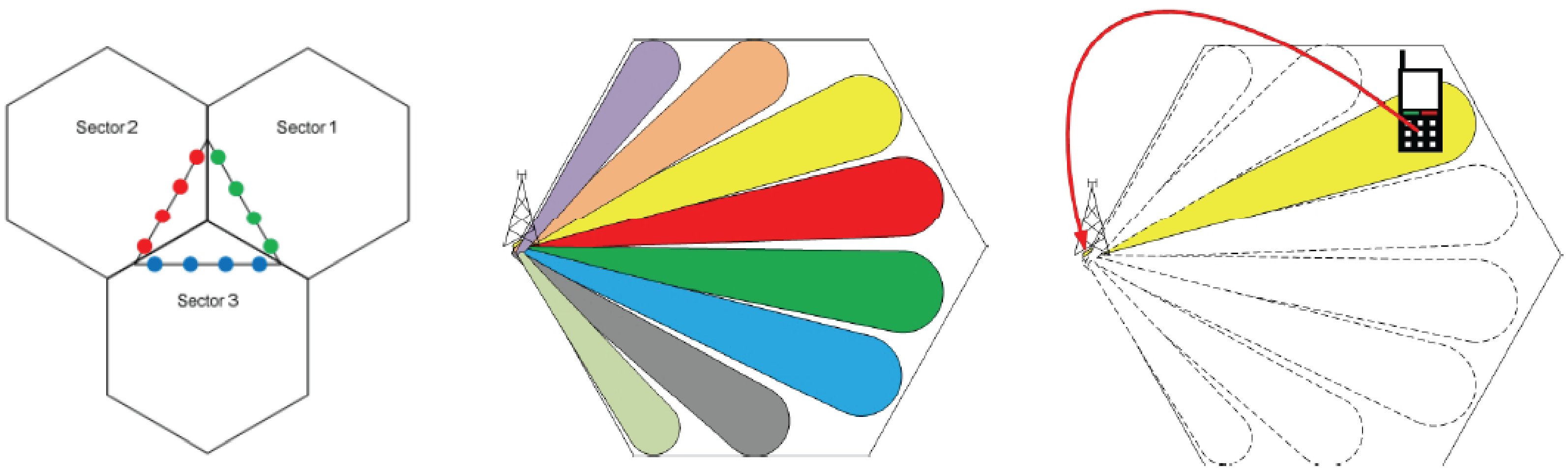
- Basic idea:
  - reuse three in the outer part of a cell, reuse one in the cell center
  - soft/partial FFR
  - dynamic/static

“Adaptive” Fractional Frequency Reuse

- Disadvantage Static FFR:
  - Single system-wide partitioning pattern
  - Adaptive to cell loads only via power masks
  - Partition sizes not adaptive to dynamic demand changes per sector
- “Adaptive” FFR:
  - Cells use only a fraction of the spectrum
  - Coordination via
    - interference
    - signaling via interface between base stations
  - Adaptive to
    - cell loads
    - other-cell interference situation

Beamforming

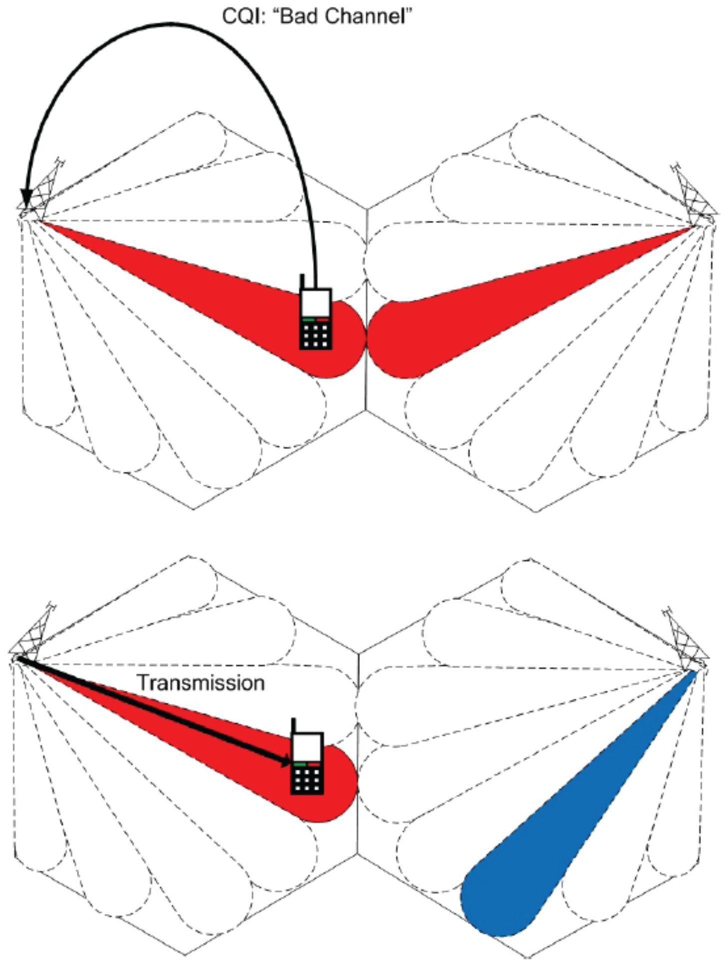
- Beamforming
  - directional transmission towards a desired user via multiple antennas
  - increases received signal strength, decreases ICI
- Codebook based beamforming
  - Uniform Linear Array (ULA) with 4 Antennas
  - Mobile station (MS) reports the most suitable Precoding Matrix Index (PMI) to the BS



source: Jan Ellenbeck, Interference Management, ITG 5.2.4 Darmstadt 2010

Inter-Cell Interference and Beamforming

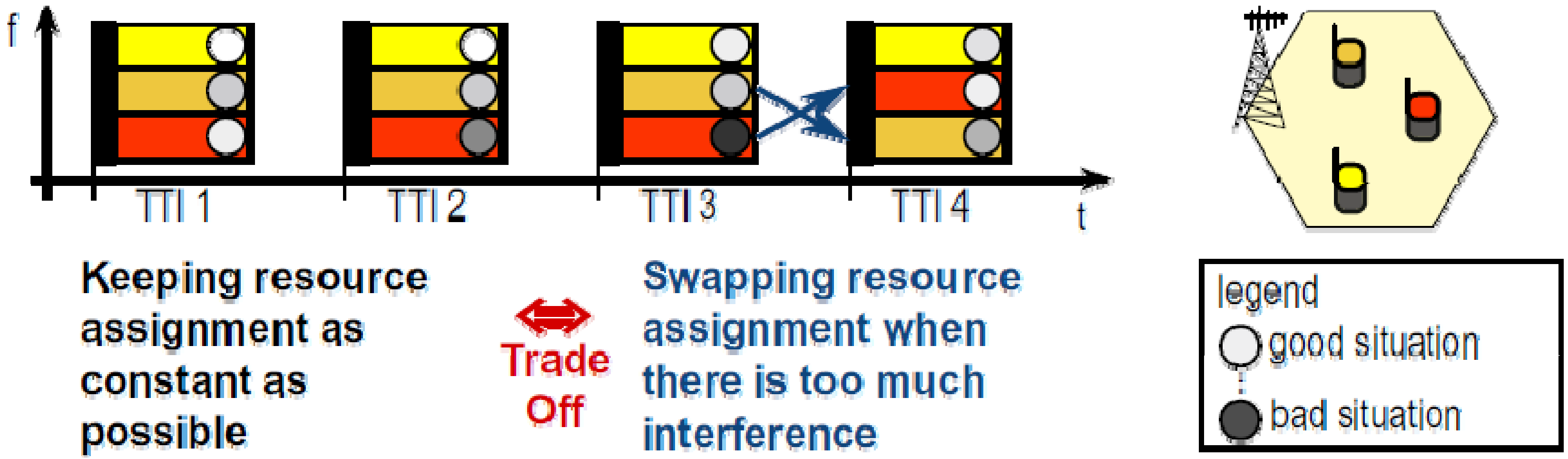
- Problem:
  - Interfering Beams
- In general, beamforming lowers interference emitted to other cells
- If beams “collide”, no SINR gain is realized
- Coordinated beamforming thus promises:
  - to increase average SINR by avoiding collisions
  - increase performance due to better link adaptation



source: Jan Ellenbeck, Interference Management ITG 5.2.4 Darmstadt 2010

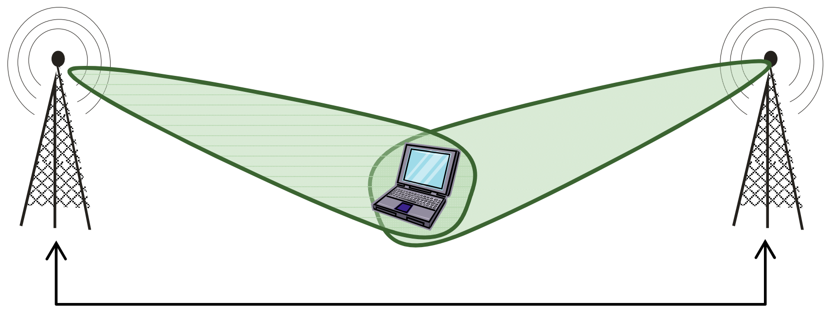
Coordinated Beamforming Approaches

- Static beam pattern
  - static allocation of resources to beams
  - interfering beams are avoided but not adaptive to cell load
- Coordinated beamforming
  - via base station communication
- Auto-Coordinated beamfoming

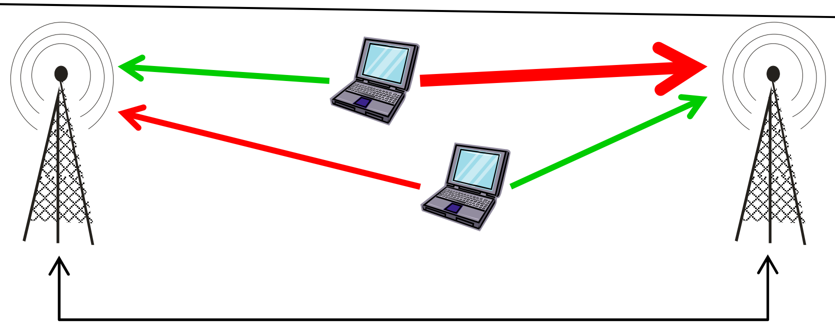


source: Matthias Kaschub, Thomas Werthmann: Interference mitigation with auto-coordinated beamforming, ITG 5.2.4 Darmstadt

Joint Processing/Transmission



Network MIMO

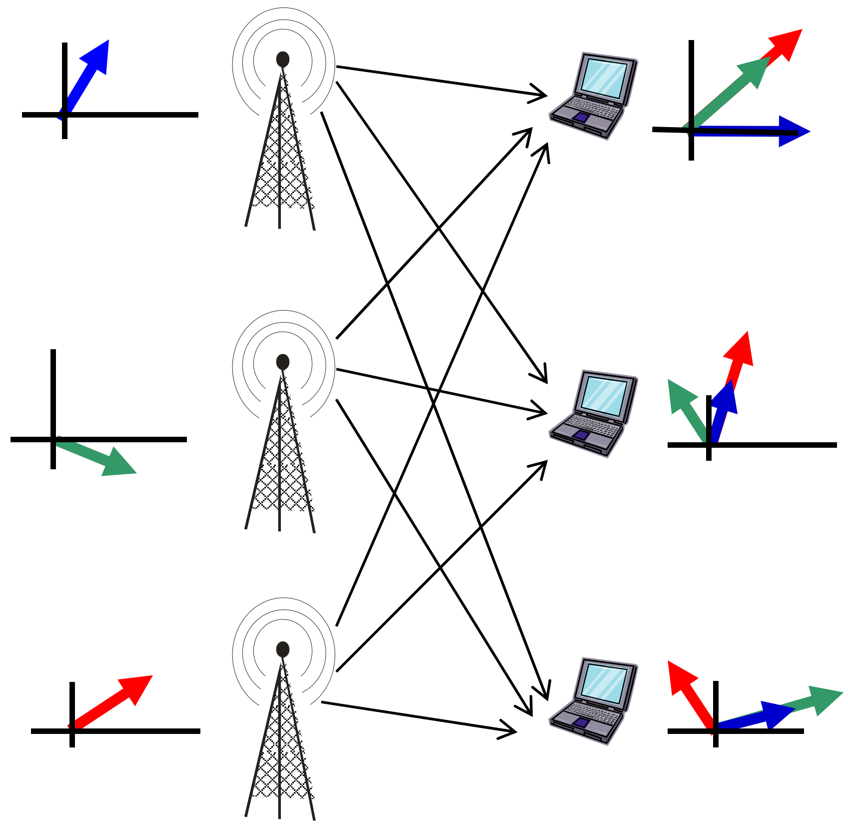


Interference Cancellation

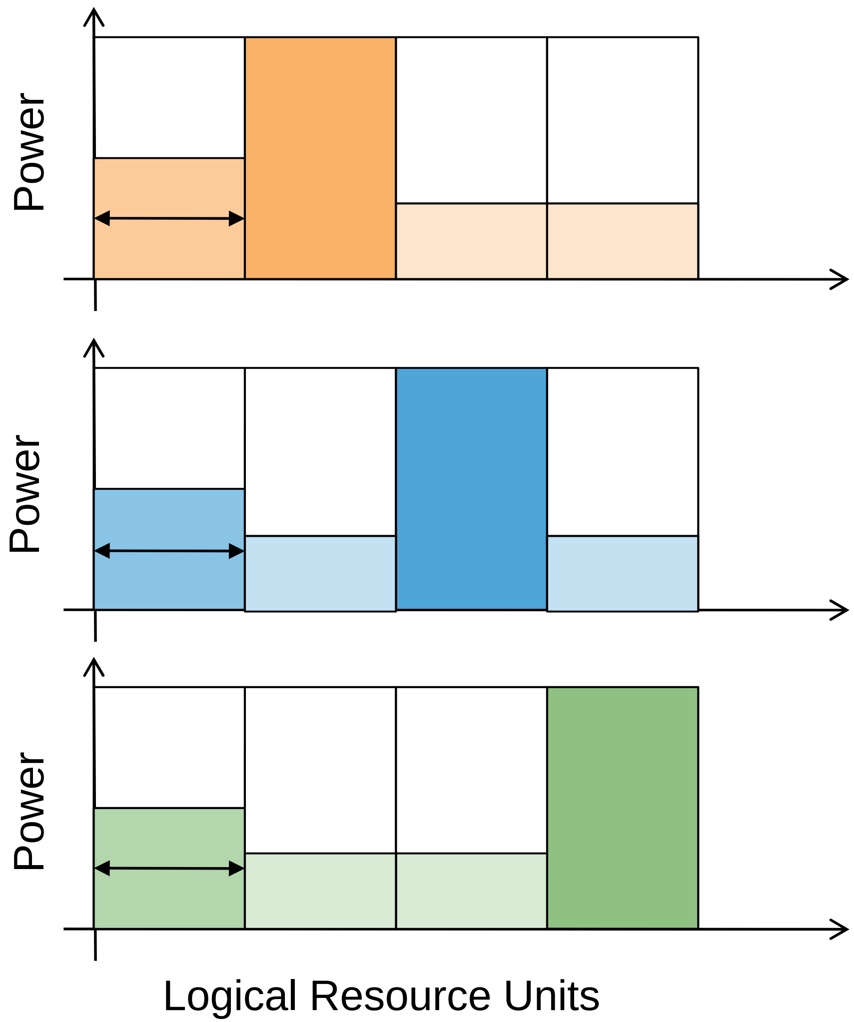
send
decoded data

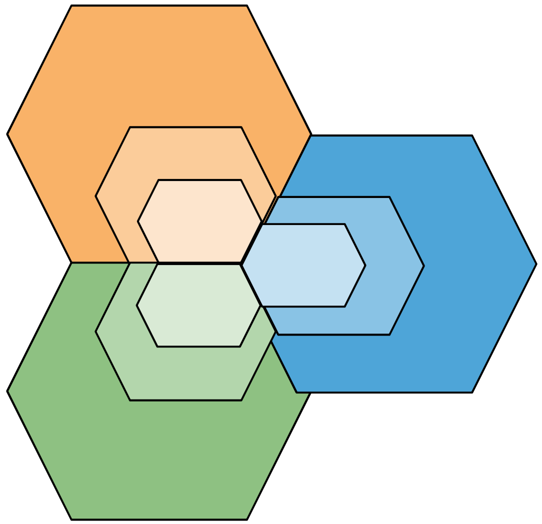
regenerate “interference”
and substract from
received signal

Interference Alignment



FFR in 802.16m





- Soft and partial FFR
- Partition distributed over whole spectrum
- System-wide size of partitions
- Cell-specific power limitations

Uplink vs. Downlink FFR

Uplink

- Traffic
  - singular small packets
    ACKs, Requests, Voice, M2M, …
  - sporadic bulk data transfer
  - full buffer model not realistic
- Capacity limitation
  - interference
  - resources
  - transmit power for few mobiles

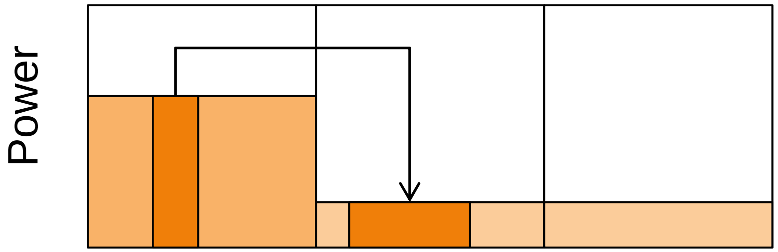
Downlink

- Traffic
  - mostly bulk data transfer
    Web pages, files, …
  - full buffer model realistic
- Capacity limitation
  - total base station transmit power

Uplink vs. Downlink FFR

▶ Downlink

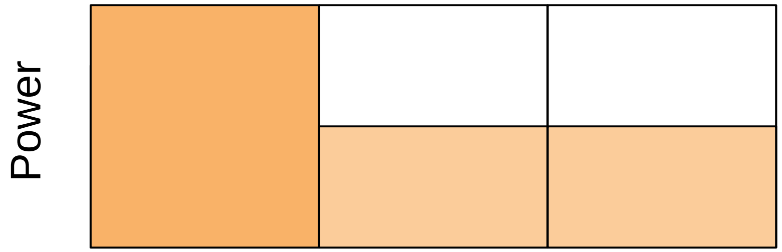
- total power shared among partitions



- benefit:
  - total power reduction by using more resources

▶ Uplink

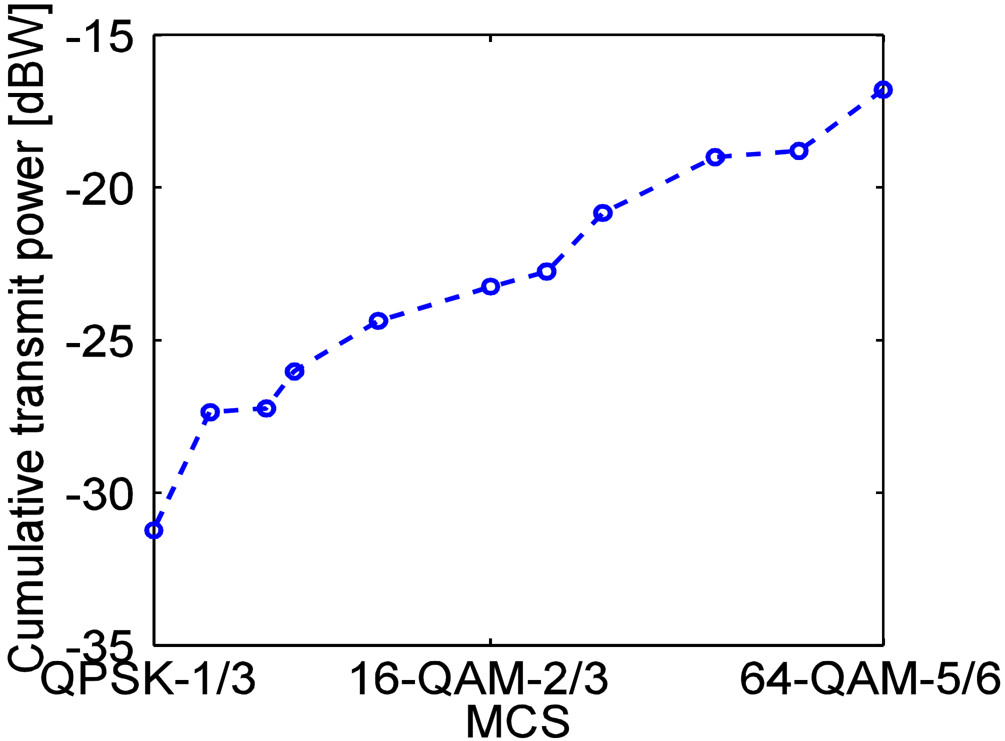
- no total power limits



- benefit:
  - more resources
- problem:
  - increased interference

Total Power Consumption

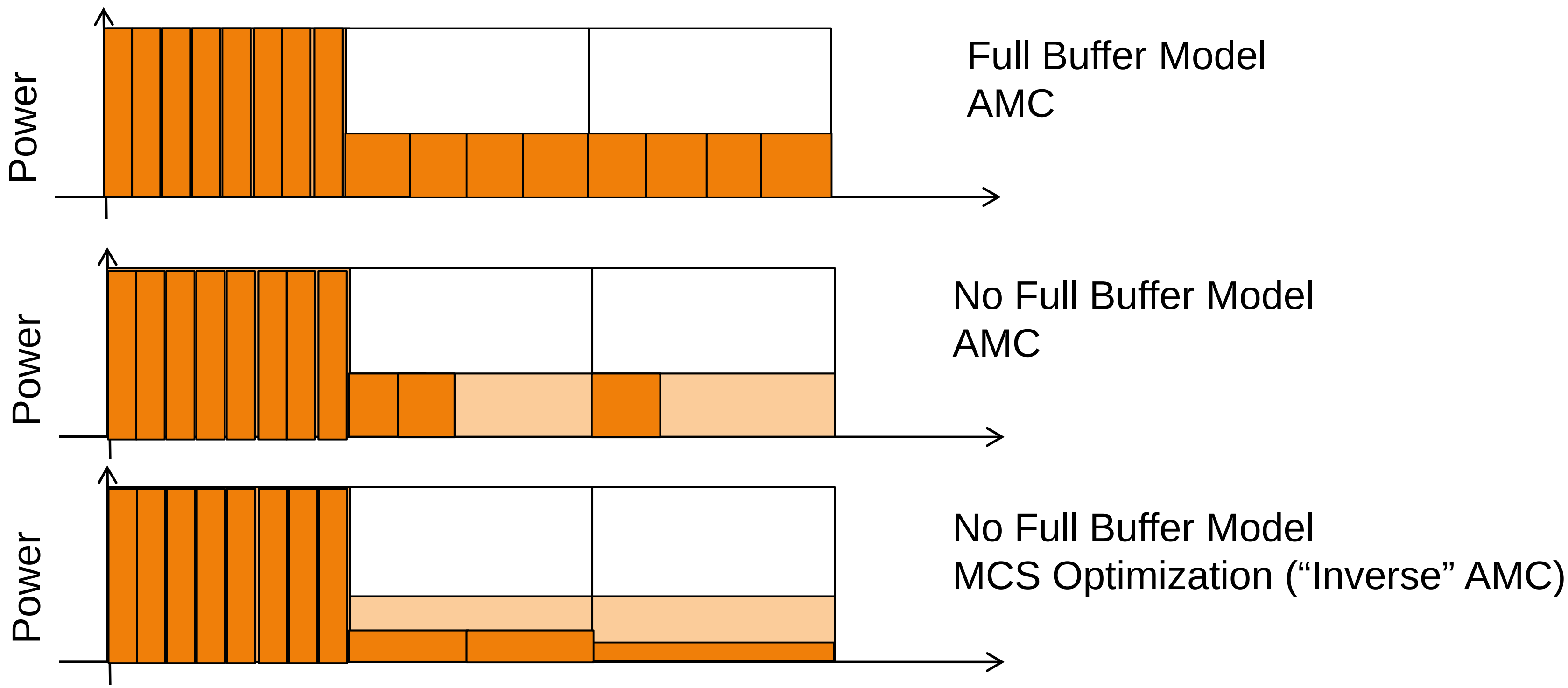
- Power Consumption for transmitting a block of data with different modulation and coding schemes (MCS)



- Less power per resource ⇨ more robust MCS ⇨ more resources ⇨less total power

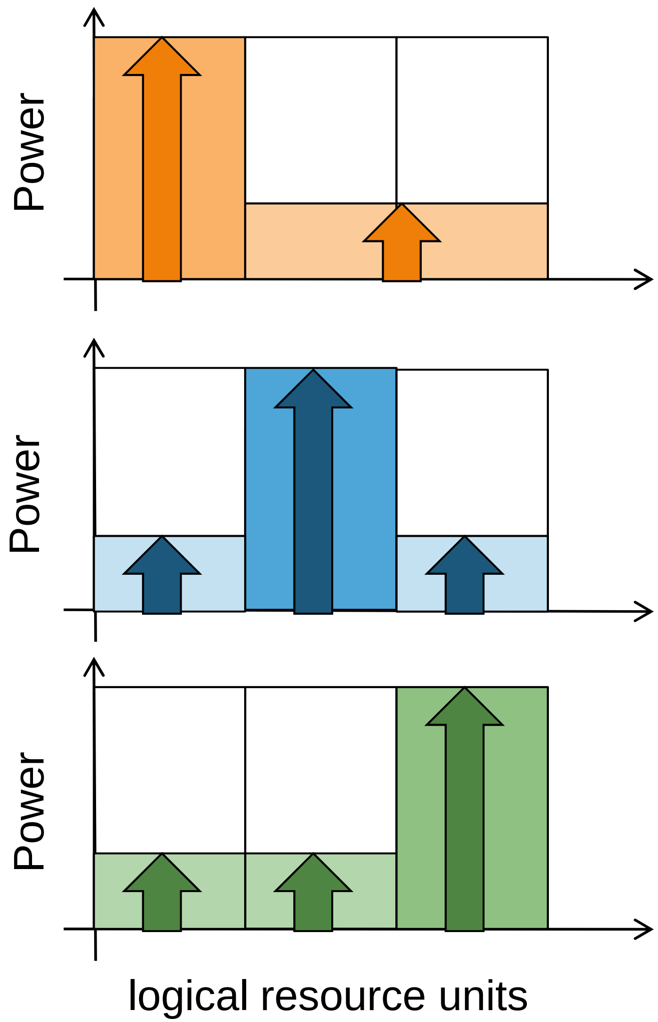
MCS Optimization on Sidebands

- Adaptive Modulation and Coding + Power Control
  - adapt MCS to achievable SINR, adapt power to target SINR

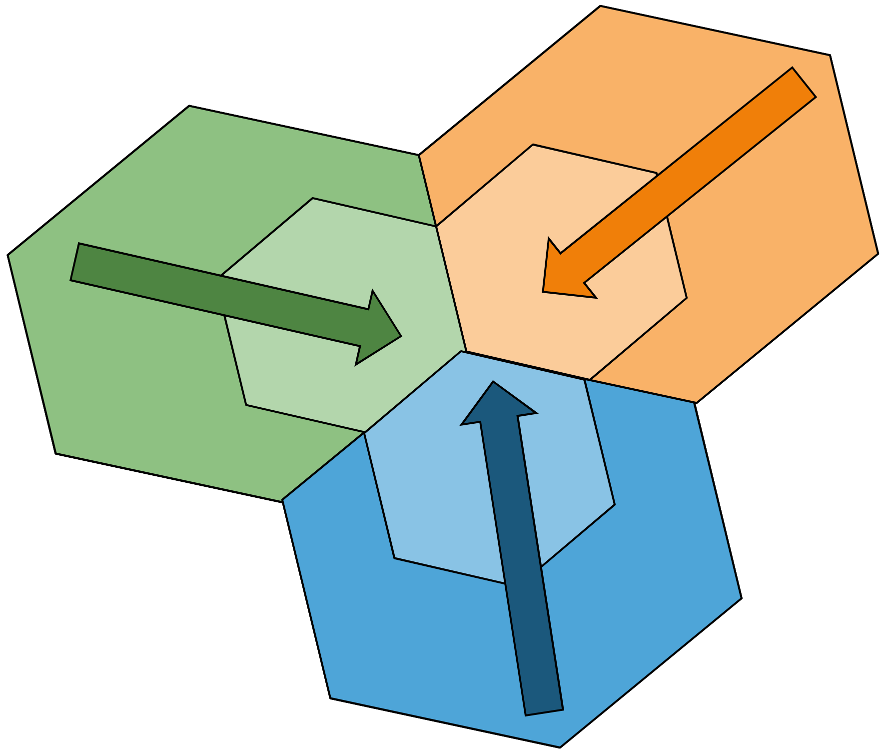


- MCS optimization
  - more robust MCS by utilizing all resources of sidebands

Structure of the Resource Allocation Algorithm



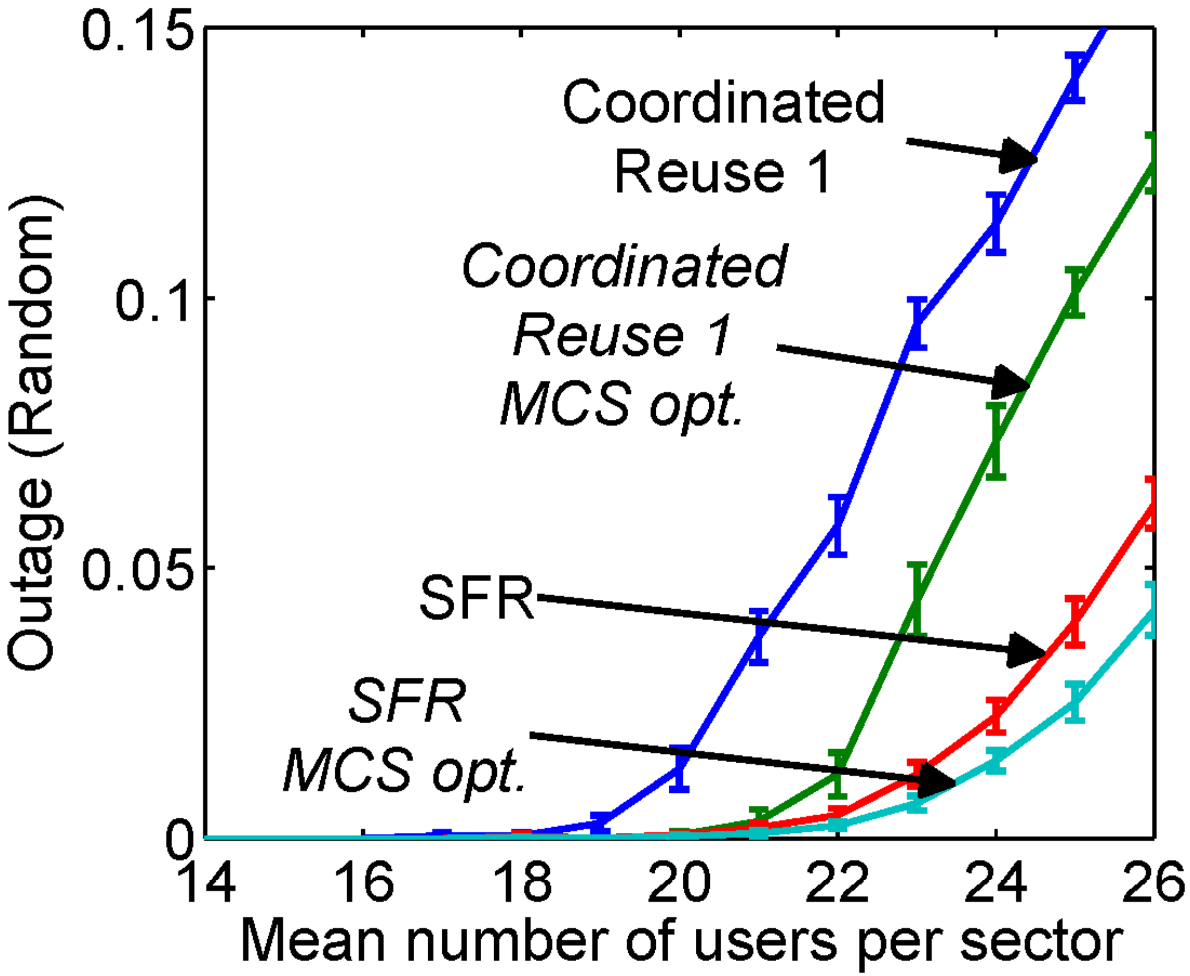
1. User order metrics
2. Home partition allocation
3. Side partition allocation
4. MCS optimization on the side partition



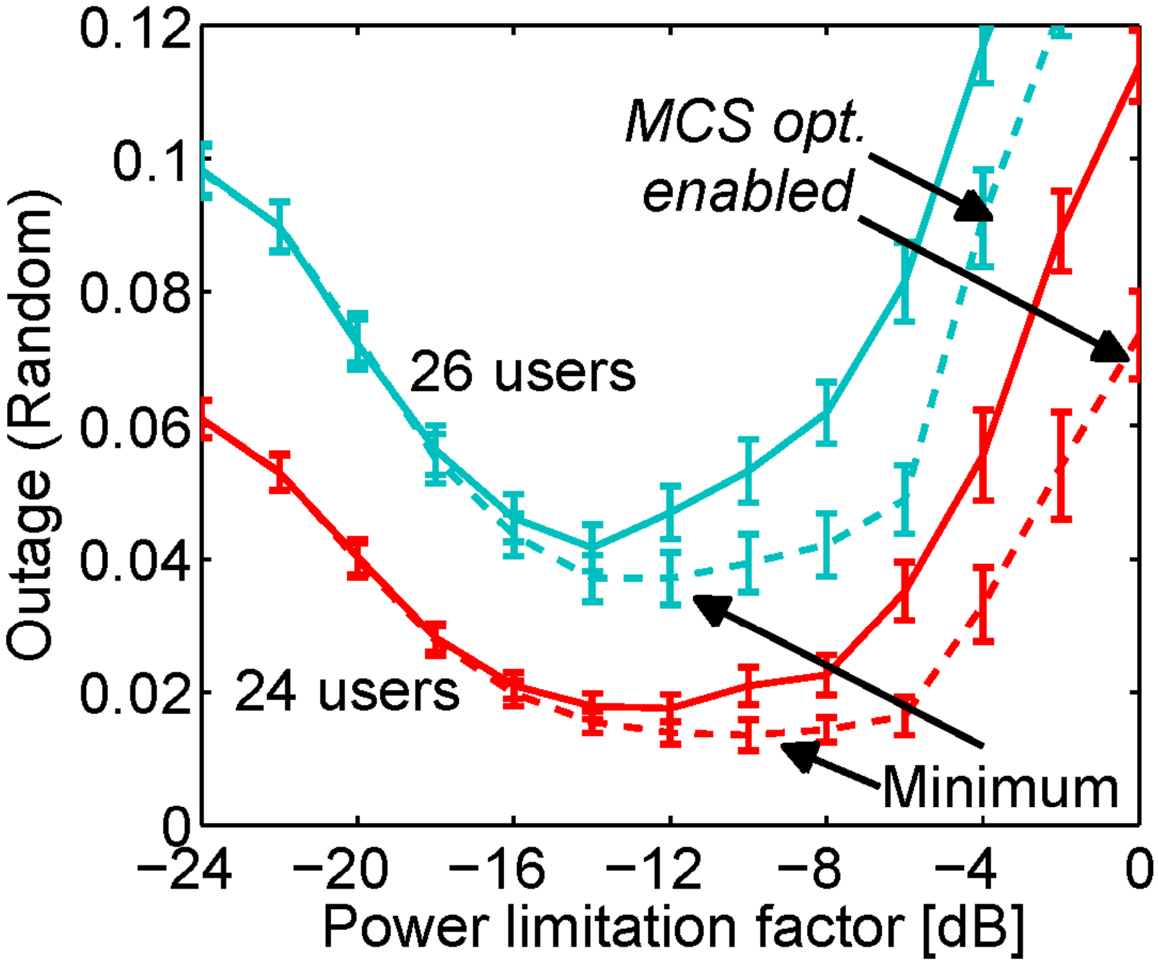
Simulation

- Scenario:
  - single frame, all users transmit fixed amount of data
  - 5x5 deployment with hexagonal 3-sector sites
  - close to 802.16m uplink
  - decentralized resource units
- Monte Carlo “Snapshot” Simulation:
  - homogeneous spatial Poison point-field
  - iterative computation
    - resource allocation
    - interference
- Performance metric:
  - outage

Increased Capacity due to MCS Optimization



Increased Robustness of Parameter Settings



Conclusion

- Trends in interference coordination
  - adaptive solutions available and required
    - e.g. for Femto Cells
  - increased communication among base stations
    - network MIMO
    - interference alignment
    - improved interference cancellation

- Uplink Soft FFR
  - increases system capacity
  - more robust power mask setting
  - statement limited to scenario
  - general concept: increase resource usage to decrease power consumption and interference