MU-MIMO with Fixed Beamforming for FDD Systems

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MU-MIMO - Motivation

MU-MIMO

- Supporting multiple users in a cell on the same time-frequency resource
- Exploit channel orthogonality of spatially separated users

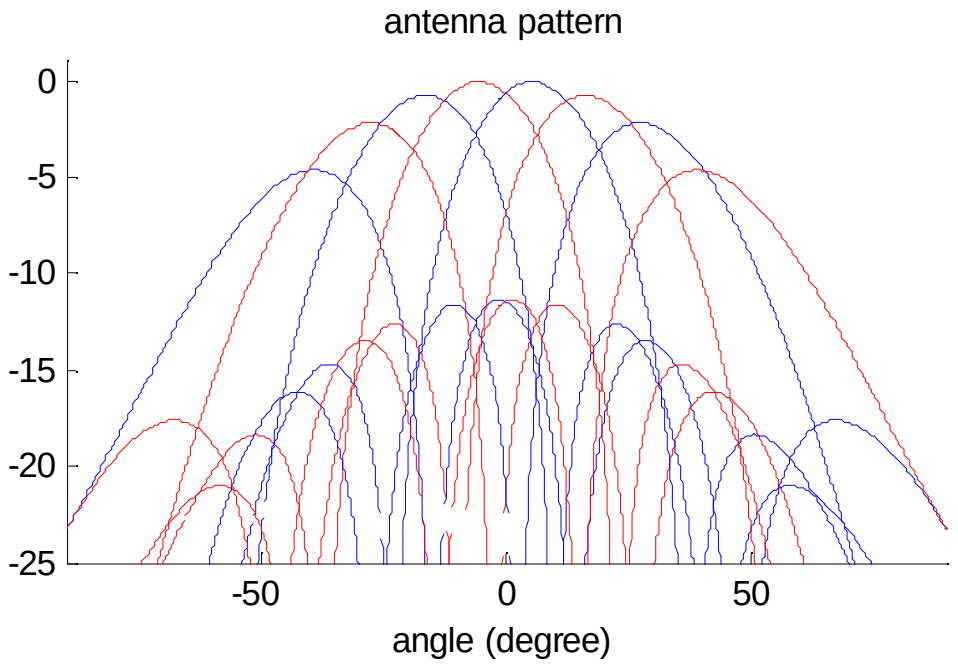
For medium- to large- size cells

- Low angular spread, low diversity order of the channel
- Short-term channel state information (CSI) may be quickly outdated in an FDD system, only long term CSI available
- ‰ go for downlink-beamforming
  - one data stream per user - allows simple one-antenna terminals
  - exploiting multi-user diversity

Beamforming for SDMA

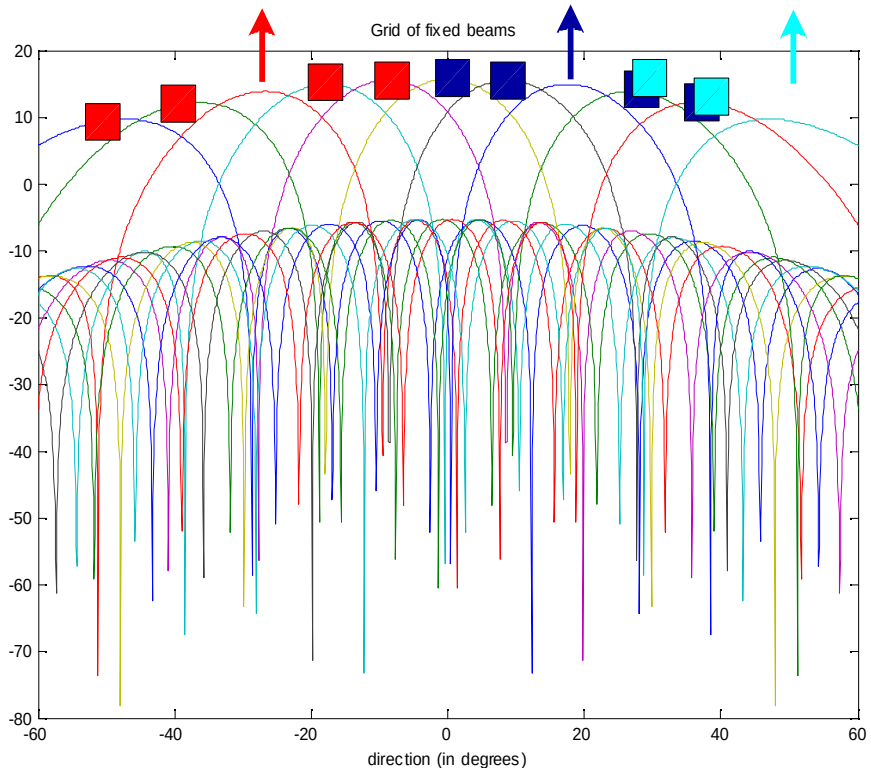
Grid of 8 fixed beams with 4 antenna elements (linear array, λ/2-spacing)
Common pilots (for all users) per antenna (pilots are not beamformed) ‰ saves radio resources

Mobile station selects best beam and signals beam index (3 bit) back to the basestation



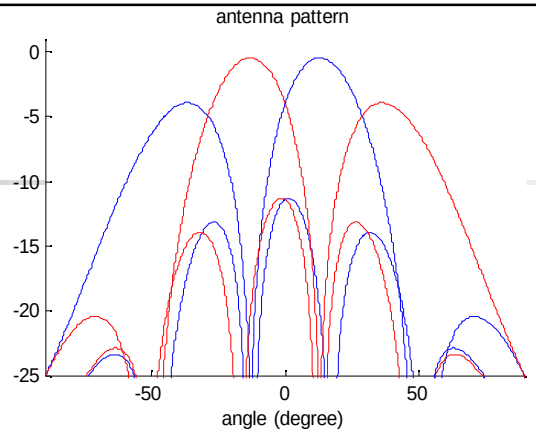
Scheduling for Fixed Beams and SDMA

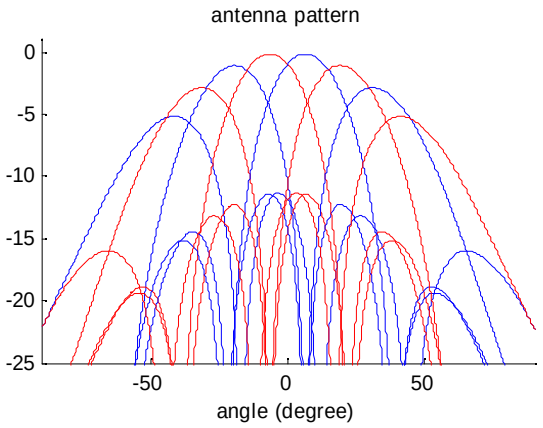
- Avoid intra-cell interference
  - by optimizing weights
  - minimum distance of simultaneous serving beams
- Scheduling scheme: User selection
  - Extension of score based scheduler
  - Plus additional beam distance constraints

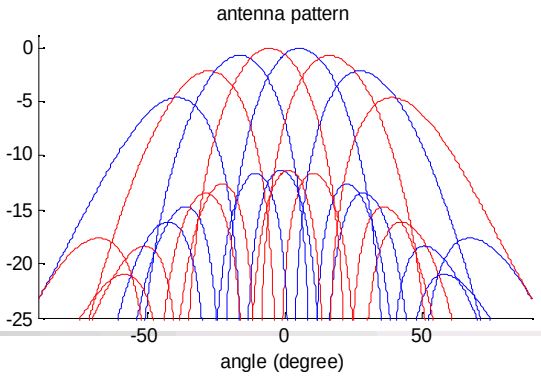


Fixed Beams – Weight design

- "Orthogonal beams"?
  - Orthogonality only holds for LOS with user AoDs falling on beam maxima
    ‰ artificial idea
- Number of beams?
  - Best beam index feedback overhead neglectable and grows with ld(NoBeams)
  - With common pilots per beam: Use as many beams as antennas
  - With common pilots per antenna: Use more beams than antennas (e.g. 8 beams for 4 antennas)
- Beam spacing?
  - Equal in linear angle space?
  - Equal in cosine space, equal crossing levels
- Fixed beams vs. (single-user) Eigenbeamforming?
  - Simulations showed that difference in performance is very small

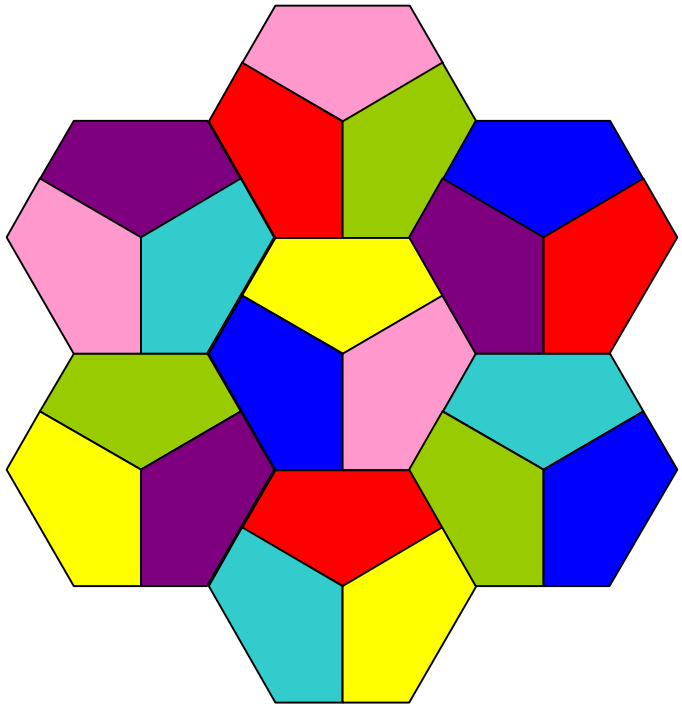






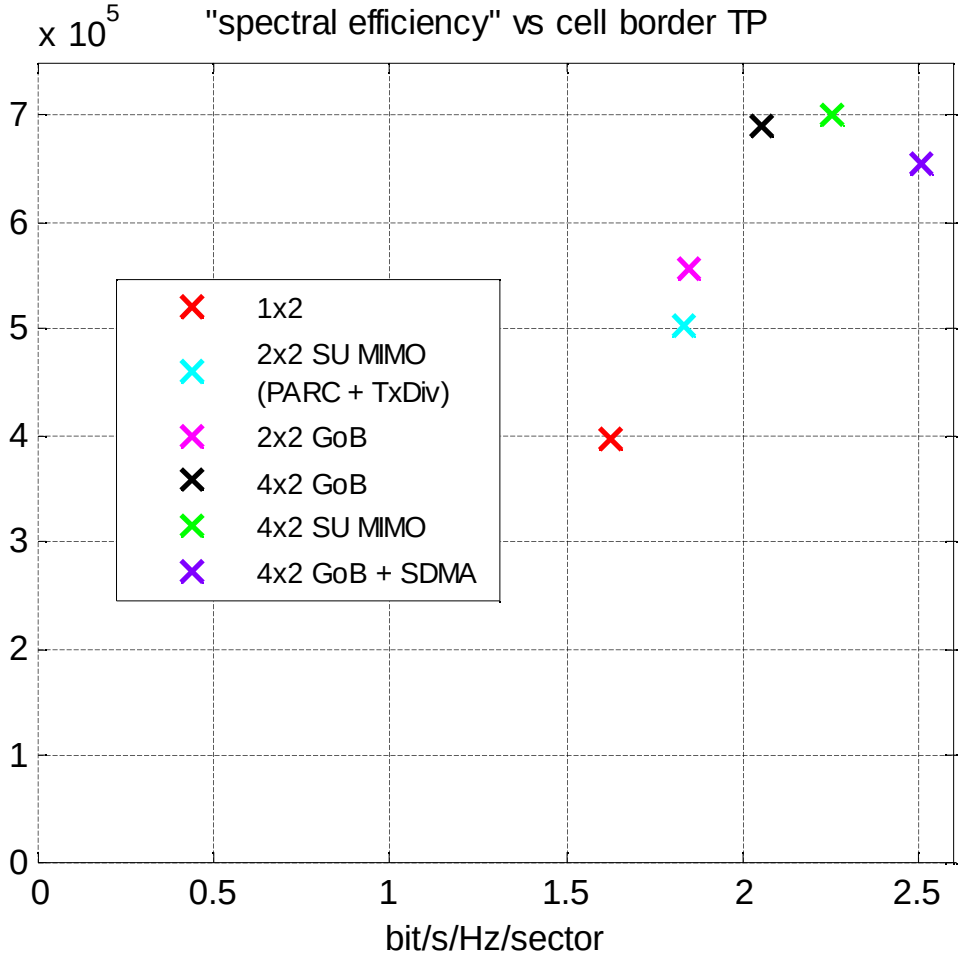
Simulation Set-up

- Playground: 7 tri-sectorized sites = 21 cells, 10 Mobile Terminals per cell
- Frequency-reuse 1
- Adaptive modulation / coding: from QPSK, R=1/9 to 64QAM, R=9/10
- Extended Spatial Channel Model, Urban Macro, 3 km/h
- HARQ included
- Pilot and control overhead explicitly simulated
- 2 antennas at mobile terminal, max. ratio combining

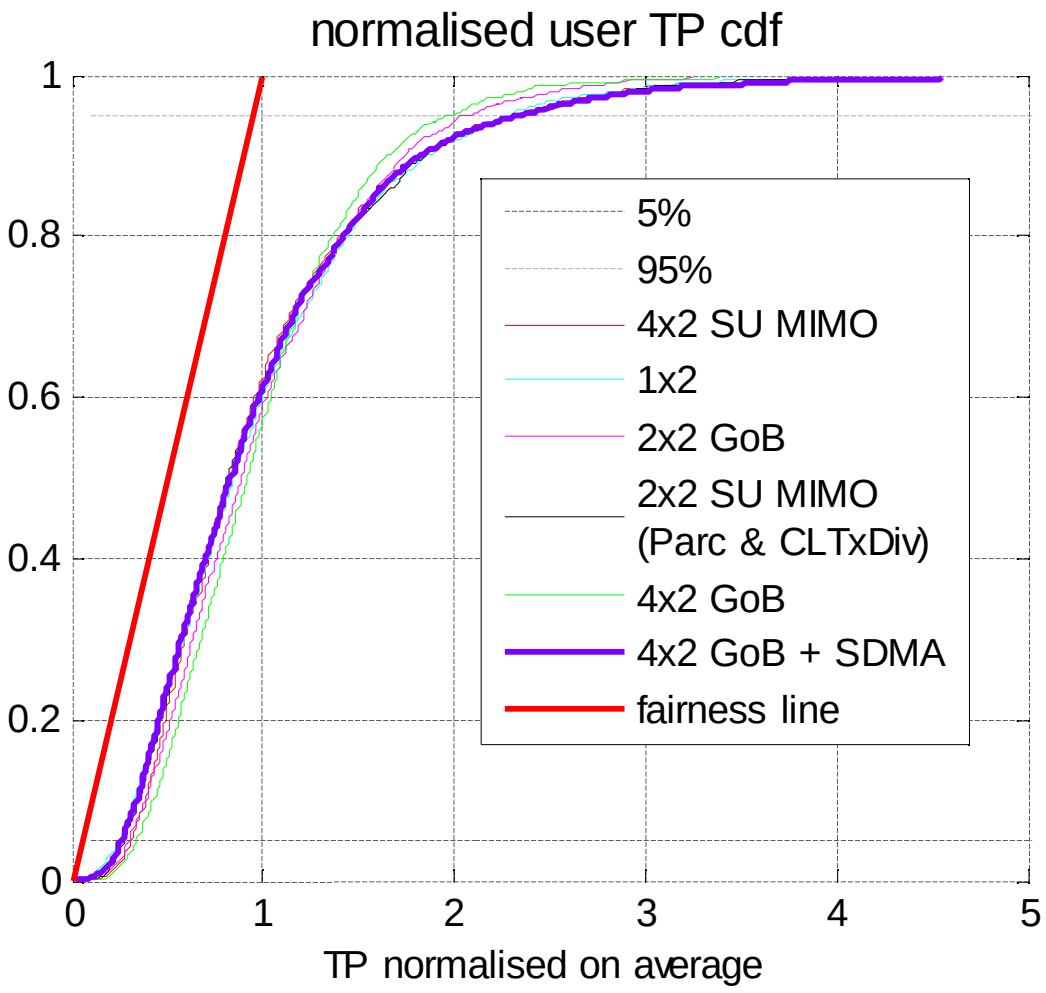


System Simulation Results

- The proposed scheme achieves a spectral efficiency of 2.5 bit/s/Hz/sector
- Outperforms SU-MIMO schemes

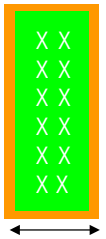


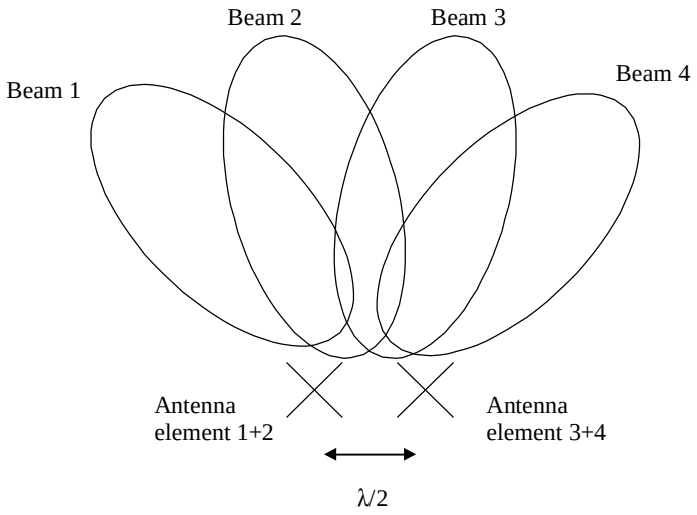
System Simulation Results

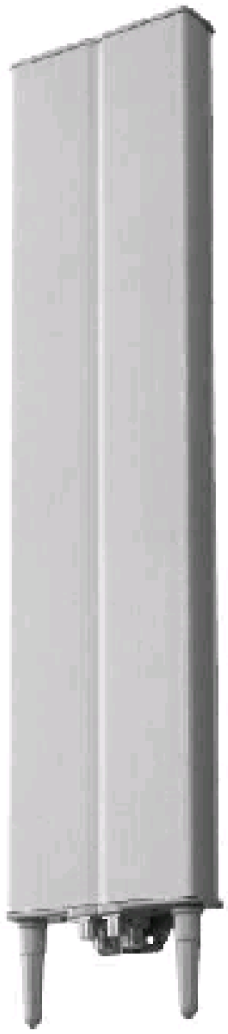


Alternative Approach for X-polarized Antennas

- 2x2 X-pol: 4 antennas in a radome of 32 cm
  - ±45° Polarization
  - 2 subarrays in λ/2 spacing
  - Very compact
  - Correlated and uncorrelated pairs offer a lot of possibilities in RX- and TX signal processing



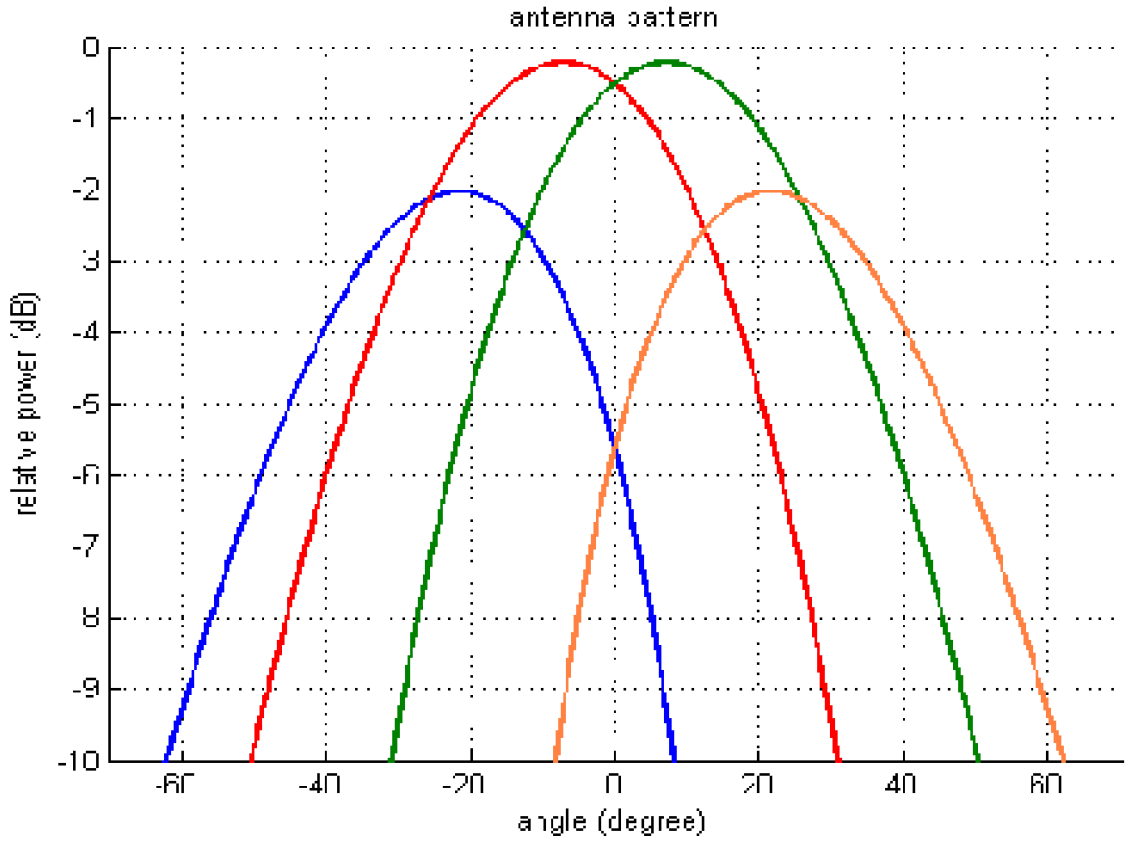




Alternative Approach for X-polarized Antennas

Beam patterns per polarization for a 2-element sub-array

- half power beam width of a single antenna element = 70 deg.
- Sub-array beams have a HPBW of about 45 deg.



Alternative Approach for X-polarized Antennas

First Component: Exploiting Correlation by Beamforming

- Each subarray uses one out of 4 different fixed beams (2 bit codebook size)
- This beam will depend on the direction of the user and will be constant over the whole band and changes only very slowly in time
  - Best suitable beam can be estimated via uplink by direction estimation algorithms for each MS
  - Alternatively this best beam index information is fed back by the MS on a very low rate feedback channel
- Up to 3dB additional gain by beamforming

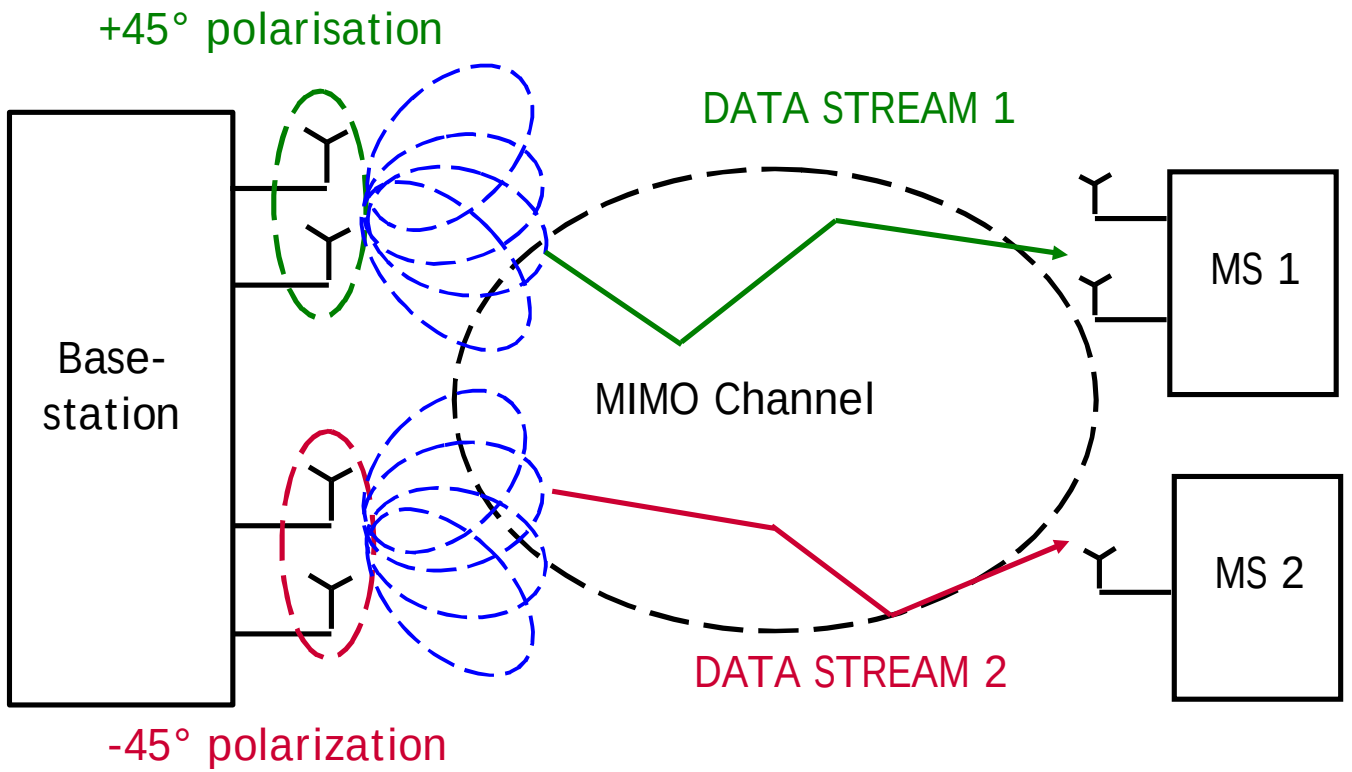
Second Component: Exploiting Decorrelation depending on MS situation

- Good channel conditions: Spatial multiplexing - one data stream per polarization, to one or two MSs
- Bad channel conditions: open-loop or closed-loop Tx-diversity, depending on MS velocity

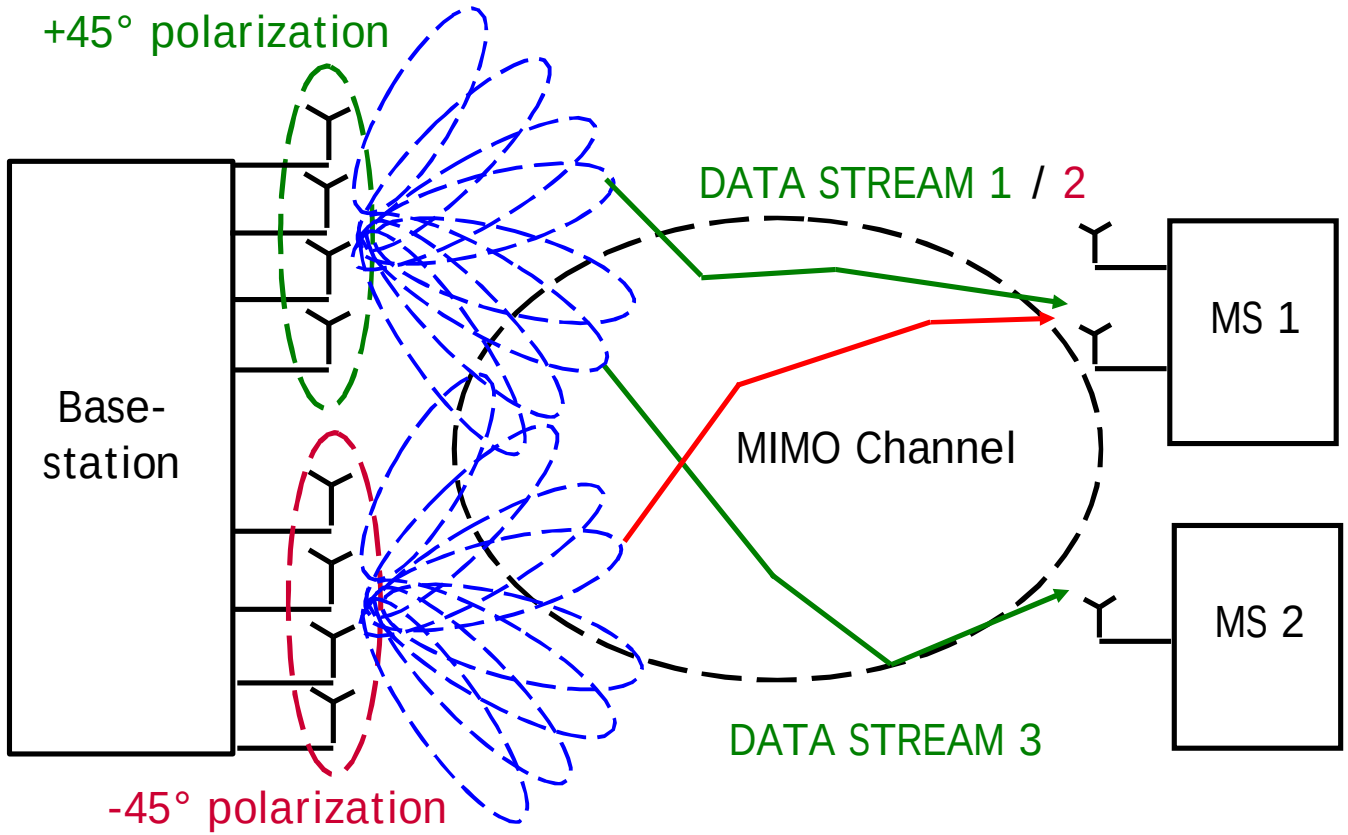
Alternative Approach for X-polarized Antennas

- For urban / sub-urban / wide area scenarios
- MU-options
  - User separation by polarization
    - One user per polarization orientation / two users per beam
  - User separation by beams
    - One user per beam
    - Use the two polarizations for spatial multiplexing or Tx-diversity, depending on channel quality and number of MS Rx antennas
    - Interesting for more than 4 Tx antennas (e.g. 8Tx@4*2 xpol), as more beams are possible and beams get narrower)

MU-MIMO: User separation by polarization



MU-MIMO: User separation by beam



MU-MIMO - Conclusion

MU-MIMO

- Based on beamforming with common pilots
- For outdoor and wide area deployment
- Beamforming schemes can be devised for different antenna configurations
- Allows simple receivers at the mobile terminal
- Allows significant enhancement of spectral efficiency
- Schemes with X-polarized antennas offer flexible combinations of beamforming and spatial multiplexing / diversity