MULTIANTENNA CELLULAR COMMUNICATIONS

CHANNEL ESTIMATION, FEEDBACK, AND RESOURCE ALLOCATION

Doctoral Thesis in Telecommunications

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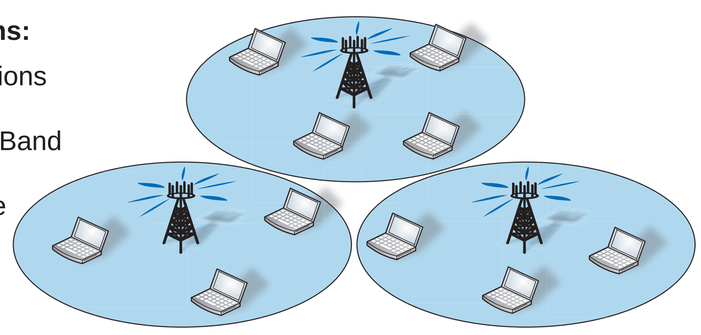
Introduction

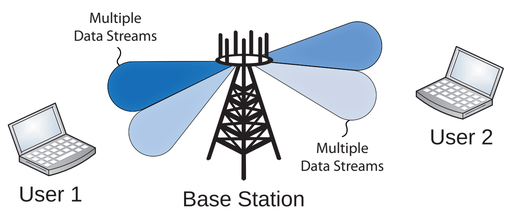
Downlink Cellular Communications:

- Multiple Transmitting Base Stations
- Multiple Receiving Users
- Sharing a Common Frequency Band
- Limited by Power Constraints
- Limited by Co-User Interference



Space-Division Multiple Access (SDMA):

- Multiantenna Transmission
- Beamforming: Spatially Directed Signals
- Combining: Spatially Directed Reception
- Serve Multiple Users - Simultaneously
- Controlled Co-User Interference



How to Measure System Performance?

Many Definitions of Single-User Performance:

- Achievable Data Rate (perfect and long coding)
- Bit Error Rate (complicated expressions)
- Mean Squared Error (difficult to interpret)

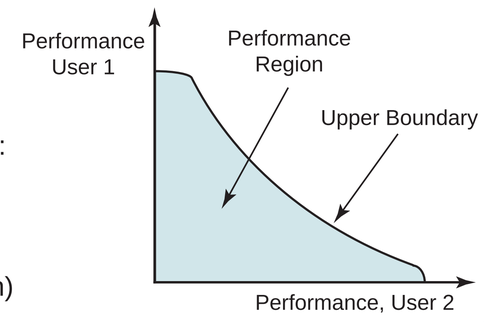
They All Improve with the Signal-to-interference-and-noise ratio (SINR) → Optimize the SINR

Multi-User Performance has Fairness Dimension:

- Divide Available Power among Users
- Create and Control Co-User Interference
- Illustrated by the Achievable Performance Region:

Any Multi-User Resource Allocation Problem:

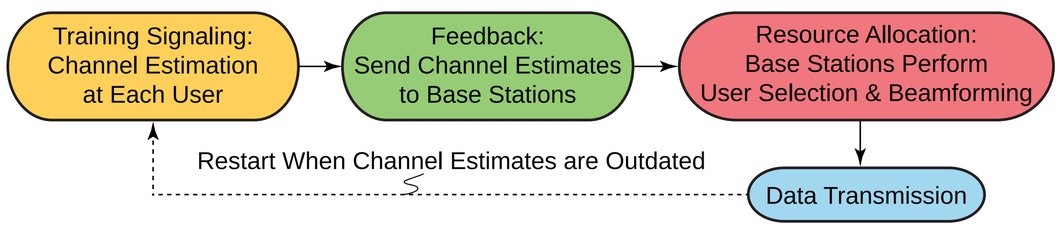
- Optimal Solution on the Upper Boundary
- Difficult to Know Which Point (region is unknown)



System Operation

SDMA Requires Accurate Channel Knowledge:

- Find Strong Channels, Compatible Users, and Good Beamforming
- Achieved By Channel Estimation and Feedback: (colors represents different parts)



Benchmark: Optimal Resource Allocation

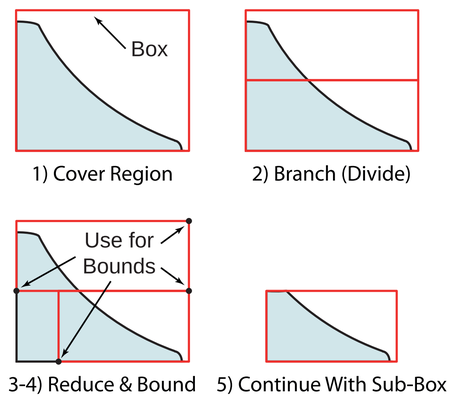
Evaluate Practical Strategies towards Optimum

- Most Resource Allocation Problems are NP-hard (e.g., sum performance and proportional fairness)
- Computationally Expensive to Solve Optimally
- Can be Seen as Search in Performance Region

Proposal: Branch-Reduce-and-Bound Algorithm

1) Cover Performance Region with a Box
2) Divide the Box into Two Sub-Boxes
3) Find Lower/Upper Bounds in Boxes
4) Calculate Lower/Upper Bounds on Optimum
5) Continue with one Sub-Box at a Time

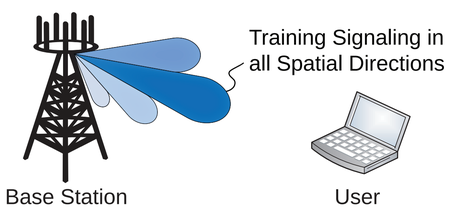
End: When Bounds on Optimum are Tight Enough



Channel Estimation

Training-Based Channel Estimation:

- Send Known Signals in All Spatial Directions
- Sufficient to Estimate Channel Behavior
- Limited by Interference and Noise

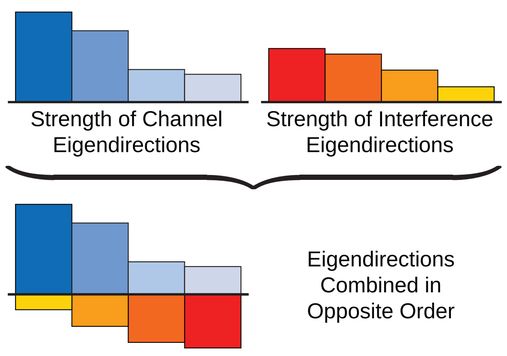


Problem: Training Signal Optimization

- Select Training Signal to Minimize Error (Mean squared error of estimate)
- Adapt to Channel and Interference Statistics (eigendirections and eigenvalues)

Proposal: Explicit Training Strategy

- Based on Statistical Eigendirections
- Concentrate on Strong Channel Directions
- Strong Directions when Interference is Weak
- Adapt to Estimation of Different Quantities



Reference: E. Björnson, B. Ottersten, "*A Framework for Training-Based Estimation in Arbitrarily Correlated Rician MIMO Channels with Rician Disturbance*," IEEE Transactions on Signal Processing, Mar. 2010.

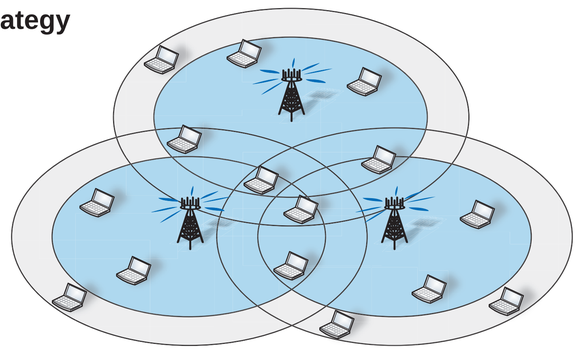
Practical Resource Allocation

Problem: Practical Resource Allocation Strategy

- Select Users and Beamforming
- Limited Computational Complexity
- Only Require Local Channel Information

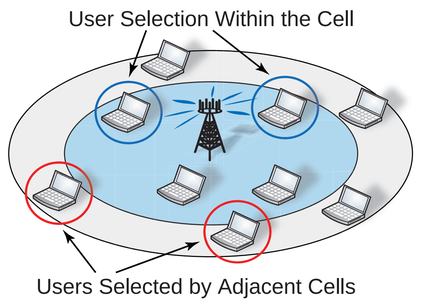
Proposal: Dynamic Cooperation Clusters:

- Adjacent Base Stations (BSs) Cooperate
- Outer Circle: Coordinate Interference
- Inner Circle: Serve with Data
- Some Users Served by Multiple BSs



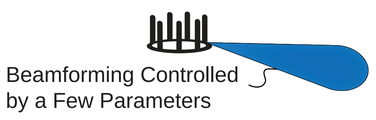
Proposal: Distributed User Selection

- Select Spatially Separated Users
- Coordinate Selection between Cells
- Strategy: Greedy Algorithm Exploiting Previous Selections in Adjacent Cells



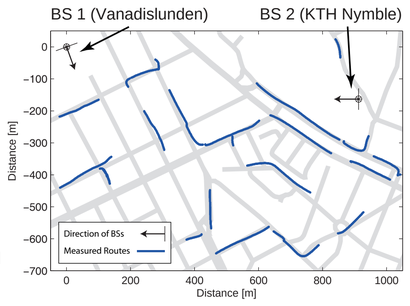
Proposal: Low-Complexity Beamforming

- Explicit Parameterization of Optimal Beamforming
- Hard to Find Optimal Parameters
- Easy to Find Parameters Giving Good Performance
- Strategy: Beamforming with Heuristic Parameters



Evaluation on Realistic Channel Measurements

- Measured Around KTH Campus (thanks to P. Zetterberg and N. Jaldén)
- Optimal vs. Practical Resource Allocation
- Confirms that Proposed Strategies Work Well
- Important to Coordinate Interference between BSs
- Joint Transmission Requires Accurate Synchronization



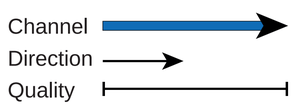
References: E. Björnson, R. Zakhour, D. Gesbert, B. Ottersten, "*Cooperative Multicell Precoding: Rate Region Characterization and Distributed Strategies with Instantaneous and Statistical CSI*," IEEE Transactions on Signal Processing, Aug. 2010.

E. Björnson, N. Jaldén, M. Bengtsson, B. Ottersten, "*Optimality Properties, Distributed Strategies, and Measurement-Based Evaluation of Coordinated Multicell OFDMA Transmission*," IEEE Transactions on Signal Processing, To appear.

Quantization and Limited Feedback

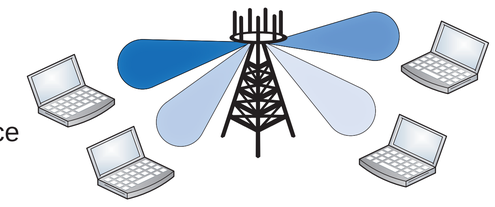
Feedback of Channel Information using Limited Number of Bits

- Channel Direction: User Selection, Beamforming
- Channel Quality: User Selection, Power Allocation



One or Multiple Streams per Multi-Antenna User?

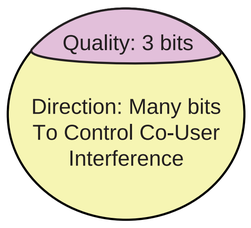
- Determines Number of Directions to Feed Back
- Answer: Only One Data Stream per User
- Enables Receive Combining to Reject Interference
- Achieves Better Effective Channels



How to Divide Bits between Direction and Quality?

- Depends on Channel Conditions and Number of Users
- Answer: ~3 Bits for Quality and Remaining Bits for Direction
- Accurate Direction Information Essential to Control Interference

Cake of Feedback Bits:



References: E. Björnson, M. Bengtsson, B. Ottersten, "*Receive Combining vs. Multistream Multiplexing in Multiuser MIMO Systems*," Proc. Swe-CTW, October 2011.

E. Björnson, K. Ntontin, B. Ottersten, "*Channel Quantization Design in Multiuser MIMO Systems: Asymptotic versus Practical Conclusions*," Proc. IEEE ICASSP, May 2011.