Wireless OFDMA Network MIMO Systems with Limited Backhaul Capacity

Aakanksha Chowdhery

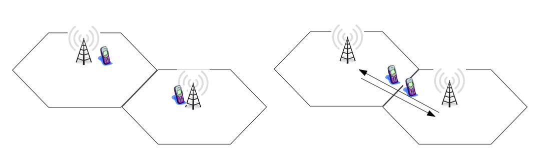
Department of Electrical Engineering, Stanford University

Introduction

- Next-generation cellular networks demand high data-rates for data and video traffic on smartphones/tablets.
- Conventional cellular networks are interference limited (with frequency reuse factor of one-third).
- Network MIMO in cellular networks mitigates intercell interference.
  - Each base-station (BS) can pre-subtract the intercell interference of the cooperating neighboring BSs.
  - Allow aggressive frequency reuse factor up to 1.
- Network MIMO can incur very high backhaul capacity in sharing the user data for interference cancellation.
- Objective: How to retain the performance gains of network MIMO when backhaul capacity is limited?

Toy Example

- The benefits of selecting a cooperation link between two BSs depends on their scheduled users and power-spectra.
- Simple Scenario: Two cells each with a base-station and a user.



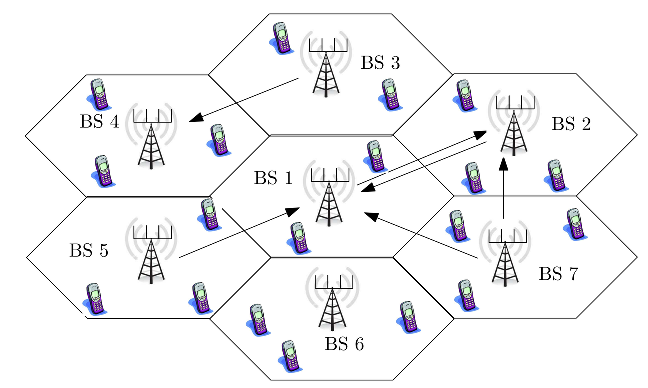
- When both the scheduled users are close to their BSs,
  - Both BSs can use low powers to transmit signals to their users.
  - Minimal benefit of sharing user data for interference cancellation.
- When both the scheduled users are near the cell-edge,
  - Both BSs can must use higher powers to transmit signals to their users.
  - Higher benefit of sharing user data for interference cancellation.
- Cellular networks - more complex scenario and more opportunity for gains at limited backhaul capacity.

Prior Work

- Clustering of the BSs into disjoint clusters where only intra-cluster interference is cancelled.
- Adding cooperation links only for the weakest set of users.
- (Information theory) Splitting the message in to common and private parts for rate-limited cooperation at the transmitter based on Han-Kobayashi strategy.

System Model

- Downlink OFDMA system



- Each BS equipped with Q antennas and serves Q users simultaneously.
- Perfect channel state information at each BS.
- Zero-forcing (ZF) precoding at each BS to cancel intra-cell interference and intercell interference of cooperating BSs.

Problem Statement

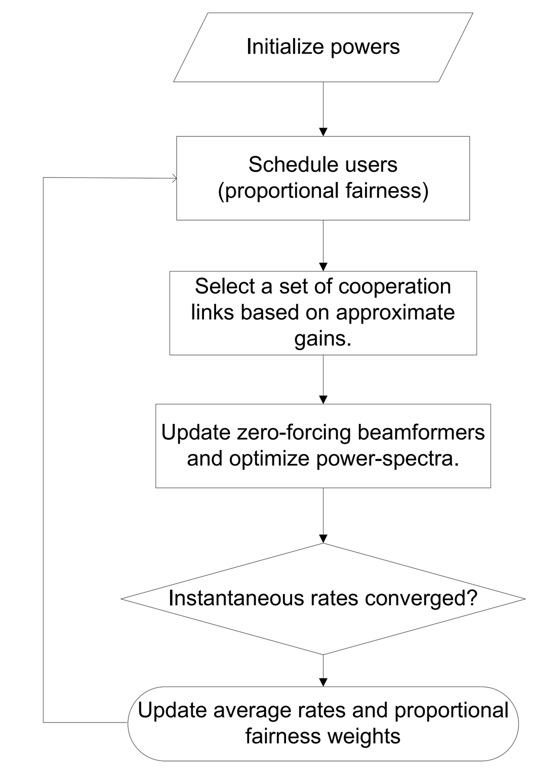
- To utilize the limited backhaul capacity, choose only a subset of frequency tones for cooperation & share the users data with neighboring BSs only on this subset of tones.
- This work maximizes the network-wide utility while satisfying the backhaul capacity constraints.
- For each BS at each frequency tone, optimize
  - Cooperation-link selection
  - User-scheduling
  - Precoder-coefficient and power-spectrum adaptation
- The joint optimization problem is a mixed discrete and continuous optimization problem.

Proposed Solution

- This work proposes a heuristic approach for finding a practical and locally optimal solution.
- Iterates over scheduling the users jointly, choosing cooperation links, and adapting precoding coefficients and power spectra.
- **User-scheduling**
  - A proportionally fair scheduler is used to select the active user on each beam in each cell on each frequency tone
  - Selects the user with largest ratio of instantaneous rate and time-averaged rate, i.e. the user with best rate who has not been served.
  - Additionally accounts for a penalty for the backhaul-capacity constraint.

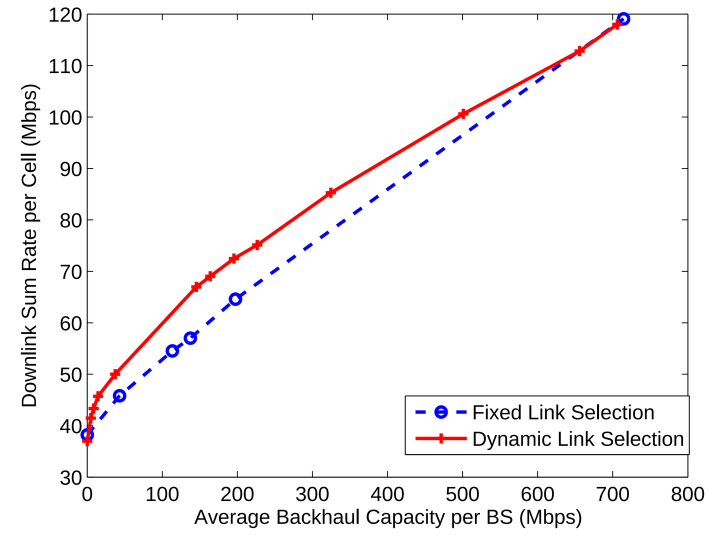
Proposed Solution

- **Cooperation link-selection**
  - A cooperation link is added from a beam to a BS if the benefit of adding this link in terms of the data-rate increase for the destination BS exceeds the backhaul-capacity cost.
  - The exact computation of cost and benefit of adding each cooperation link is a nontrivial task. Use approximation.
- **ZF precoding coefficients optimization**
  Precoding coefficients are chosen so that intracell interference between different beams within each cell and intercell interference of cooperating BSs is completely eliminated.
- **Power-spectra optimization**
  With the cooperation links, user schedules, and precoder coefficients fixed, the power spectrum adaptation step optimizes the transmit power spectra by solving the network-utility maximization problem using a nonlinear optimization method such as the interior-point method.



Simulation Results

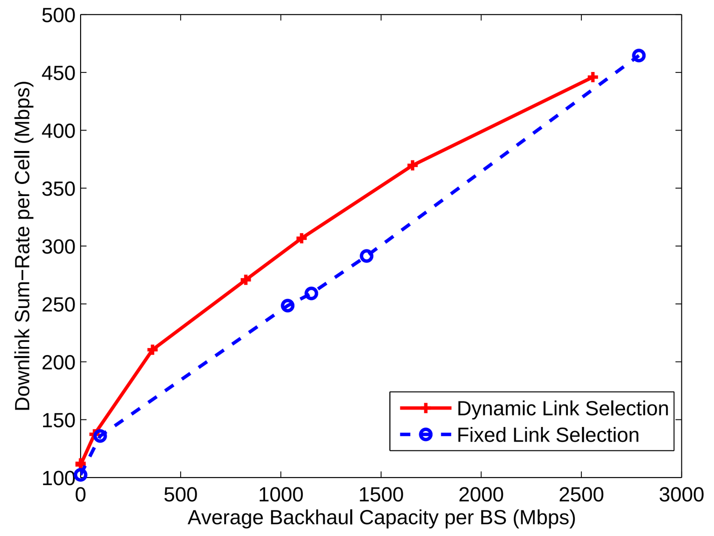
$Q = 1$ antenna per BS, BS-to-BS distance $d = 800$m, Downlink sum rate per cell vs. backhaul capacity



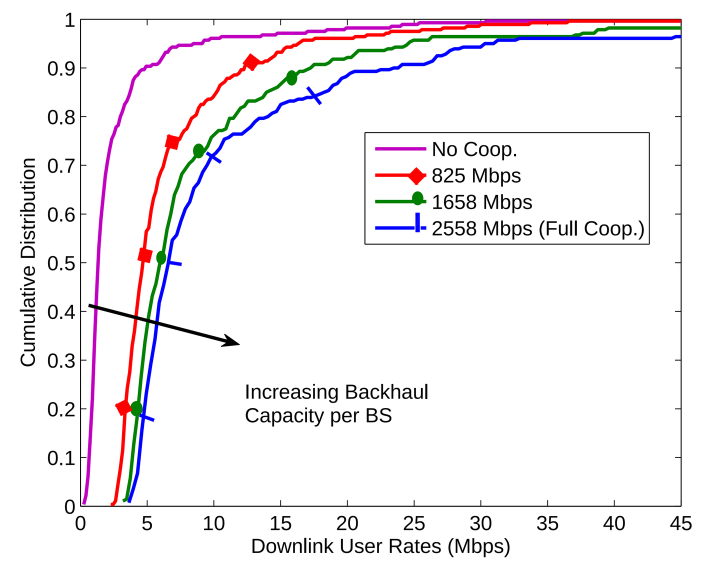
Simulation Results

$Q = 4$ antennas per BS, BS-to-BS distance $d = 800$m

- Downlink sum rate per cell vs. backhaul capacity



- Cumulative distribution functions of downlink user rates for different backhaul capacities



Simulation Setup: 40 users per cell, 64 tones over 10MHz bandwidth, Total transmit power of 49dBm per antenna at each BS, Multipath time delay profile of ITU-R M.1225 PedA, Distance-dependent path-loss model $L = 128.1 + 37.1\log_{10}(d_0)$, where d_0 is the distance in km, Rayleigh fading. The users are uniformly distributed within each cell.

Conclusions

- The benefit of network MIMO can be significant even with limited backhaul capacity.
- However, such benefit comes at a substantial cost in network optimization as well as the need for obtaining the channel state information of the entire network.

References

[1] D. Gesbert, S. Hanly, H. Huang, S. Shamai, O. Simeone, and W. Yu, “Multicell MIMO cooperative networks: A new look at interference,” IEEE J. Selected Areas Commun., vol. 28, no. 9, pp. 13801408, Dec. 2010.

[2] S. Mehryar, A. Chowdhery, and W. Yu, “Dynamic Cooperation Link Selection for Network MIMO Systems with Limited Backhaul Capacity,” accepted in IEEE International Conference on Communications (ICC), Jun. 2012.

[3] A. Chowdhery, W. Yu and J. M. Cioffi , “Cooperative Wireless Multicell OFDMA Network with Backhaul Capacity Constraints,” IEEE International Conference on Communications (ICC), Jun. 2011.

* Joint work with W. Yu, J. M. Cioffi, S. Mehryar

Contact information: Aakanksha Chowdhery – Email: *achowdhe@stanford.edu*; Web: *http://www.stanford.edu/∼achowdhe*