BEAMFORMING UTILIZING CHANNEL NORM FEEDBACK IN MULTIUSER MIMO SYSTEMS

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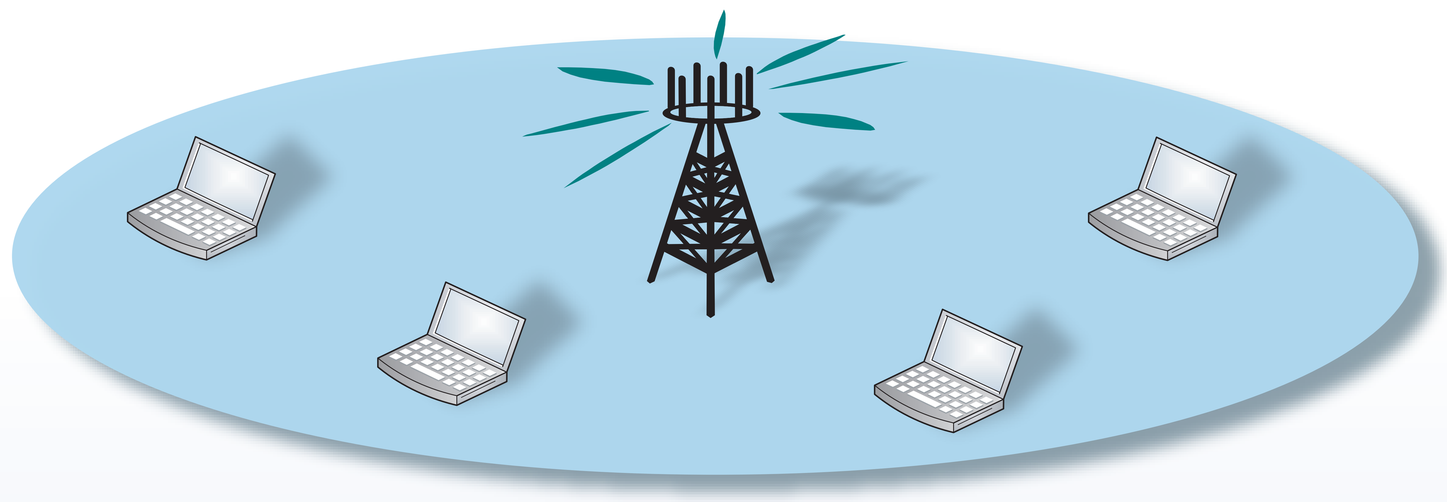


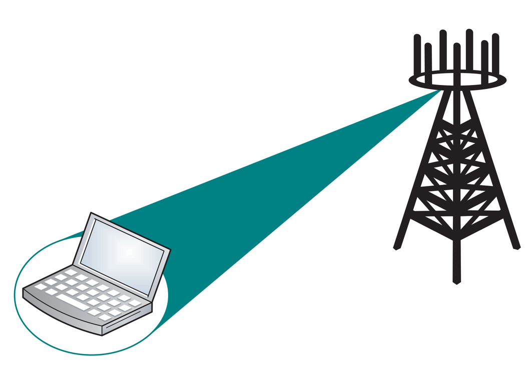
– There is spatial information in the channel norm, especially when it is strong.

– This motivates beamforming communication with channel norm feedback.

Spatial Correlation, example

- Elevated base station, n_T antennas.
- Multiple users, n_R antennas.
- Partial channel information at base station.

Some directions are more favorable to a user:



Consider two real-valued Gaussian distributed variables

$$v_i \in \mathcal{N}(0,\sigma_i^2), \quad i = 1,2.$$

What information is gained of v_i if the norm $\|(v_1,v_2)\|^2 = v_1^2 + v_2^2$ is observed?

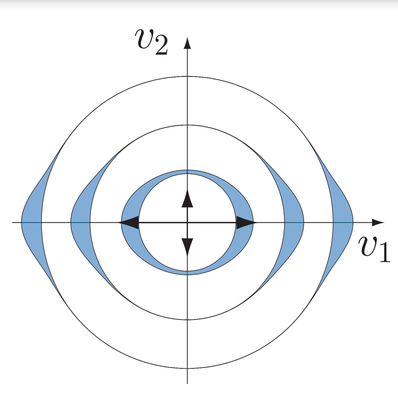


Figure 1: The shaded area shows how the probability mass is distributed over the circle, representing a given norm. The inner arrows indicate the standard deviation. Observe that the probability mass is more focused for larger norms.

System Model

Channel model:
Rayleigh fading MIMO channel to user k:

$$\mathbf{H}_k = [\mathbf{h}_{k,1},\ldots,\mathbf{h}_{k,n_R}]^H$$

with independent $\mathbf{h}_{k,i} \in \mathcal{CN}(\mathbf{0},\mathbf{R}_k)$.

The received vector (user k):

$$\mathbf{y}_k(t) = \mathbf{H}_k \mathbf{w}_{T_k} s_k(t) + \mathbf{n}_k(t),$$

with beamforming vector $\mathbf{w}_{T_k}$, symbol $s_k(t)$ and AWGN $\mathbf{n}_k(t) \in \mathcal{CN}(\mathbf{0},\sigma_k^2\mathbf{I})$.

Limited Feedback Strategy

A strategy is needed to determine:

- The beamforming vector for user k.
- The corresponding SNR (and supported rate).

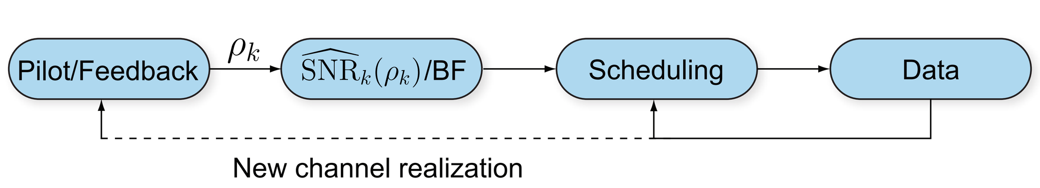
Opportunistic beamforming:

- The beamformer is chosen at random.
- Each user feeds back its SNR.
- Advantage: Knowledge of the SNR,
  Disadvantage: Neglects spatial information.

Channel norm supported eigenbeamforming:

- Each user feeds back its channel norm ρ_k.
- The beamformer is determined using conditional channel statistics.
- Advantage: Exploits spatial information,
  Disadvantage: Requires SNR estimation.
- *This strategy is analyzed in the paper.*

System Operation



Channel information:
Only $\mathbf{R}_k$ and $\rho_k = \max_i \|\mathbf{h}_{k,i}\|^2$, for each user k, is known to the base station.

Antenna Selection

- Only the strongest receive antenna is used.
- The channel norm is ρ_k.

MMSE estimation of SNR:

$$E\{\mathrm{SNR}_k|\rho_k\} = E\left\{\frac{|\mathbf{h}_{k,\text{strongest}}^H \mathbf{w}_{T_k}|^2}{\sigma_k^2}\middle|\rho_k\right\} = \frac{\mathbf{w}_{T_k}^H \widehat{\mathbf{R}}(\rho_k)\mathbf{w}_{T_k}}{\sigma_k^2}$$

$$V\{\mathrm{SNR}_k|\rho_k\} = \frac{E\{|\mathbf{h}^H\mathbf{w}_T|^4|\rho_k\} - (\mathbf{w}_T^H\widehat{\mathbf{R}}(\rho_k)\mathbf{w}_T)^2}{\sigma_k^4}$$

Closed-form expressions for $\widehat{\mathbf{R}}(\rho_k)$ and $E\{|\mathbf{h}^H\mathbf{w}_T|^4|\rho_k\}$ are previously known.

Receive Beamforming

- The antennas are combined to maximize the SNR.
- The norm of the strongest receive channel is ρ_k.
- The other channel norms are known to be smaller.

MMSE estimation of SNR:

$$E\{\widetilde{\mathrm{SNR}}_k|\rho_k\} = \frac{\mathbf{w}_{T_k}^H \widehat{\mathbf{R}}(\rho_k)\mathbf{w}_{T_k}}{\sigma_k^2} + (n_R-1)\frac{\mathbf{w}_{T_k}^H \widehat{\mathbf{R}}(0\leq\rho\leq\rho_k)\mathbf{w}_{T_k}}{\sigma_k^2}$$

$$V\{\widetilde{\mathrm{SNR}}_k|\rho_k\} = V\{\mathrm{SNR}_k|\rho_k\} + (n_R-1)V\{\widetilde{\mathrm{SNR}}_k|0\leq\rho\leq\rho_k\}$$

Closed-form expressions for $\widehat{\mathbf{R}}(0 \leq \rho \leq \rho_k)$ and $V\{\widetilde{\mathrm{SNR}}_k|0 \leq \rho \leq \rho_k\}$ are derived.

Simulation Results

- Proportional fair scheduling.
- Rich scattering around the users.

Capacity estimation based on:

$$E\{\mathrm{SNR}_k|\rho_k\} - \alpha\sqrt{V\{\mathrm{SNR}_k|\rho_k\}},$$

with α chosen to achieve outage probability 5%.

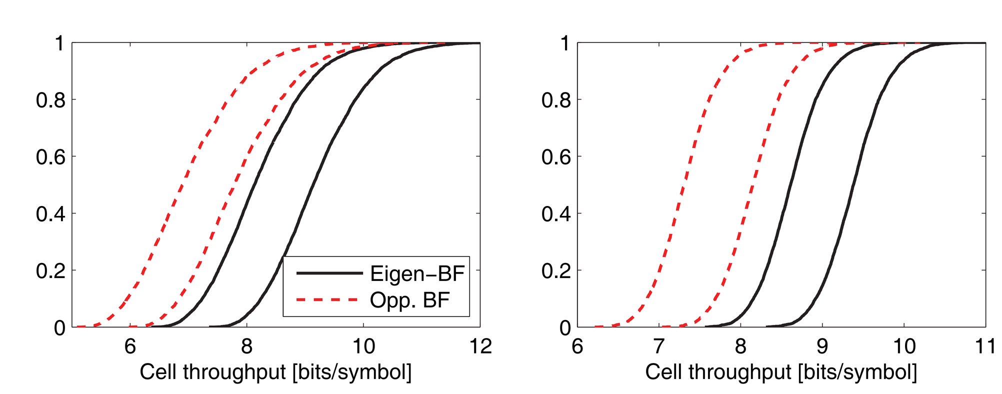


Figure 2: The CDF (over scenarios) of the cell throughput in a system with a transmitting eight-antenna UCA and four receive antennas per user. *Opportunistic beamforming* is compared to the proposed *Feedback supported eigenbeamforming* for different receive strategies: antenna selection and receive beamforming (increasing performance). The angular spread is 15 degrees.

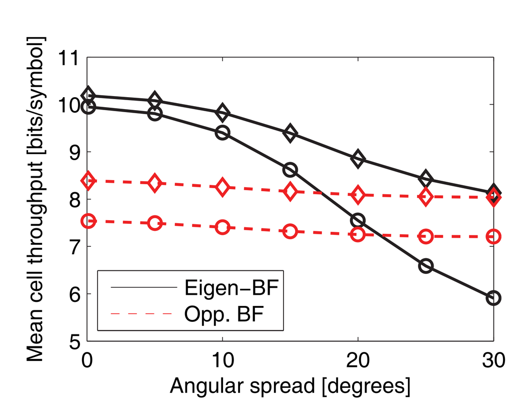


Figure 3: The mean cell throughput for different angular spreads. The proposed channel norm supported eigenbeamforming with antenna selection (circles) and receive beamforming (diamonds) is compared to the corresponding opportunistic beamforming.

– The channel norm provides substantial spatial information.

– Two simple channel norm feedback strategies are proposed that outperform opportunistic beamforming with the same amount of feedback.