BS-Side Estimation for Reduced Feedback Best-M Scheme in OFDM Systems

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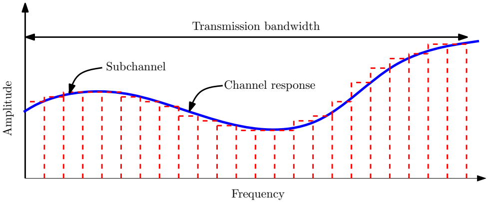
Orthogonal frequency-division multiplexing (OFDM)

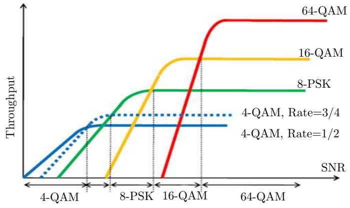
- Divides the channel into multiple orthogonal subchannels
- Enables parallel transmission



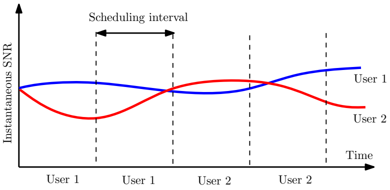
- Widely used because:
  - avoids inter-symbol interference in multipath channels
  - resource allocation between the users is made easier
- Adopted in standards such as long term evolution (LTE) and LTE-advanced

Scheduling and rate adaptation

- Scheduling: BS determines which user to serve
- Rate adaptation: choosing the rate of transmission



Rate adaptation

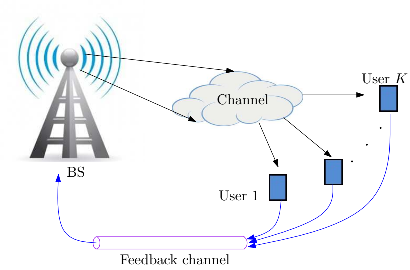


User scheduling

- Advantages: improves spectral efficiency and avoids worst-case designs
- Challenge: need channel knowledge at BS

Feedback from users

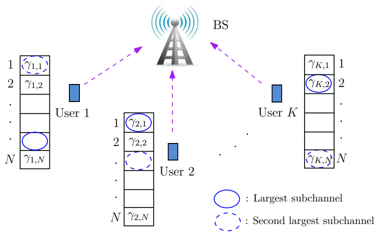
- Channel information must be fed back to the BS in the uplink
  - expends uplink radio resources
  - feedback increases as the number of users and subchannels increase



- Complete feedback is impractical and reduced feedback schemes are needed
- Several have been proposed: threshold-based, one-bit scheme, clustering, best-M scheme, hybrid schemes etc.

Best-M scheme

- Users feed back M largest subchannel SNRs and their subchannel indices



Subchannels

	1	2	3	4
User 1	$\gamma_{1,1}$	–	–	–
User 2	–	–	$\gamma_{2,3}$	–
User 3	–	–	$\gamma_{3,3}$	–

Best-M feedback for $M = 1$

- Degradation in throughput occurs due to:
  1. instances of no user feedback on a subchannel
  2. loss in multi-user diversity
- Use subchannel correlation to improve the throughput
- Notations for best-M feedback:
  - Reported indices: $\mathbf{x}_{k,M} = [i_1(k), \ldots, i_M(k)]$
  - Reported SNRs: $\mathbf{s}_{k,M} = [s(k, i_1(k)), \ldots, s(k, i_M(k))]$

Minimum mean square error (MMSE) approach

- Generates the MMSE estimate of an unreported subchannel's SNR

Lemma

The MMSE estimate given the best-M feedback $(\mathbf{s}_{k,M}, \mathbf{x}_{k,M})$ is a conditional expectation:

$$\hat{\gamma}_{k,n} = \mathbb{E}\left[\gamma_{k,n} \middle| \mathbf{s}_{k,M}, \mathbf{x}_{k,M}\right]$$

- Incorporates subchannel correlation and the best-M feedback

Subchannels

	1	2	3	4
User 1	$\gamma_{1,1}$	–	–	–
User 2	–	–	$\gamma_{2,3}$	–
User 3	–	–	$\gamma_{3,3}$	–

Best-M feedback for $M = 1$

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Subchannels

	1	2	3	4
User 1	$\gamma_{1,1}$	$\hat{\gamma}_{1,2}$	$\hat{\gamma}_{1,3}$	$\hat{\gamma}_{1,4}$
User 2	$\hat{\gamma}_{2,1}$	$\hat{\gamma}_{2,2}$	$\gamma_{2,3}$	$\hat{\gamma}_{2,4}$
User 3	$\hat{\gamma}_{3,1}$	$\hat{\gamma}_{3,2}$	$\gamma_{3,3}$	$\hat{\gamma}_{3,4}$

After estimation

Alternate view: Throughput-optimal approach

- Objective is to maximize the downlink throughput
- Define feedback-conditioned goodput of rate R_l for user k on subchannel n as $G_n(k,l) = R_l \mathbb{P}\left(\gamma_{k,n} \geq T_l | \mathbf{s}_{k,M}, \mathbf{x}_{k,M}\right)$
- Represents the average number of successfully transmitted bits if rate R_l is used given the best-M feedback

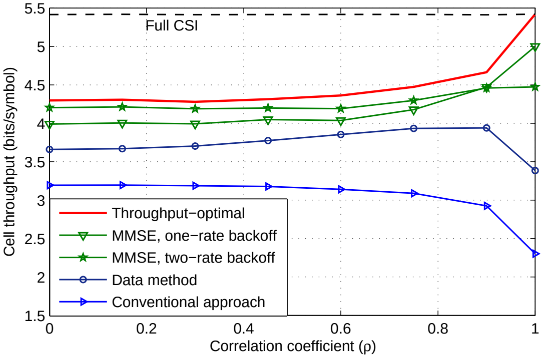
Result

Let $m_n(k) = \text{argmax}_{1 \leq l \leq L} \{G_n(k,l)\}$. Then, the optimal user ω_n^* and the MCS π_n^* for transmission on subchannel n are:

$$\omega_n^* = \underset{1 \leq k \leq K}{\arg\max} \{G_n(k, m_n(k))\},$$

$$\pi_n^* = m_n(\omega_n^*).$$

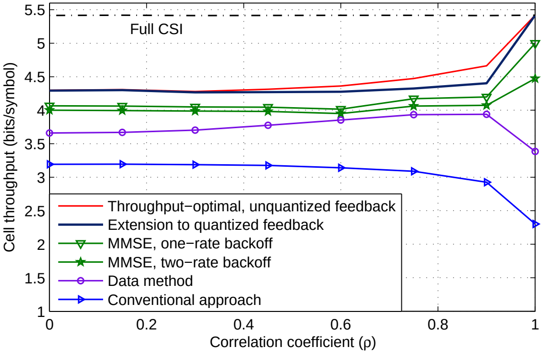
Throughput benchmarking for $M = 1$



- $K = N = 10$
- $\Omega_k = \Omega\alpha^{k-1}$
- $\Omega = 9$ dB, $\alpha = 1.4$
- $\mathbb{E}\left[H_{k,n}H^*_{k,m}\right] = \Omega_k\rho^{|n-m|}$

- Proposed approaches achieve a higher throughput
- MMSE approach with an appropriate rate backoff is near-optimal

Results for quantized feedback and $M = 1$



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- $\mathbb{E}\left[H_{k,n}H^*_{k,m}\right] = \Omega_k\rho^{|n-m|}$

- Loss with quantized feedback is negligible for $\rho \leq 0.45$
- Proposed approaches outperform benchmark approaches

Conclusions

- Proposed two approaches to systematically incorporate subchannel correlation and best-M feedback
- Outperformed benchmark approaches without additional feedback
- Throughput-optimal approach gives a fundamental limit on the achievable throughput
- MMSE approach with an appropriate rate backoff achieves throughput close to the optimal approach
- Future work:
  - extension to multiple antenna systems
  - incorporating other imperfections like channel estimation errors, feedback delay etc.