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Reducing Feedback Requirements of the Multiple Weight Opportunistic Beamforming Scheme via Selective Multiuser Diversity

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Presentation Outline

• Introduction to Multiuser Diversity
• Opportunistic Beamforming and multiple weighting vector transmission
• Threshold assisted Selective Multiuser Diversity
• Integration of Selective Multiuser Diversity with Multiple Weighting Vector Opportunistic Beamforming
• Uplink Feedback Overhead Comparison
• Conclusions
Introduction to Multiuser Diversity

- Multiuser Diversity can improve the sum capacity of the downlink and uplink of a Rayleigh fading channel.
- Independent fading from different users increases the probability of identifying at least one strong channel ($h_{\text{max}}$) onto which resources can be allocated to.
- By scheduling only the user that can best utilize resources, total system throughput is maximised.
Opportunistic Beamforming and multiple weighting vector transmission

- Multiple antennas at the Base Station (OB) introduce random power and phase fluctuations, altering the perceived channel at the Mobile Station.
- Multiuser Diversity and consequently, OB, require SNR feedback for every scheduling instant from Mobile Stations.
Opportunistic Beamforming and multiple weighting vector transmission

- In the presence of few active users, multiple weighting vectors increase the number of perceived channels to users (MWOB).
- Using $Q$ different random weighting vectors, Multiuser Diversity for $K$ users increases from $\log(\log(K))$ to $\log(\log(QK))$.
- Transmission of $Q$ vectors per slot, increases the downlink slot overhead, due to the finite length of these vectors (minislots).
- Typical minislot lengths about 5-10% of total downlink slot.
Opportunistic Beamforming and multiple weighting vector transmission

- Defining $L$ as the total downlink slot length, and $\tau$ the minislot length, maximum throughput when $Q$ weighting vectors are used:

$$T_Q(t) = (L - \tau Q) \max_{q=1\ldots Q, k=1\ldots K} R_{q,k}(t)$$

- Due to the minislot overhead, the use of multiple vectors is constrained.
- For a given number of users, and specified minislot length, an optimum number of vectors exists, giving the best trade-off between downlink overhead and Multiuser Diversity gains.
Opportunistic Beamforming and multiple weighting vector transmission

- The number of optimum weighting vectors will converge to 1 (conventional OB) for an increasing number of users. The rate of convergence depends on the minislot length.
Opportunistic Beamforming and multiple weighting vector transmission

- The abrupt changes in rate are attributed to a change in the number of weighting vectors used.
Threshold assisted Selective Multiuser Diversity

- Multiuser Diversity requires Channel State Information (CSI) in the form of instantaneous SNR from all Mobile Stations for all feedback units.
- However, only strong channels have a realistic chance of acquiring resources.
- Hence, can allow only users with strong channels to feedback CSI.
- Decision on user eligibility for scheduling based on a threshold level.
**Threshold assisted Selective Multiuser Diversity**

- Normalized feedback load for Selective Multiuser Diversity:
  \[ \overline{F} = \frac{P(t)}{K} \]
  \( P(t) \): users above the threshold

- For an i.i.d Rayleigh fading channel with an average SNR = \( \overline{\gamma} \) and a threshold \( \gamma_{th} \), normalized load is expressed as:
  \[ \overline{F} = e^{-\frac{\gamma_{th}}{\overline{\gamma}}} \]

- Define user outage, as the probability that no users have channels higher than the threshold level as:
  \[ P_o = \left(1 - e^{-\frac{\gamma_{th}}{\overline{\gamma}}} \right)^K \]
Threshold assisted Selective Multiuser Diversity

- Selective Multiuser Diversity (SMUD) maintains system throughput (average SNR=0dB) with a 3dB threshold level. Higher thresholds converge at a higher number of users.
Integration of SMUD in OB with multiple weighting vector transmission-Motivations for feedback reduction

- Conventional OB with multiple weighting vector transmission increases uplink feedback overhead by a factor of $Q$.
- Scheduler needs to be aware of instantaneous channel conditions at least at the rate at which the channel is changing. Feedback rate increases at higher user mobility.
- Future wireless communications perform scheduling on the spectral domain as well, augmenting uplink feedback requirements.
- This factor can mitigate Multiuser Diversity gains, reaching a bottleneck point in capacity.
Integration of SMUD in OB with multiple weighting vector transmission

- A higher threshold can achieve the same converge as conventional OB, due to the expected throughput increase arising from the use of multiple weighting vectors.
Integration of SMUD with Multiple Weighting Vector

Opportunistic Beamforming

- Distribution of user outage probability confirms throughput results.
- The use of multiple weighting vectors allows an increase in maximum tolerable threshold level, for a target user outage probability.

Outage Probabilities for Conventional and Multiple Weight OB
Uplink Feedback Overhead Comparison

- Can the higher threshold of the proposed scheme, result in a reduced uplink overhead due to a more efficient user selectivity?
- i.e. does this higher threshold result in a smaller number of eligible users?
- Normalised feedback load for OB with multiple weighting vector transmission:

\[ \bar{F} = \frac{Q_{opt} P(t)}{K} \]
Uplink Feedback Overhead Comparison

- Consider normalised feedback load for conventional and multiple weighting vector OB.
- Assume minislot length of 5% of total downlink slot.
- Optimum number of vectors, $Q_{opt}=3$. (valid for over 20 Mobile Stations).
- Optimum threshold level for conventional OB: 3dB
- Optimum threshold level for OB with multiple weighting vectors: 5dB
Uplink Feedback Overhead Comparison

- A high threshold level results in a reduction in uplink feedback overhead. However, user outage increases degrading performance.
- Multiple weighting OB @ 5dB requires similar uplink feedback overhead with conventional OB @ 3dB
Conclusions

• The performance of Opportunistic Beamforming with multiple weighting vectors has been examined under a reduced feedback scheme.

• Proposed approach has shown to not only increase downlink rates of conventional Opportunistic Beamforming, through the use of multiple vectors, but also offset the associated (Q-fold) increases in uplink feedback overhead.

• This result is quite significant as it allows Multiple Weighting OB to be employed in next generation wireless where uplink feedback requirements are expected to increase.