Uplink Scheduling Criteria Comparison for V-BLAST Users

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Introduction: Multiple Input Multiple Output (MIMO) Channels

• A MIMO channel is a wireless link between $MT$ transmit and $MR$ receive antennas.

• MIMO channels boost the information capacity of wireless systems by order of magnitude [Telater95][Foschini98].

\[
H(t) = \begin{pmatrix}
h_{11}(t) & \cdots & h_{1M_T}(t) \\
\vdots & \ddots & \vdots \\
h_{M_T1}(t) & \cdots & h_{M_TM_T}(t)
\end{pmatrix}
\]
Introduction: Open Loop MIMO Communication Systems

- Spatial Multiplexing
  - Differential Block Coding [Tar00]
  - Block Coding [Ala98][Tar99a]
  - Trellis Coding [Tar98]

- Transmit Diversity
  - STBC

- MIMO Fading Channel

- STBC Combiner and Detector

- V-BLAST [Wal99]

- D-BLAST [Fos96]
Uplink Scheduling for Multiuser Systems with Spatial Multiplexing

• In a multiuser environment, each user has different channel statistics.
• Scheduling transmission to the user with the best channel condition at each time leads to a form of selection diversity known as multiuser diversity.
• In SISO, MaxSNR scheduling maximizes the capacity of the uplink [Kno95] and downlink [Tse97].
Our focus is on

- Scheduling for uplink MIMO system.
- Scheduling and STBC aren’t a good match [Gozali03].
- We focus on scheduling for spatial multiplexing systems selecting a single user at a time and we focus on practical detection algorithms, such as V-BLAST, SMZF and SMSD.
System Model

- Average SNR is assumed to be the same for all users.
- The base station scans the users.
- The user with the best channel condition is allowed to transmit.
- The received signal from user $k$ is:
  \[ y_k = H_k x_k + \eta_k \]
Scheduling Algorithms

- **Optimal MIMO capacity maximizing scheduler**
  \[
  C_{\text{max}} = \max_{k=1,2,...,K} C_k \quad \text{where}
  \]
  \[
  C_k = \log_2 \left( \det \left( I_{M_R} + \frac{\text{SNR}}{M_T} H_k H_k^H \right) \right)
  \]

- **MaxSNR scheduler** selects the user with maximum MIMO channel power \( \text{trace}(H_k H_k^H) \)

- **RR**: Round robin scheduling allows each user to transmit in a time-division fashion regardless of their channel condition.
Scheduling Algorithms

• **V-BLAST capacity maximizing scheduler**

  V-BLAST capacity is dominated by the weakest layer [Pap02]

  \[
  C_{VBLAST}^{ZF} = M_T \cdot \min_{i=1,2,\ldots,M_T} \left\{ \log_2 \left( 1 + \frac{\text{SNR}}{M_T \| W_{ZF,i} \|^2} \right) \right\}
  \]

  Thus, the scheduler selects the user with \( \min_{k=1,\ldots,K} \{ w_k \} \) where

  \[
  w_k = \max_{i=1,2,\ldots,M_T} \left\{ \| W_{ZF,i}^k \|^2 \right\}
  \]
Scheduling Algorithms

- **MinES: Minimum Eigenspread**

  \[ k = \arg \min_{k=1,...,K} \left\{ s_k = \frac{\lambda_{\max,k}}{\lambda_{\min,k}} \right\} \]

  \( \lambda_{\max} \) and \( \lambda_{\min} \) are the largest and smallest eigenvalues of \( H_k H_k^H \)

- **MaxMinSV: Maximum Minimum Singularvalue**

  \[ k = \arg \max_{k=1,...,K} \left\{ \rho_{\min,k} \right\} \text{ where } \rho_{\min} = \frac{\rho_{\max}}{\sqrt{s}} \]

  \( \rho_{\min} \) is the smallest singularvalue of \( H_k \)
Advantage of V-BLAST compared to SISO and SIMO systems
Simulation results of V-BLAST uplink scheduling

10% Outage at 4x4 MIMO Channels at 15dB

K=10 Users, 4x4 QPSK V-BLAST
Effect of Suboptimal Detection

2x2 MIMO Channels at 15dB

4x4 MIMO Channels at 15dB

Within 1 bps/Hz

Within 2.5 bps/Hz
Scheduling for Spatial Multiplexing with Sphere Decoder

K=10 Users, 4x4 MIMO at 8bps/Hz

10% Outage at 4x4 MIMO Channels and at 15dB

BER

SNR

Rate bps/Hz

Users
Uplink MIMO Scheduling Conclusions

• We found the V-BLAST capacity maximizing scheduler.
• We showed that scheduling based on maximum MIMO capacity doesn’t work well for a V-BLAST system.
• We compared several scheduling algorithms and found that MaxMinSV scheduling performs close to MaxVBLAST capacity scheduler.
• The difference between V-BLAST and SMZF performance is not substantial, especially at low number of antennas and large number of users.