Comparative Study of MIMO-OFDM Uplink Scheduling Criteria

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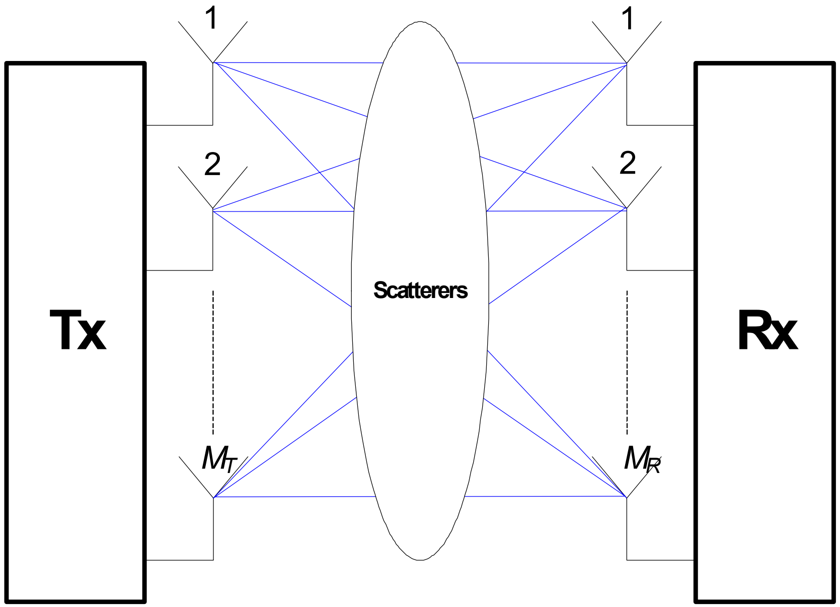
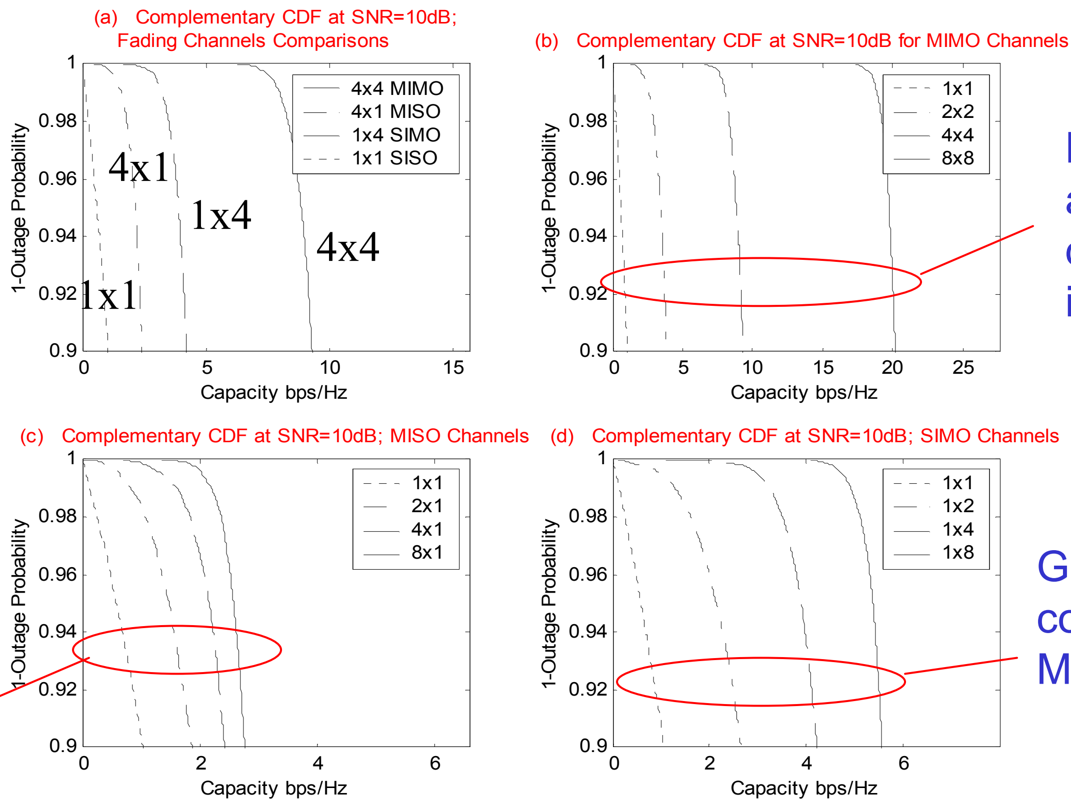
Introduction: Multiple Input Multiple Output (MIMO) Channels

- A MIMO channel is a wireless link between M_T transmit and M_R receive antennas.
- MIMO channels boost the information capacity of wireless systems by order of magnitude [Telater95][Foschini98].



$$\mathbf{H}(t) = \begin{pmatrix} h_{11}(t) & \cdots & h_{1M_T}(t) \\ \vdots & \ddots & \vdots \\ h_{M_R 1}(t) & \cdots & h_{M_R M_T}(t) \end{pmatrix}$$

MIMO Capacity

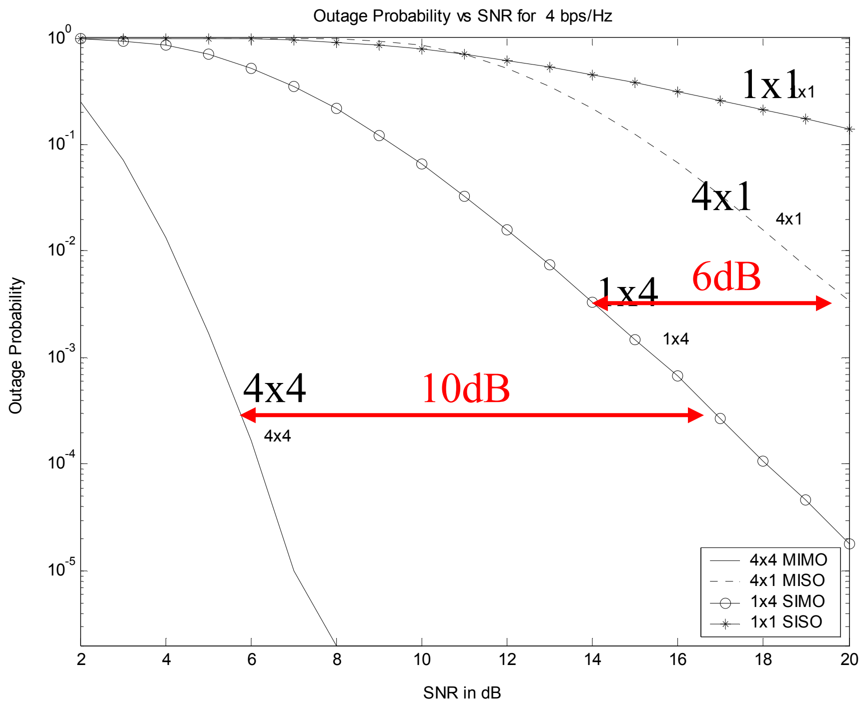


Doubling number of antennas, doubles the information capacity

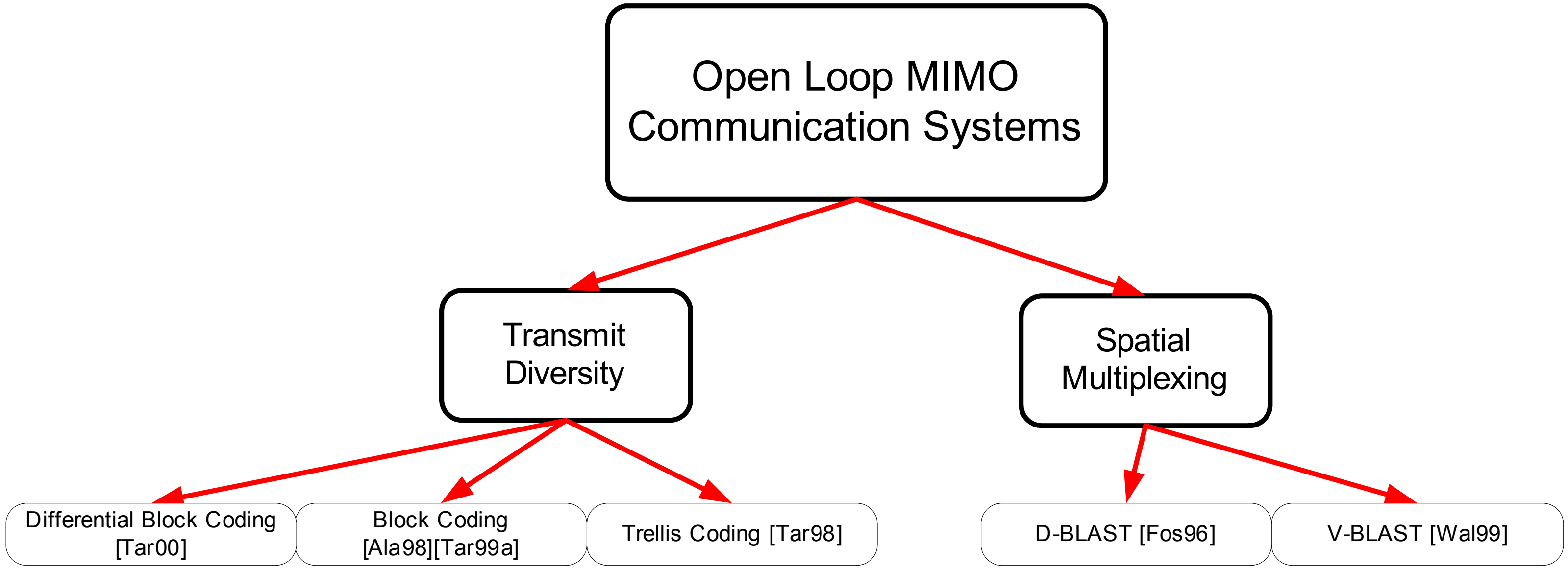
Good gains but not comparable to MIMO

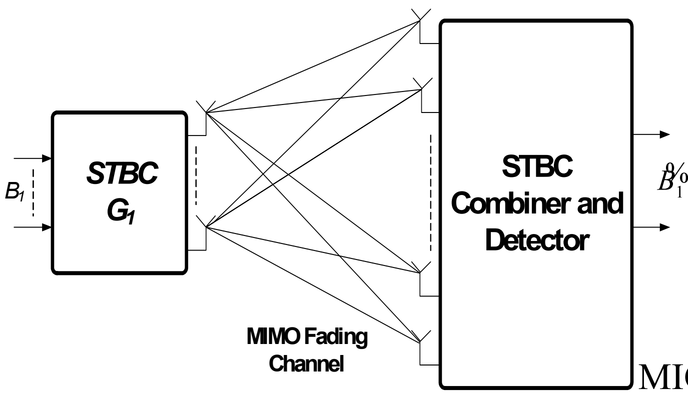
Diminishing returns

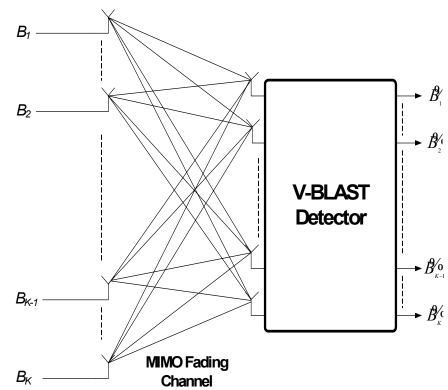
MIMO Outage Probability



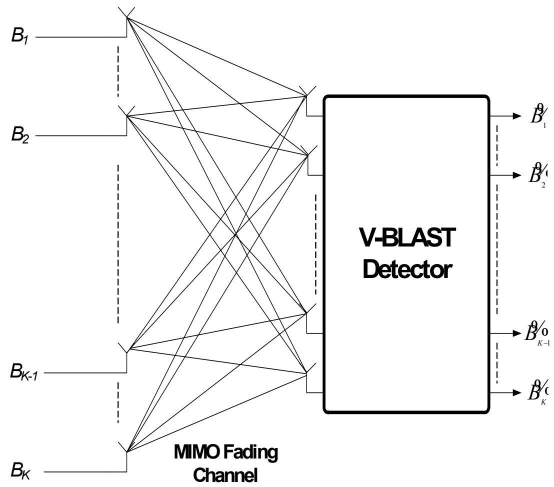
Introduction: Open Loop MIMO Communication Systems

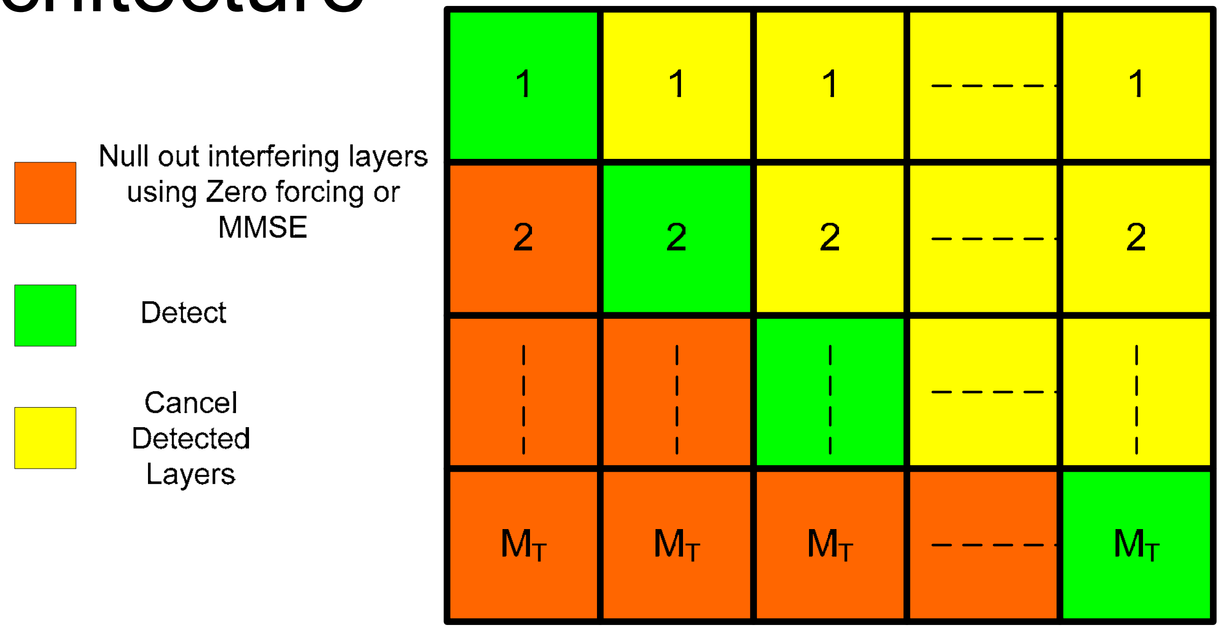


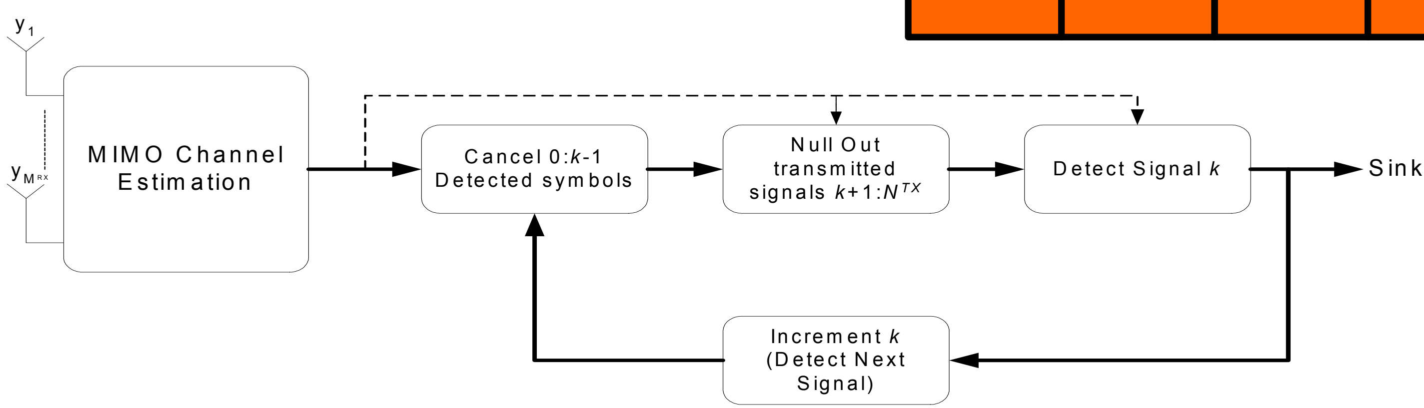




Vertical BellLabs LAyered Space Time (VBLAST) architecture







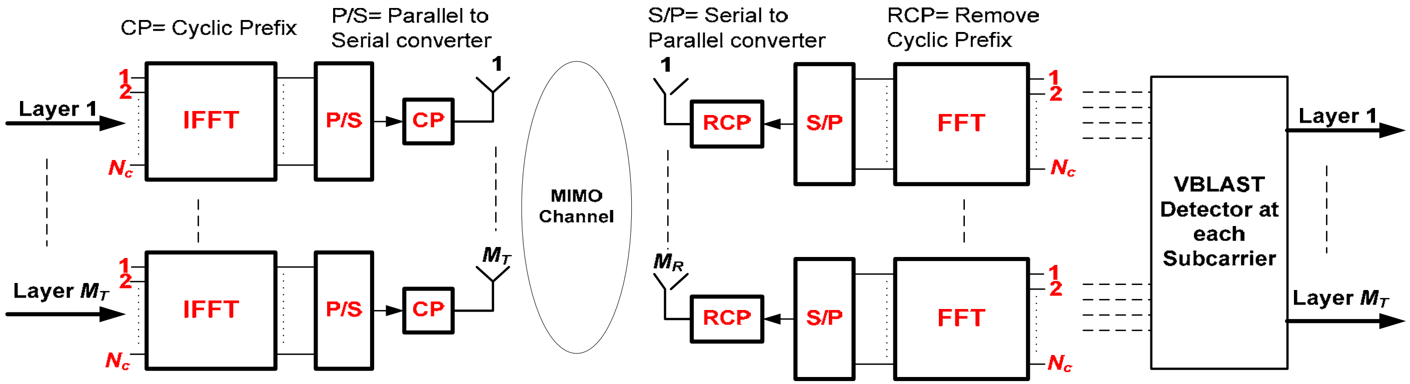
Uplink Scheduling for Multiuser Systems with Spatial Multiplexing

- 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

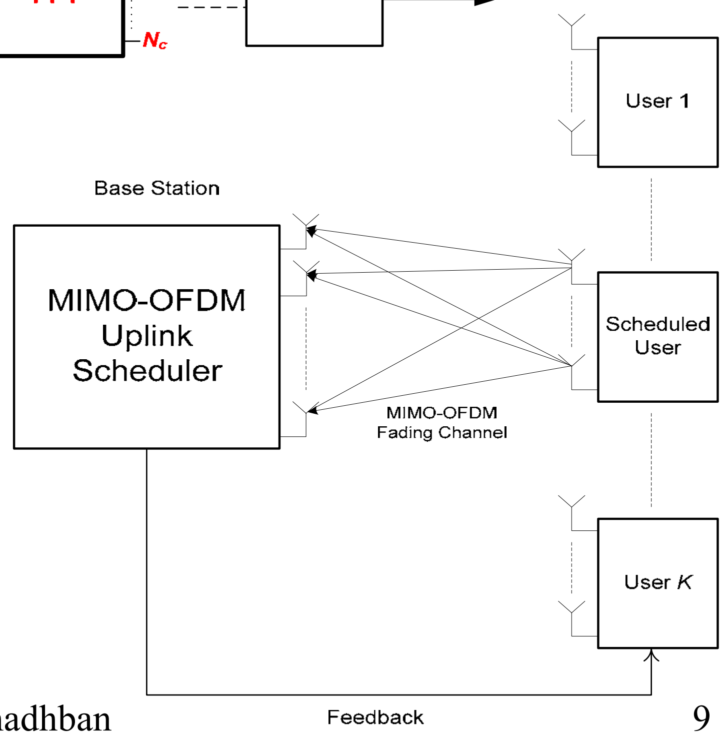
- Scheduling for uplink MIMO-OFDM system.
- Scheduling and STBC aren’t a good match [Gozali03].
- We focus on scheduling for spatial multiplexing systems selecting a single user at a time and we focus on practical detection algorithms, specifically V-BLAST.

System Model



the received signal for user k and at the i^{th} subcarrier is :

$$\mathbf{y}_{k,i} = \mathbf{H}_{k,i}\mathbf{x}_{k,i} + \boldsymbol{\eta}_{k,i}$$



Scheduling Algorithms

- Optimal MIMO capacity maximizing scheduler

$$\max_{k=1,\ldots,K}\left\{\min_{i=1,\ldots,N_c}\left\{\log_2\left(\det\left(\mathbf{I}_{M_R}+\frac{SNR}{M_T}\mathbf{H}_{k,i}\mathbf{H}_{k,i}^H\right)\right)\right\}\right\}$$

- **MaxSNR** scheduler selects the user with maximum MIMO channel power $\max_{k=1,\ldots,K}\left\{\min_{i=1,\ldots,N_c}\left\{trace\left(\mathbf{H}_{k,i}\mathbf{H}_{k,i}^H\right)\right\}\right\}$

- **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]

$$C_{VBLAST}^{ZF} = M_T \cdot \min_{i=1,2,\ldots,M_T} \left\{ \log_2 \left(1 + \frac{SNR}{M_T \left\| \mathrm{W}_{ZF,i} \right\|^2} \right) \right\}$$

  Thus, the scheduler selects the user with

$$\max_{k=1,\ldots,K} \left\{ \min_{i=1,\ldots,N_c} \left\{ C_{VBLAST}^{ZF} \left(\mathbf{H}_{k,i} \right) \right\} \right\}$$

Scheduling Algorithms

- **MinMaxES:** Minimum Eigenspread

$$\min_{k=1,\ldots,K}\left\{\max_{i=1,\ldots,N_c}\left\{s\left(\mathbf{H}_{k,i}\mathbf{H}_{k,i}^H\right)\right\}\right\} \quad \textbf{where} \quad s\left(\mathbf{H}_{k,i}\mathbf{H}_{k,i}^H\right)=\lambda_{\max}/\lambda_{\min}$$

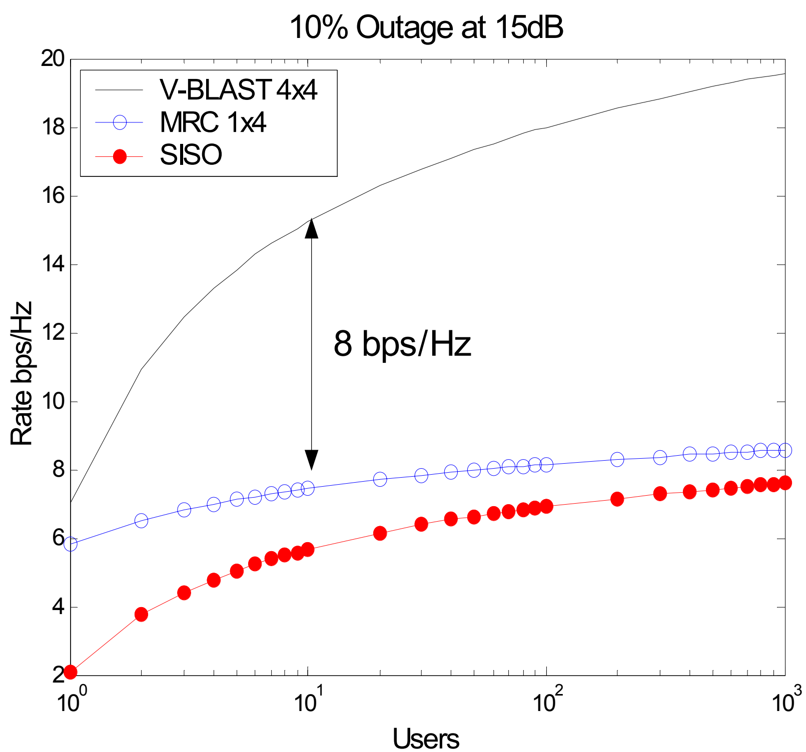
$\lambda_{\max}$ and $\lambda_{\min}$ are the largest and smallest eigenvalues of $\mathbf{H}_k\mathbf{H}_k^H$

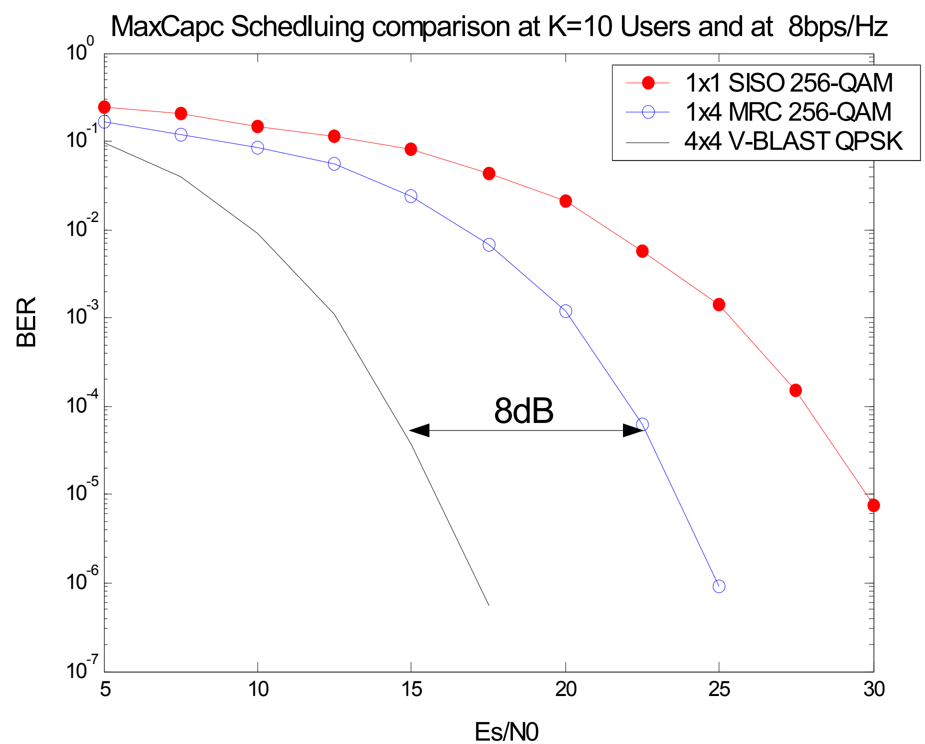
- **MaxMinSV:** Maximum Minimum Singularvalue

$$\max_{k=1,\ldots,K}\left\{\min_{i=1,\ldots,N_c}\left\{\rho_{\min}\left(\mathbf{H}_{k,i}\right)\right\}\right\} \quad \textbf{where} \quad \rho_{\min}=\frac{\rho_{\max}}{\sqrt{s}}$$

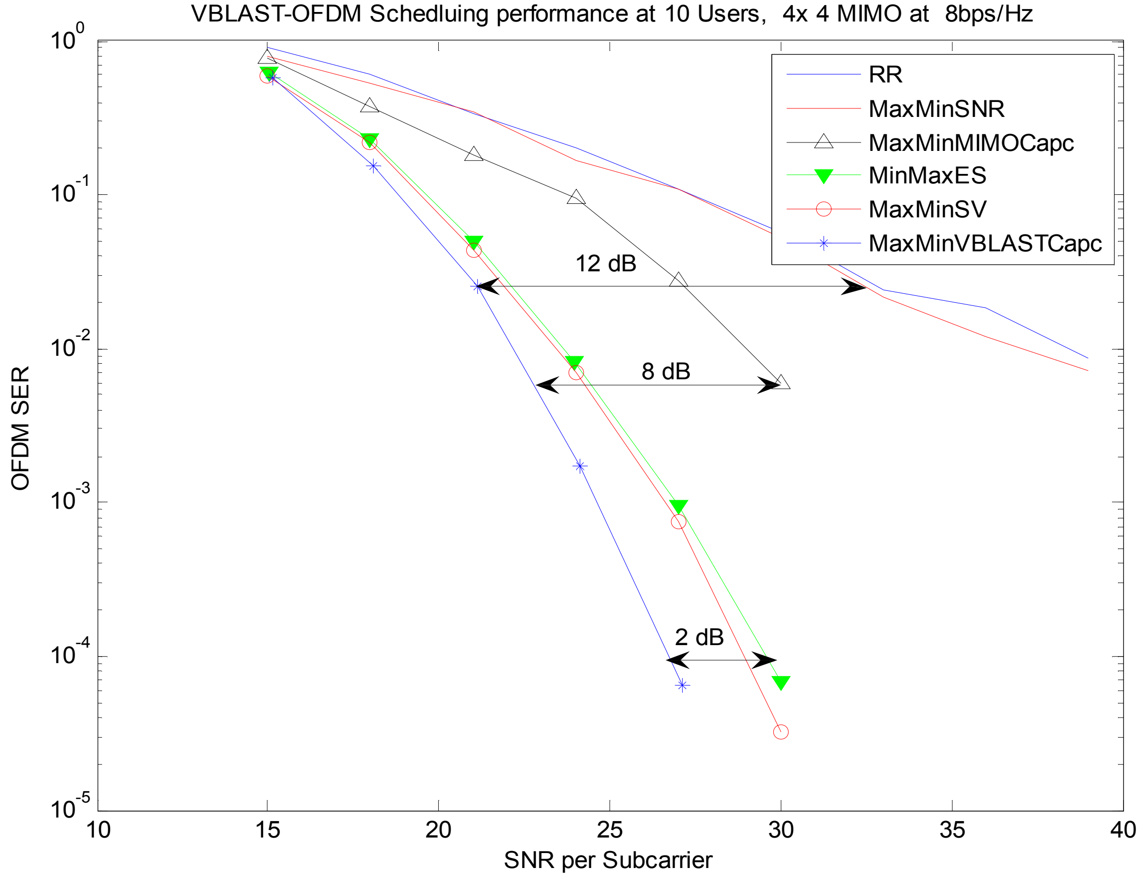
$\rho_{\min}$ is the smallest singularvalue of $\mathbf{H}_{k,i}$

Advantage of V-BLAST compared to SISO and SIMO systems

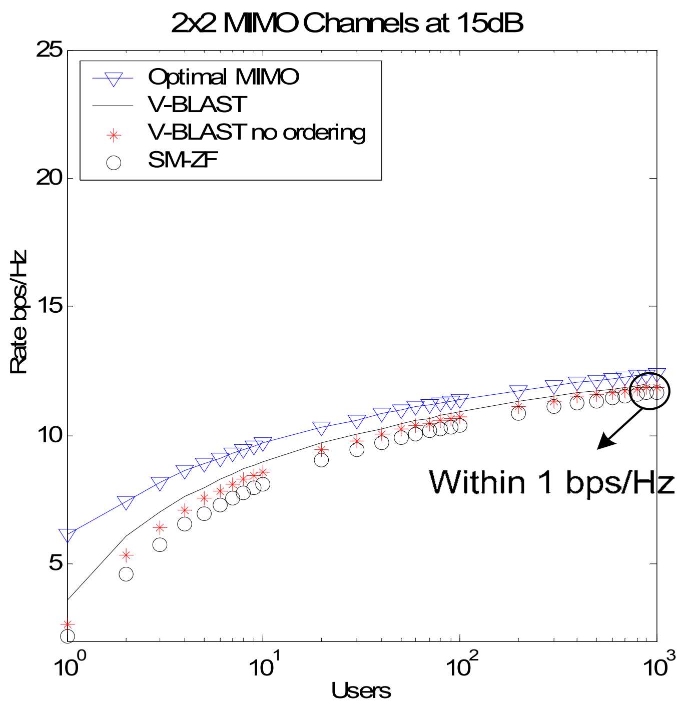


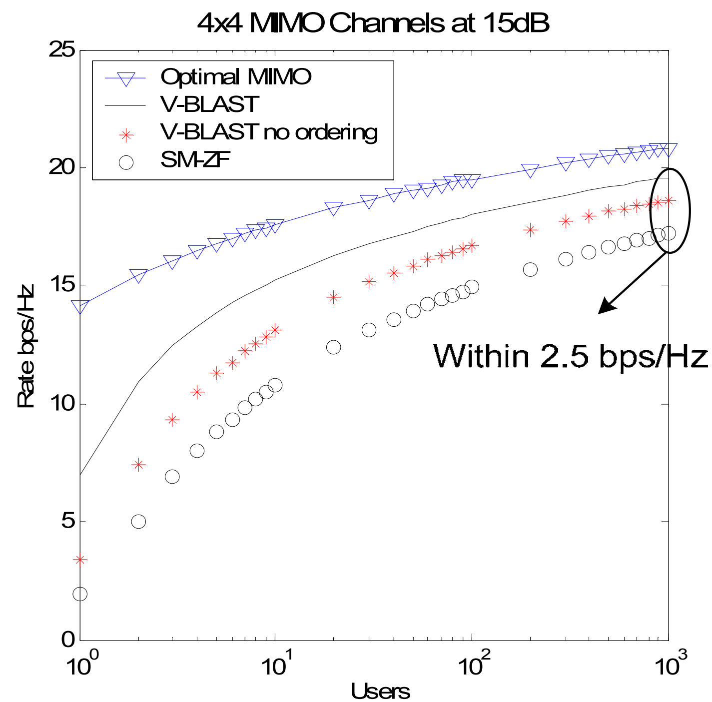


Aggregate OFDM SER of 4x4 QPSK MIMO-OFDM uplink scheduling at 64 subcarriers and over FSC of length four



Effect of Suboptimal Detection





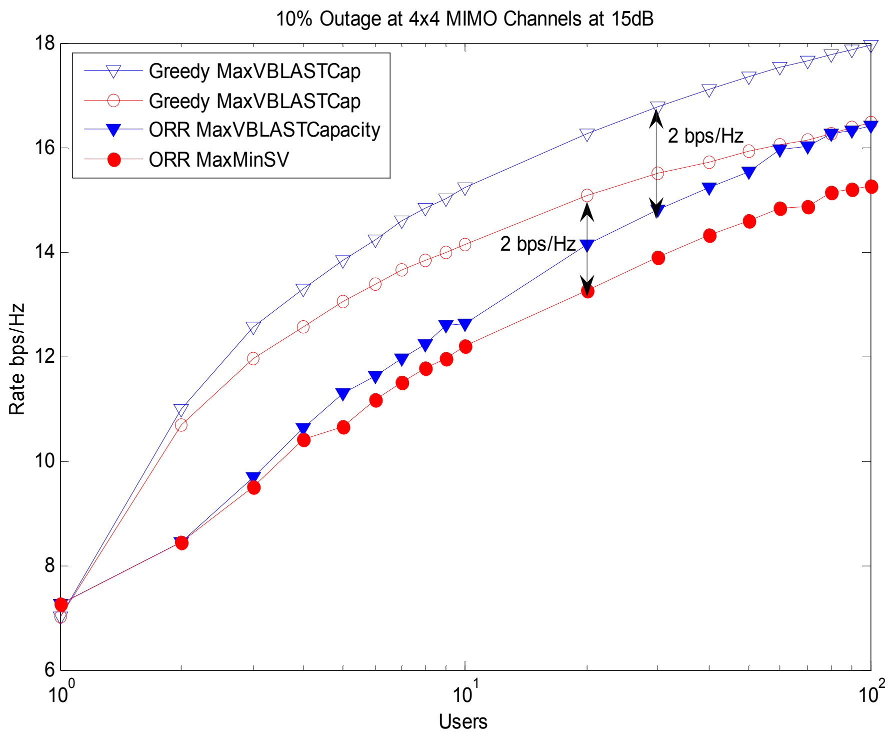
Scheduling and Fairness Issue

- The greedy algorithm selects the best user irrespective of other users.
- Fairness is considered in this work.
  - Opportunistic Round Robin
  - Proportional Fair

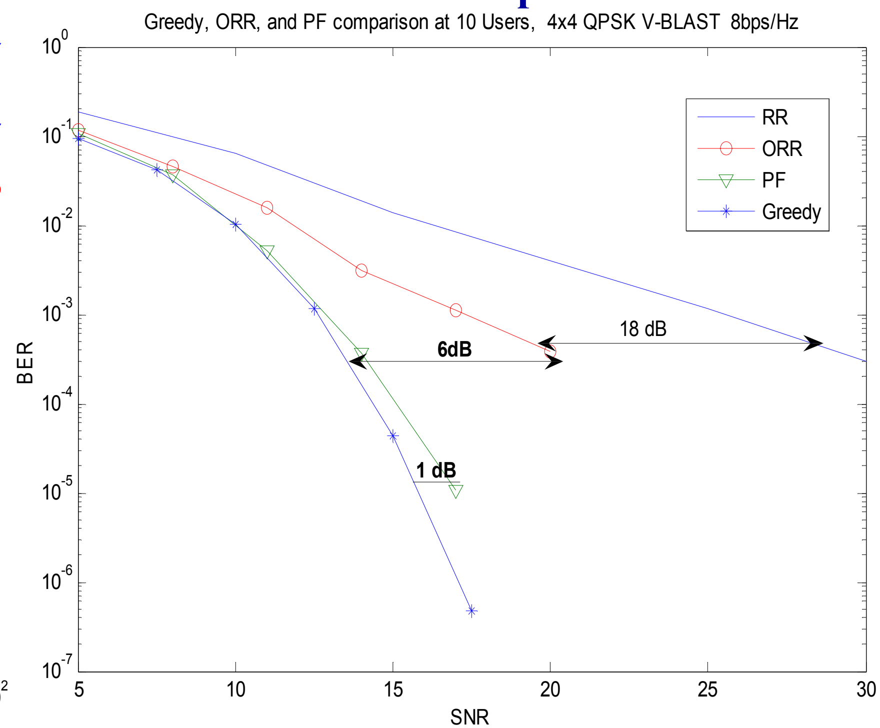
$$PF(\Psi) = \frac{\Psi}{T_k}$$

Comparison: Greedy vs. ORR and PF

10% outage capacity comparison of Greedy and ORR schedulers over 4x4 MIMO channels and at SNR=15dB



Greedy, PF and ORR at 10 users and over 4x4 MIMO Channels using MaxVBLASTCapc scheduler



Uplink MIMO-OFDM Scheduling Conclusions

- We presented and compare scheduling algorithms for MIMO-OFDM users based on V-BLAST scheme.
- We showed that scheduling based on maximum MIMO capacity doesn’t work well for V-BLAST systems neither based on Maximum SNR.
- We compared several scheduling algorithms and found that MaxMinSV scheduling performs close to MaxVBLAST capacity scheduler.