Performance Evaluation of Opportunistic Round Robin Scheduling for V-BLAST Users over MIMO Channels

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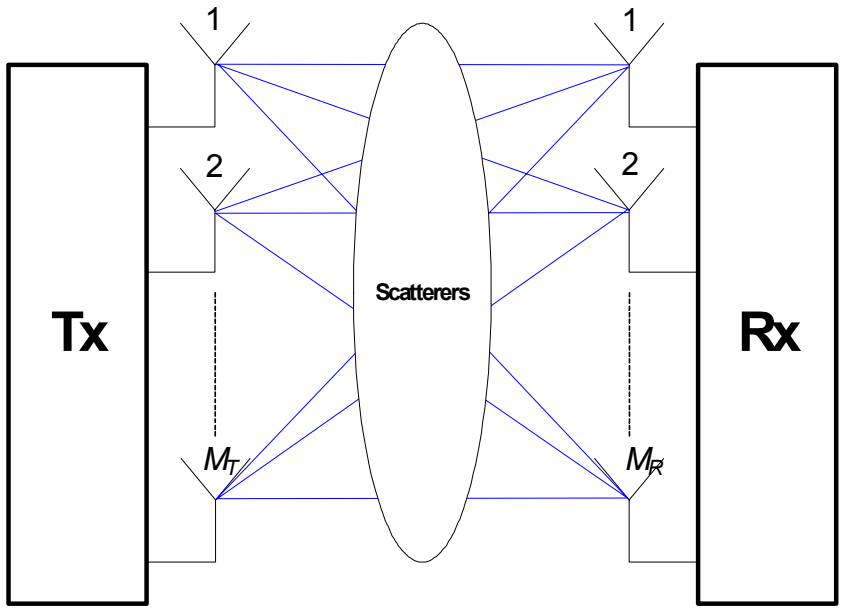
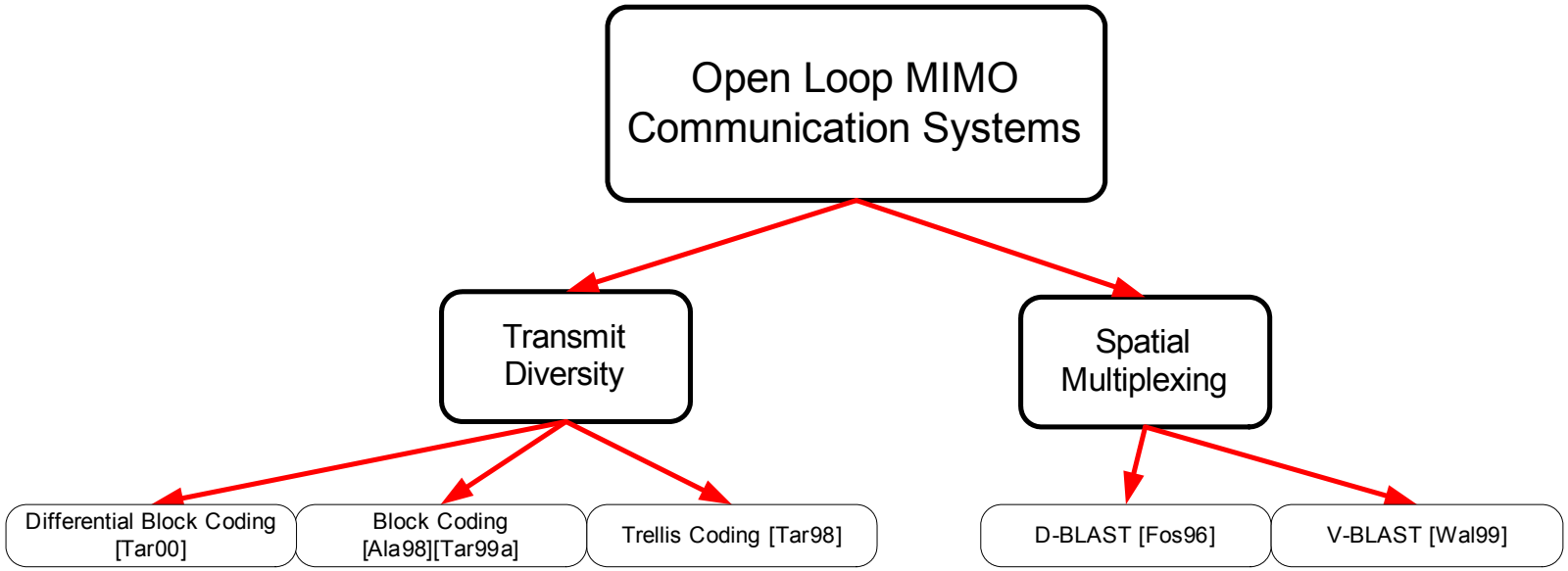
Introduction: Multiple Input Multiple Output (MIMO) Channels

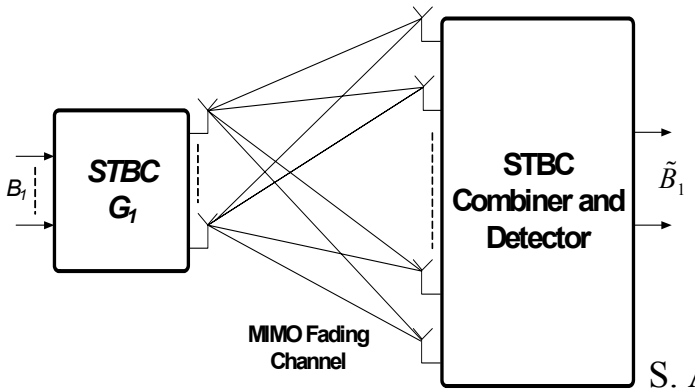
- A MIMO channel is a wireless link between M_T transmit and M_R receive antennas.
- MIMO channels boost the information capacity of wireless systems by order of magnitude [Telater95][Foschini98].

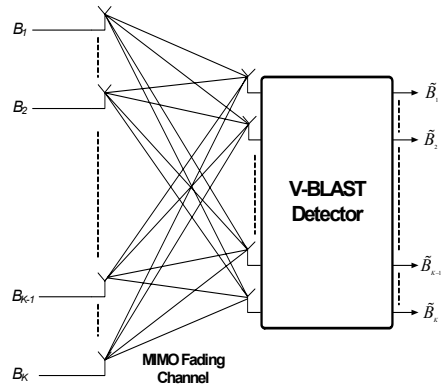


$$\mathbf{H}(t) = \begin{pmatrix} h_{11}(t) & \cdots & h_{1M_T}(t) \\ \vdots & \ddots & \vdots \\ h_{M_R 1}(t) & \cdots & h_{M_R M_T}(t) \end{pmatrix}$$

Introduction: Open Loop MIMO Communication Systems







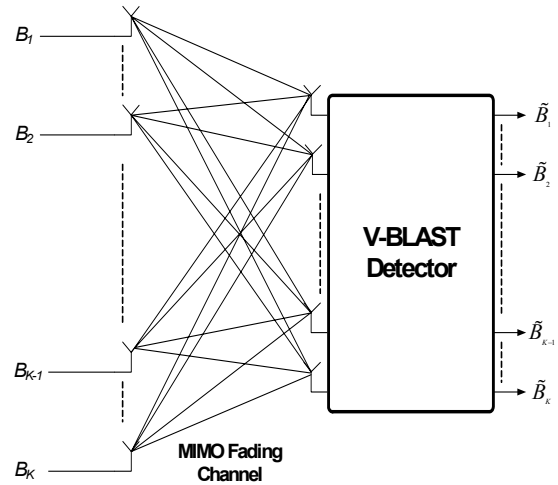
Uplink Scheduling for Multiuser Systems with Spatial Multiplexing

- 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 using V-BLAST scheme.

Vertical BellLabs LAyered Space Time (VBLAST) architecture

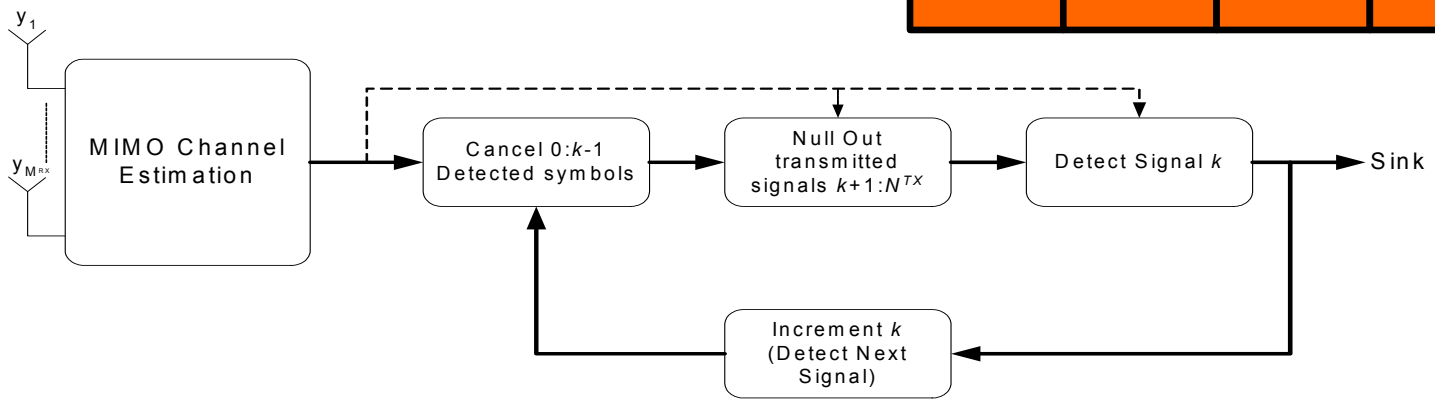


Null out interfering layers using Zero forcing or MMSE

Detect

Cancel Detected Layers

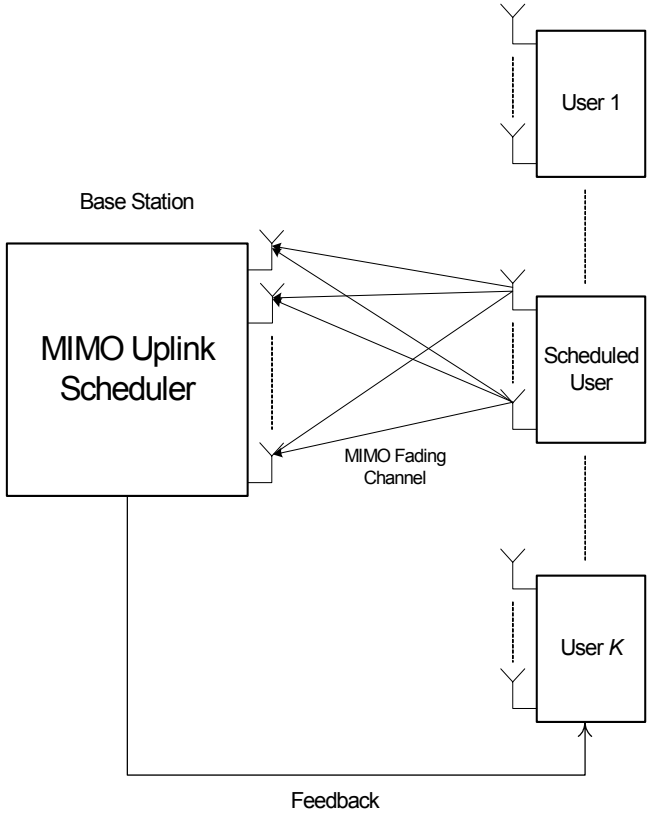
1	1	1	- - - -	1
2	2	2	- - - -	2
⋮	⋮	⋮	- - - -	⋮
M_T	M_T	M_T	- - - -	M_T



System Model

- **Average SNR is assumed to be the same for all users.**
- **The base station probe all uses.**
- **The user with the best channel condition is allowed to transmit.**
- **The received signal from user *k* is:**

$$\mathbf{y}_k = \mathbf{H}_k \mathbf{x}_k + \boldsymbol{\eta}_k$$



Scheduling Algorithms

- Optimal MIMO capacity maximizing scheduler

$$C_{\max} = \max_{k=1,2,\ldots,K} C_k \ ; \text{where}$$

$$C_k = \log_2\left(\det\left(\mathbf{I}_{M_R} + \frac{SNR}{M_T}\mathbf{H}_k\mathbf{H}_k^H\right)\right)$$

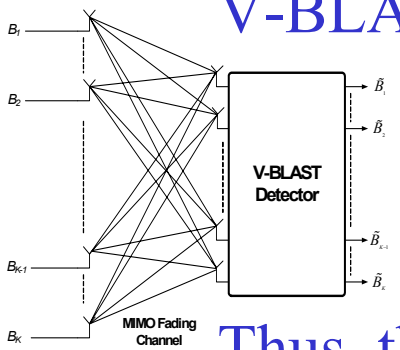
- MaxSNR scheduler selects the user with maximum MIMO channel power $\left(trace(\mathbf{H}_k\mathbf{H}_k^H)\right)$

- 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]



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

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

$$w_k = \max_{i=1,2,\ldots,M_T} \left\{ \left\| \mathrm{W}_{ZF,i}^{k} \right\|^2 \right\}$$

Scheduling Algorithms

- MinES: Minimum Eigenspread

$$k = \arg \min_{k=1,\ldots,K} \left\{ s_k = \frac{\lambda_{\max,k}}{\lambda_{\min,k}} \right\}$$

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

- MaxMinSV: Maximum Minimum Singularvalue

$$k = \arg \max_{k=1,\ldots,K} \left\{ \rho_{\min,k} \right\} \qquad \text{where} \qquad \rho_{\min} = \frac{\rho_{\max}}{\sqrt{s}}$$

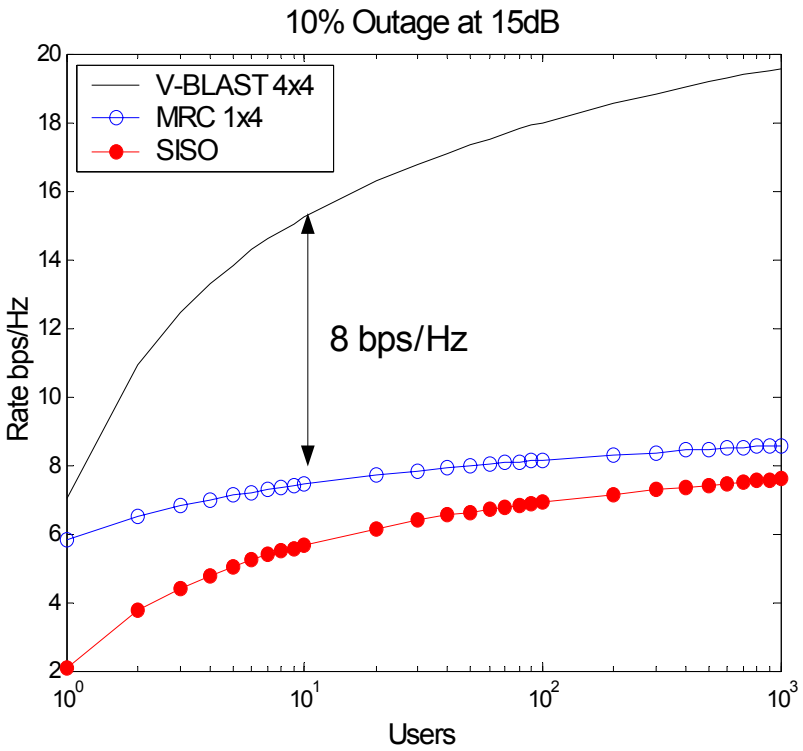
$\rho_{\min}$ is the smallest singularvalue of $\mathbf{H}_k$

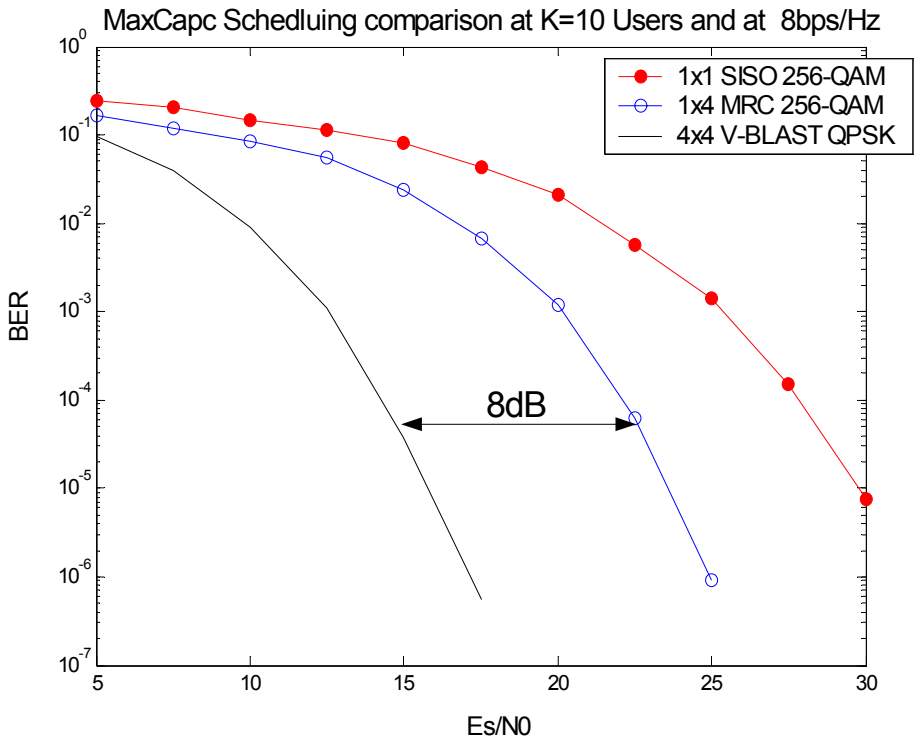
Scheduling and Fairness Issue

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

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

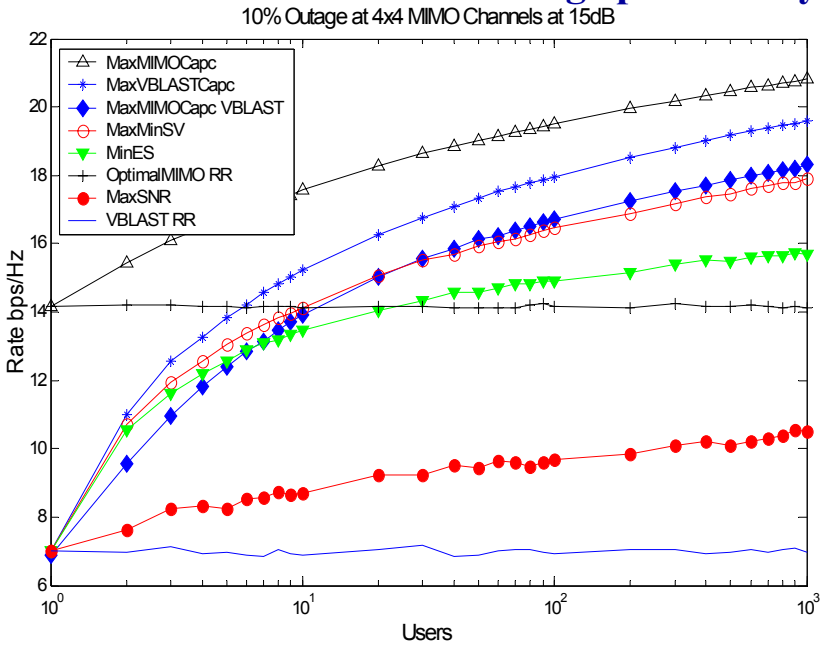
Advantage of V-BLAST compared to SISO and SIMO systems



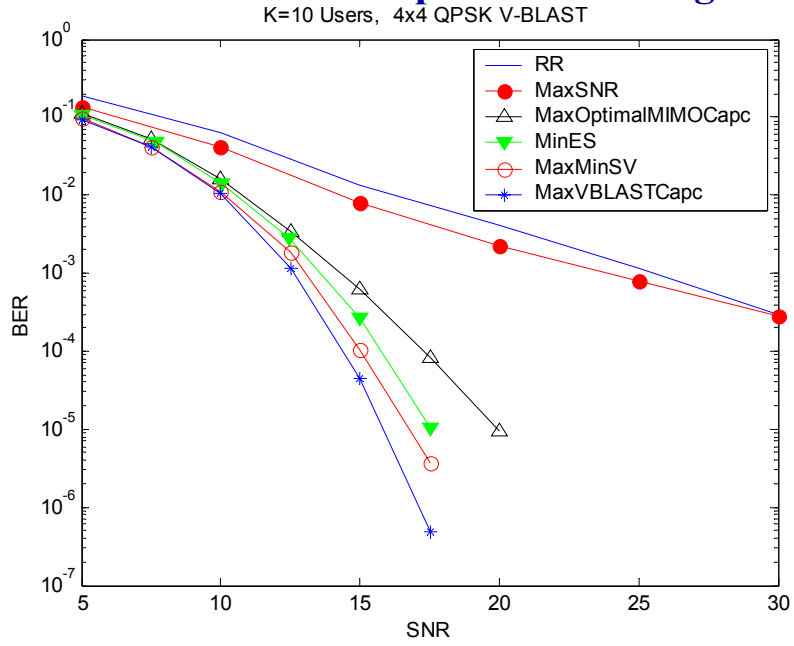


Greedy Scheduling

Capacity versus number of users over 4x4 MIMO channels and at 10% outage probability

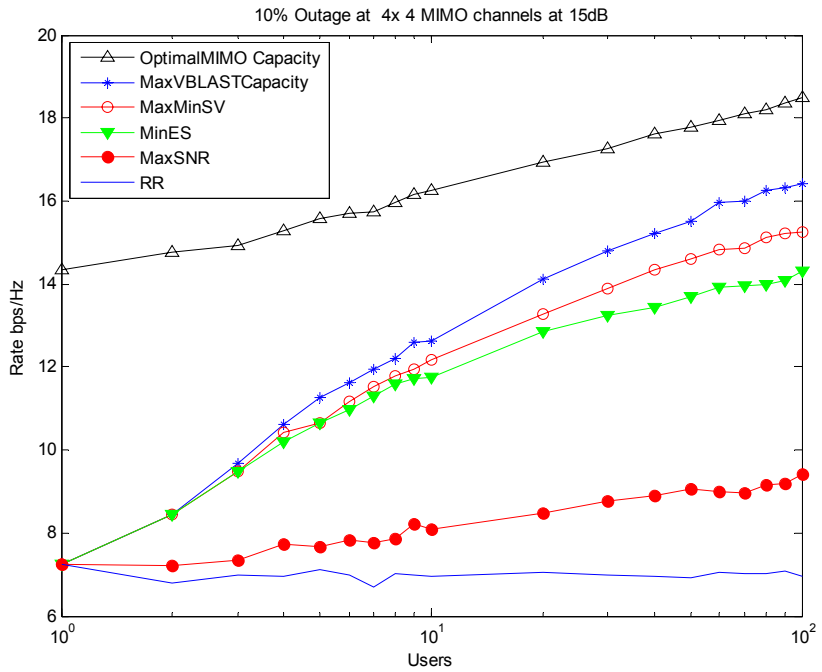


Aggregate BER of 4x4 QPSK V-BLAST users with uplink scheduling

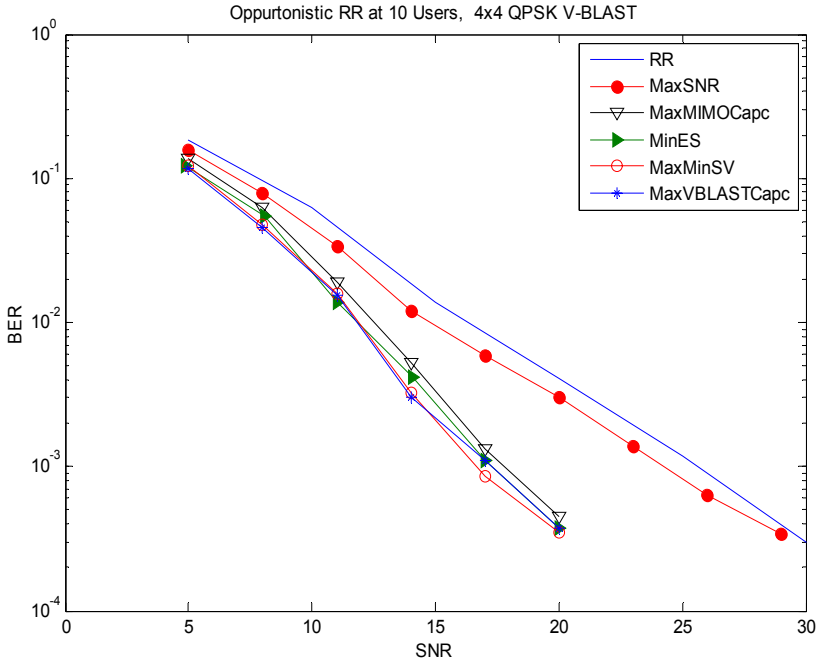


ORR Scheduling

ORR 10% outage capacity versus number of users over 4x4 MIMO channels and at 15dB.

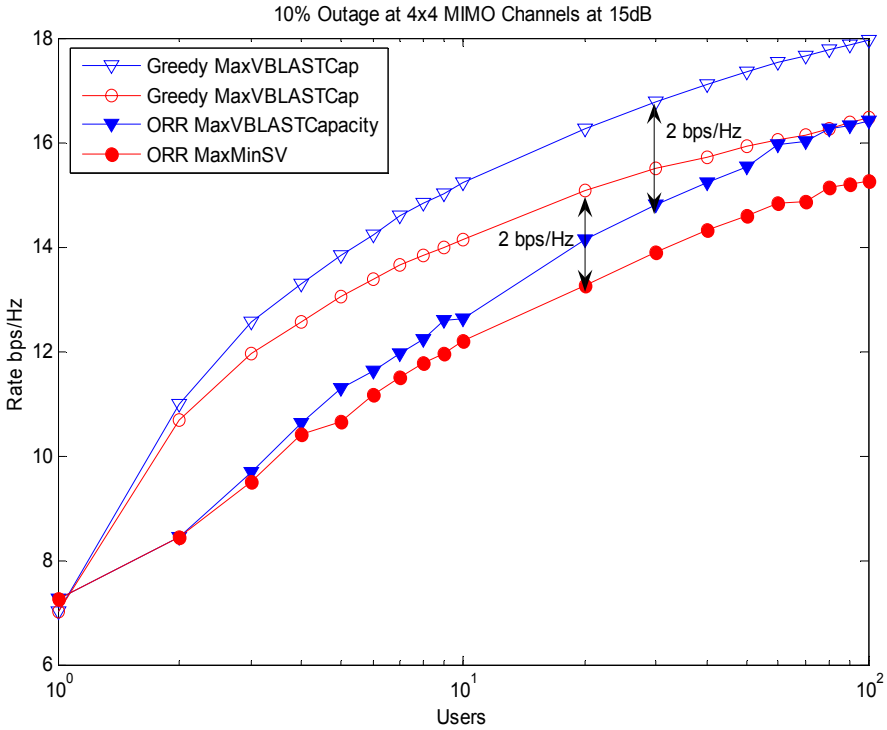


ORR scheduling aggregate BER of 4x4 QPSK V-BLAST users

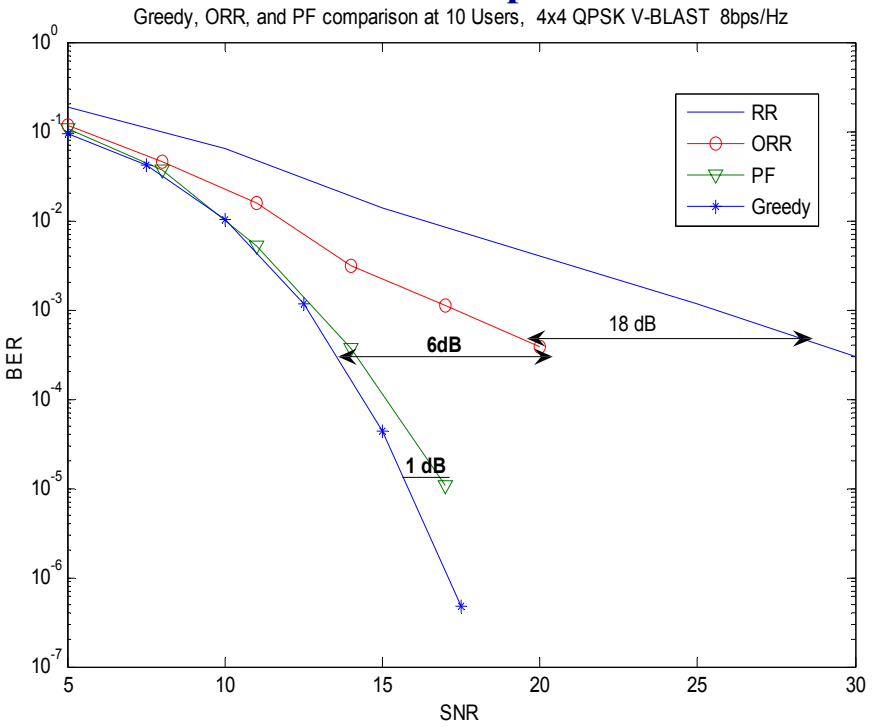


Comparison: Greedy vs. ORR

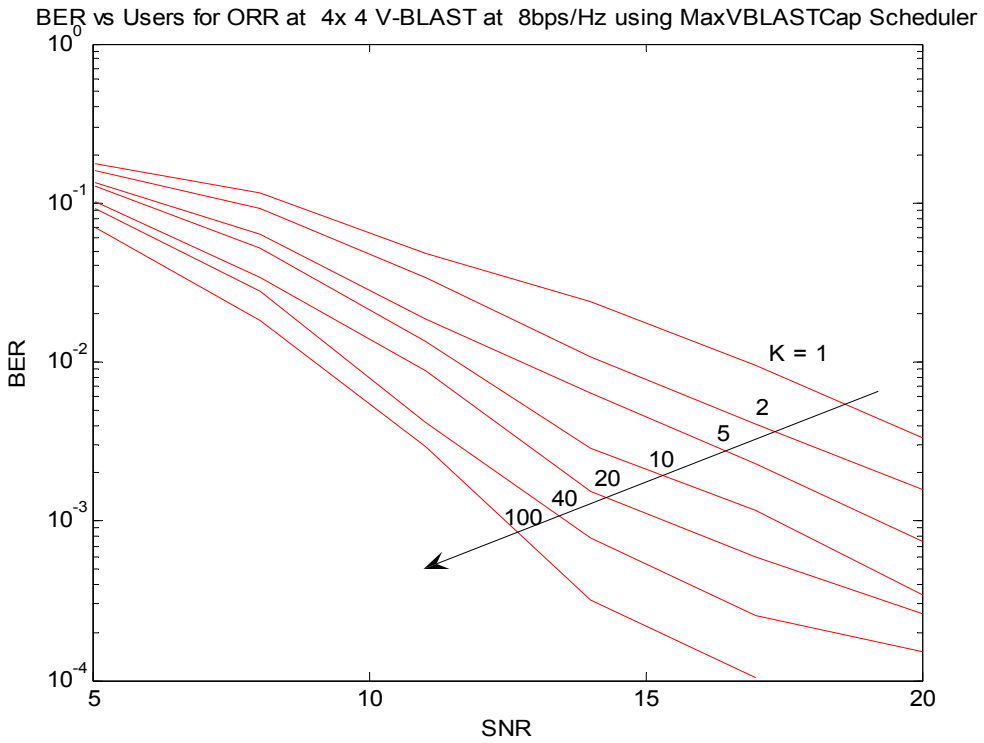
10% outage capacity comparison of Greedy and ORR schedulers over 4x4 MIMO channels and at SNR=15dB



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



Effect of Multi-user diversity of ORR scheduling algorithm over 4x4 MIMO channels. Number of users (K =1 to 100)



Conclusions

- This paper evaluates the performance of several scheduling criteria for V-BLAST.
- Fair algorithms are also proposed.
- The ORR doesn't capture the whole multiuser diversity advantage but it provides scheduling gains compared to RR (around 18 dB).