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Throughput simulations for MIMO and transmit diversity enhancements to HSDPA

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Outline

- Goals
- Single Antenna System Methodology
- Multi-Antenna System Methodology
- Link Simulation Parameters
- System Simulation Parameters
- Results
- Conclusions

Goals

- This contribution describes scheduling simulation results for HSDPA when there are up to 4 transmit antennas at the base station and 4 antennas at the terminals

- Establish system simulation methodology for multiple antenna scenarios

- Evaluate the throughput as a function of the number of users for different antenna configurations and show
  - impact of multiple antennas on the throughput for different scheduling algorithms
  - the interaction of antenna diversity and multi-user diversity from scheduling

Goals

- Throughput study does not capture
  - Multi-slot transmission and Hybrid ARQ
  - Error in C/I estimation
  - Feedback delay in C/I reporting
  - Fast cell-site selection
  - Channel correlations across antennas or multi-path Fading
  - Coverage (simulations are based on interference limited scenarios)
- Results will give insight into relative performance improvements from the use of multi-antenna techniques in flat fading

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Simulation Methodology for Single Antenna

- System simulation is dynamic in that it captures the fast fading (Rayleigh) and slow fading (Log Normal) as a function of time for each user
- Link level static (AWGN) simulations are done to generate the FER Vs Ec/Ior for each data rate, modulation and coding scheme
- Each slot is 3.33msec and is sampled every 0.667 ms leading to 5 samples per second

Simulation Methodology for Single Antenna

- Assuming 80% of power is devoted to HSDPA channel, Ec/Ior is calculated for each user for each sample.
- Average Ec/Ior is obtained by averaging over the 5 samples in a slot which is then used to determine the FER for each data rate
- FER calculated is used to determine whether the packet was transmitted successfully or not
  - Target FERs are to maximize throughput (R (1-FER))

Symbolic Description

- **Calculation of Ec/Nt at each terminal:**

$$h_1(t) - \text{rayleigh fading}$$

$$\left(\frac{E_c}{N_t}\right)(t) = \left(\frac{E_c}{N_t}\right)_{loc}\left(|h_1(t)|^2\right)$$

$$\text{where, } \left(\frac{E_c}{N_t}\right)_{loc} = \frac{b g_1 G_1 A(q_1)}{\sum_{k=2}^{19} g_k G_k A(q_k)} \frac{E_c}{I_{or}}$$

$$b - \text{power fraction for data}$$

$$g - \text{shadow fading gain}$$

$$G - \text{path loss}$$

$$A(q) - \text{sector antenna gain}$$

Simulation Methodology for Single Antenna

- Traffic Model
  - all users are assumed to have infinite load
  - actual traffic models will be considered in the next round of results
- Performance Metric
  - Average sector throughput as a function of number of users served for different antenna configurations and scheduling algorithms
- Max C/I, Proportional fair max(R/R_avg), round-robin

Simulation Methodology for Multiple Antennas

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- What is different from single antenna case?
  - Multiple independent Rayleigh fade processes $h_{i,j}(t)$ are simulated for each user, one for each transmit-receive pair
  - Ec/Ior calculation now depends on how antennas are used
- FER vs Ec/Ior curves are still applicable for diversity transmission (STTD) and reception (maximal ratio combining)
- For MIMO or Code reuse, Ec/Ior is not a sufficient parameter for determining FER
  - alternate metric will be stated

Diversity Transmission and Reception

- **Modified Ec/Ior formula for M transmit antennas and N receive antennas**

$$\left(\frac{E_c}{\hat{I}_{or}}\right) = \left(\frac{E_c}{\hat{I}_{or}}\right)_{loc} \frac{1}{M} \sum_{i=1}^{M} \sum_{j=1}^{N} | h_{i,j} |^2$$

- **To determine FER, static (AWGN) FER Vs Ec/Ior curves can still be used with the above formula for Ec/Ior calculation**

- **For M=2, STTD achieves above Ec/Ior. For M > 2, it will serve as an upper bound on throughput**

MIMO Transmission

- **We propose to use the capacity of the matrix channel H as the metric**

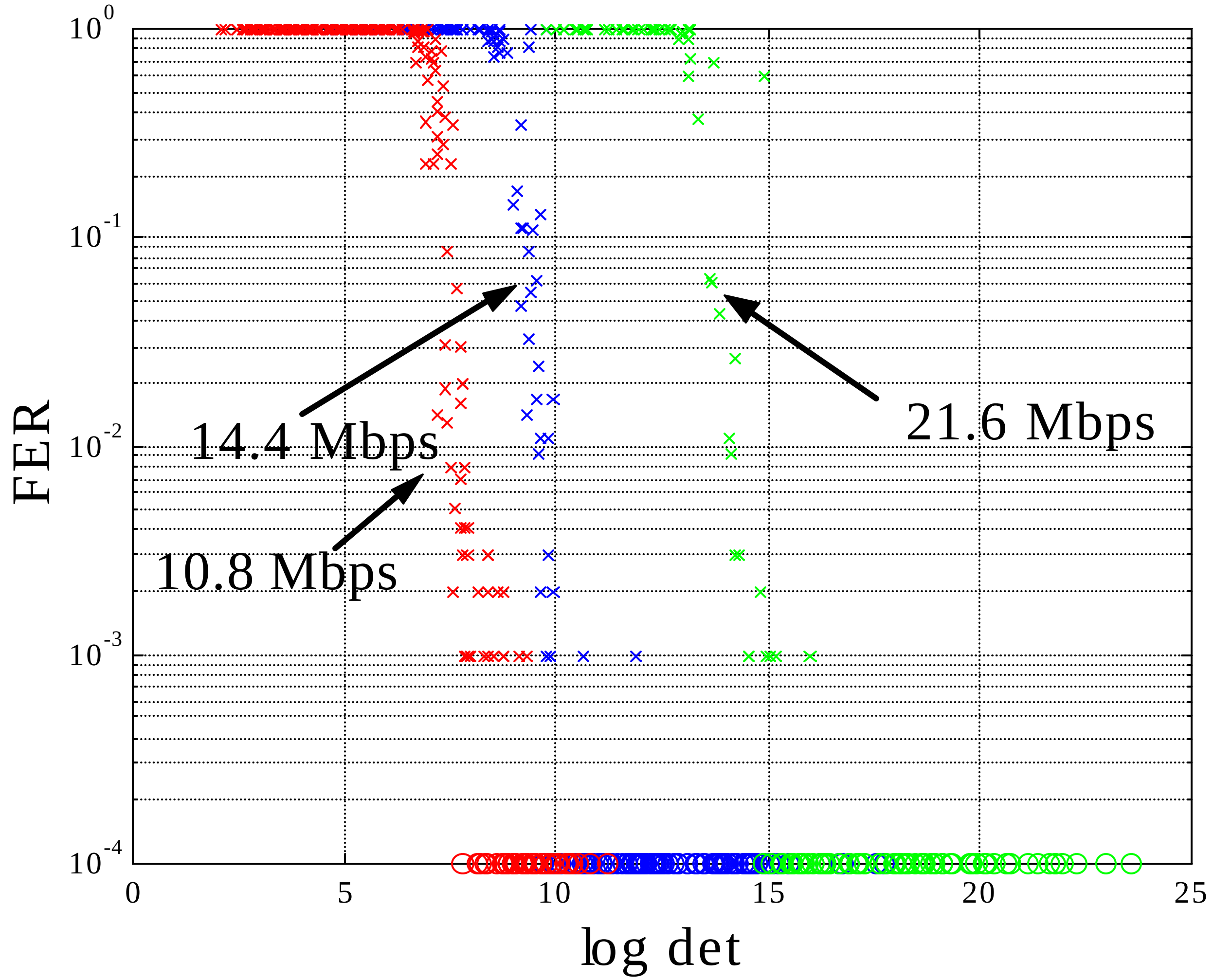
$$C = \log\det\left(\mathbf{I} + \frac{1}{M}\left(\frac{E_c}{\hat{I}_{or}}\right)_{loc} l\,\mathbf{H}\mathbf{H}^t \right)$$

where $(\mathrm{H})_{\mathrm{i,j}} = h_{i,j}$

and l = spreading gain

- **Intuitively appealing**
- **Justified by simulation results**
- **Alternate metrics simpler to compute can also be found**

Metric For 4 Tx , 4 Rx



Link Simulation - Data Rates for 1X1, 2X1, 4X1

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These Rates are common to Diversity and Code Reuse

20 codes with spread factor 32 used in all cases

Data Rate (Mbps)	Code Rate	Modulation	Mode
2.4	½	QPSK	STTD/MRC
3.6	¾	QPSK	STTD/MRC
4.8	½	16 QAM	STTD/MRC
7.2	¾	16 QAM	STTD/MRC
10.8	½	64 QAM	STTD/MRC

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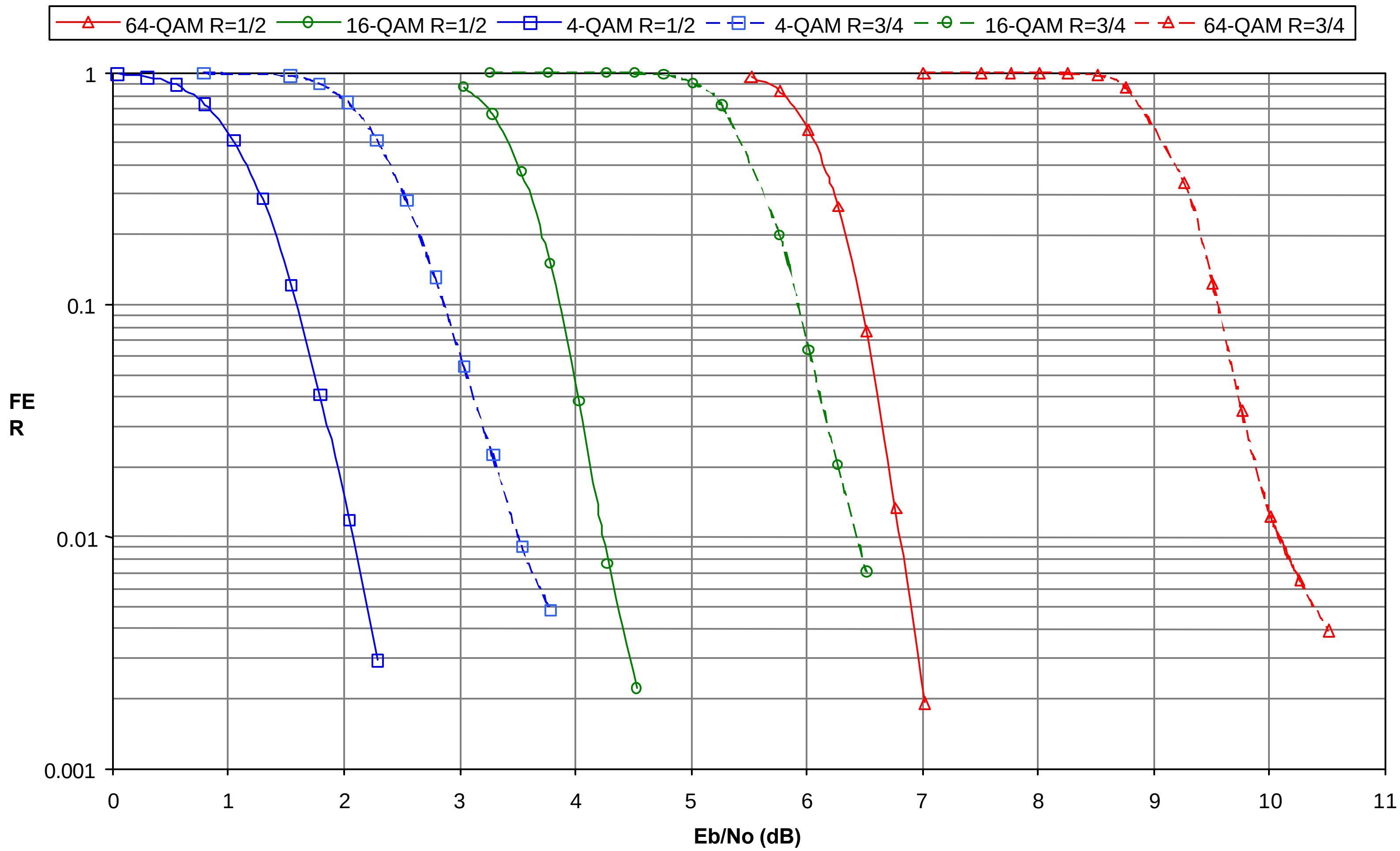
Data Rates for 4 Tx 4 Rx with Code Reuse

Data Rate (Mbps)	Code Rate	Modulation	Mode
2.4	½	QPSK	TD/MRC
3.6	¾	QPSK	TD/MRC
4.8	½	16 QAM	TD/MRC
7.2	¾	16 QAM	TD/MRC
10.8	~ ½	QPSK 4 streams	Code Reuse
14.4	¾	QPSK 4 streams	Code Reuse
21.6	¾	8 PSK 4 streams	Code Reuse

Static Link Level Curves (From Motorola)



System Simulation Parameters

PARAMETER	VALUE	COMMENTS
Number of Cells (3 sectored)	19	2 rings of interferers
Log-Normal Shadowing	8.9 dB	No correlation
Propagation Model	28.6+35log10(d) dB	Does not matter for interference limited simulation
Speed	3 km/Hr	Jakes model
Fast Cell-site Selection	Only once per drop	Helps combat slow fading only

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System Simulation Parameters

PARAMETER	VALUE	COMMENTS
Delay Spread Model	Single Path Rayleigh	Flat Fading only simulated
Site to Site distance	Irrelevant	Interference limited case
Carrier Frequency	1.9 MHZ	
Antenna Horizontal Pattern	70 deg (-3 dB)	
Overhead Channel Power	20 %	

Scheduling Approach for MIMO

- Determine the throughput achieved by each modulation and coding scheme (with or wihout code-reuse) as

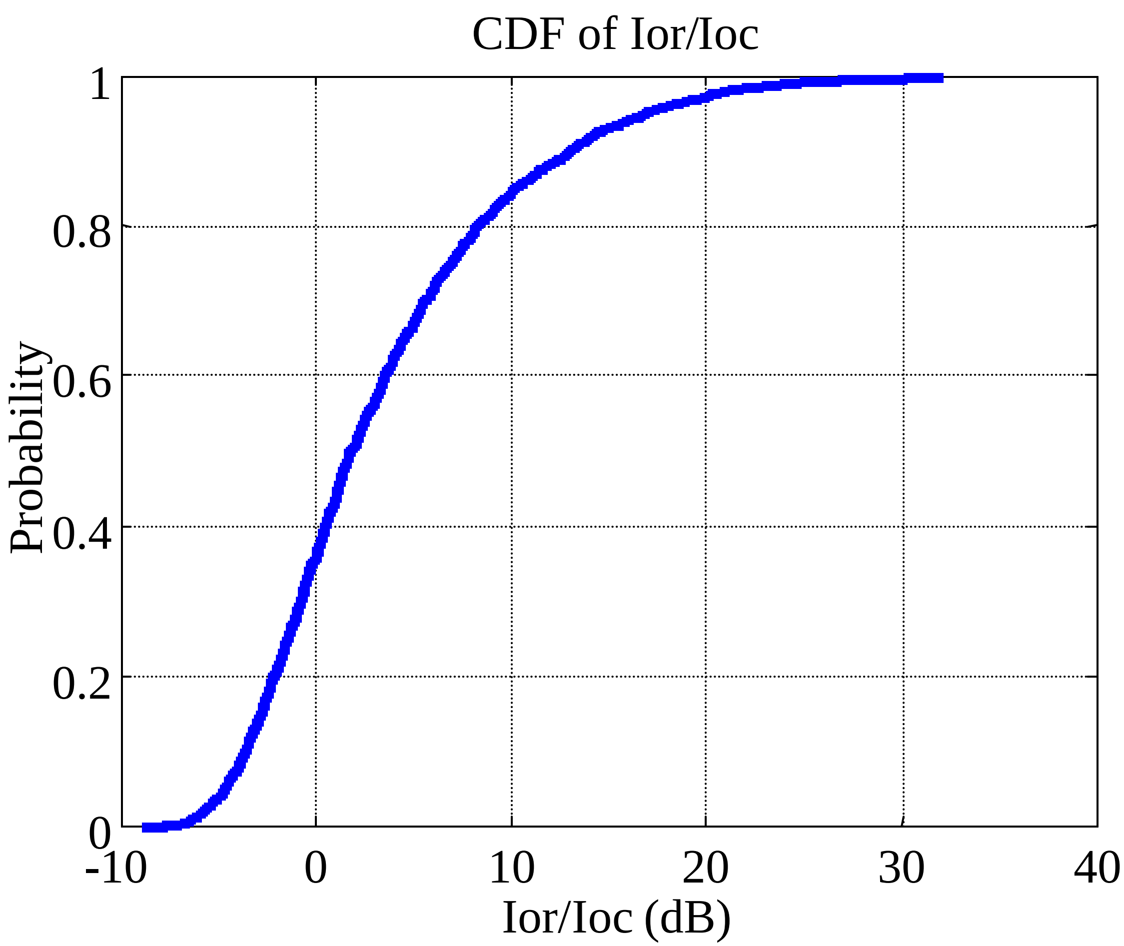
$$\text{Throughput}_{\text{i}} = \max_i R_i (1 - \text{FER}_i)$$

- The FER is a function of Ec/Ior for diversity transmission schemes
- FER is a function of the metric *C* for Code Reuse schemes
- The throughputs for the different data rates are sufficient input to the scheduling algorithms to determine which user to transmit to

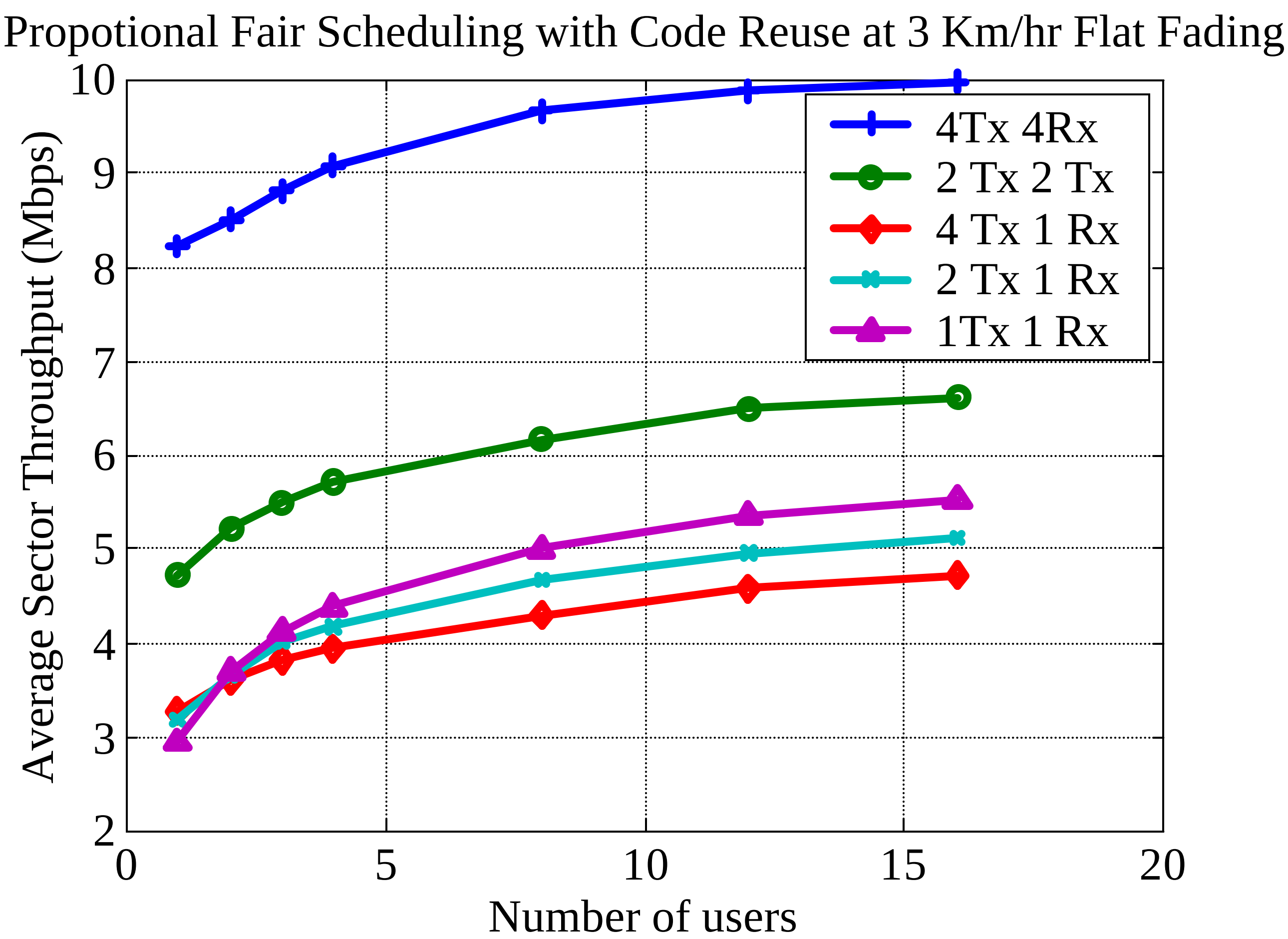
Simulation Details

- The FER as function of the Ec/Nt is used to determine if the packet is in error or not.
- Throughput for each user is calculated by computing the number of successfully transmitted bytes.
- After one second of simulation the users are moved to a different location within the cell
- Simulation is performed for 30 minutes and average sector throughputs are obtained

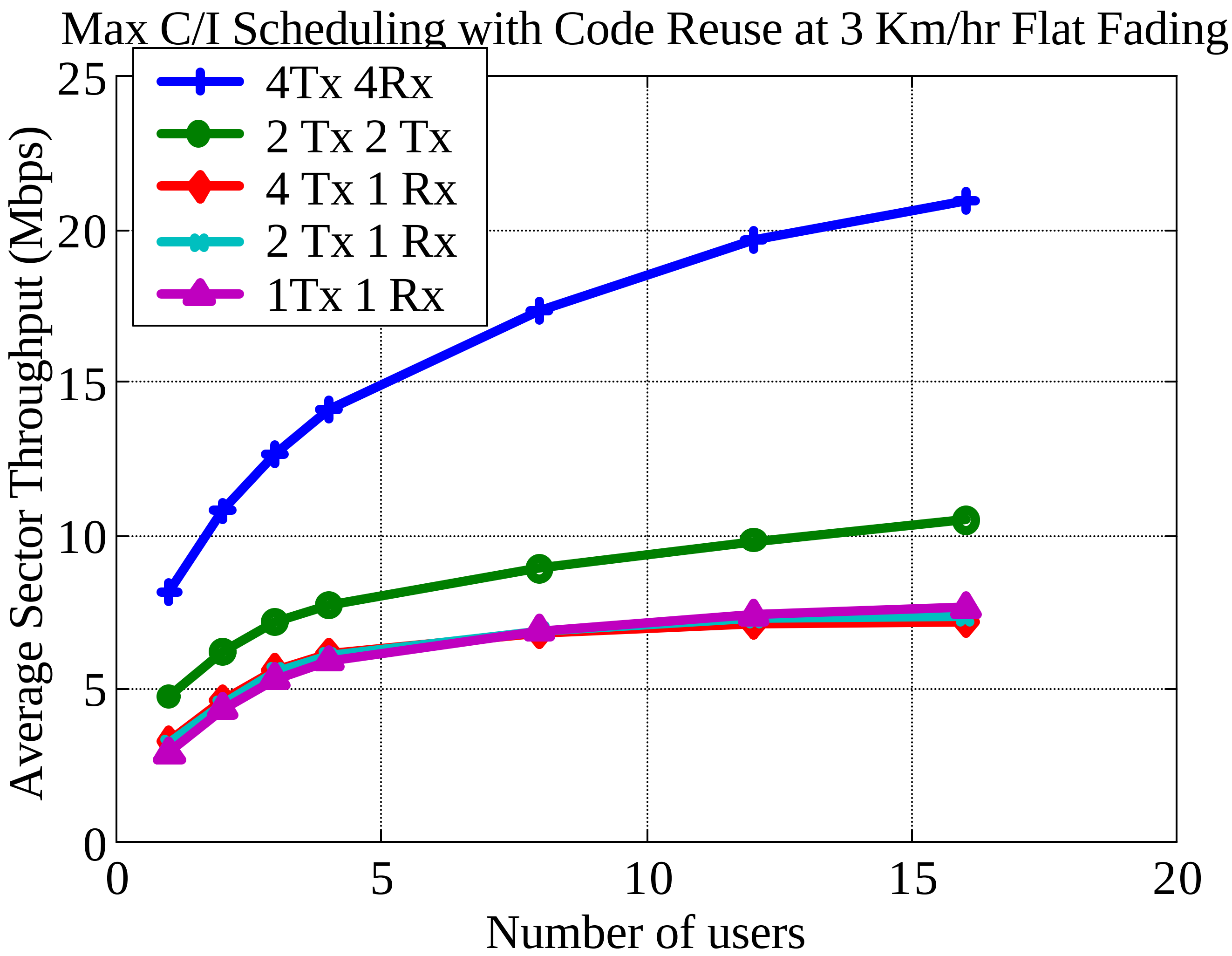
CDF of Geometry for System Simulations



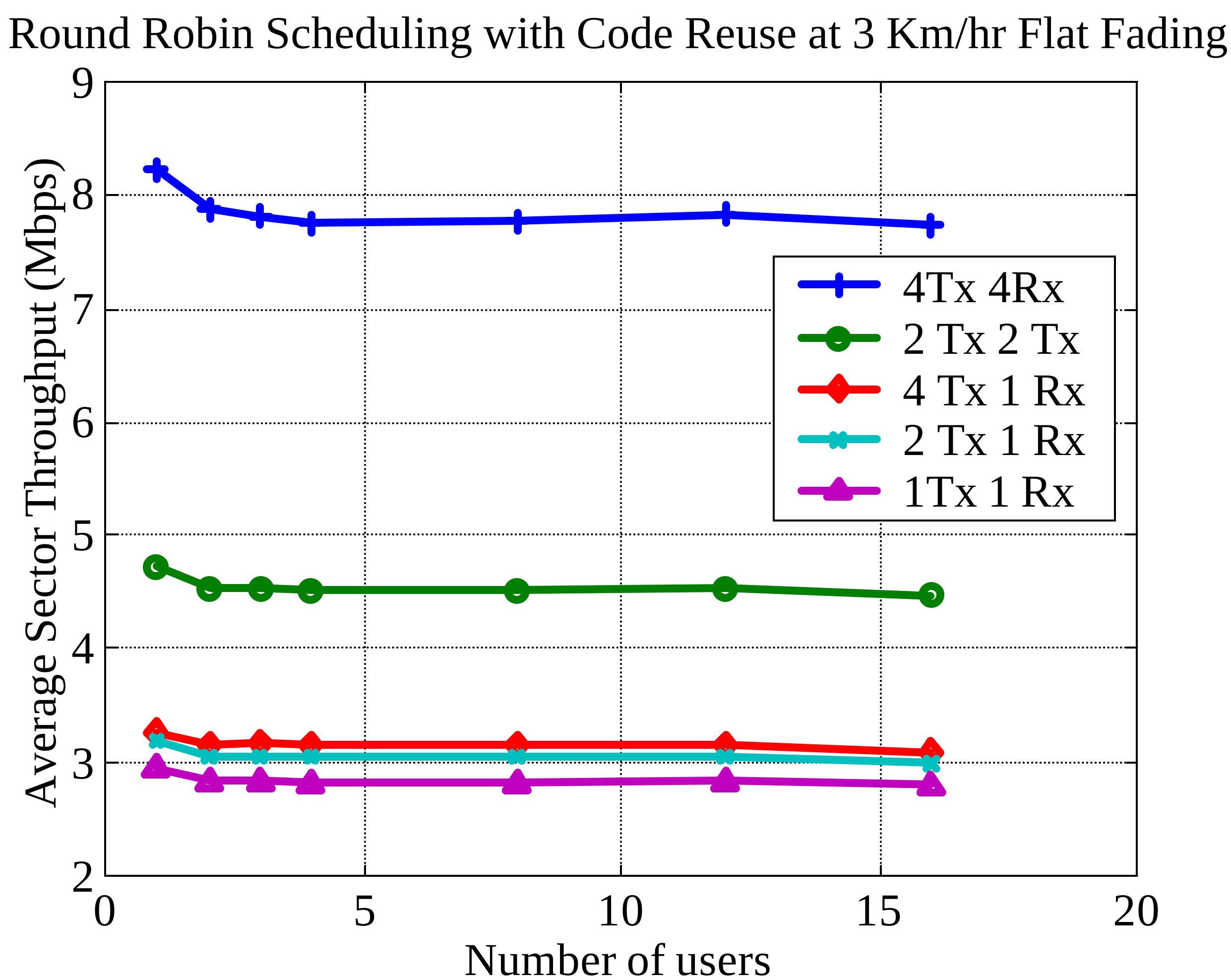
Proportional Fair Scheduling - 3 Km/hr



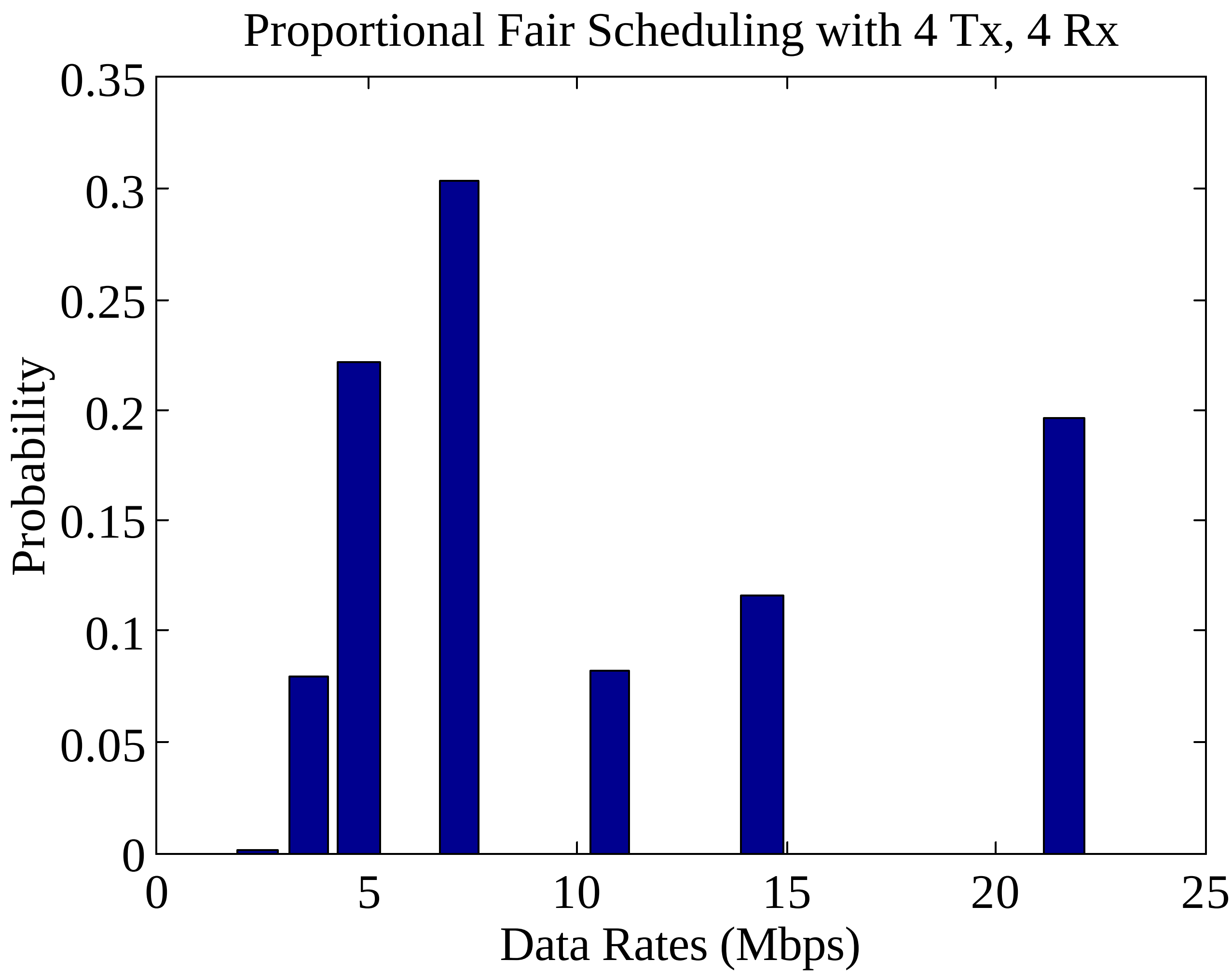
Max (Ec/lor) Scheduling 3 km/hr



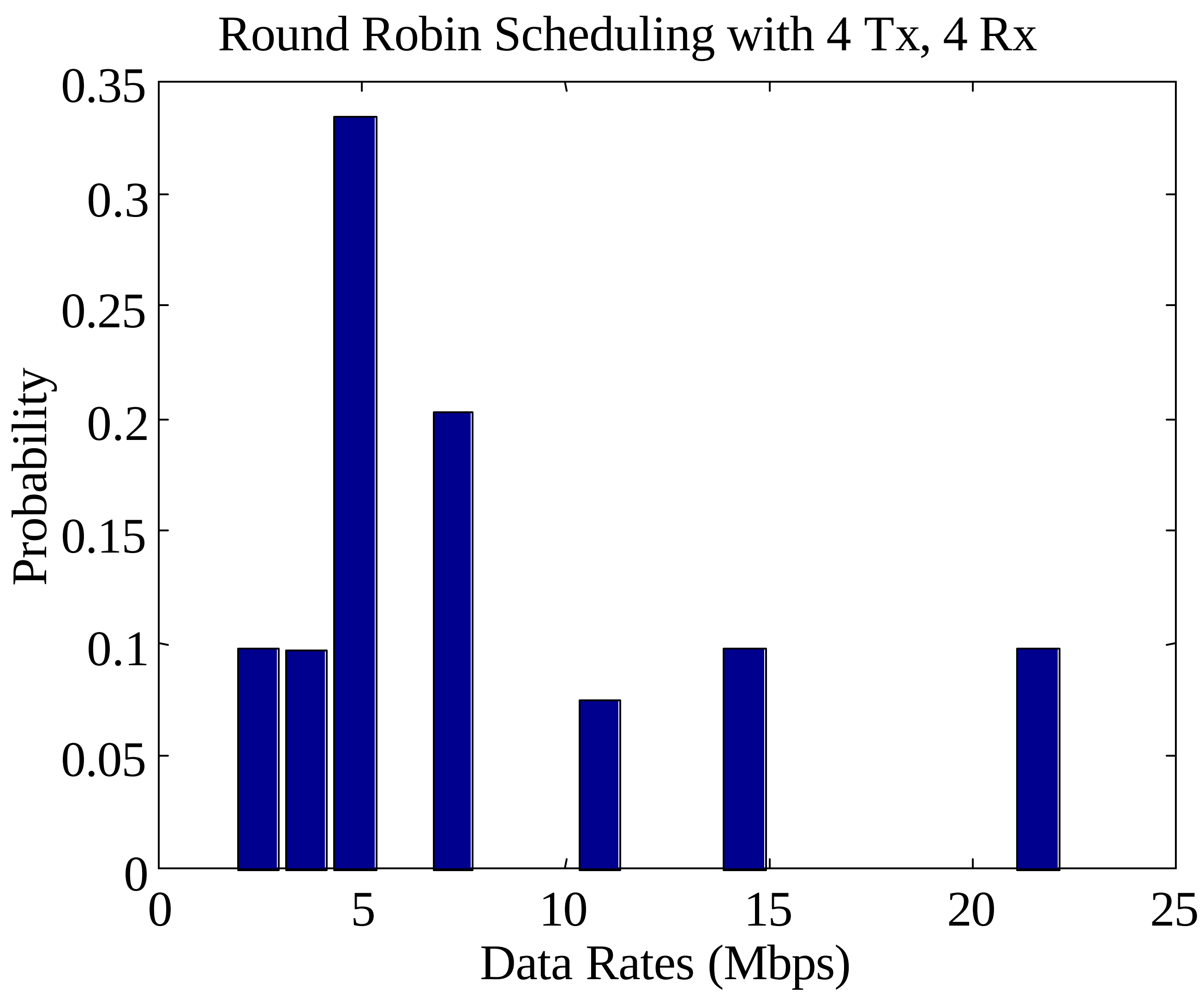
Round Robin Scheduling - 3 Km/hr



Histogram of Rates - Proportional Fair



Histogram of Rates for Round Robin



How does BLAST Compare with 4 Tx, 4 Rx Diversity Option?

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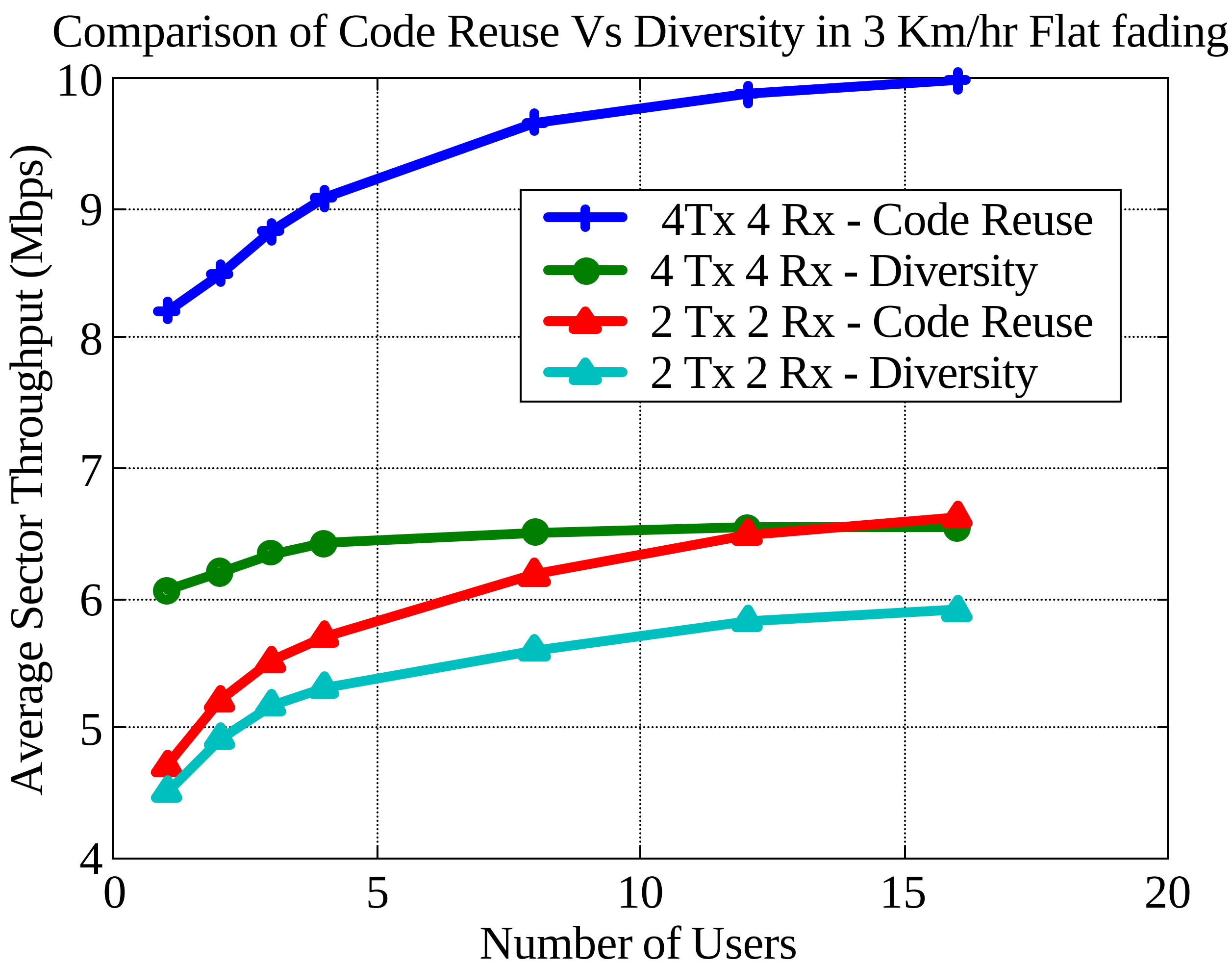
Comparison of BLAST with Diversity



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Caveats

- Gains are for all data system. For voice and data system power available for data would be reduced, decreasing the gains

- Same overhead power of 80% is used for both single antenna and multiple antenna systems in these simulations. Additional power would be required for training other antennas

- Gains can be reduced in frequency-selective fading and if simpler detectors are used

- Option of reducing transmit power instead of going to higher rates was not considered for diversity system

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Summary

- The transmit diversity gains generally diminish with increasing number of users due to multi-user diversity gains for channel-aware scheduling schemes
- Transmit diversity hurts performance for proportional fair scheduling
- Throughput results looks promising - Code reuse gives significant gains for flat fading