A Random Beamforming technique in MIMO Broadcast Channels

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OUTLINE

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Motivation

Both the base station and the receiver has one antenna.

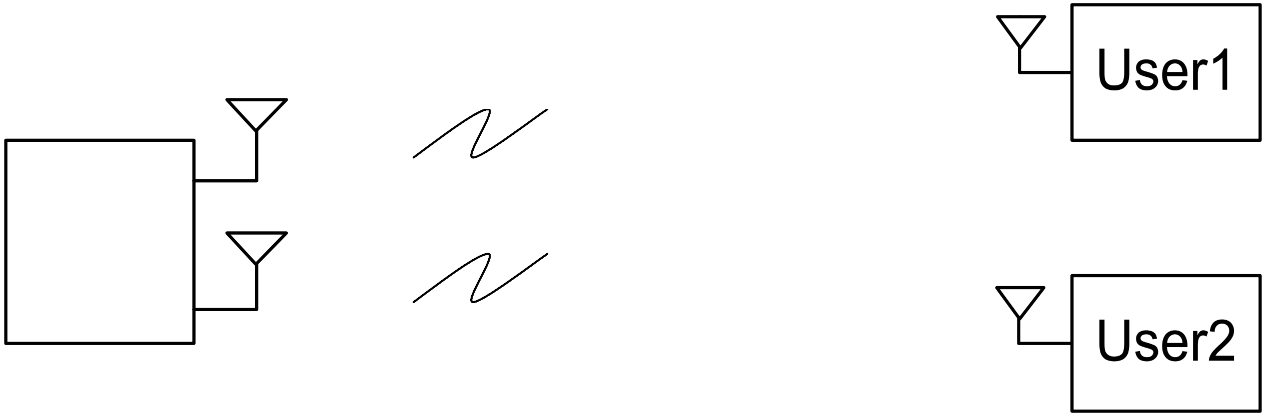
→ Degraded broadcast channel

Selecting the best user and sending data only to that user is optimal!

'Optimal' means 'maximizing the sum rate'

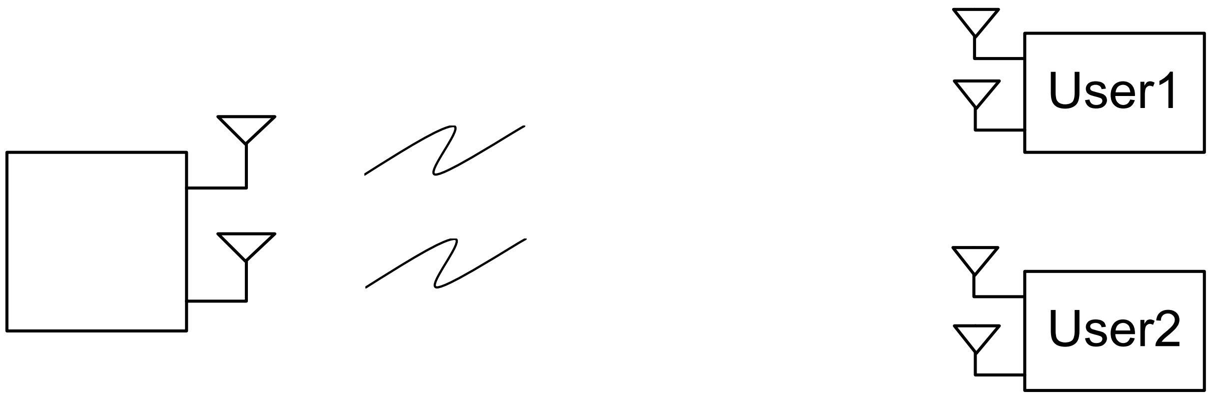
What if BS has more than one antenna

→ Non-degraded Broadcast channel



Selecting only one best user is not optimal

More general case



Multiple antennas at the base station

Multiple antennas at each receiver

→ General MIMO Gaussian broadcast channel

→ It is not always reasonable to assume that perfect channel knowledge can be made available to the Tx.

PART I

Sum Capacity

Transmitter beamforming

- Sub-optimal technique that supports simultaneous transmission to multiple users on a broadcast channel
- Consider the interference from other users as noise

$$\mathrm{SINR}_{i,m} = \frac{\mathrm{P}_m \left|\mathbf{H}_i \mathbf{v}_m\right|^2}{1 + \sum_{k \neq m}^{\mathrm{M}} \mathrm{P}_k \left|\mathbf{H}_i \mathbf{v}_k\right|^2}, \qquad m = 1, \ldots, \mathrm{M}$$

$$\mathrm{R} = \mathrm{E}\left\{\sum_{i=1}^{\mathrm{M}} \log(1 + \mathrm{SINR}_{i,m})\right\} = \mathrm{M}\,\mathrm{E}\left\{\log(1 + \mathrm{SINR}_{i,m})\right\} \stackrel{(a)}{\leq}$$

$$\mathrm{M} \log(1 + \mathrm{E}\left\{\mathrm{SINR}_{i,m}\right\}) \approx \mathrm{M} \log(1 + \frac{1}{\mathrm{M} - 1}) < 1.$$

Suppose each receiver feeds back its maximum SINR

- Then, the transmitter assigns beams to the users with the highest corresponding SINR
- The sum rate capacity

$$R \approx E\left\{\sum_{m=1}^{M} \log(1+\max_{1\le i\le N} SINR_{i,m})\right\} = M\,E\left\{\log(1+\max_{1\le i\le N} SINR_{i,m})\right\}$$

- The lower and upper bounds depend on the distribution of SINR

$$M\int_{1}^{\infty}\log(1+x)Nf(x)F^{N-1}(x)dx \le R \le M\int_{0}^{\infty}\log(1+x)Nf(x)F^{N-1}(x)dx$$

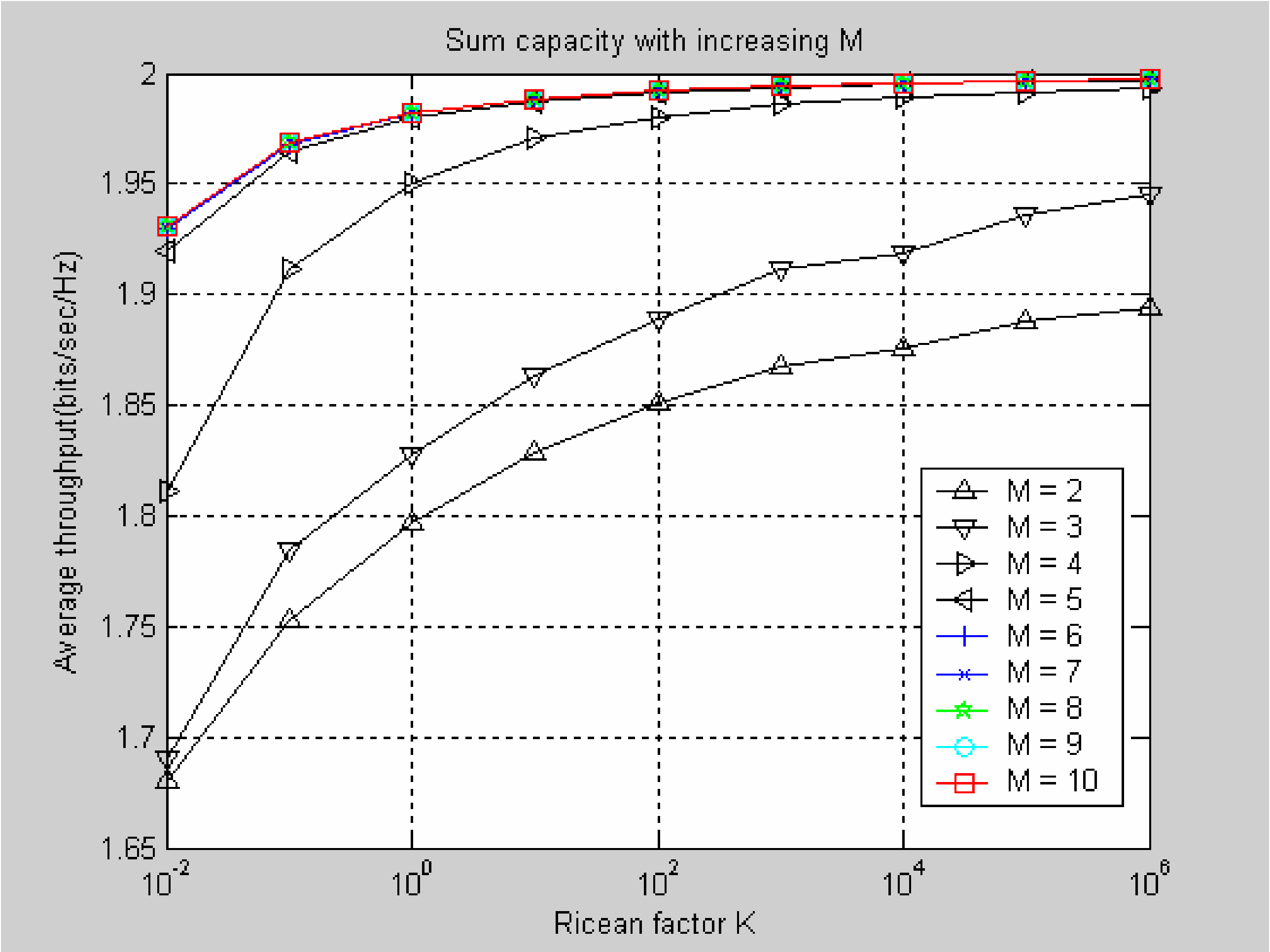
Part II

Simulation Results

Simulation Setup

- Ricean fading channel H
- N (Num. of Users) = 2
- Receive antenna at each receiver = 1
- P1 = 5, P2 = 5
- Varying M (Num. of Tx antennas)
- AWGN
- Orthonormal Tx beamforming

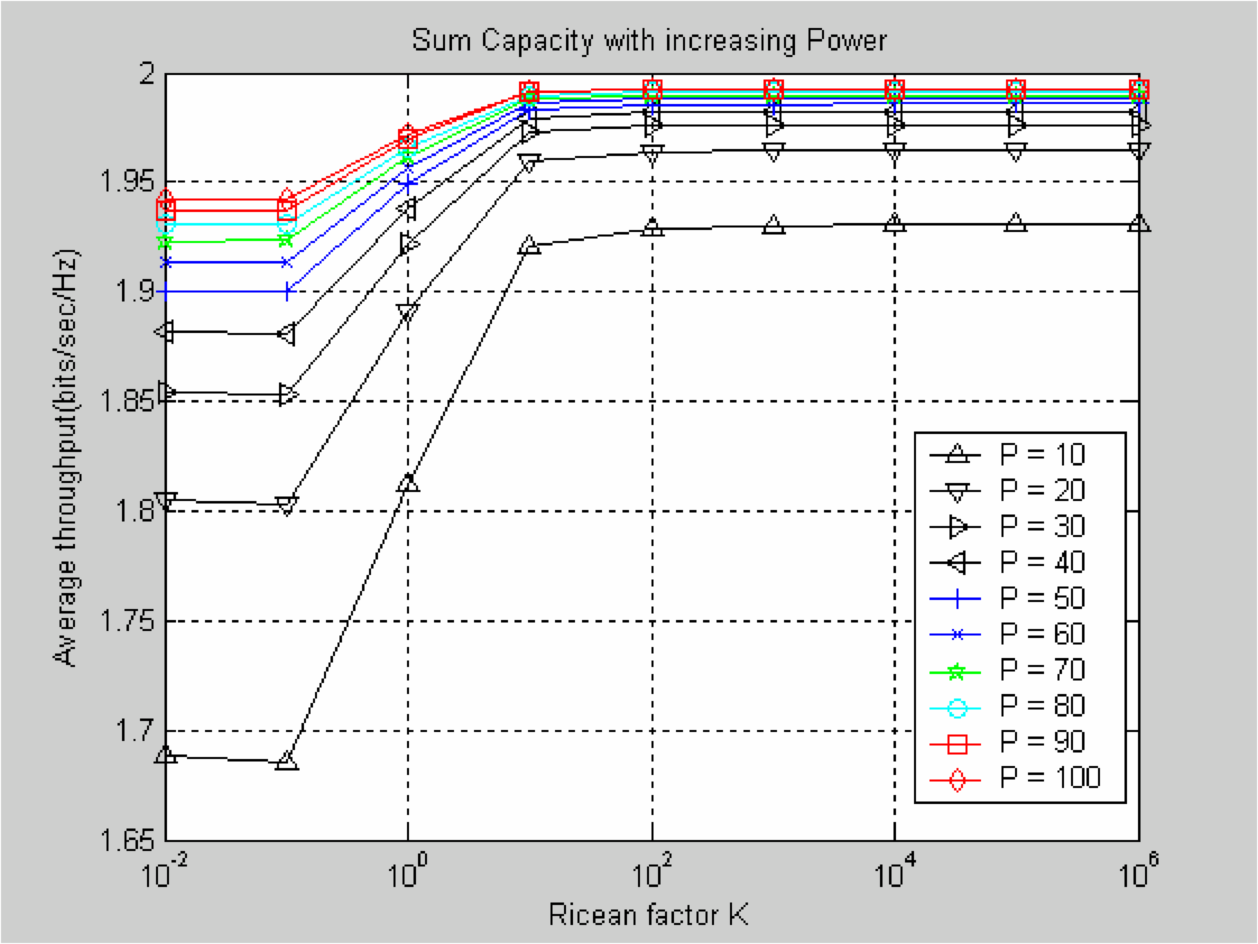
Result


Sum capacity with increasing M
Average throughput(bits/sec/Hz)
Ricean factor K
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
10^-2
10^0
10^2
10^4
10^6
M = 2
M = 3
M = 4
M = 5
M = 6
M = 7
M = 8
M = 9
M = 10

Simulation Setup

- Ricean fading channel H
- N (Num. of Users) = 2
- M (Num. of Tx antennas) = 2
- Receive antenna at each receiver = 1
- Varying Power P, P1=P2=P/2
- AWGN
- Orthonormal Tx beamforming

Result

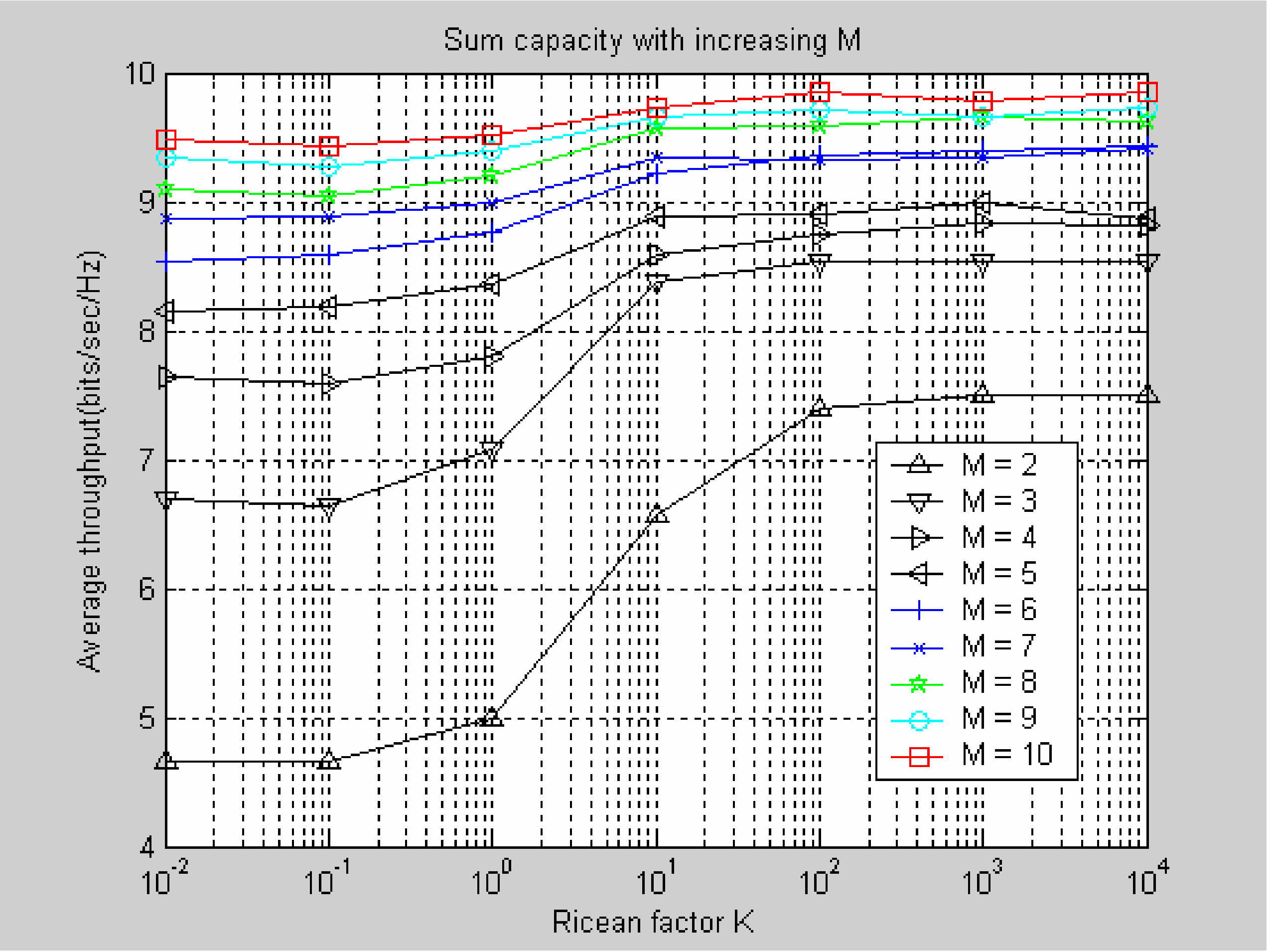


Sum Capacity with increasing Power
Average throughput(bits/sec/Hz)
Ricean factor K
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
10^{-2}
10^{0}
10^{2}
10^{4}
10^{6}
P = 10
P = 20
P = 30
P = 40
P = 50
P = 60
P = 70
P = 80
P = 90
P = 100

Simulation Setup

- Ricean fading channel H
- N (Num. of Users) = 2
- Receive antenna at each receiver = 1
- P1 = 5, P2 = 5
- Varying M (Num. of Tx antennas)
- AWGN
- Normalized Tx beamforming maximizing SINR

Result



Sum capacity with increasing M
Average throughput(bits/sec/Hz)
Ricean factor K
10
9
8
7
6
5
4
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
M = 2
M = 3
M = 4
M = 5
M = 6
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Simulation Setup

- Ricean fading channel H
- N (Num. of Users) = 2
- M (Num. of Tx antennas) = 2
- Receive antenna at each receiver = 1
- Varying Power P, P1=P2=P/2
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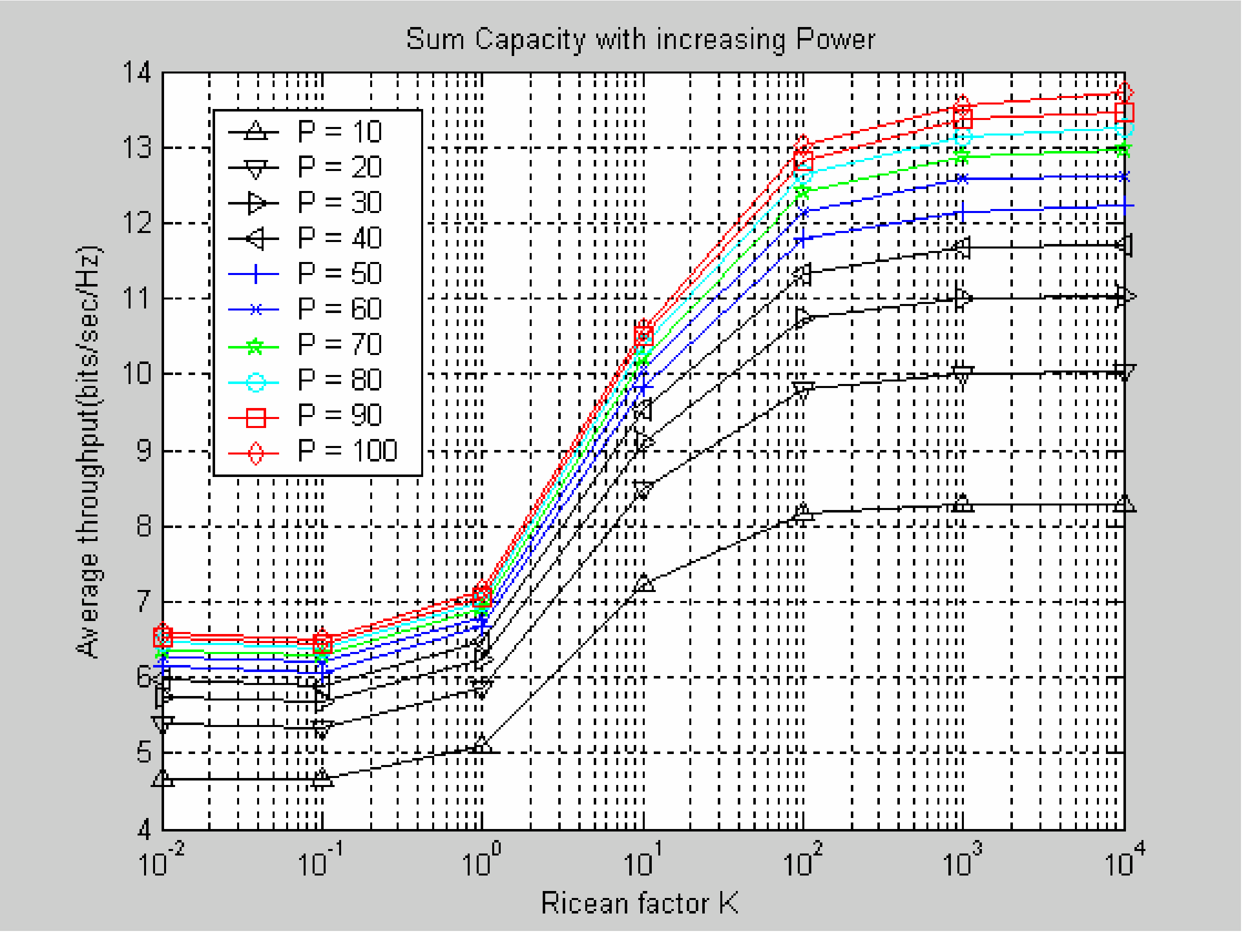
- Normalized Tx beamforming maximizing SINR

Result



Sum Capacity with increasing Power
Average throughput(bits/sec/Hz)
Ricean factor K
14
13
12
11
10
9
8
7
6
5
4
10^-2
10^-1
10^0
10^1
10^2
10^3
10^4
P = 10
P = 20
P = 30
P = 40
P = 50
P = 60
P = 70
P = 80
P = 90
P = 100

Conclusions

- As Ricean factor K goes from zero (models a Rayleigh fading channel) to infinity (models a deterministic fading channel), the capacity increases at first, and then it is saturated.

- As M gets large, the capacity increases, however, when M is large enough, the system becomes interference-dominated.

- Sending M random beamforms to different users is optimal in that it uses M beamforms efficiently than the method where all the M beamforms are concentrated to one user with the best overall channel