MBER Transmit Precoding for the Rank-Deficient MIMO-Aided Internet of Things

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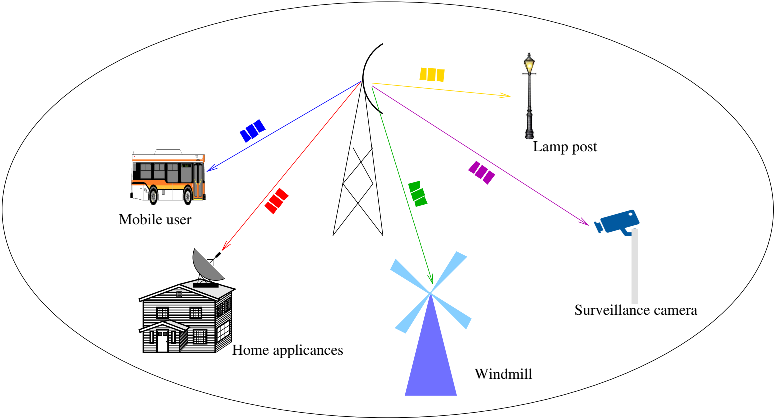
Overview

Motivation



- Wide-variety of physical objects will be assigned to internet realizing the idea of IoT
- Devices more than the number of RF chains will be connected in the same time-frequency resource
- This results in a rank-deficient system

Motivation

- To design a precoder matrix with low complexity which can accommodate more devices than the number of antennas
- This comes at the cost of reduced rate to some users

The sum-rate of the system is constant

- The aim of our design is to minimize the bit error ratio (BER) while accommodating more users

System Model

Received Signal Vector

$$\mathbf{y} = \mathbf{H}\mathbf{P}\mathbf{x} + \mathbf{n}, \tag{1}$$

where

$$\mathbf{H} = \sqrt{\frac{L}{L+1}}\mathbf{H}_{\text{LOS}} + \sqrt{\frac{1}{L+1}}\mathbf{H}_{\text{NLOS}}, \tag{2}$$

$\mathbf{P}$ is the precoder matrix aimed to design, while $\mathbf{n}$ is the complex Gaussian noise vector.

Objective

- Probability of error for a QPSK system

Real Part

$$P_{eR}(\mathbf{P}) = \frac{1}{KM^K} \sum_{q=1}^{M^K} \sum_{k=1}^{K} Q\left(\frac{\text{sgn}(\mathcal{R}[x_k^{(q)}])\mathcal{R}[\mathbf{h}_k \mathbf{P} \mathbf{x}^{(q)}]}{\sigma_n/\sqrt{2}} \right)$$

Imaginary Part

$$P_{eI}(\mathbf{P}) = \frac{1}{KM^K} \sum_{q=1}^{M^K} \sum_{k=1}^{K} Q\left(\frac{\text{sgn}(\mathcal{I}[x_k^{(q)}])\mathcal{I}[\mathbf{h}_k \mathbf{P} \mathbf{x}^{(q)}]}{\sigma_n/\sqrt{2}} \right)$$

S. Chen *et al.* "Adaptive Minimum Symbol Error Rate Beamforming Assisted Detection for Quadrature Amplitude Modulation," TWC 2008.

Objective

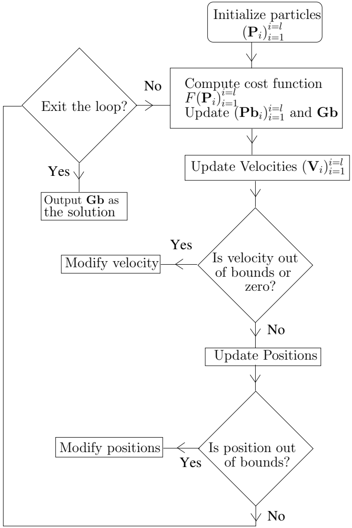
- Average total $P_e(\mathbf{P}) = \frac{P_{eR}(\mathbf{P})+P_{eI}(\mathbf{P})}{2}$

Objective Function

$$\mathbf{P}_{\text{MBER}} = \min \ P_e(\mathbf{P}) \quad s.t. \ \|\mathbf{Px}\|_{\text{F}}^2 \leq P_t, \tag{3}$$

- No closed form solution
- To solve (3), we invoke a genetic algorithm, namely particle swarm optimization (PSO)

Sketch of PSO Algorithm



A. Ratnaweera, *et al.*, "Self-organizing hierarchical particle swarm optimizer with time-varying acceleration coefficients," IEEE Trans. Evolu. Comput., 2004.

Full Rank System

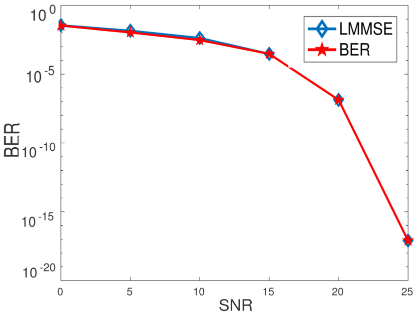


Figure: 4 users connected to BS with 4 RF chains. The normalized system load (NSL) is $\frac{4}{4}$

Table: System parameters.

Parameters	Values
Number of Particles	40
Modulation	QPSK/BPSK
N_t	4
K (users)	4
L (Rician factor)	30 dB
θ	$\theta^{\circ} = \{0, 30, -10, -25\}$

Simulation Results

Rank-Deficient System

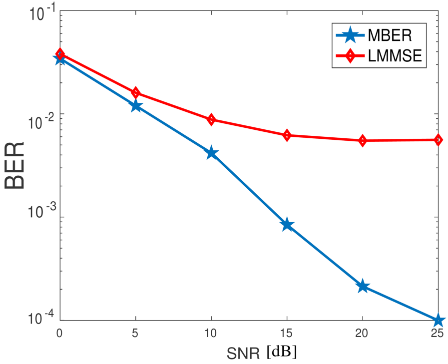


Figure: 7 users connected to BS with 4 RF chains. The NSL is $\frac{7}{4}$.

Table: System parameters.

Parameters	Values
Number of Particles	40
Modulation	QPSK/BPSK
N_t	4
K (users)	7
θ	$\theta^\circ = \{0, 10, -10, -25, 50, -40, 90\}$

Simulation Results

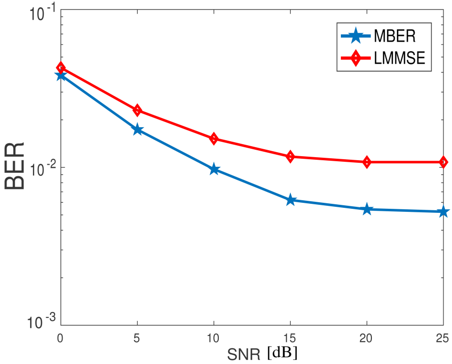


Figure: 7 users connected to BS with 4 RF chains. The NSL is $\frac{7}{4}$.

Table: System parameters.

Parameters	Values
Number of Particles	40
Modulation	QPSK/BPSK
N_t	4
K (users)	7
L (Rician factor)	30 dB
θ	$\theta^\circ = \{0, 10, -10, -25, 50, -40, 60\}$

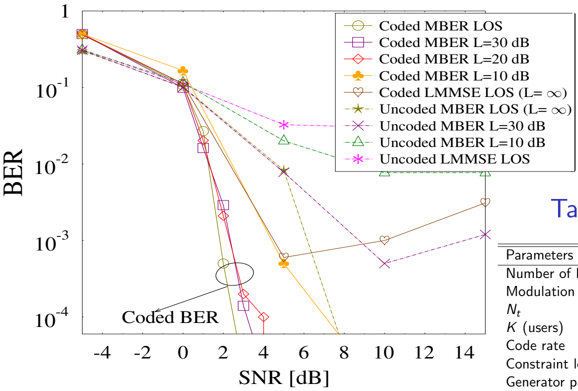


Figure: 5 users connected to BS with 3 RF chains. The NSL is $\frac{5}{3}$.

Table: System parameters.

Parameters	Values
Number of Particles	40
Modulation	QPSK/BPSK
N_t	3
K (users)	5
Code rate	1/2
Constraint length	7
Generator polynomials (in octal)	171, 133
θ	$\theta^{\circ} = \{0, -20, 20, 40, -40\}$.

Conclusions

- MBER assisted precoding technique can accommodate more users than the number of RF chains in the same time-frequency resource
- Sum rate of the system is constant
- BER performance is affected by both Rician fading factor and angular position of the users

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