Raptor Code for Selecting a Receiver Antenna

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She received her Ph.D. degree from the School of Higher Technology, Canada in 2021.

Her research interests

- Computer network architectures, algorithms and protocols, computer and network security
- Radio mobile communication systems engineering (LTE, 5G & 6G)

Publications & Activities

- Benzid, Djedjiga, et Michel Kadoch. 2019. « Fountain Codes and Linear Filtering to Mitigate Pilot Contamination Issue in Massive MiMo ». *Network and Communication Technologies*, vol. 4, p. 1.
- Benzid, Djedjiga, et Michel Kadoch. 2019b. « Raptor code and massive MiMo for secure wireless delivery in 5G ». *Journal of Electrical and Electronic Engineering*, vol. 7, nº 6, p. 134-142.
- Benzid, Djedjiga, et Michel Kadoch. 2018. « Raptor code to mitigate Pilot contamination in Massive MiMo ». *Procedia Computer Science*, vol. 130, p. 310-317.
- Benzid, Djedjiga, Kadoch Michel, Zhengwei Chang, Jizhao Lu et Rongke Liu. 2020. « LDPC for receive antennas selection in massive MiMo ». In *2020 International Wireless Communications and Mobile Computing (IWCMC)*. p. 322-325. IEEE

1. Aims and contributions of our paper

In our paper, we aimed at:

- Developing a valuable and reliable model for receiving antenna selection under imperfect CSI.
- Reducing energy consumption and complexity of processing in massive-MiMo.

Contributions of our study are:

- We made a water filling algorithm based on Raptor codes
- Raptor codes are used to enhance the performance of the model by retrieving the most reliable message.
- Water filling algorithm based maximum capacity criterion is employed to select the optimal subset of antennas using Raptor decoded messages

2. Massive Multiple-input multiple-output

- Massive Multiple-Input Multiple-Output (m-MIMO) is a promising technique that uses hundreds of antennas at the transmitter and receiver to improve channel performance in Fifth Generation (5G) wireless networks.
- A large number of antennas implies the addition of the radiofrequency (RF) chain elements at both links’ ends. Which increases the cost and complexity of processing in m-MiMo.
- The problem can be fixed with a successive selection method in MiMo conventional. A powerful solution where a subset of the available antennas at the transmitter and receiver are selected.
- However, this method is inefficient for the massive MIMO system because of the significant number of antennas which increases the complexity of the processing.
- Furthermore, the m-MIMO system suffers from pilot contamination which makes the selection of the optimal subset of receive antennas more complex.

3.1 Related work

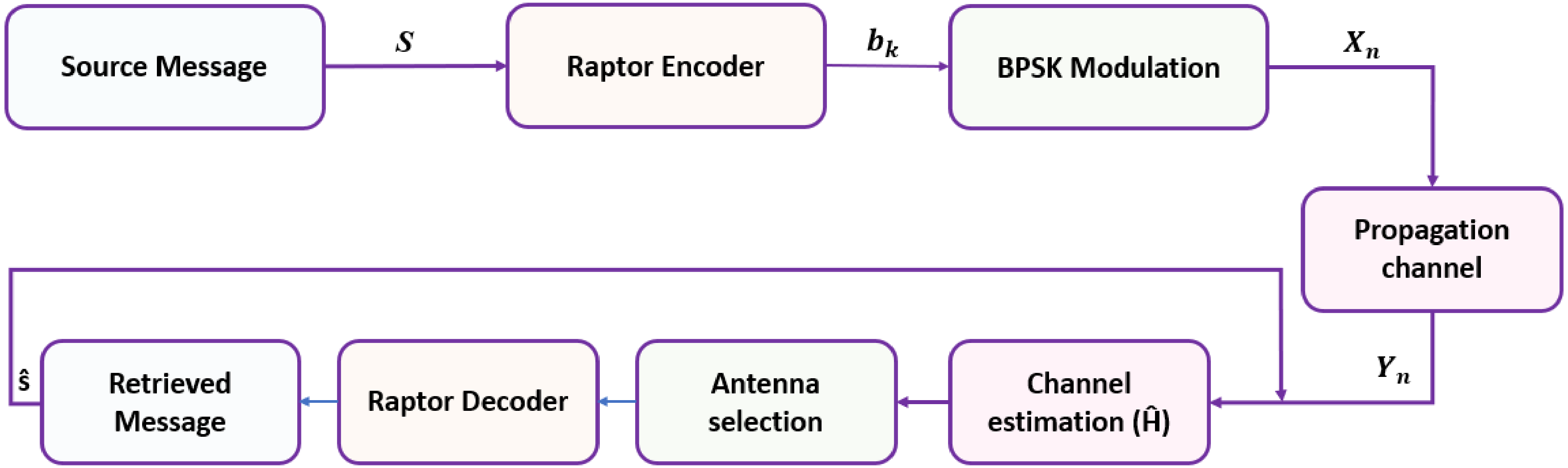
- [1] A maximum sum-rate criterion is considered in this article in order to find the optimal number of antennas that reduces power consumption.
- [2] Proposes a maximization of capacity and sum rate as selection criteria,
  - the study is done on transmit antenna selection in the downlink of massive MIMO, several measurement campaigns in the 2.6 GHz frequency range are done using convex optimization to select the antenna subset that maximizes the dirty-paper coding (DPC) capacity in the downlink.
  - The authors assume that a perfect channel state information (CSI) is available at the transmitter.
- [3] proposes an optimal antenna based on a binary searching algorithm using the maximizing energy criterion.
  - The authors aim to ensure energy efficiency in the massive MIMO system under imperfect channel estimation at the transmitter.

3.2 Related work

- [4] The selected antennas are combined with nonorthogonal multiple access (NOMA) to extremely achieve high spectral efficiency in the 5-the generation (5G).
- [10] an antenna selection method that considers pilot contamination issues,
  - a water-filling algorithm combined with a Low-Density Parity-Check (LDPC) to find the optimal subset of the antennas that maximised the ergodic capacity is presented in this paper.
  - LDPC decoder retrieves the received symbols. The recovered message is then used to estimate the gain H.
  - The estimated channel is employed to select the optimal subset of antennas that satisfied the maximum capacity criterion.

3.2 System Model

The system model is represented bellow:



$\boldsymbol{H}$: ***The channel gains form the channel matrix*** $\boldsymbol{H} = [\boldsymbol{h_{ij}}] \in \mathbb{C}^{N_r \times N_t}$.

- $\mathrm{h_{ij}} \sim \mathcal{CN}(0,1)$Are identically independent distributed $(\mathrm{i.i.d.})$.
- H is known to the transmitter but not to the receiver.
- $\boldsymbol{N_r}$=nomber of the receive antennas
- $\boldsymbol{N_t}$: nomber of transmit antennas; $N_r \geq N_t$

3.3 System Model

- **At the transmitter :**
  - The source block message s_k is encoded to produce the codeword b_k
  - The codeword modulated by BPSK to generate the symbol vector x_k
  - The x_k symbols are transported over a slow flat fading channel
- **At the receiver :**
  - the channel output is obtained as y_k at the channel estimator control node.
  - The signal after filtering is represented as follows:

$$\boxed{\boldsymbol{Y} = \boldsymbol{HX} + \boldsymbol{N}}$$

$\boldsymbol{N}$: The Gaussian noise vector

- $N \in C^{N_r}$ i.i.d. $CN(0, N0)$ variables so that $E\left[NN^{\dagger}\right] = \sigma_n^2 I_{Nr}$.
- $N^{\dagger}$ denotes transposed matrix of the conjugate matrix

3.4 System Model

- The decoding process is started to retrieve the message using the belief propagation (BP) algorithm to achieve the soft decoding process.
- The likelihood ratios (LLR) of the channel for each coded bit are expressed as follows [8]:

$$\boxed{Z_0 = \frac{2\hat{H}}{\sigma_n^2} Y}$$

- $\hat{H}$ is the estimated random variables coefficients of H. The channel estimation is calculated using the MMSE as in [7]:. $\hat{H}$ is given by:

$$\boxed{\hat{H} = R_{HH}\left(R_{HH}\hat{S}\hat{S}^T + \sigma_n^2 I\right)^{-1}\hat{S}^T Y}$$

3.5 System Model

- The estimated channel is used to select an optimal subset of antenna based on the capacity maximization criterion as follows:

$$C(\Delta) = arg \max_{\substack{\Delta_i \in \{0,1\} \\ \sum_i \Delta_i = L_r}} log_2 \, det(I + \Delta(U\Sigma^2 U^H)$$

- Δ: subdet of antenna
- $U\Sigma^2 U^H$: single value decomposition of $\widehat{\mathrm{H}}\widehat{\mathrm{H}}^T$

4.1 Simulation results

- The proposed model is evaluated under the following parameters.
- **Raptor Parameters:**
- The codeword length of LDPC encoding = 80000 bits,
- message length = 980 bits,
- code rate = 0.98.
- Degree of distribution of the Luby Transform (LT) encoding is the same as that used in [18]and is as follows:

$$\Omega(x) = 0.008x + 049x^2 + 0.166x^3 + 0.073x^4 + 0.083x^5 + 0.056x^8 + 0.037x^9 + 0.056x^{19} + 0.025x^{65} + 0.003x^{66}.$$

- **m-MIMO system parameters:**
- Receive antennas=16
- Transmit antennas =8
- subset of the selected receive antennas Lr=12.

4.2 Simulation results

Four scenarios are performed for Figure 1:

1) Scenario 1: represents the proposed method under perfect CSI, without performing the antenna selection method (shown in black with an asterisk),
2) Scenario 2: depicts the proposed method all antennas are selected. CSI is estimated using the Raptor decoded symbols (blue with circular markers),
3) Scenario 3: describes an exhaustive method (used in conventional MiMo), the number of selected antennas Lr=12. CSI is estimated using the Raptor decoded symbols (red with a triangle pointing to the right),
4) Scenario 4: illustrates the proposed method where Lr=12. CSI is estimated using Raptor decoded symbols (black with a plus sign).

4.2 Simulation results

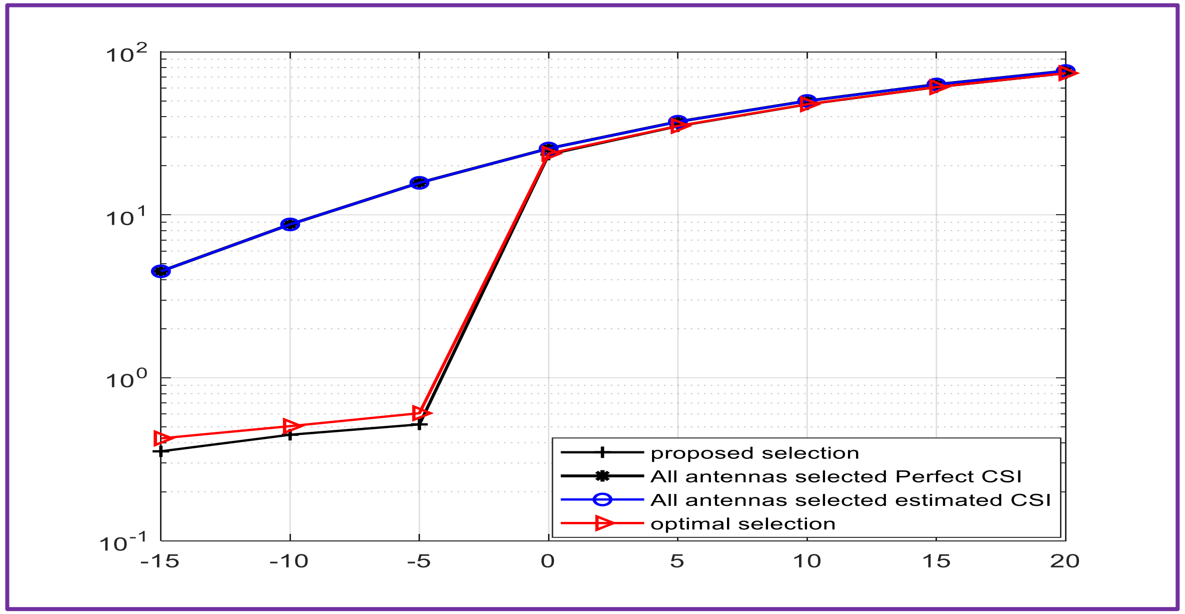


Figure 1 Ergodic capacity Vs received SNR

- The first and second scenarios are superposed because they meet the same ergodic capacity values regardless of SNRs.
- The ergodic capacity of the two latest scenarios remains low when the SNR is between -15dB and -5dB since the channel cannot be estimated in this interval (outage).
- The ergodic capacity approaches the values of the first two scenarios for an SNR>0. since the message is completely recovered and the channel is correctly estimated. For the following simulations, we only consider the values when SNR>0.

4.3 Comparison of effectiveness

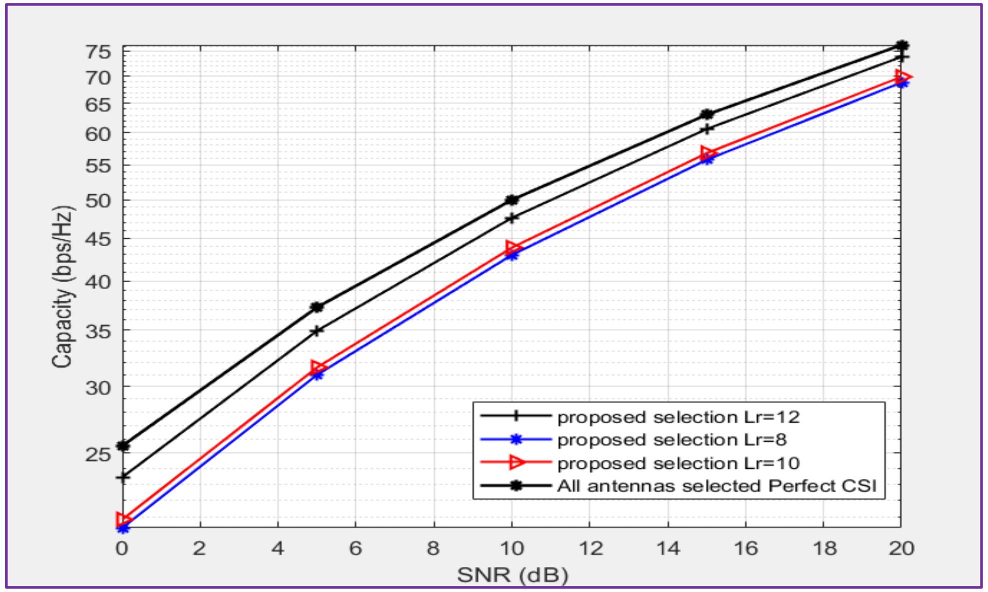


Figure 2 Ergodic capacity Vs SNR

- Figure 2 illustrates the ergodic capacity for different numbers of selected receive antennas Lr, Lr=12, 10 and 8.
- The results show that Lr=12 reaches values close to the optimum.

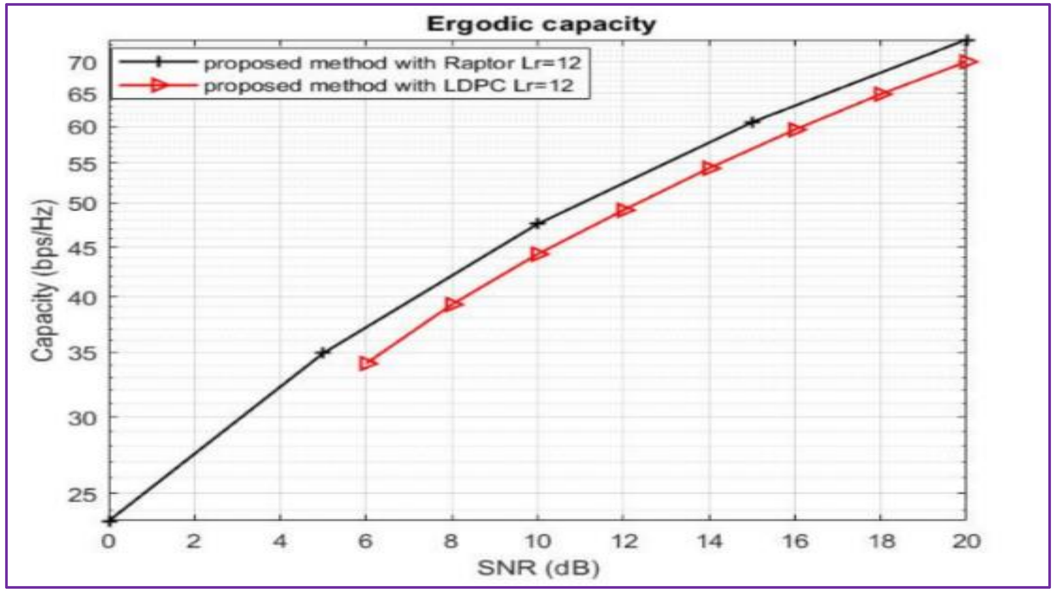


Figure 3 Ergodic capacity Vs SNR

- Figure 3 compares the results of the Raptor-based antenna optimizations and LDPC- based antenna optimizations method proposed in previous work [10].
- The channel estimated with Raptor code attains higher optimal capacity than the channel estimated with LDPC code.

5. Conclusion

- We propose an antenna selection method performed under imperfect CSI.
- Our solution uses conjointly an antenna selection algorithm based on mutual information maximization and the Raptor decoded information symbols.
- The Raptor decoded message estimates the channel, and the water-filling algorithm selects the highest-performing subset of antennas using the estimated channel.
- This method requires less transmit power and avoids overload in the network since the symbols pilots are not sent. This contributes to reducing energy consumption and processing resources
- Simulation results show that the ergodic capacity reaches near-optimal values using Raptor codes than LDPC codes.

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