Abstract

Multicast beamforming is an efficient technique for increasing the capacity of multi-antenna systems.

- Active antenna selection saves hardware and energy resources.
- However, multicast with active antenna selection is NP-hard.
- Prior art uses semidefinite relaxation techniques and first-order SCA to obtain approximate solutions.
- Still far from implementation in real-time.
- Neural network-based approach will be used to obtain a real-time antenna selection solution.
- Numerical results show that the efficiency of the proposed machine learning approach relative to the prior state-of-art

Background

Multicast beamforming: Two basic design problems

- Non-convex and NP-hard problems.
- Semidefinite relaxation (SDR)-based approaches have been shown effective in identifying near-optimal solutions for both problems.
- First-order methods have been used to obtain approximate solutions to the problem [Konar’17]

Joint multicast beamforming and antenna selection

- SDR technique is used to get an approximate solution. [Mehanna’13]
- Saddle-Point Mirror-Prox (SP-MP) algorithm is used to obtain sub-optimal solution [Salah’18]

Multicast transmit beamforming is an efficient technique for increasing the capacity of multi-antenna systems.

Proposed Approach

Two stage approach:

1. Stage 1: Training a deep neural network to map the second order information of the channel to binary vector that attains the max SNR
2. Stage 2: Solve a reduced size problem using the SP-MP algorithm to get the corresponding beamforming vector.

Training the neural network:

- The second order information is used to train the network $A_{nn} = h_nh_n^H$, $\forall n \in [1, \cdots, M]$ saves network resources and internal conversions
- But, $A_{nn}$ is a hermitian matrix only upper triangular part can be used in training

How can we obtain the training data set?

- The SP-MP algorithm is used to generate the training data set.
  - very fast convergence rate and high solution quality
  - The $-1$ training contains the tuple $\{x_i, s_i\}$, where the output is a binary vector that corresponds to the set of active antennas for a given input.

Proposed Approach (cont.)

Neural network setting

- The neural network has two hidden layers
- The input size is $MN$ while the output size is $N$
- The number of nodes in the first layer is double the input size while in the second one is the same size of the input
- The activation function of both layers is Log-Sigmoid.

Testing stage steps

1. Channel realizations are generated following the same distribution as the training stage
2. The upper triangular parts of the second order information matrices are fed to the neural network
3. The largest $K$ out of the $N$ outputs are considered to be the set of active antennas
4. The SP-MP algorithm is utilized to solve a reduced size problem with the set of active antennas to get the corresponding beamforming vector that attains the max-min SNR

Baseline Algorithms:

- Exhaustive search
  - optimal solution but very expensive
  - used as upper bound
- Random selection
  - very cheap but the worst performance
  - used as lower bound
- Semi-definite relaxation
  - High quality solution but expensive when $N$ increases
  - Mirror prox SCA
  - High quality and low complexity solution
  - The best one across the benchmarked algorithms
  - still can not be implemented in real-time due to the binary search procedure

Experiments

Simulation parameters:

- We consider a scenario with $N = 6$ and $M = 10$
- The downlink channels are modeled as random vector drawn from normal distribution
- The noise variance was set to 1
- The total transmission power was set to 10

Neural network parameters:

- In the training stage, 30000 channel realizations were used
- 3% of them used for validation
- The learning rate was set to 0.01

Results and Conclusion

- Proposed a two-stage approach that can handle the joint antenna selection and multicast beamforming problem.
- Key idea: Leveraging the computational efficiency of the DNN to solve the problem in real-time.
- Simulations demonstrated that the proposed DNN with the MP algorithm provides substantial computational relative to traditional methods