Cross-Layer Optimization for MIMO-Based Mesh Networks

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Research Motivation
- How to apply MIMO in networking environments is still poorly understood
- Very little study conducted on multi-hop MIMO-based mesh network in the literature

System Model
- A MIMO-Based Mesh Network:
  - $N$ MIMO-Enabled Nodes
  - $L$ Possible MIMO Links
  - $F$ Sessions
  - Channel gain variation is slow enough
  - Each node is assigned a non-overlapping band $B_n$
  - Each node is subject to a maximum power limit $p_{o,n}^{	ext{max}}$

Goal: Maximize the sum of network utility functions of the MIMO-Based Mesh Network

Formulation
- CRPBA: Maximize

\[
\sum_{f=1}^{F} \ln(s_f)
\]

subject to

- $X \succ 0$
- $S_{f} = a_{f}(s_{f}, \omega_{f}) \succ 0 \forall f$
- $(1, S_{f}) = 0 \forall f$
- $(S_{f})_{ii} = s_{f} \forall f$
- $\sum_{f} \text{Tr}(Q_{f}) \leq P_{o,f}^{	ext{link}} \forall f$
- $\sum_{f} \text{Tr}(W_{f}) \leq B_{o} \forall f$
- $Q_{f} \succeq 0, \ W_{f} \succeq 0, \ f = 1, 2, \ldots, F$

Variables: $X, \ Q_{f}, \ W_{f}$

Reference

Gradient Projection Method Based on Matrix Differential Calculus
- Gradient Computation:

\[
G_{W_{f}} \triangleq \nabla W_{f} \Theta_{\text{link}} = n \log_{2} \det \left( I + \rho h_{f} H_{f} H_{f}^{H} \right)
\]

\[
G_{Q_{f}} \triangleq \nabla Q_{f} \Theta_{\text{link}} = \frac{2W_{f} n \rho}{\ln 2} \left( I + \rho H_{f} Q_{f} H_{f}^{H} \right)^{-1} H_{f}
\]

A Hermitian Matrix

- Projection Task: Simultaneously project $Q(n)$ to $W$ scalars and $Q(n)$ to $H$ Hermitian matrices on $\Omega_{n}$

- Construct a Block Diagonal Matrix $D_{n}$
  - A block diagonal matrix $D_{n}$, to find $D_{n} \in \Omega_{n}$
  - such that $D_{n}$ minimizes $\| D_{n} - D_{n}^* \|$ subject to $\text{Tr}(E_{f}^{(n)} D_{n}) \leq B_{f}$, $\text{Tr}(E_{f}^{(n)} D_{n}) \leq P_{o,f}^{	ext{link}}$, $D_{n} \succeq 0, \ f = 1, 2, \ldots, F$

- Structure: Linear Constraints, Quadratic Objective
- Belongs to the class of "Matrix Nearness" Problems (Hard). We design a polynomial-time algorithm