Wireless Network Simplification

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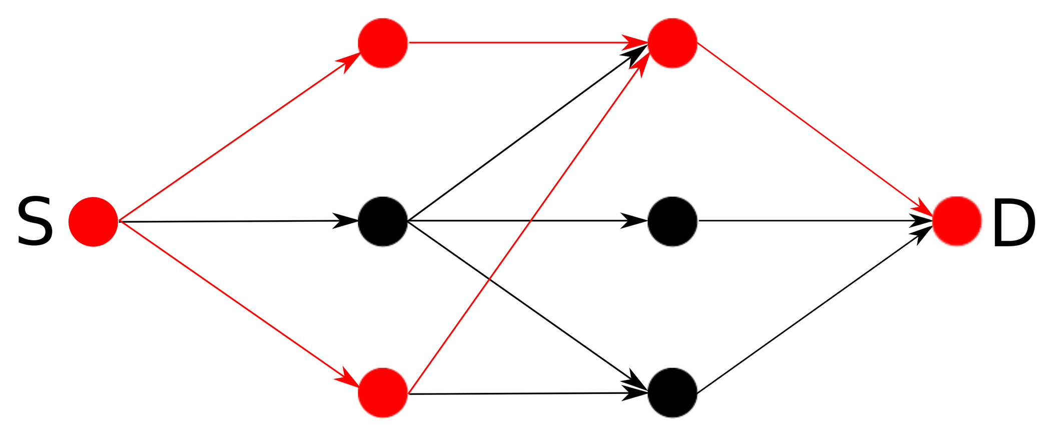


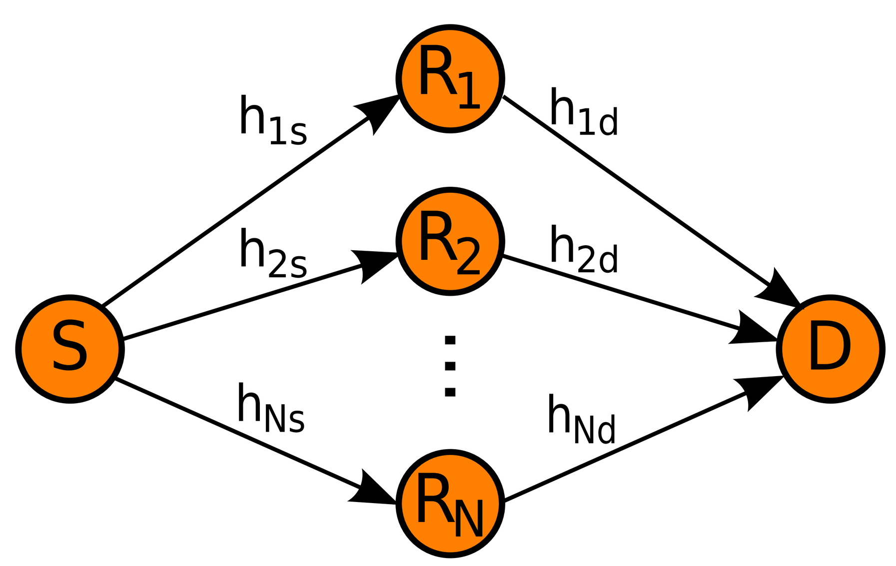
Objective:

Maintain a good fraction of the network capacity by using only a small subset of the relays.

Motivation

- Using fewer relays allows us to reduce operational complexity.
- Understanding the critical links leads to better resource utilization.
- Unexpectedly, simplification provides better approximations for the capacity of wireless networks than existing results in the literature.

Gaussian Diamond Network



The source is connected to the relays through a broadcast channel; the relays are connected to the destination through a multiple-access channel with arbitrary channel configurations $\{h_{ij}\}$. The source is equipped with n_s transmit antennas and the destination is equipped with n_d receive antennas.

Previous Work

Single Antenna Diamond Network

Theorem [1]: In every every N-relay diamond network with $n_s = n_d = 1$, there exists a subset of k relays which alone provide a capacity C_k

$$C_k \geq \frac{k}{k+1}C - G,$$

where C is the capacity of the N-relay network. G is a constant independent of the channel configurations and the operating SNR of the network.

By using only k relays, we can achieve approximately a fraction $\frac{k}{k+1}$ of the N-relay capacity.

Multiple Antenna Diamond Network

Define α_i to be the individual capacity from the source to relay R_i and β_i to be the individual capacity from relay R_i to the destination.

Theorem [2]: When $\alpha_i = \alpha$ and $\beta_i = \beta$, $n_s = 2$ and $n_d = 2$, in every N-relay diamond network, there exists a 2-relay subnetwork such that

$$C_2 \geq C - G$$

where C is the capacity of the entire network and G is a constant independent of the channel configurations and the operating SNR.

When $n_s = 2$ and $n_d = 2$, we can approximately achieve the capacity of the whole network by using only 2 relays if each source-relay relay-destination link has the same capacity.

The theorem does not hold when α_i and β_i are arbitrary: we can construct networks with $n_s = 2$ and $n_d = 2$ where the largest 2-relay subnetwork only provides half of the capacity of the entire network.

Main Problem

Extend the simplification framework to wireless networks with arbitrary configurations and arbitrary number of antennas.

We Explore

- MIMO Simplification
  Consider a MIMO channel with n_t transmit and n_r receive antennas, and capacity $C_{n_r \times n_t}$. Assume $n_r \geq n_t$. There exists a subset of n_t receive antennas which achieve a capacity
  $$C_{n_t \times n_t} \geq C_{n_r \times n_t} - G$$
  where G is a constant independent of the channel configurations and the operating SNR. An analogous result holds when $n_t \geq n_r$.
- Submodular flows
  For any subset of links A_i, the capacities across those links $\alpha(A_i)$ satisfies:
  $\alpha(A_1) \leq \alpha(A_2)$ if $A_1 \subseteq A2$
  $\alpha(A_1 \cup A_2) \leq \alpha(A_1) + \alpha(A_2) - \alpha(A_1 \cap A_2)$
- Non-Shannon type inequalities for entropy
  Suppose X, Y, Z are jointly Gaussian random variables.
  Let $I(X,Y) = \min(I(X,Y), I(X,Z), I(Y,Z))$, then:
  $$\min(I(X,Z), I(Y,Z)) \leq I(X,Y) + 2$$
  Intuitively, if X and Y are close to independent, then Z cannot simultaneously give a lot of information about both X and Y.

References

[1] C. Nazaroglu, A. Özgür, and C. Fragouli, "Wireless Network Simplification: the Gaussian N-Relay Diamond Network", *IEEE International Symposium on Information Theory (ISIT) 2011*

[2] C. Nazaroglu, A. Özgür, J. Ebrahimi, and C. Fragouli, "Network Simplification: the Gaussian N-Relay Diamond Network with Multiple Antennas", *IEEE International Symposium on Information Theory (ISIT) 2011*