Opportunistic Cooperation for Improving the Stability Region

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Introduction

Motivation
- Cooperative relaying provides spatial diversity and enhances communication rates in wireless networks
- Utilize multipacket reception capability (MPR) by allowing simultaneous transmissions of user and relay opportunistically

Previous Work
- Exploit cooperative relaying at the physical layer; adopt simple collision channel model and schedule transmissions of user and relay separately

Our Approach
- Exploit cooperation at the MAC layer
- Investigate the composite effects of cooperative relaying and multipacket reception capability
- Evaluate the resulting stability region, characterize the optimal transmission probability of the relay

Trade-off

Single Transmission vs Simultaneous Transmissions
- \( S \) transmits only
- \( R \) may overhear \( S \) and enable cooperation

Network Model
- Independent arrivals to users \( S_1 \) and \( S_2 \): \( \lambda_1, \lambda_2 \)
- Standard MPR channel model
- \( q^{(m)}_n = \text{P}[\text{packet from } m \text{ is received at node } n \mid \text{users in set } M \text{ transmit}] \)
- \( S_1 \) has a better user-destination channel than \( S_1 \); \( S_2 \) relays \( S_1 \)'s packets if those packets are not decoded by \( d \), but decoded by \( S_2 \)
- Opportunistic transmission: If \( S_1 \) transmits, \( S_2 \) transmits with probability \( p \) if it’s backlogged; to optimize this \( p \) such that the resulting stability region is maximized

Opportunistic Cooperation Scheme
- If \( Q_1 \neq 0 \), \( S_1 \) transmits w.p. 1
  - then if \( Q_2 \neq 0 \), \( S_2 \) transmits w.p. \( p \)
- If \( Q_1=0 \), \( Q_2 \neq 0 \), \( S_2 \) transmits w.p. 1

Methodology
- Queues are coupled, thorny problem
  - Step 1: Stochastic dominance approach
  - \( S \) and \( R \) transmit simultaneously
  - Both transmissions might be successfully decoded
  - The relaying capability of \( R \) is sacrificed

Results
- \( \eta - q^{(1)}_1 (1 - q^{(d)}_1) q^{(d)}_1 (1 - q^{(d)}_2) q^{(2)}_1 - q^{(2)}_1 + q^{(d)}_1 - q^{(d)}_2 q^{(d)}_2 > 0 \)
  - \( p^* = 1 \), for \( q^{(d)}_1 < q^{(d)}_2 \)
  - \( p^* = \frac{q^{(2)}_1 + q^{(d)}_1 - q^{(d)}_2 q^{(d)}_2 - q^{(2)}_1}{q^{(2)}_1 + q^{(d)}_1 - q^{(d)}_2 q^{(d)}_2} \), for \( q^{(d)}_1 = q^{(d)}_2 \)

Conclusion and Application

Conclusion
- Cooperation improves the stable throughput region, all users simultaneously increase stable throughput rates
- Under certain channel conditions, opportunistic scheme achieves higher performance gains; the resulting stability region is convex

Application
- If the channels are strong enough to support simultaneous transmissions, opportunistic scheme by scheduling the relay to transmit together with the user with some probability can be more beneficial to the whole network