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[Opportunistic Cooperation for Improving the Stability Region]

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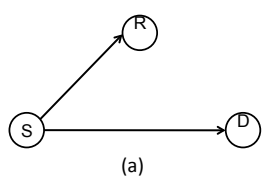
Introduction

- **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

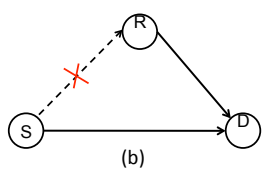
Trade-off

- **Single Transmission vs Simultaneous Transmissions**



(a)

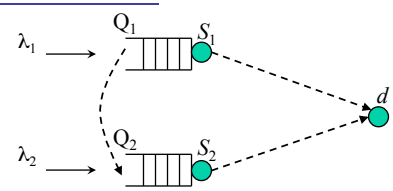
- S transmits only
- R may overhear S and enable cooperation



(b)

- S and R transmit simultaneously
- Both transmissions might be successfully
- The relaying capability of R is sacrificed

Network Model



- Independent arrivals to users S_1 and S_2: λ_1, λ_2
- Standard MPR channel model

$q^{(n)}_{m|M}$=**P**[packet from m is received at node n | users in set M transmit]

- S_2 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 $\boldsymbol{p}$ if it's backlogged; to optimize this p such that the resulting stability region is maximized

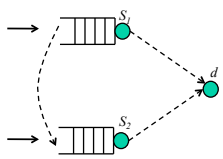
Opportunistic Cooperation Scheme

- If $Q_1 \neq 0$, S_1 transmits w.p. 1
  - then if $Q_2 \neq 0$, S_2 transmits w.p. $\boldsymbol{p}$
- 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



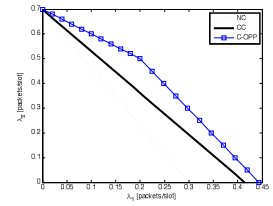
- If $Q_1 \neq 0$, S_2 always transmits w.p $\boldsymbol{p}$; transmits a dummy packet if it's empty
- Queues decoupled in the dominant system → stability region tractable
- The original system and the dominant system are "indistinguishable" at the boundary

➢Step 2: Constraint optimization problem, to determine the optimal transmission probability at the relay ($\boldsymbol{p}^*$) *s.t.* the resulting stability region is maximized

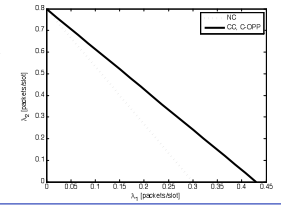
Results

- **if** $\eta = q^{(2)}_{1|1}(1-q^{(d)}_{1|1})q^{(d)}_{1|1,2} + (q^{(2)}_{1|1} + q^{(d)}_{1|1} - q^{(2)}_{1|1}q^{(d)}_{1|1})q^{(d)}_{2|1,2}$
$- (q^{(2)}_{1|1} + q^{(d)}_{1|1} - q^{(2)}_{1|1}q^{(d)}_{1|1} - q^{(d)}_{1|1,2})q^{(d)}_{2|2} > 0$
  - $p^*=1$, for $\lambda_1 \le q^{(d)}_{1|1,2}$

$$p^* = \frac{q^{(2)}_{1|1} + q^{(d)}_{1|1} - q^{(2)}_{1|1}q^{(d)}_{1|1} - \lambda_1}{q^{(2)}_{1|1} + q^{(d)}_{1|1} - q^{(2)}_{1|1}q^{(d)}_{1|1} - q^{(d)}_{1|1,2}}, \text{ for } \lambda_1 > q^{(d)}_{1|1,2}$$



- **if** $\eta < 0$
  - $p^*=0$, reduces to the conventional scheme



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