Motivation

- Two-way traffic: ad-hoc and peer-to-peer systems.
- Likely scenario: multiple intermediate relays cooperatively assisting end nodes.
- Impact of stochastic arrivals: how do we best communicate two-way stochastic traffic using the intermediate relays and how do the resulting stability regions compare?
- Policies with queues at relays (hop-by-hop scheduling) or without queues at relays (immediate forwarding).

Methodology

- Throughput optimal policy: All queues must be bounded for input rates in the stability region.
- Multiple relays, two-way stochastic traffic [Ciftcioglu-Yener-Berry 2008]
  - Rate allocation and relaying technique determined according to channel conditions and queue states jointly.
- Models: (i) queues at relays (ii) no queuing at relays
  - Objective: Compare the resulting stability regions
  - Network flow problem

Transmission Policy

Alternatives

- Phase I: Information transmitted from sources to the relays
- Phase II: Information transmitted from relays to end nodes
  - Relays beamform to both directions \(\rightarrow\) power splitting
  - One relay transmits to both directions \(\rightarrow\) power splitting
  - One relay forwards data with XOR network coding

Hop-by-Hop scheduling with queues at relays
- Schedule either Phase I or Phase II operation:
  - Phase I: determine relay(s) to send, operating rate point
  - Phase II: select relay(s) to be used and forwarding strategy with power splitting parameter \(\rightarrow\) beamforming or superposition coding selected.

Immediate forwarding
- Two phases scheduled jointly, time division determined

Stability Regions—Analysis

Set of arrival rate vectors \(\rho_1, \rho_2\) supported
- Assume only cooperative traffic forwarded by both relays \(S(=2,3)\)

Hop-by-Hop scheduling

\[
\begin{align*}
\rho_1 &= f_{1,2} = f_{3,4} \\
\rho_2 &= f_{3,4}
\end{align*}
\]

Flow conservation equations

<table>
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<tr>
<th>(\Delta R_{1,2})</th>
<th>(\Delta R_{3,4})</th>
<th>(\Delta R_{5,6})</th>
<th>(\Delta R_{7,8})</th>
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Immediate forwarding

\[
\begin{align*}
\rho_1 &= f_{1,2} \\
\rho_2 &= f_{3,4}
\end{align*}
\]

\(\lambda = \min[(\Delta R_{1,2}), (\Delta R_{3,4}), (\Delta R_{5,6}), (\Delta R_{7,8})] \in [0,1]

Phase I:
- Phase I—operation: operating point is one of the two MAC corner points of each mode.
- Sources use one of a finite number of rates.
- Queues at relays

Immediate Forwarding (IF):
- Compute Phase I vs Phase II durations in each slot
- Coding rates from a continuum

Simulation Results—Queue Backlogs

- Equal channel gains
- Mean arrival rate from both sources identical.
- Higher load supported with multiple relays—beamforming
- 2-hop operation outperforms 4-hop operation

Observations & Forward Look

- Queuing at the relays and immediate forwarding result identical stability regions for static channel gains with different design trade-offs for larger networks.
- Hop-by-hop: Better for >2 serial relays (line network)
- Immediate forwarding: Better for >2 parallel relays in two-hop scenario.
- Relative congestion levels and channel conditions determine the resource allocation policy.
- Future work: Exploit the time variations in the channel to find throughput optimal policies.
- Future work: Non-decode and forward relay and throughput optimal strategies.