Virtual MISO Triggers in Wi-Fi-like Networks

Oscar Bejarano
Edward W. Knightly

Signal Outage in Fading Channels

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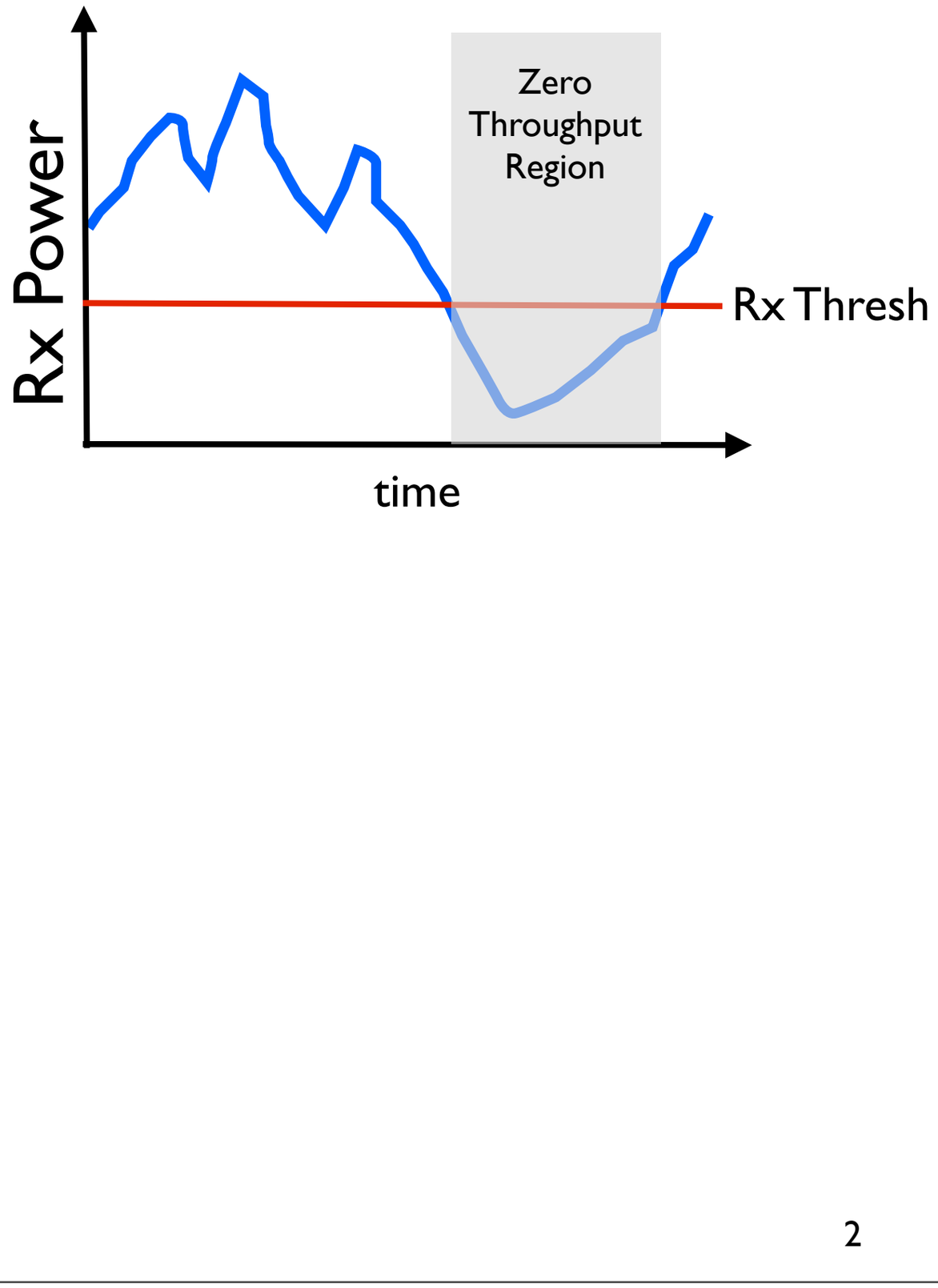

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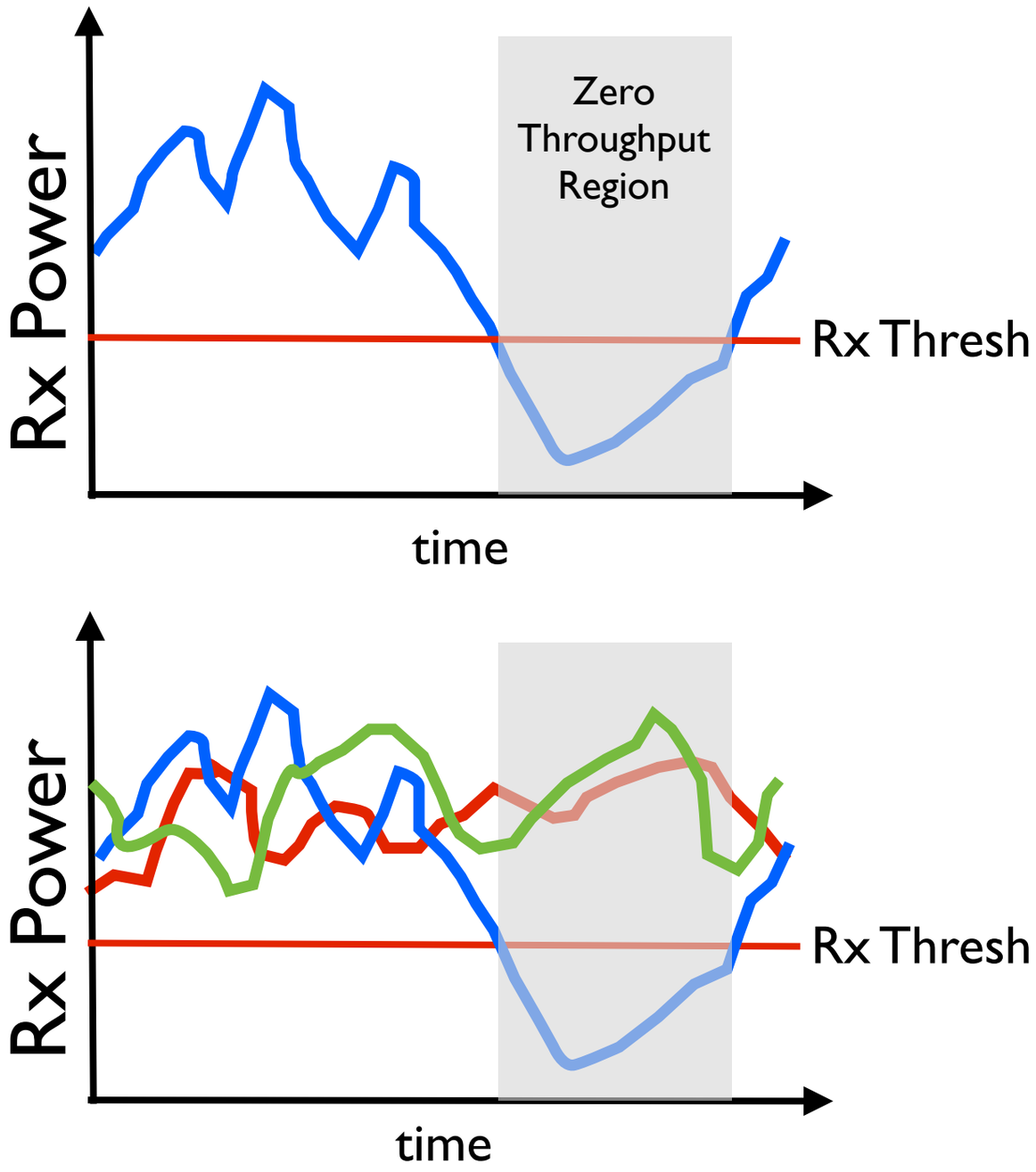

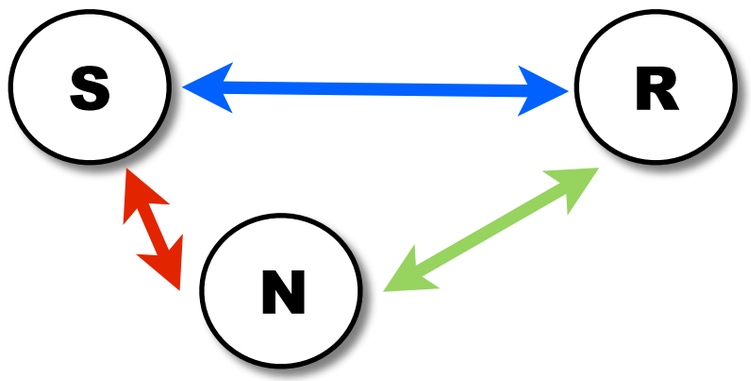

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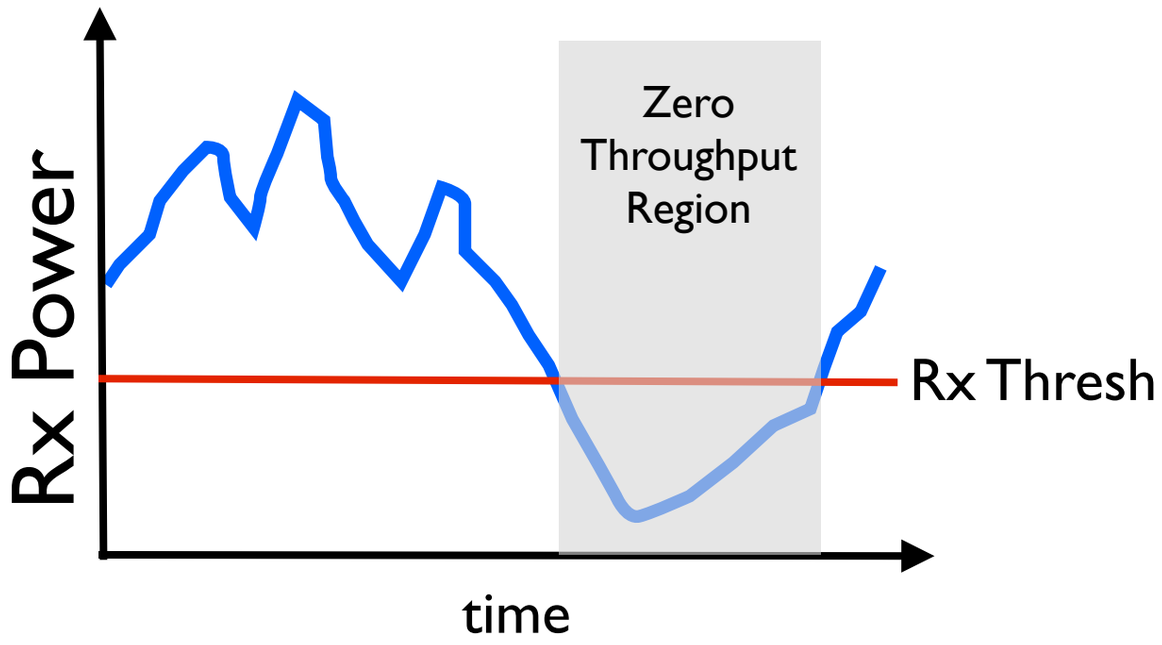

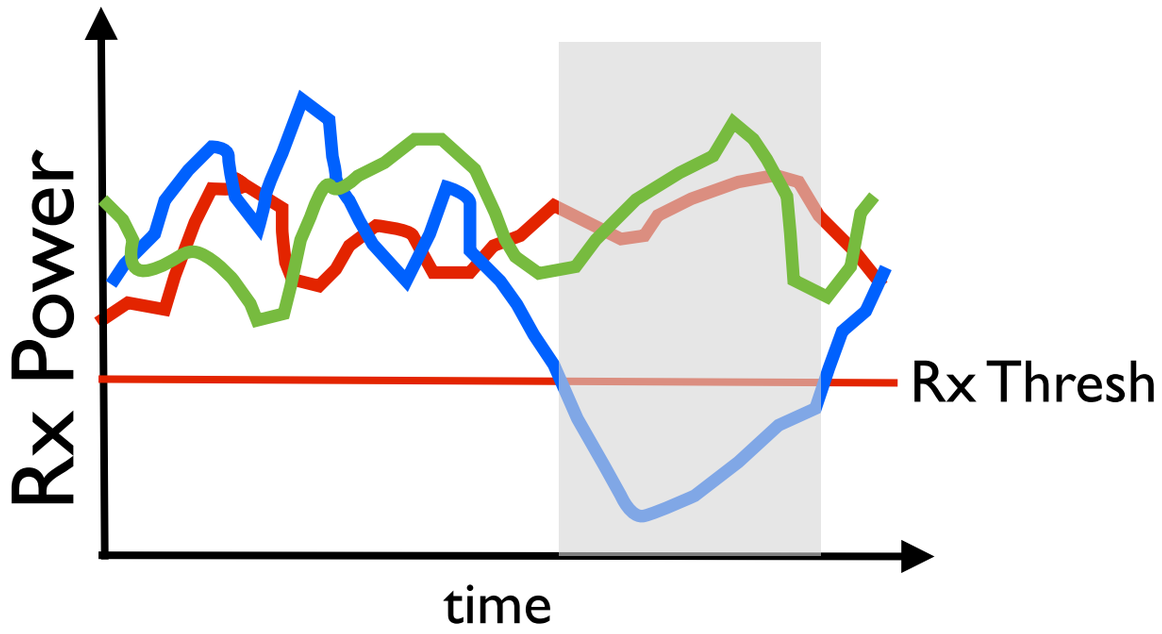

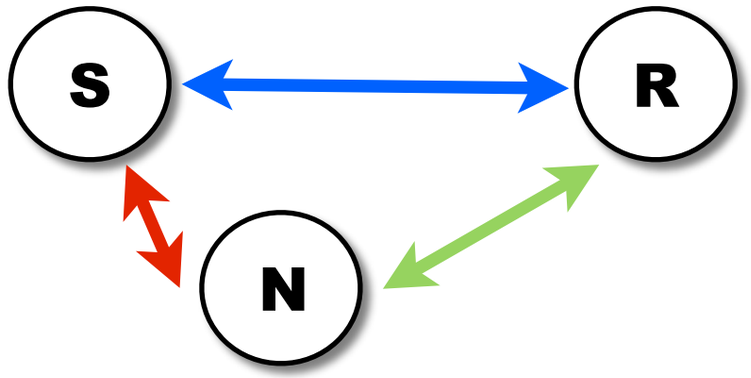

How do we exploit this *independence* among different paths?

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Transmit Spatial Diversity

- Multiple transmit antennas (antenna array) separated in distance, transmit redundant signals
- Consider:
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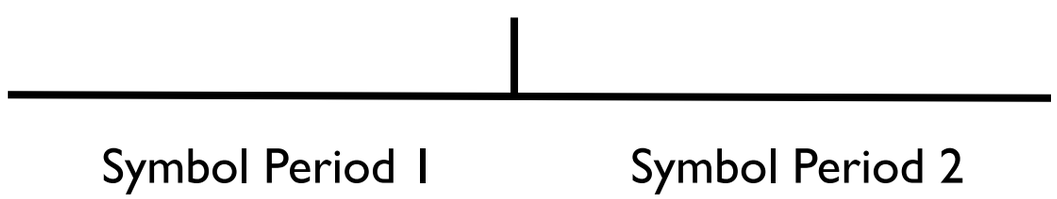
  - Orthogonal Space-Time Block Codes (i.e., Alamouti Scheme)



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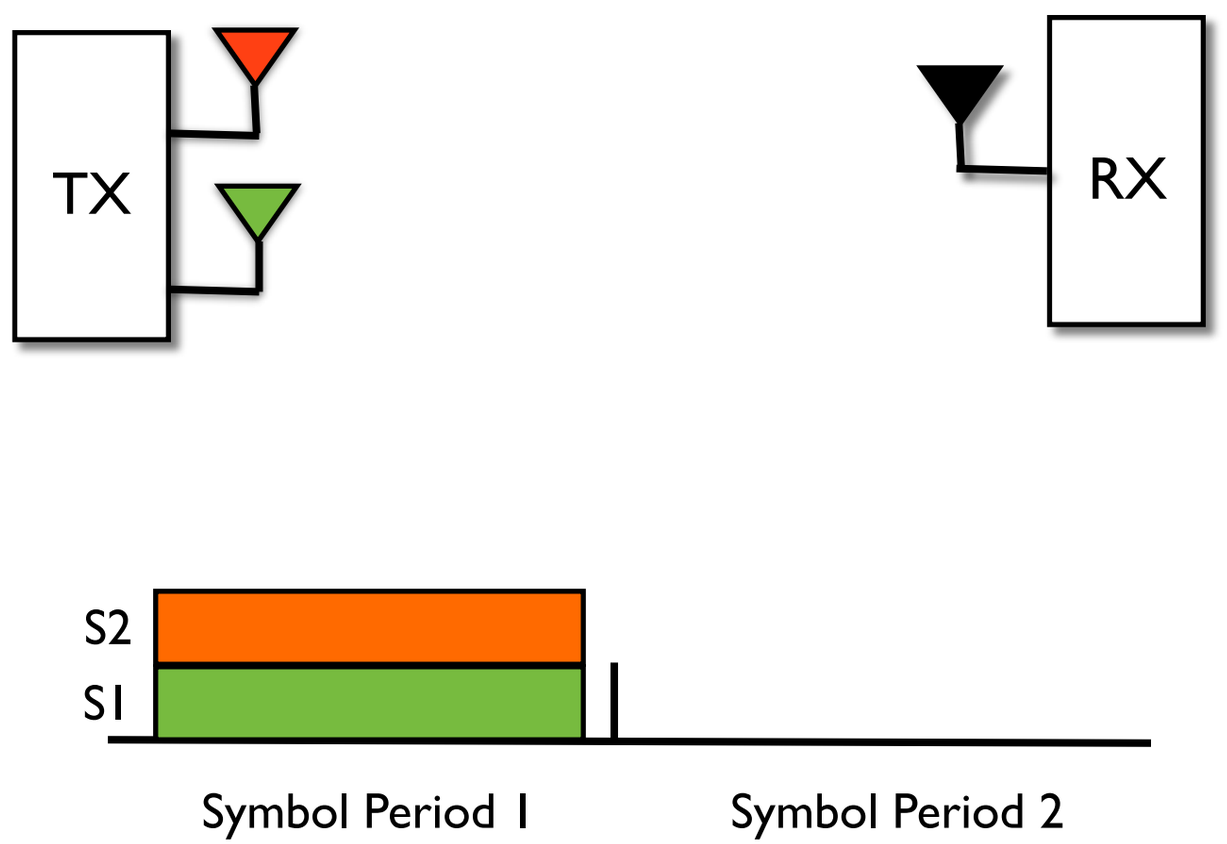

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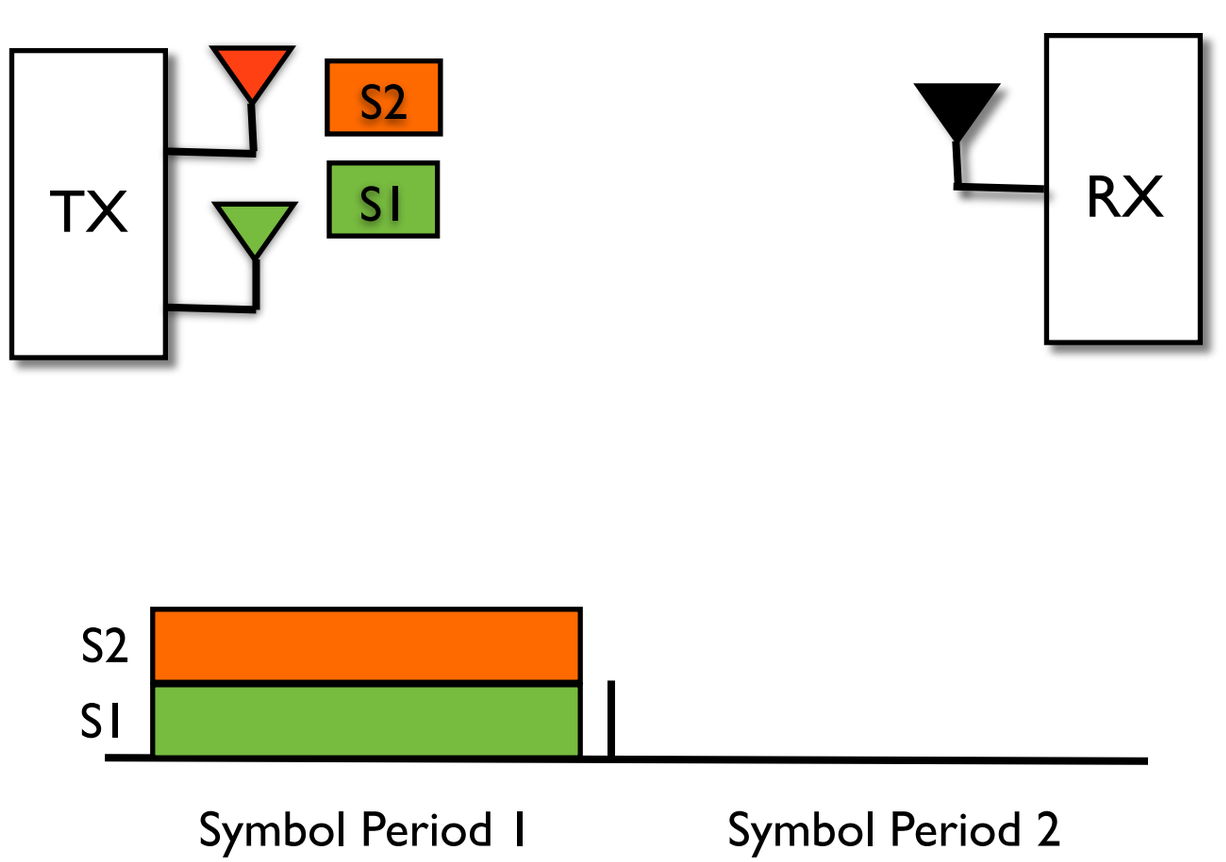

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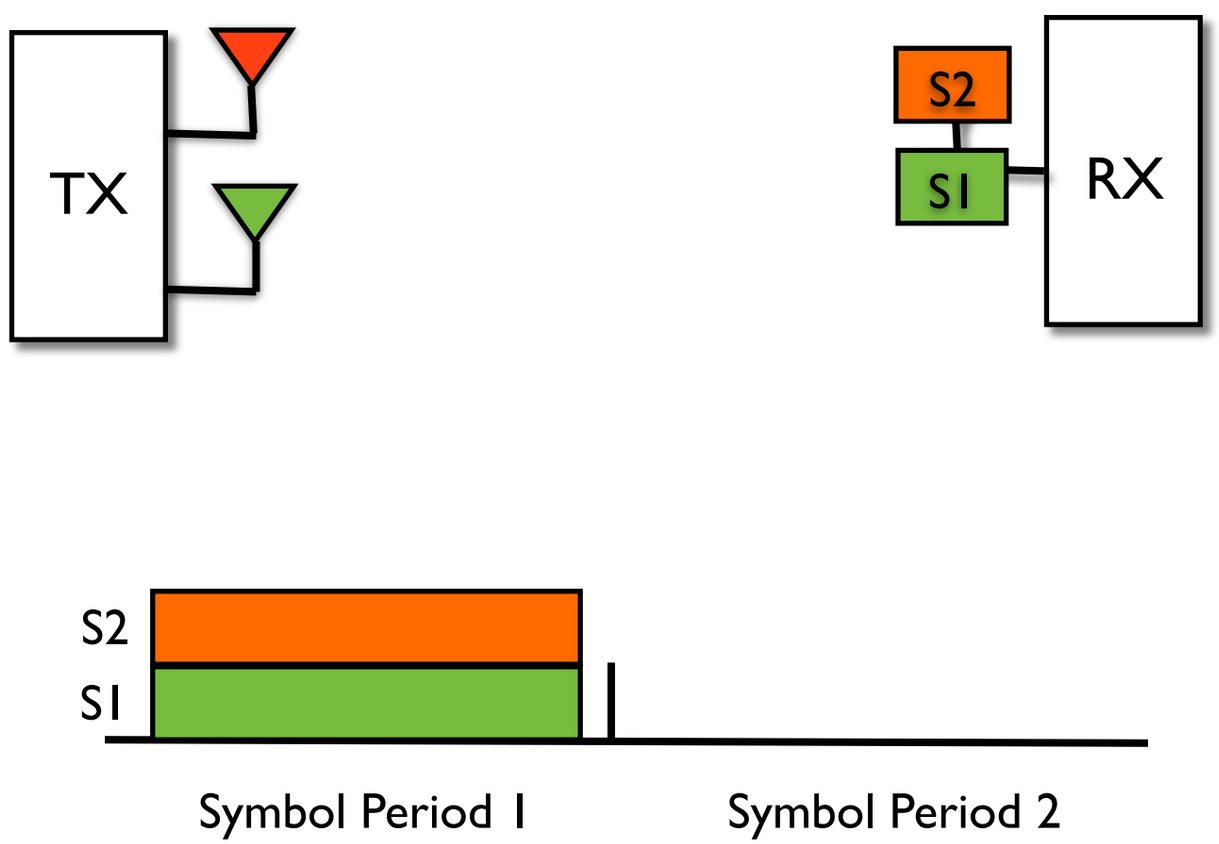

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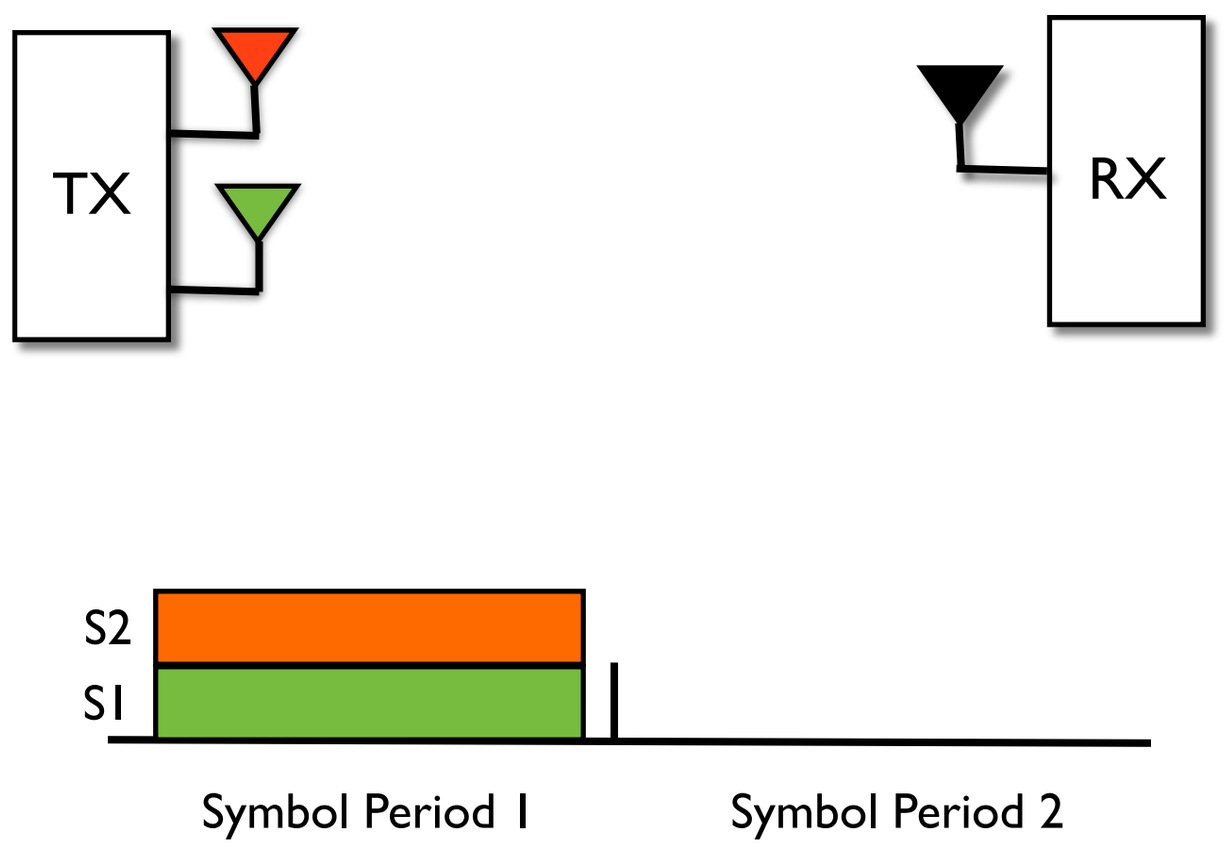

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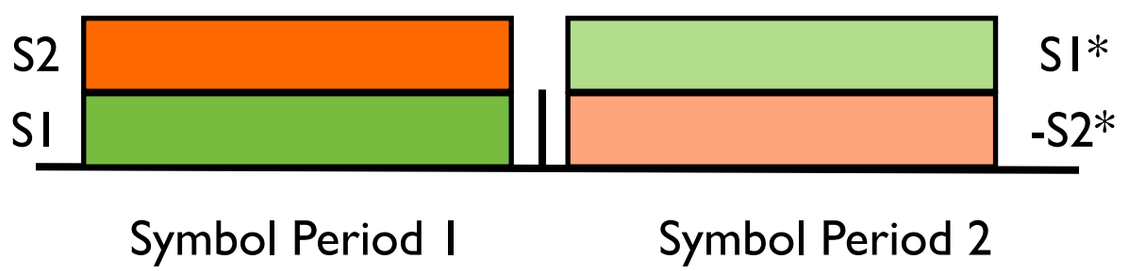

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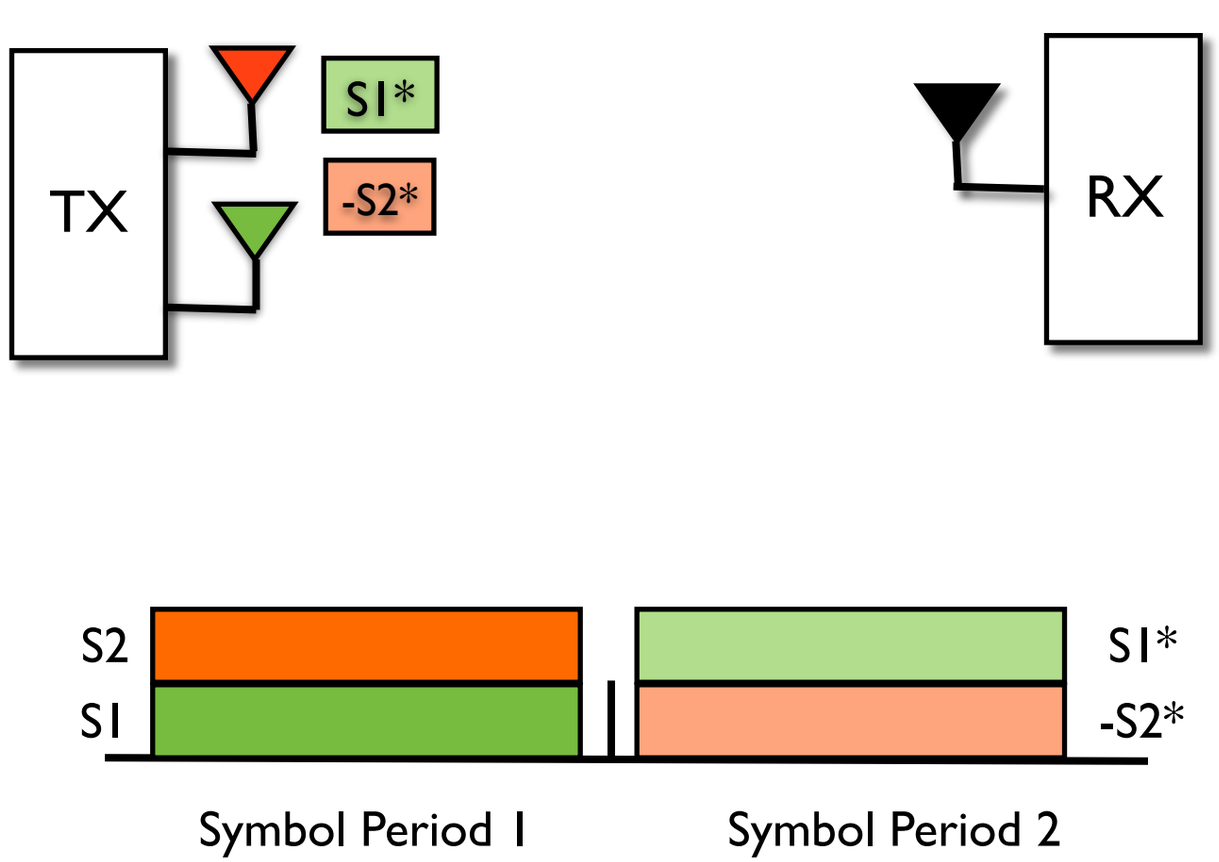

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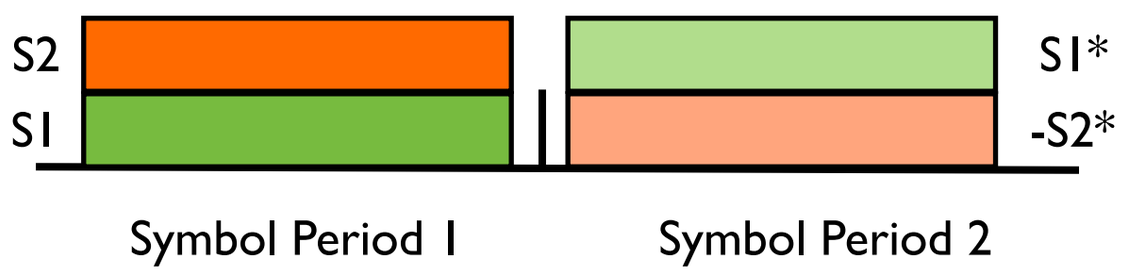

For *maximal transmit diversity gains*, we require antenna separation difficult to achieve in mobile devices

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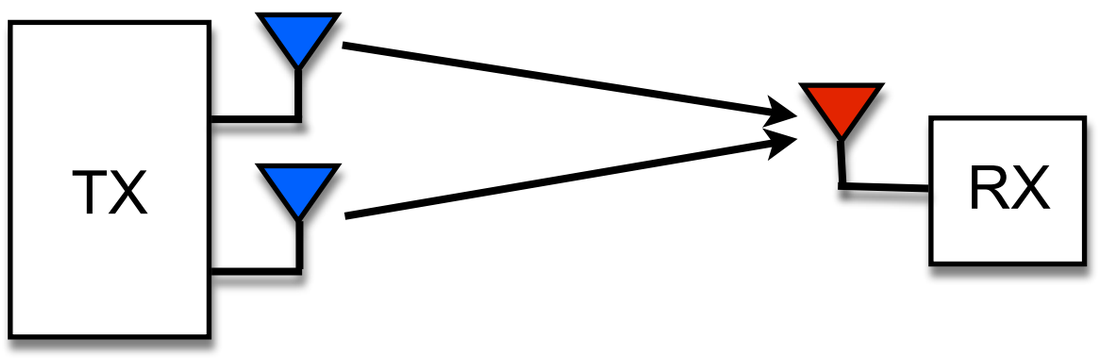
   1.1. Distributed System

   1.2. Single-Antenna Nodes

General Tx Diversity → vMISO/Cooperation



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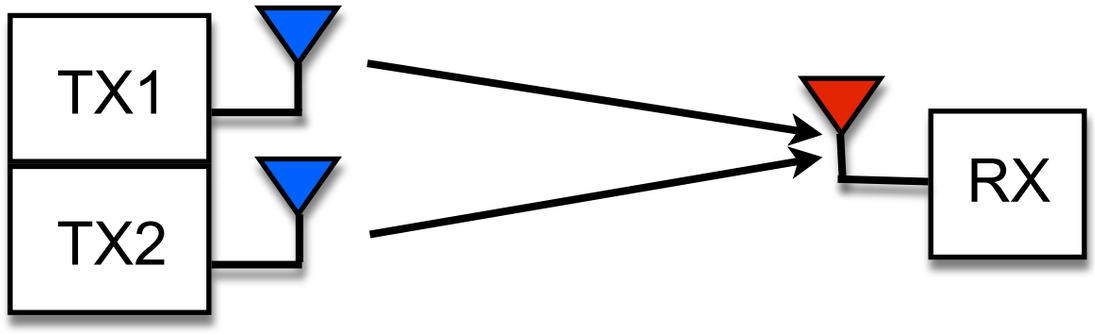

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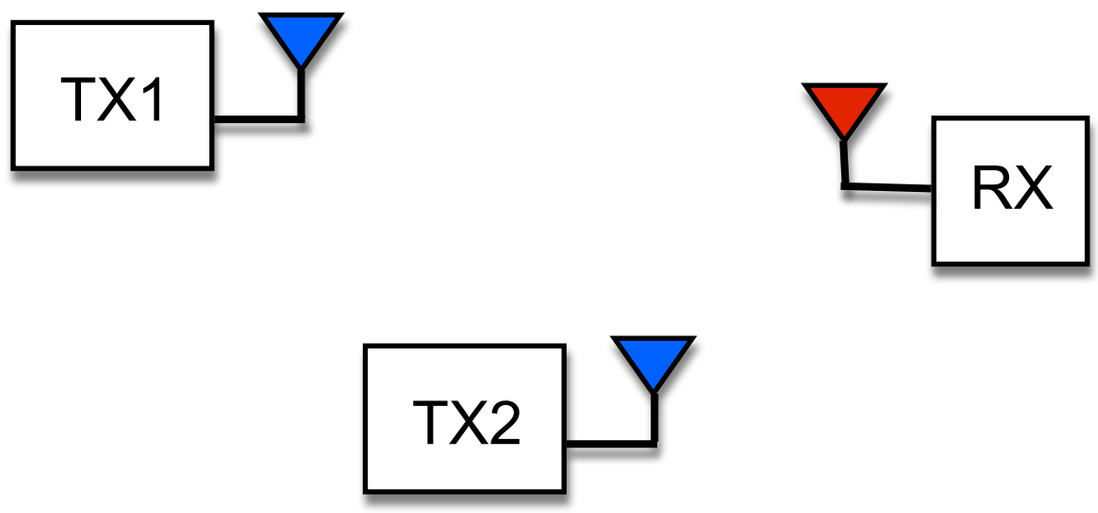

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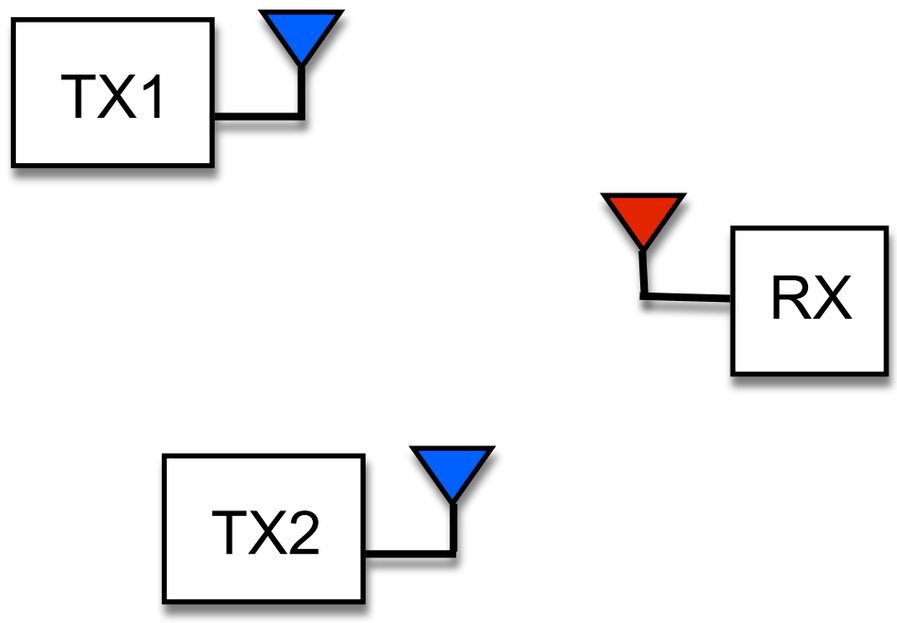

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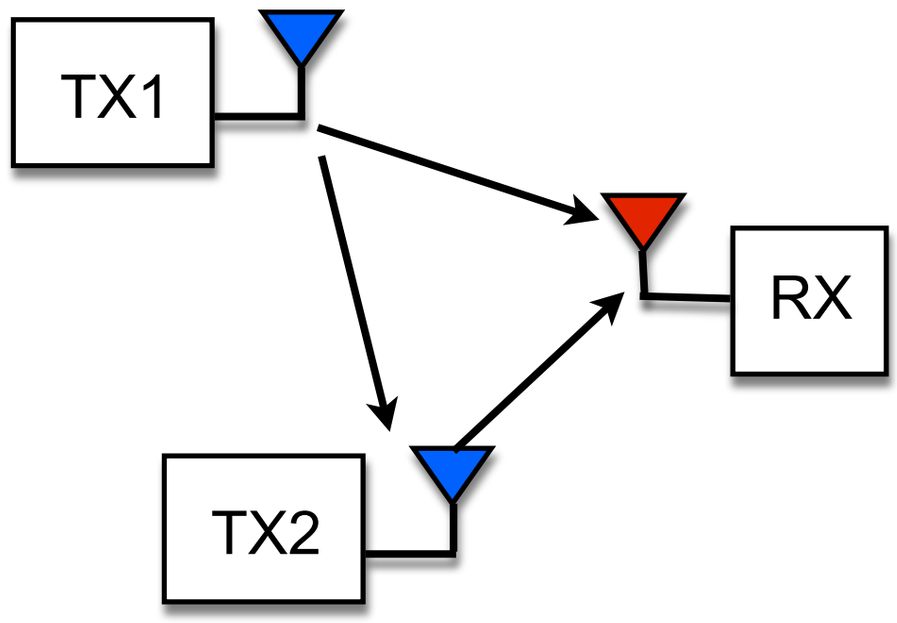

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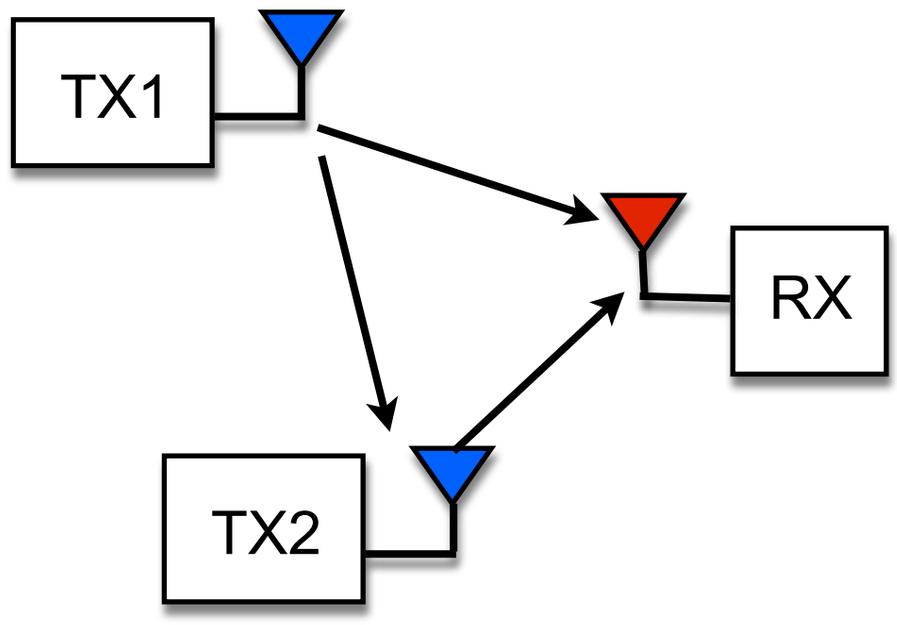

Use Alamouti Scheme

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vMISO Protocol Design Challenges

Triggering vMISO - Establish a criteria and mechanism used to trigger vMISO transmissions, i.e., how and when?

Cooperator/Relay Selection - Select a neighboring user as cooperator

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In particular, to provide the understanding needed to design *trigger policies* that maximize throughput performance gains

trigger policies → when should the cooperator be used?

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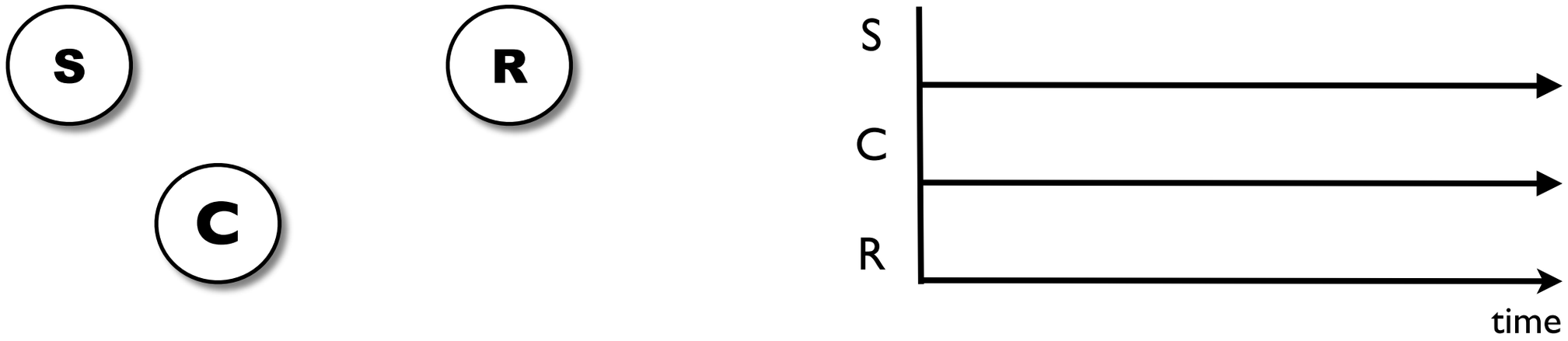

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Reacts to Failure

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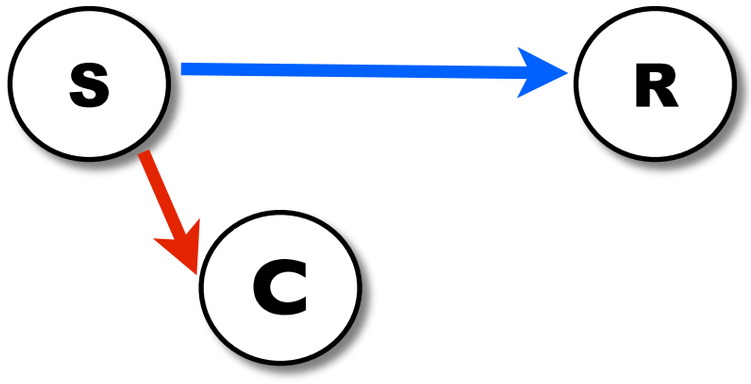

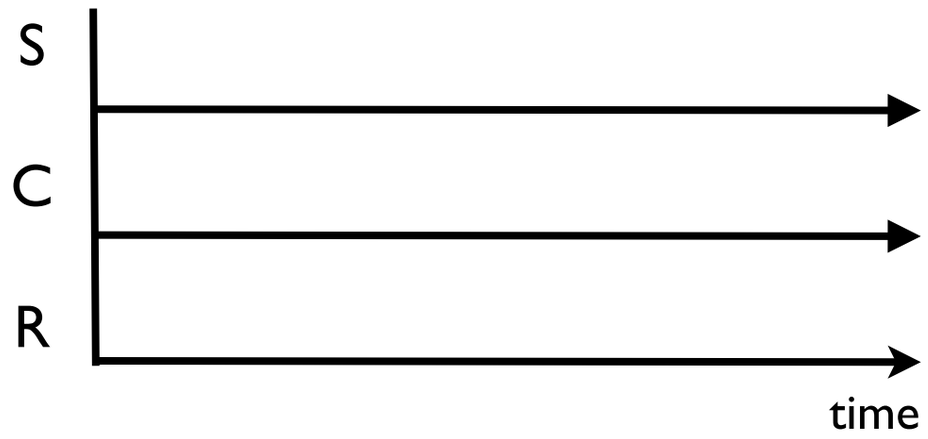

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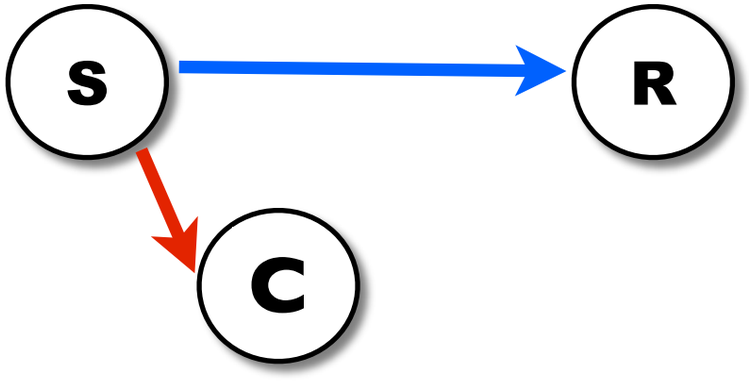

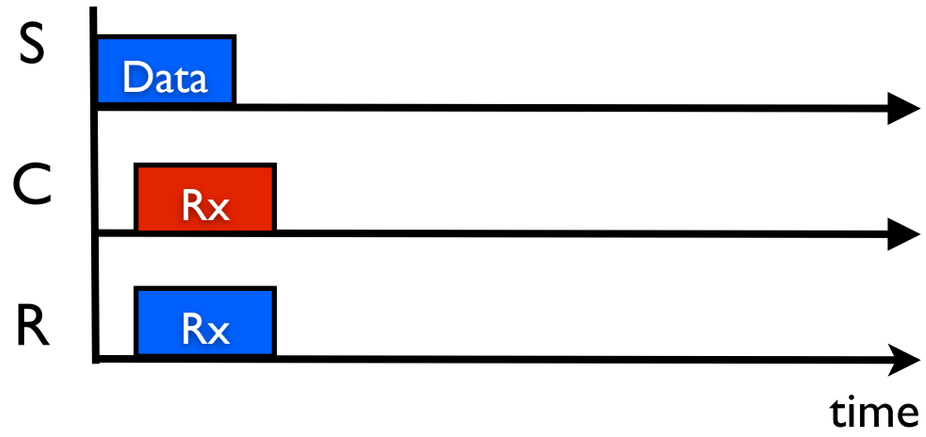

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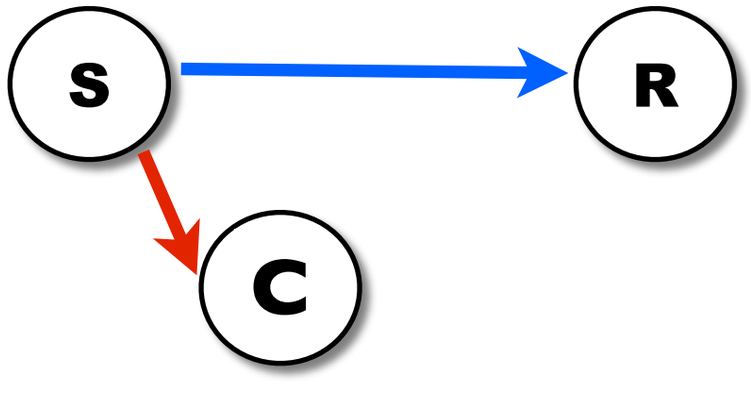

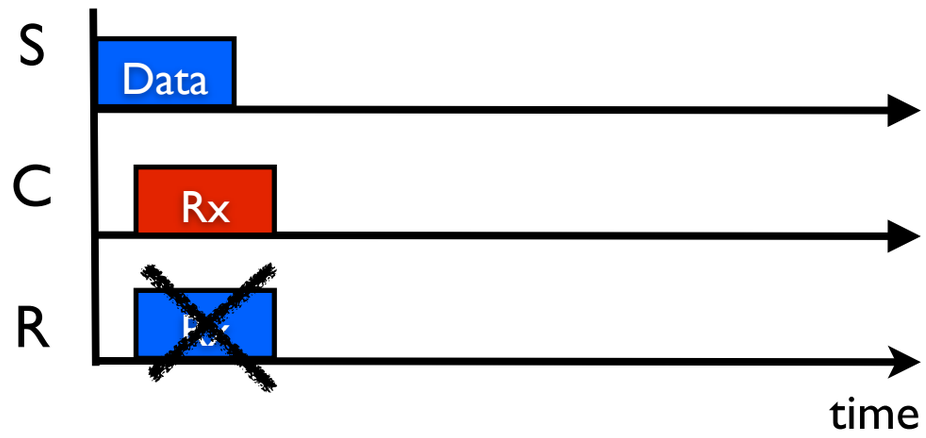

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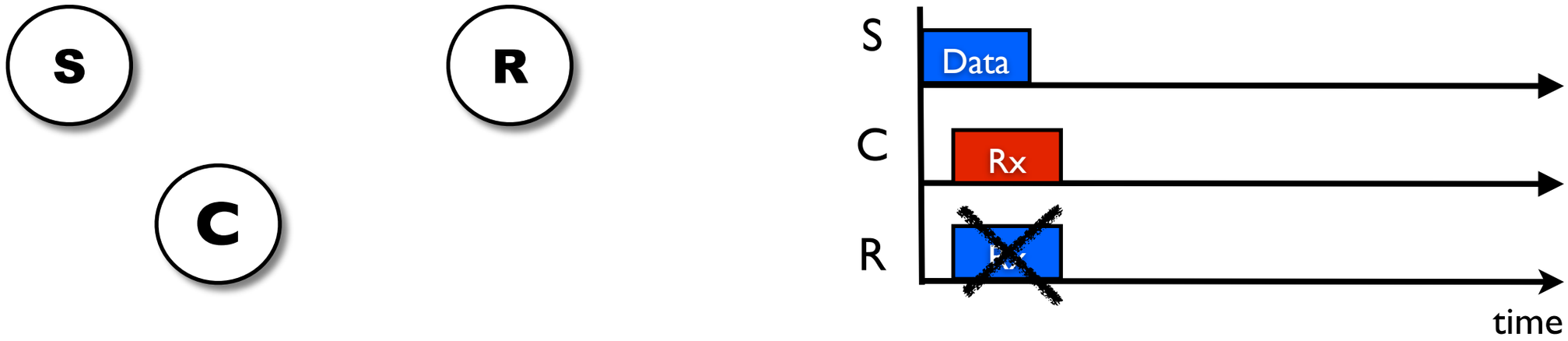

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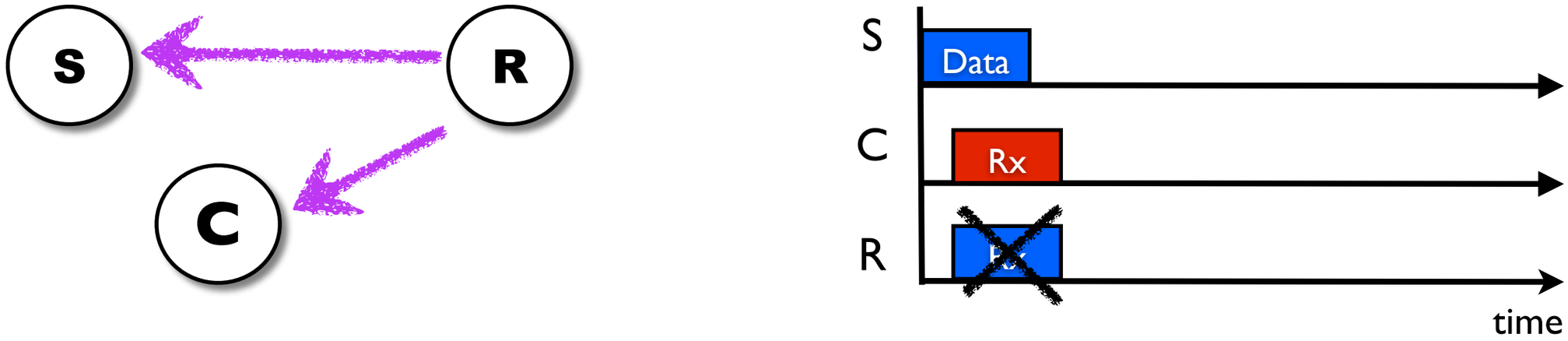

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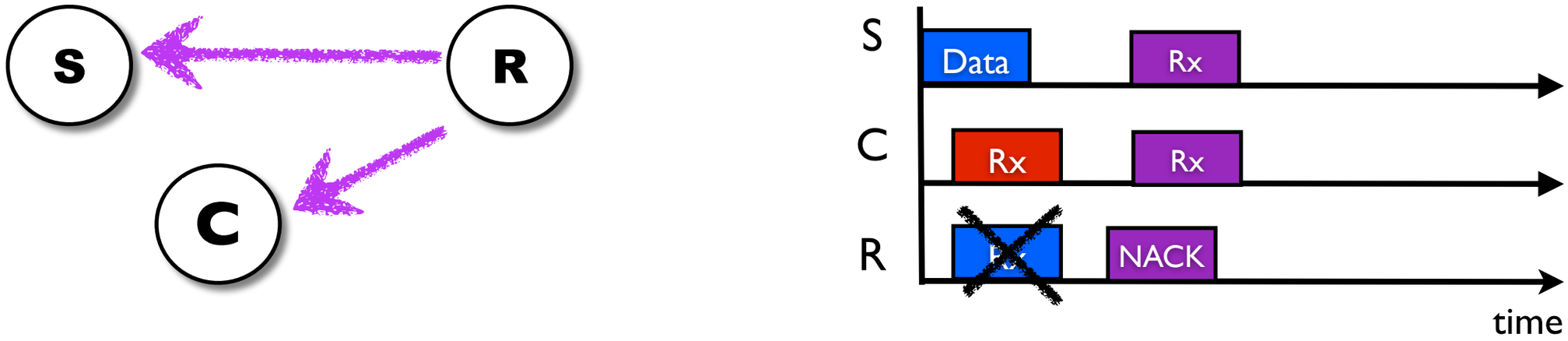

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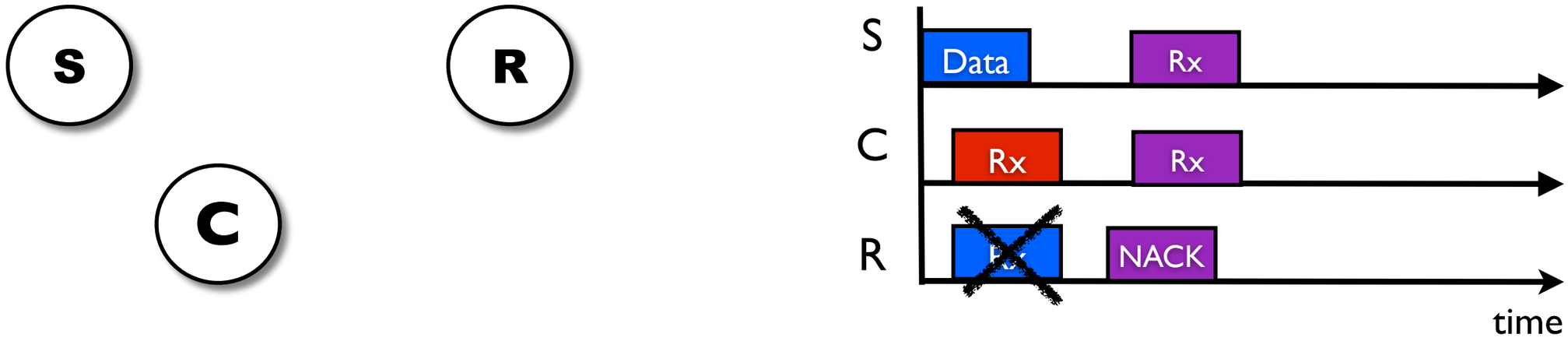

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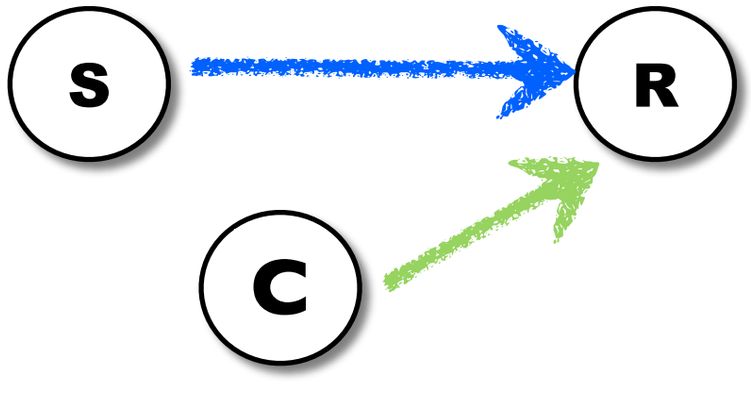

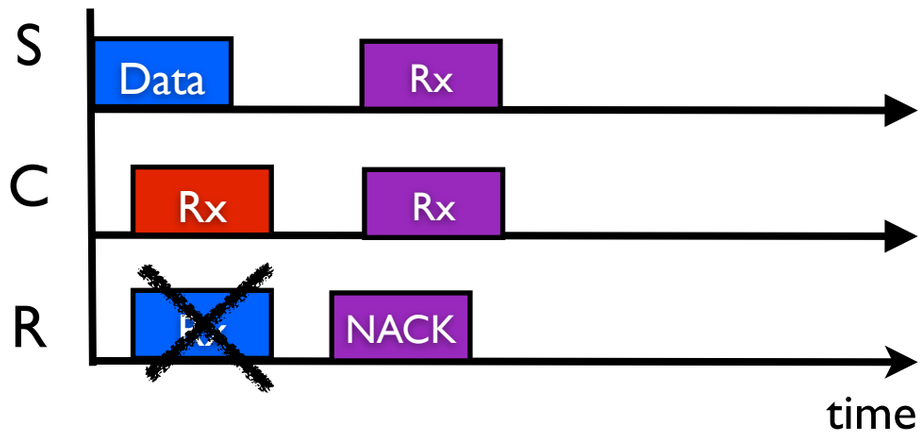

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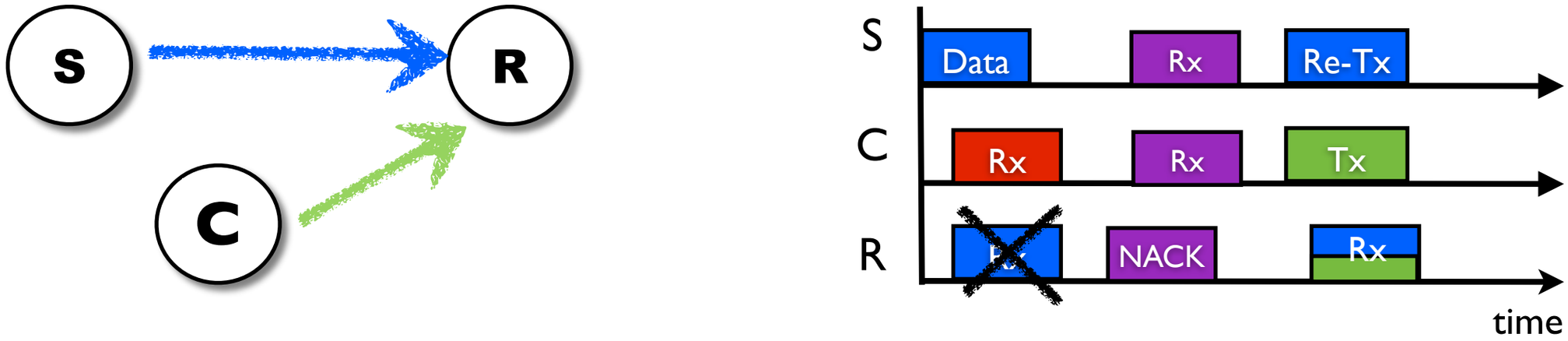

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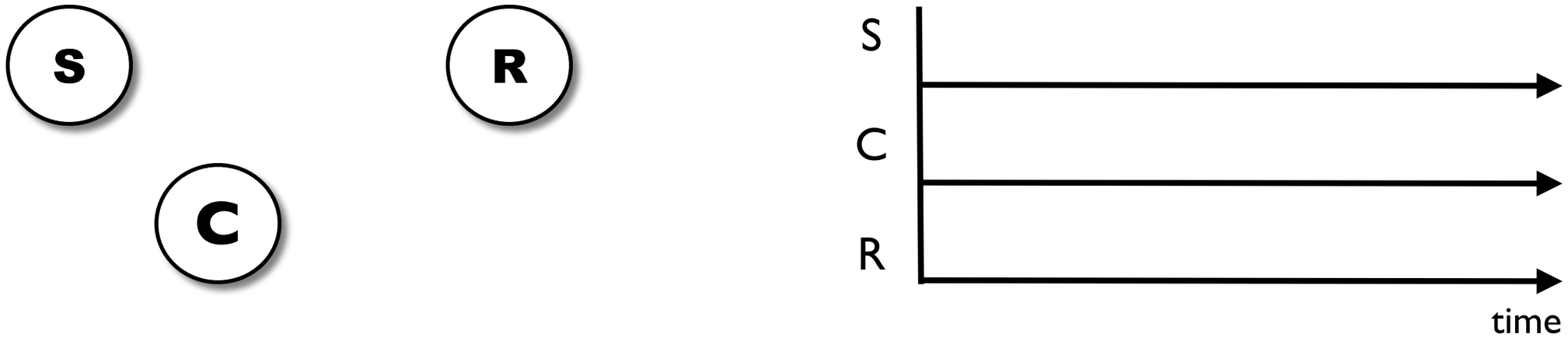

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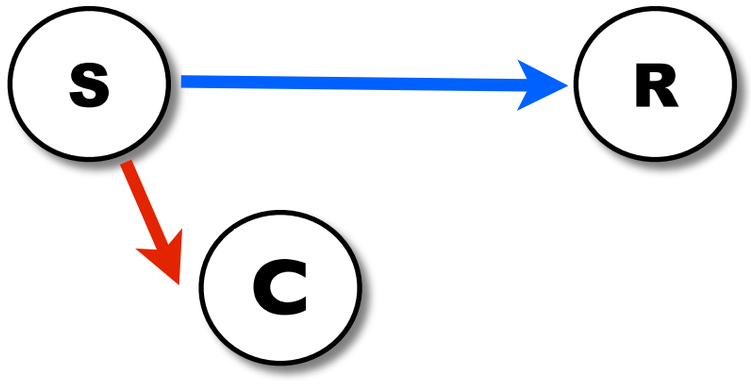

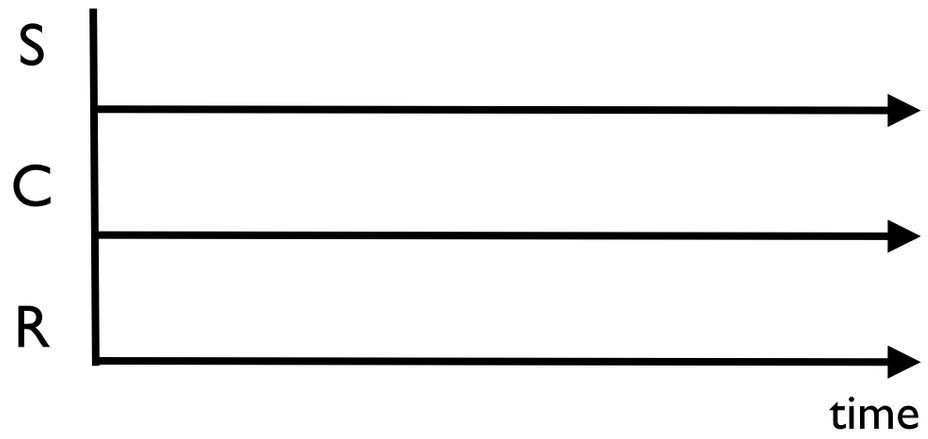

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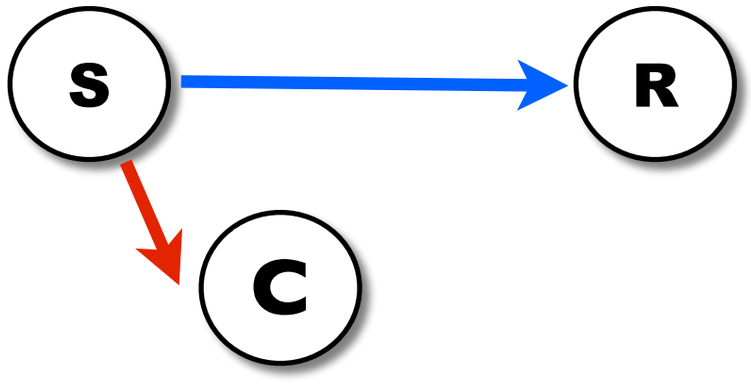

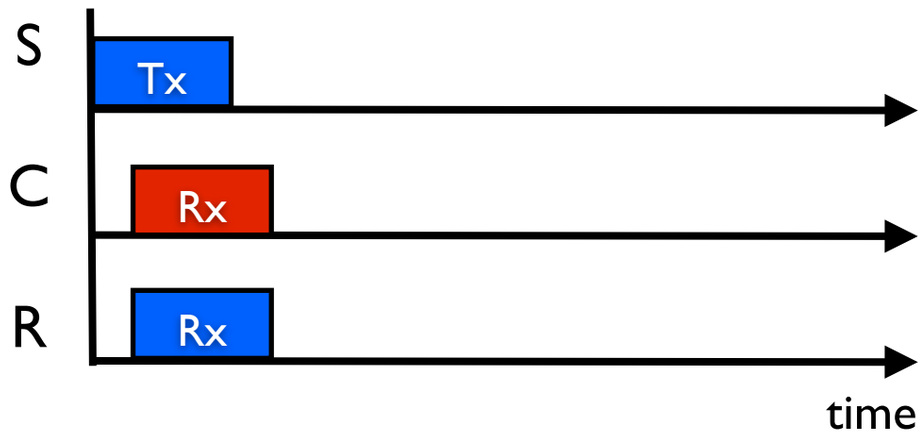

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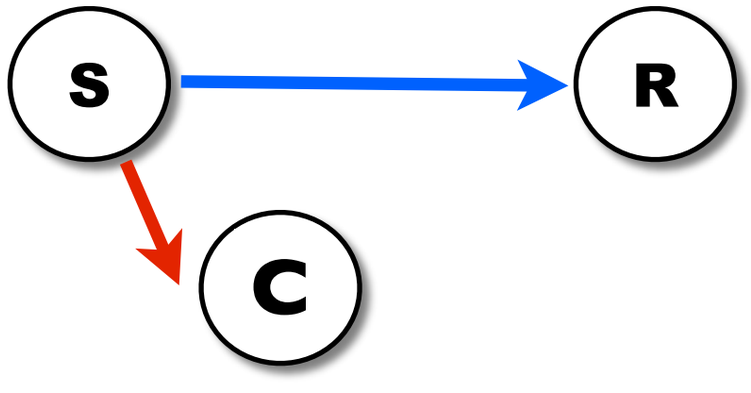

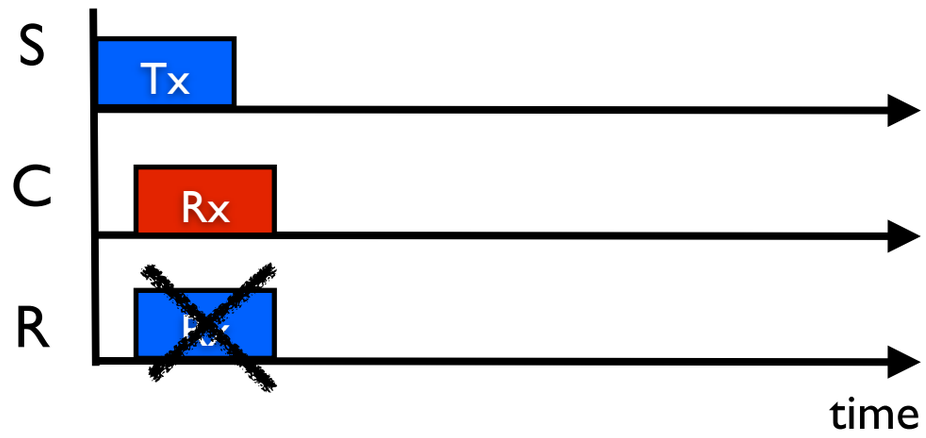

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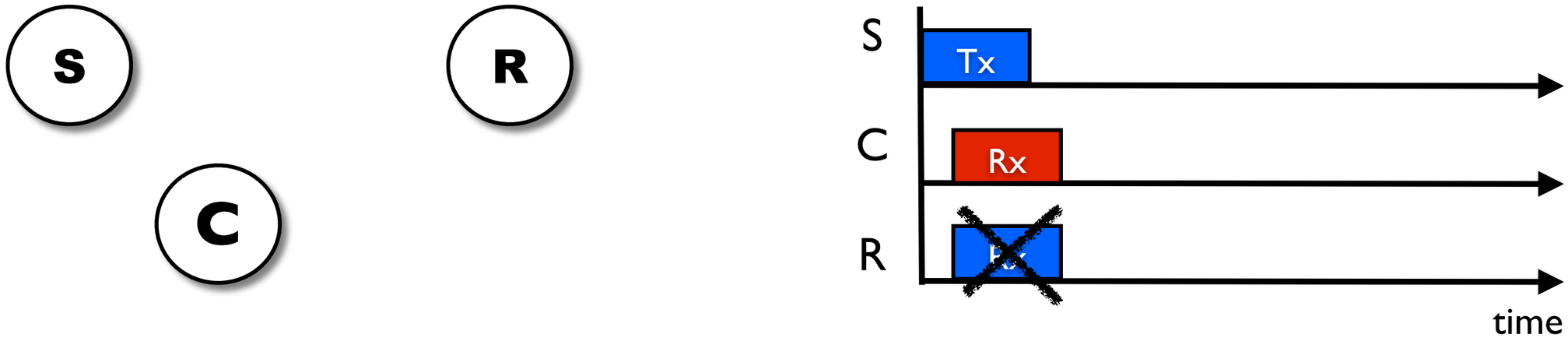

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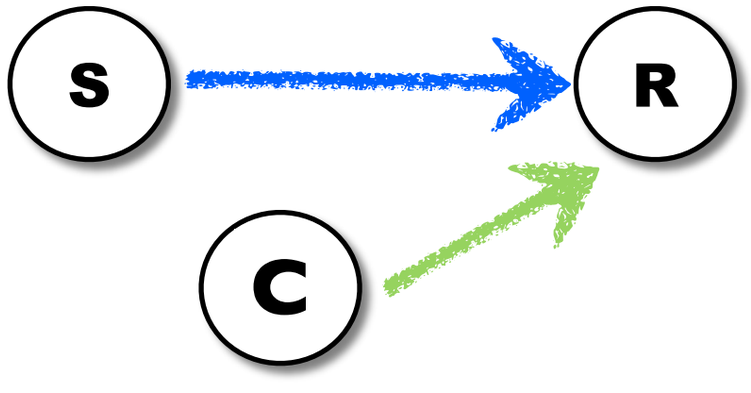

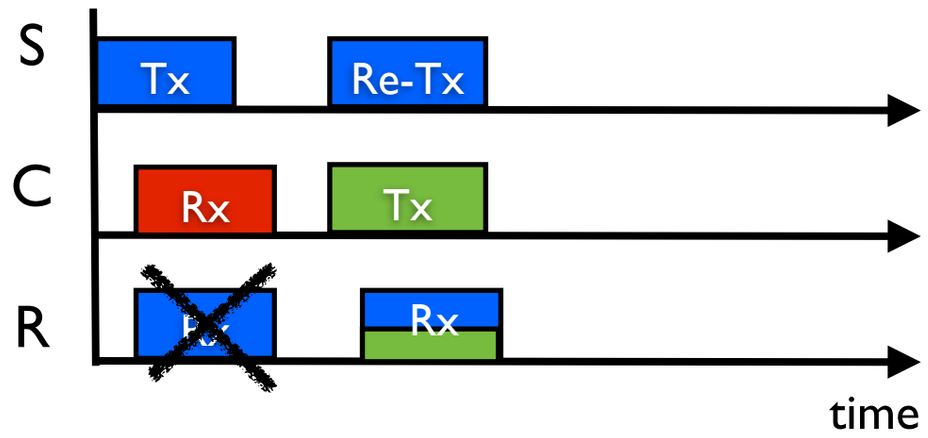

1) Initial transmission - Sender to Receiver
2) Neighboring node overhears transmission
3) Simultaneous coded retransmission (from Sender and Cooperator)

Prevents Failure

vMISO Triggers

1. Method employed to invoke a vMISO transmission:
   1.1. Reactive (On-Demand) - *Reacts* to a failed packet transmission
   1.2. Proactive - *Prevent* packet failures in an already known bad channel

We will show results only for Reactive

2. *Trigger policies* to identify scenarios in which vMISO transmissions yield a net throughput gain (or loss)

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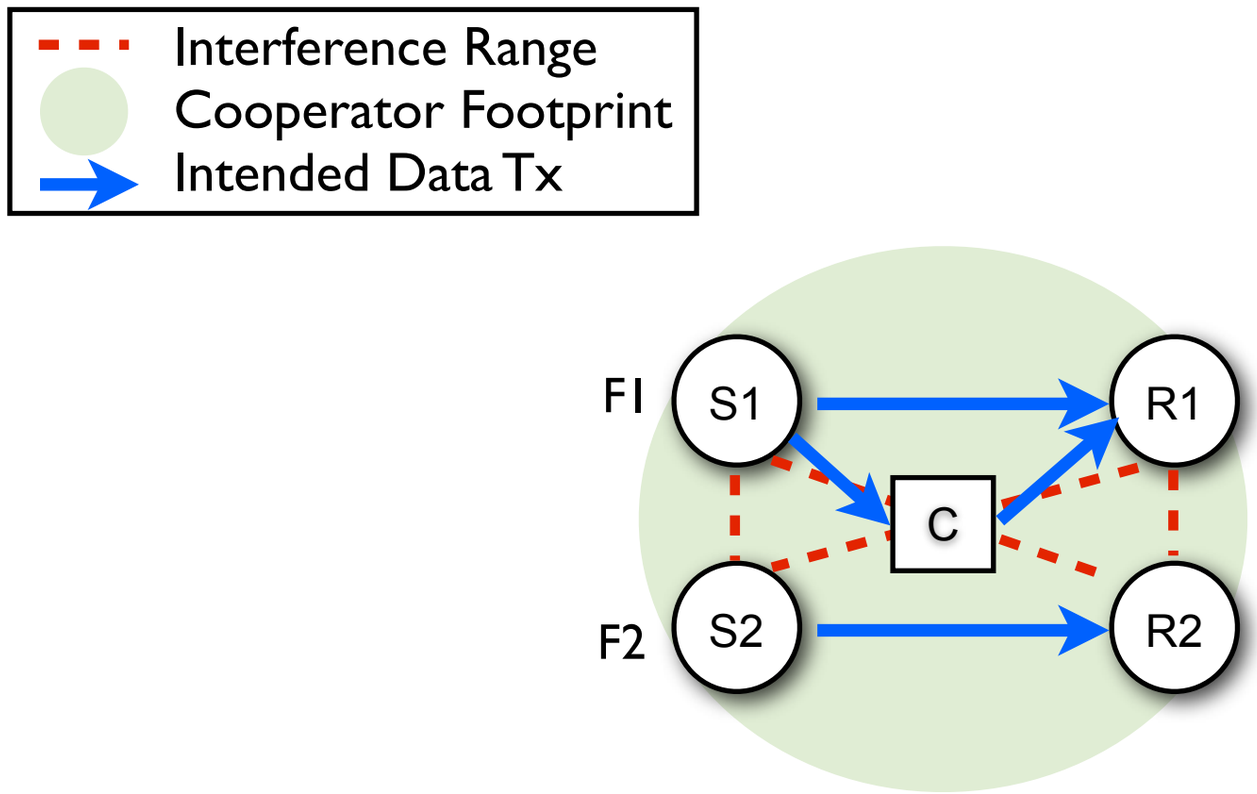
RICE

Trigger Policies in WLANs



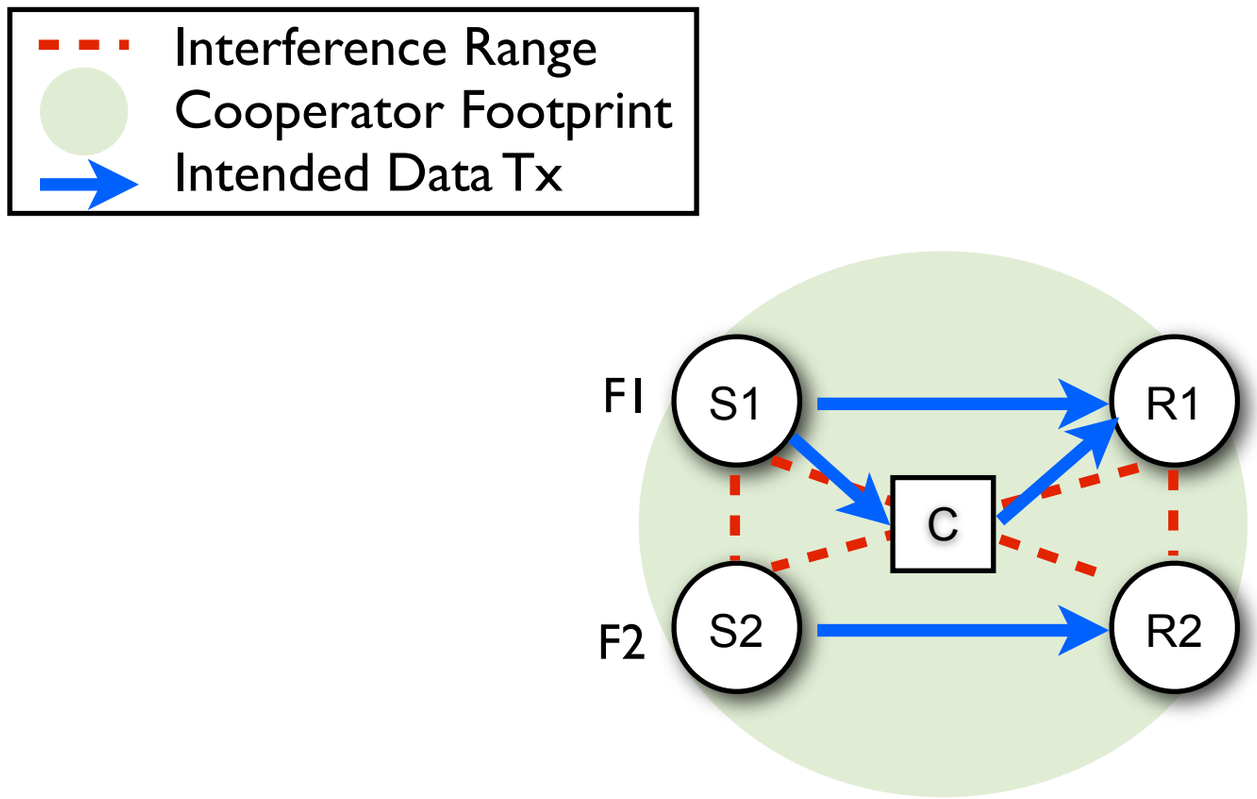
Fully Connected

High throughput gains for F1

Little to no cooperator interference with F2

Identify when the cooperator should or should not be used

Trigger Policies in WLANs



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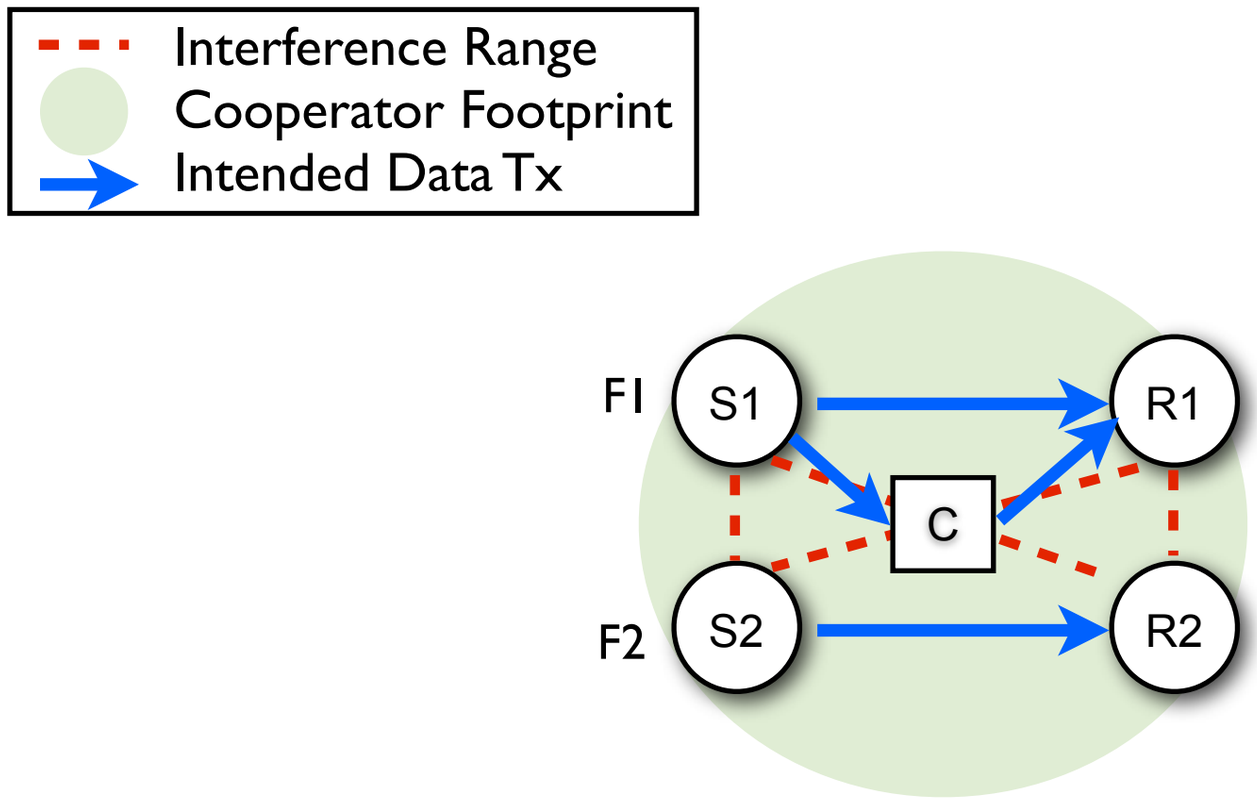

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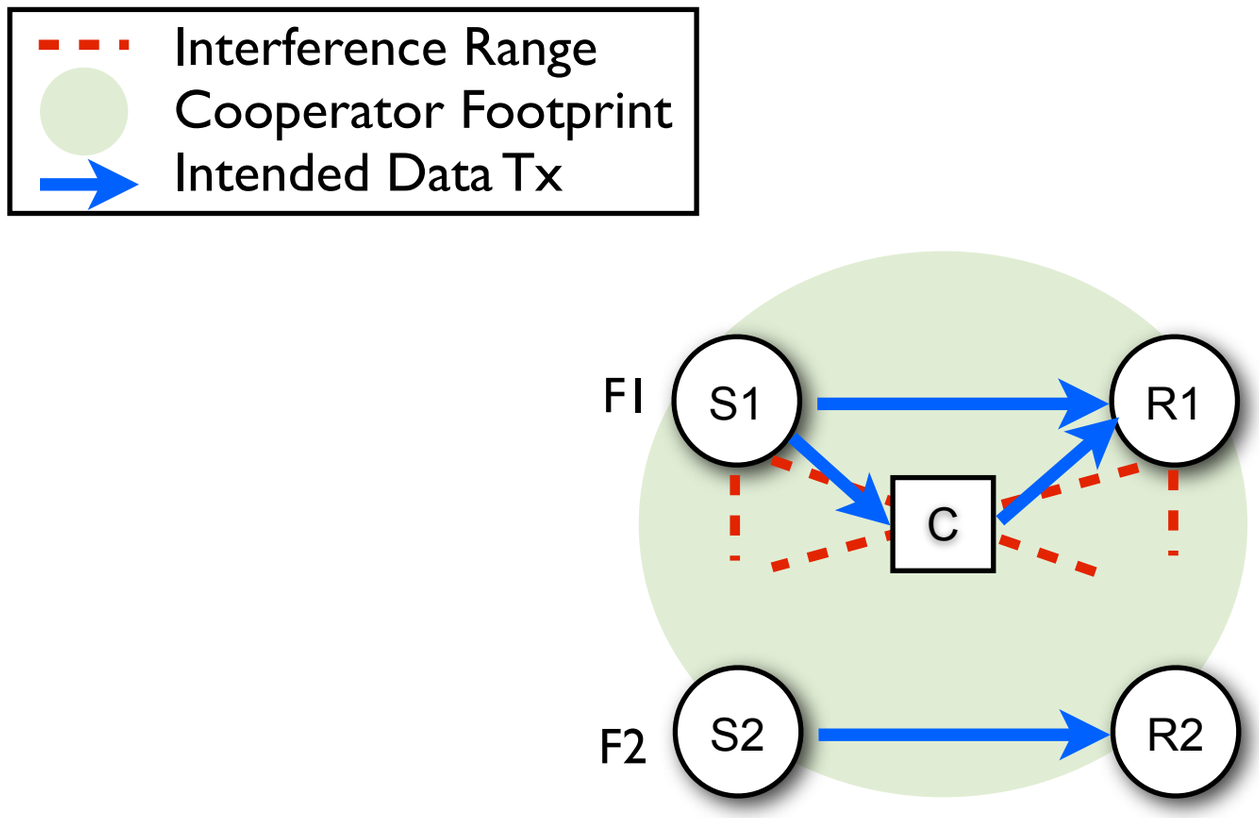

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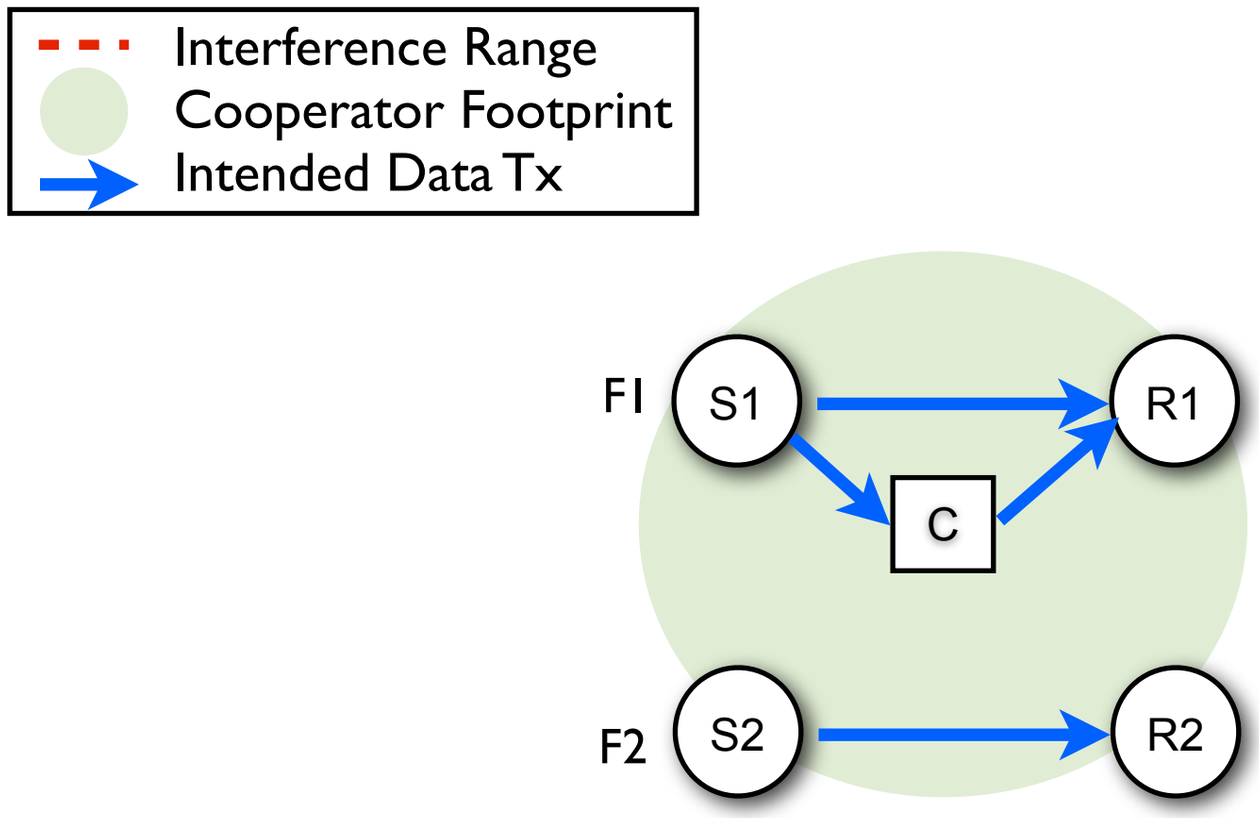

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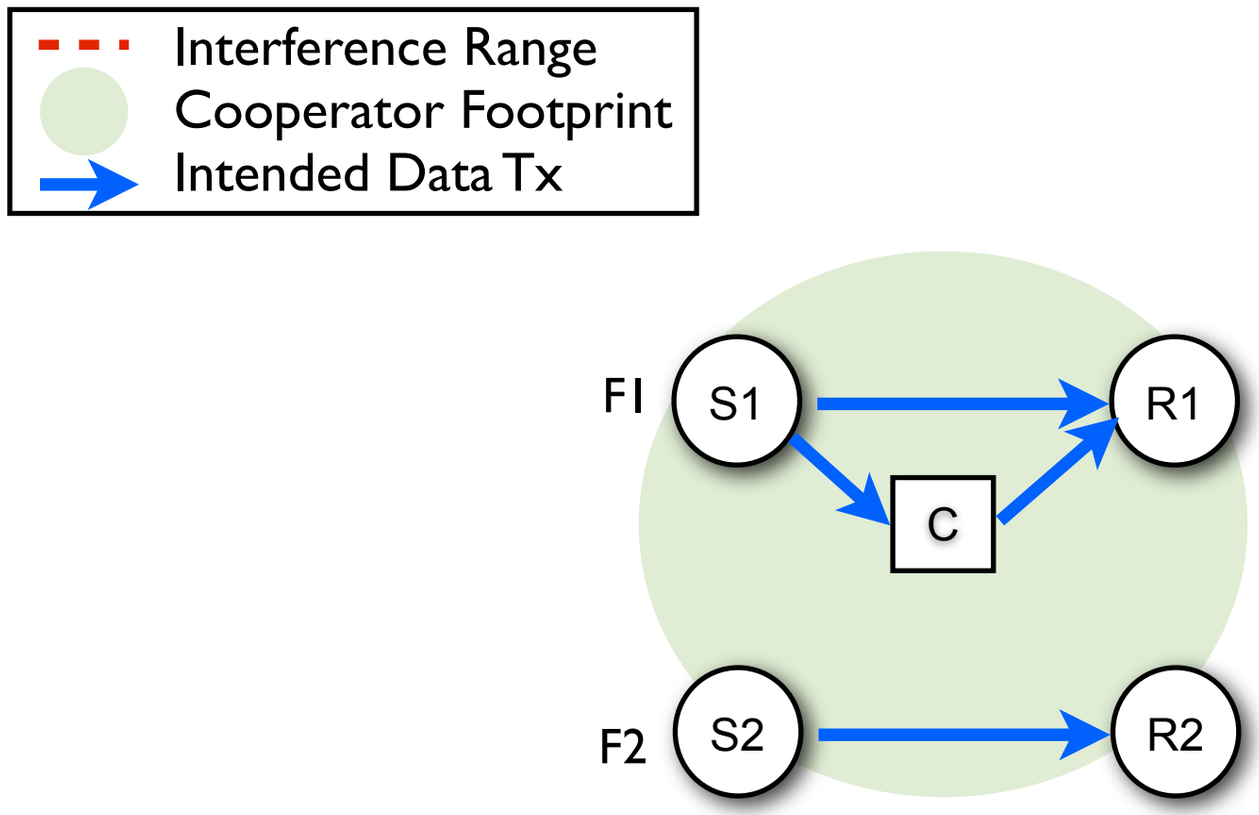

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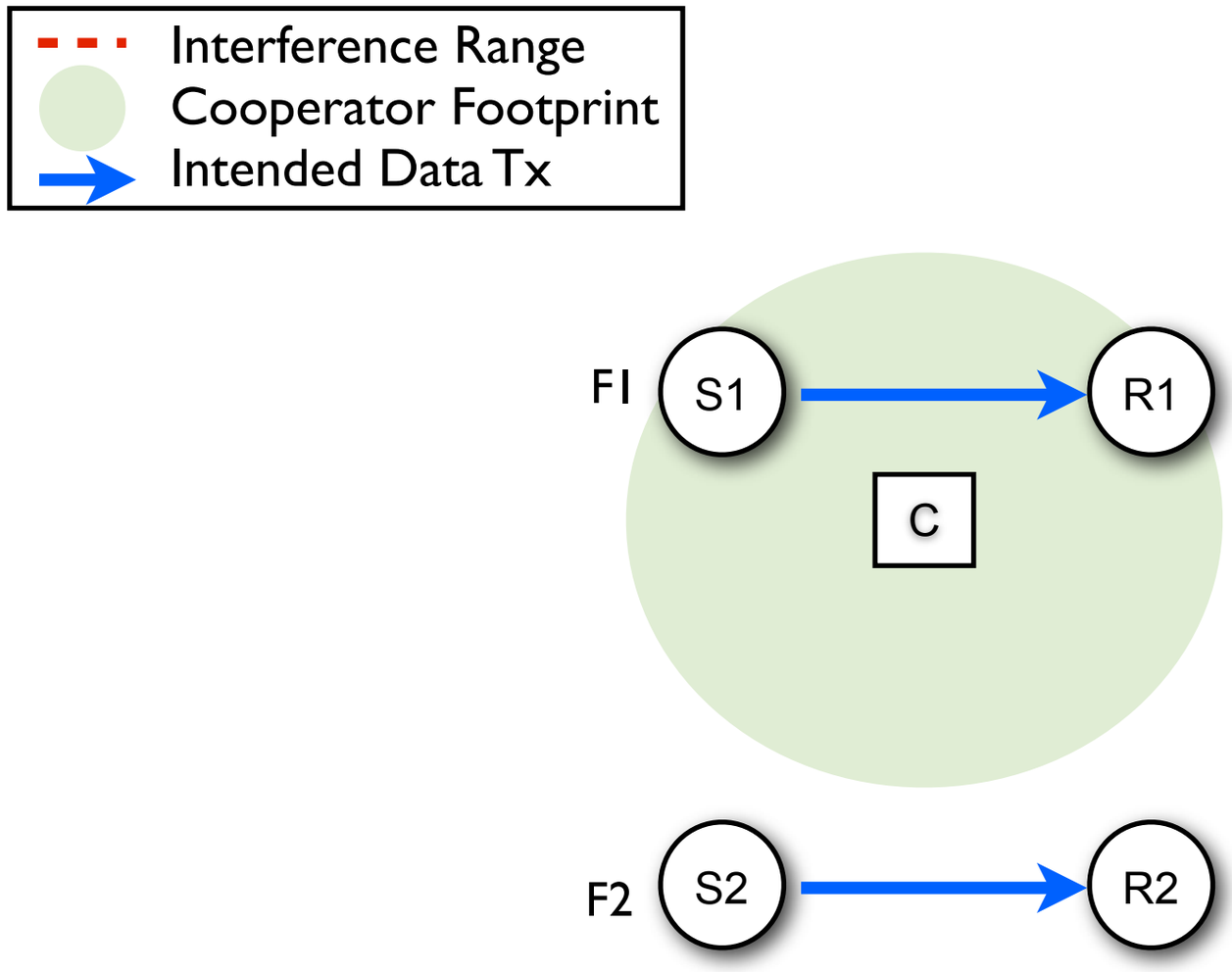

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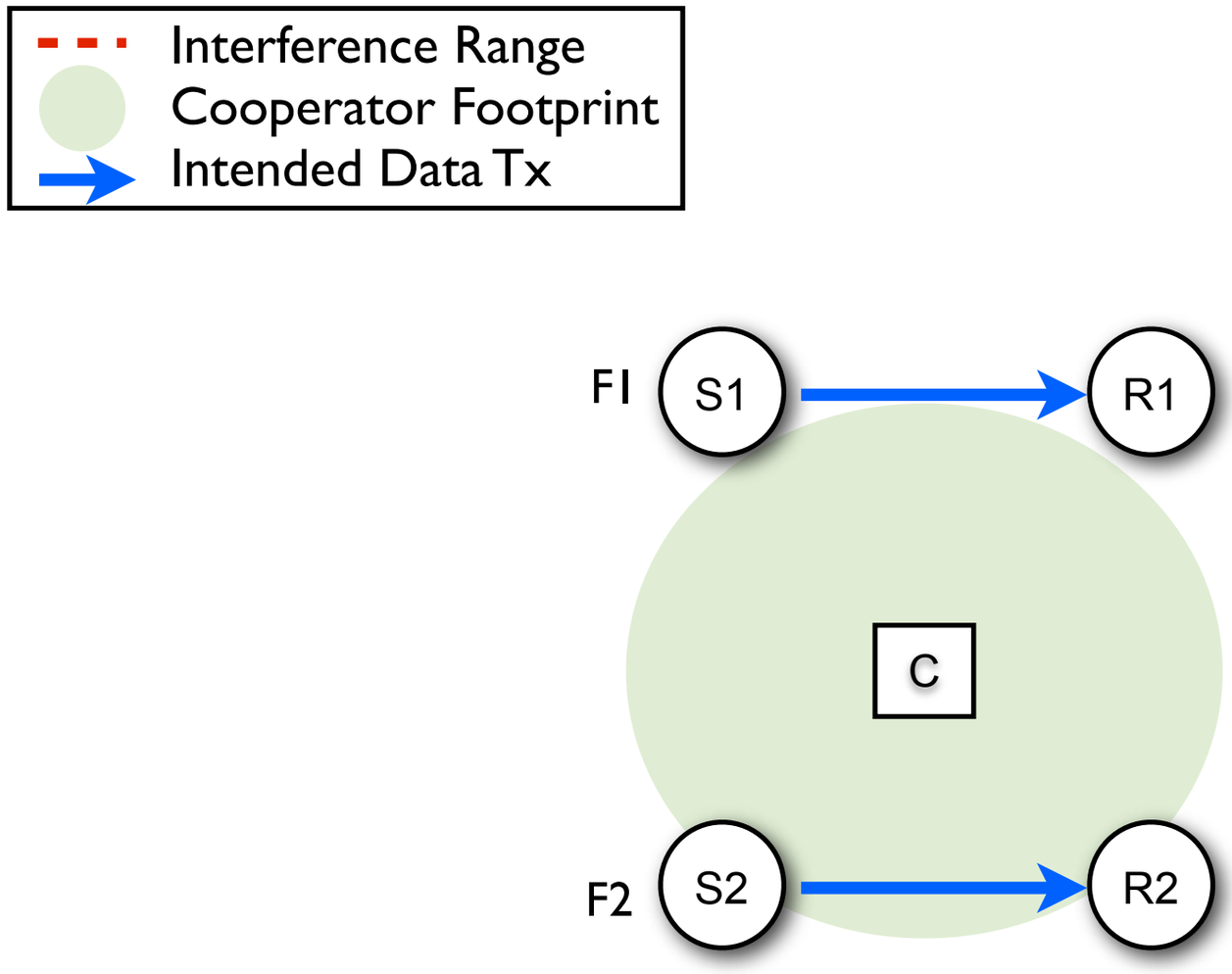

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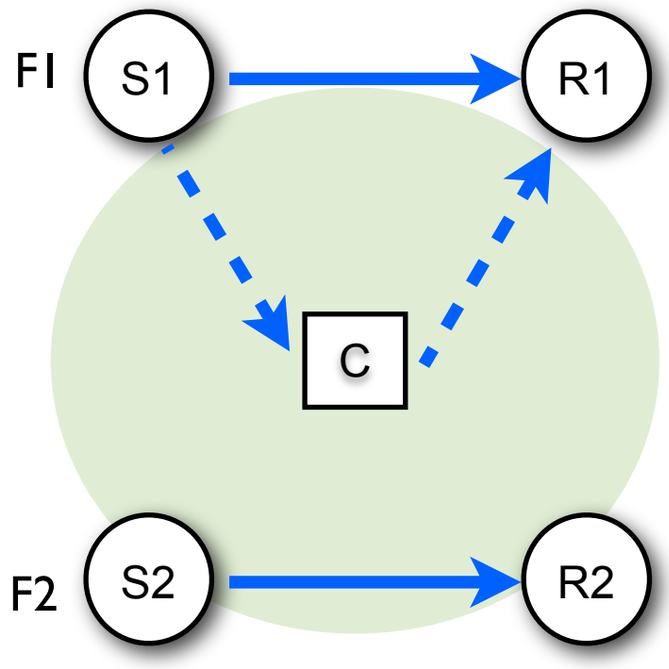

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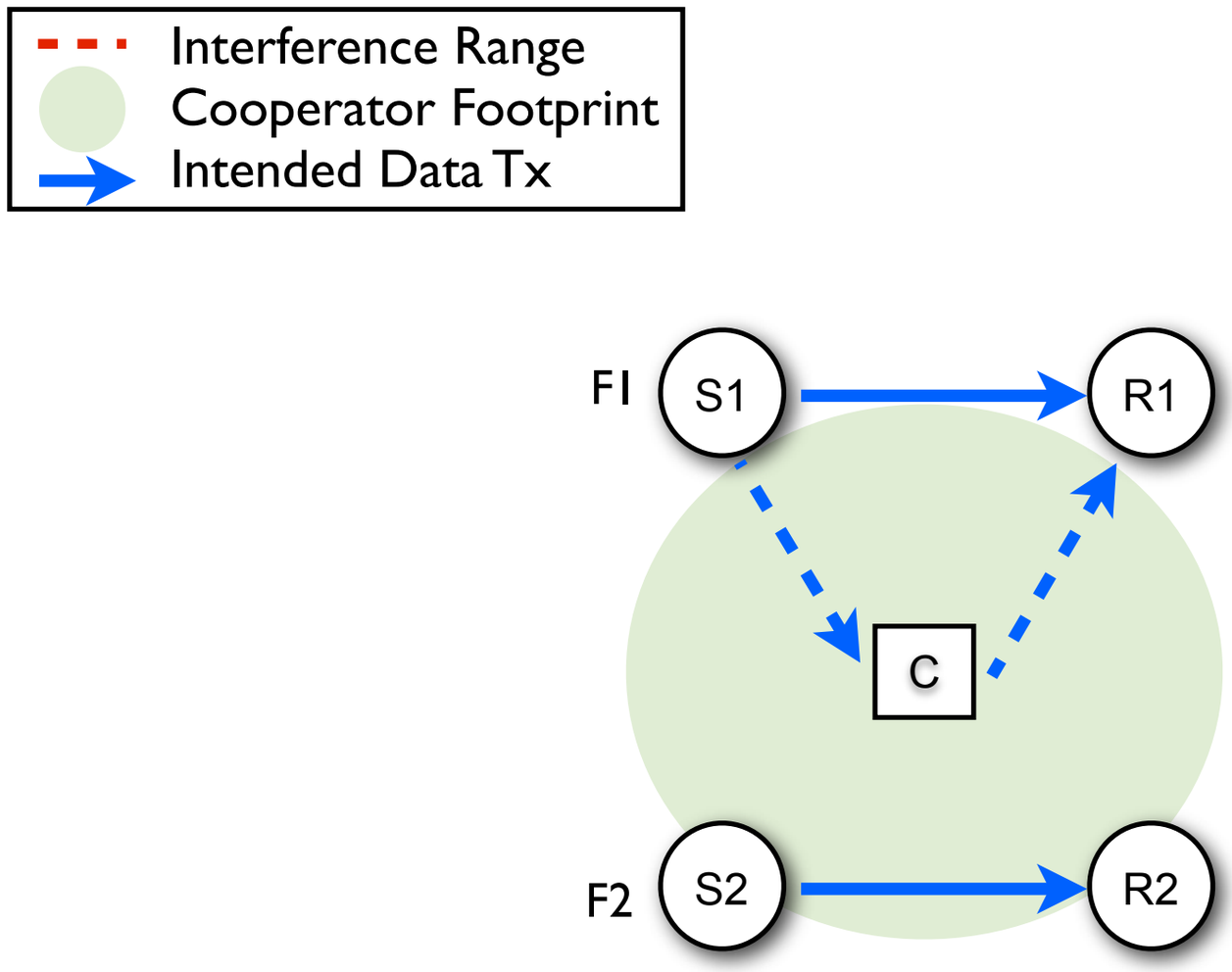

Low

~~High~~ throughput gains for F1

Little to ~~no~~ cooperator interference with F2

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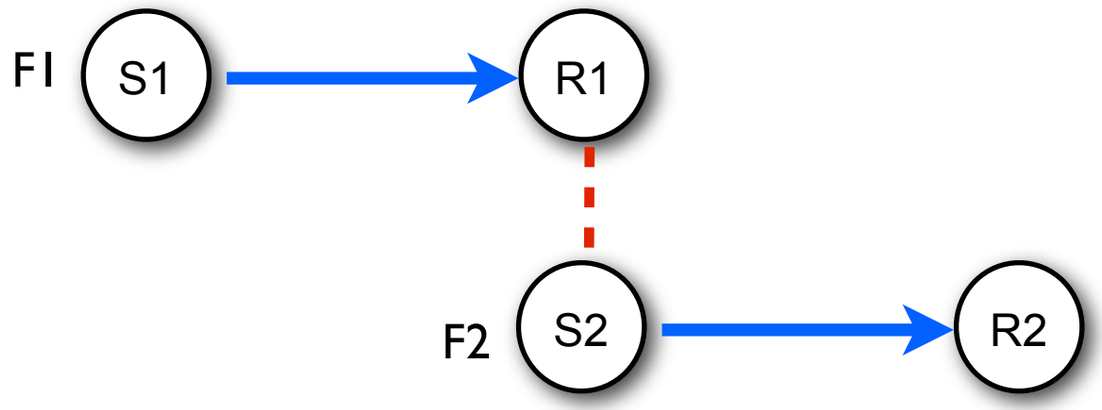
RICE

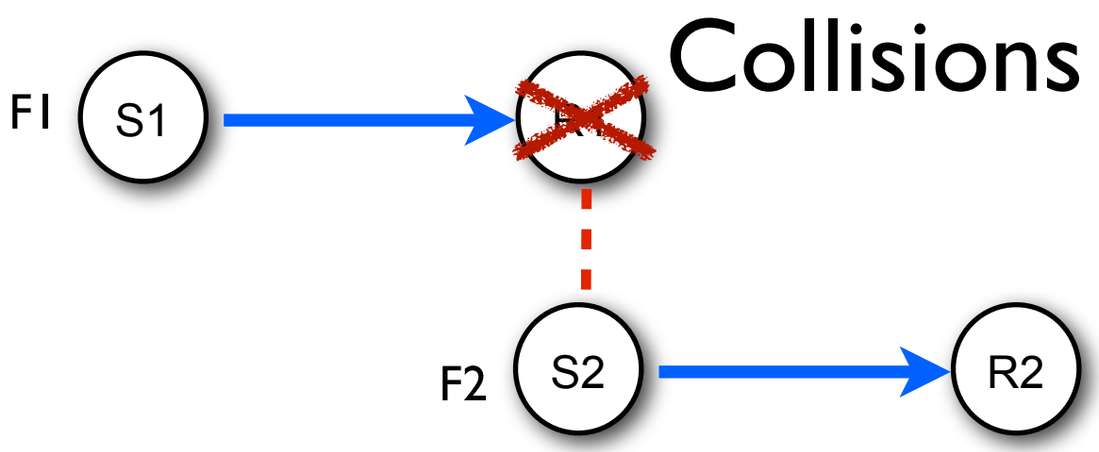
Trigger Policies in WLANs



Information Asymmetry

Identify when the cooperator should or should not be used

Trigger Policies in WLANs



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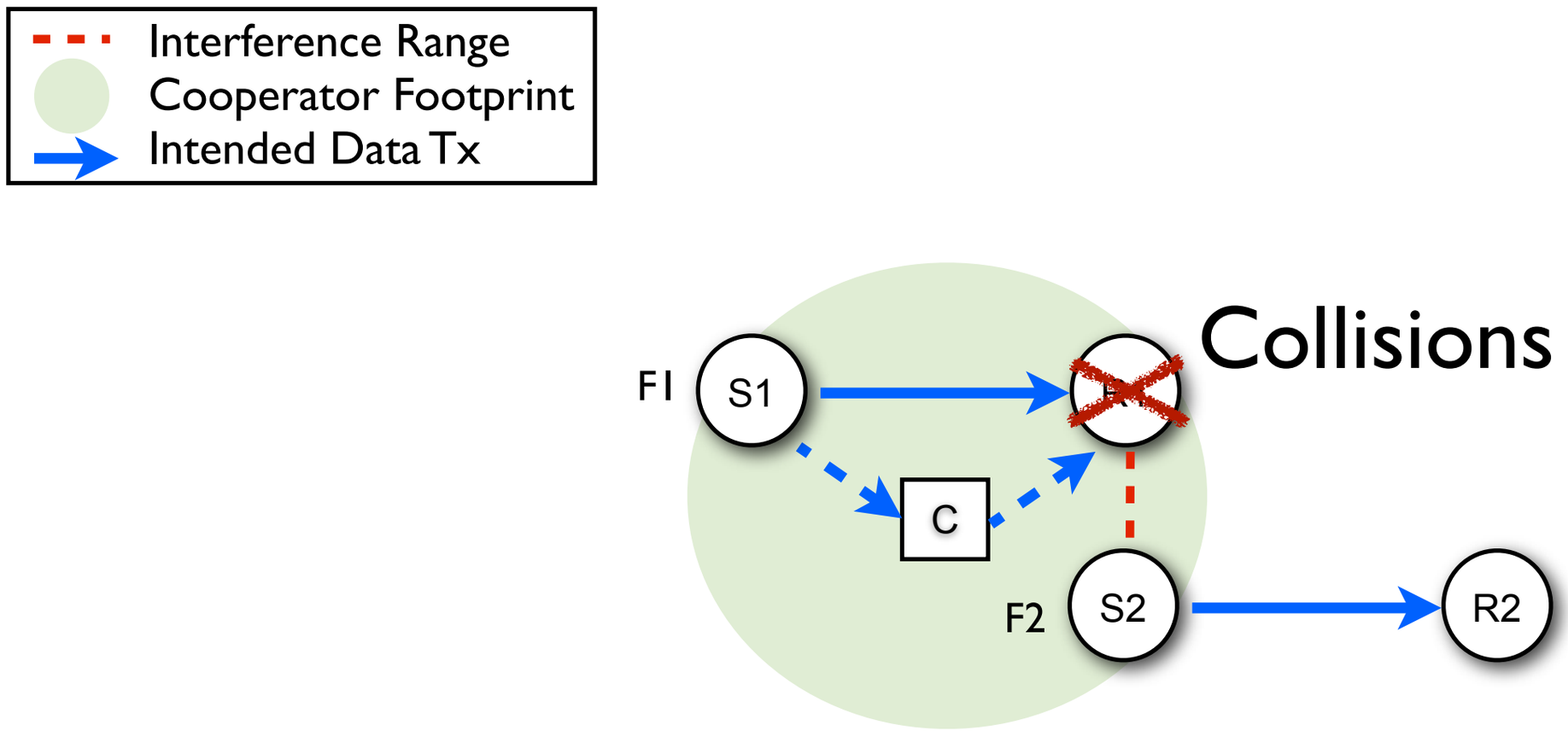

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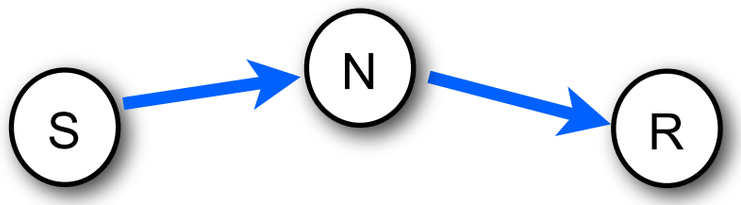
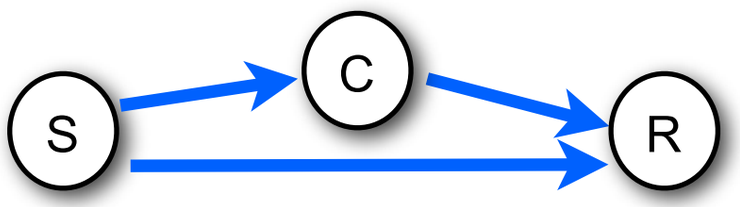
Multi-Hop



Transmissions Over Shorter/Higher Quality Links
VS
Transmit Diversity or/and 2x Tx Power

vMISO



Low Tx Rate

⋮

Fewer Losses

⋮

Lower vMISO Gains

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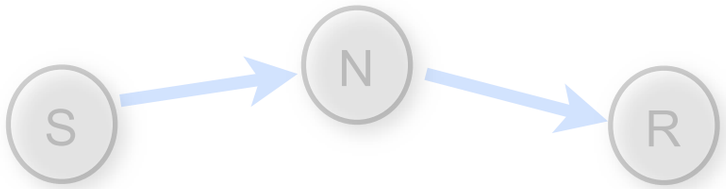

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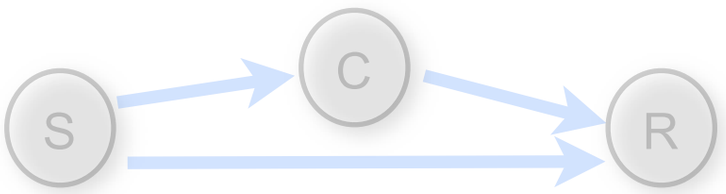

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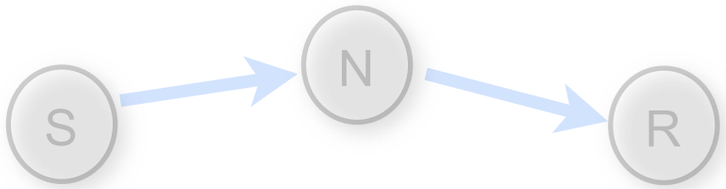

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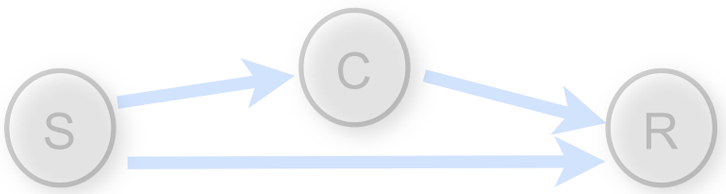

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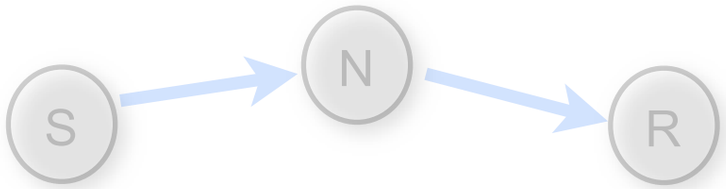

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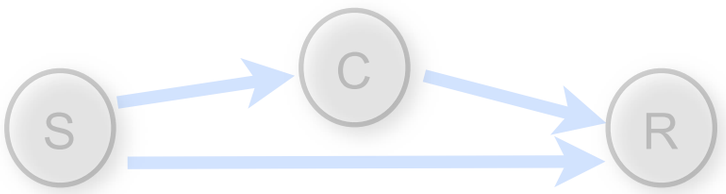

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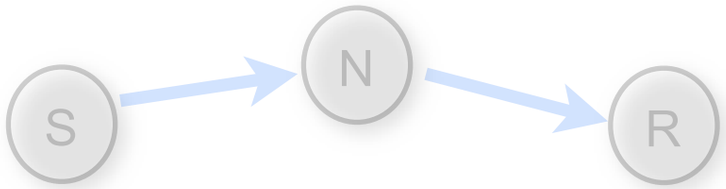

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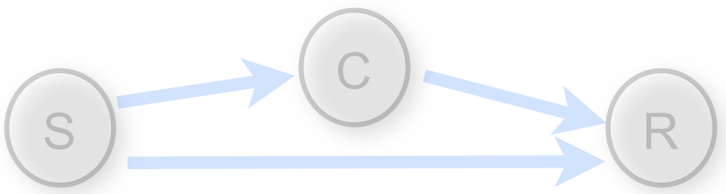

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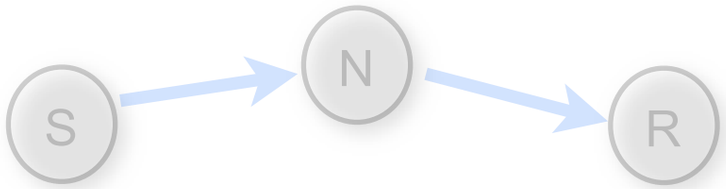

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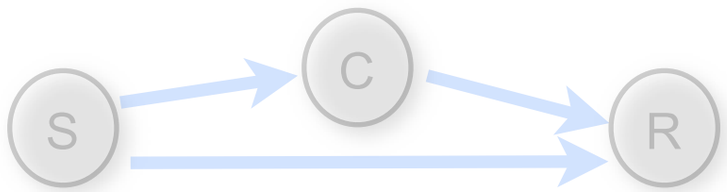

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Higher

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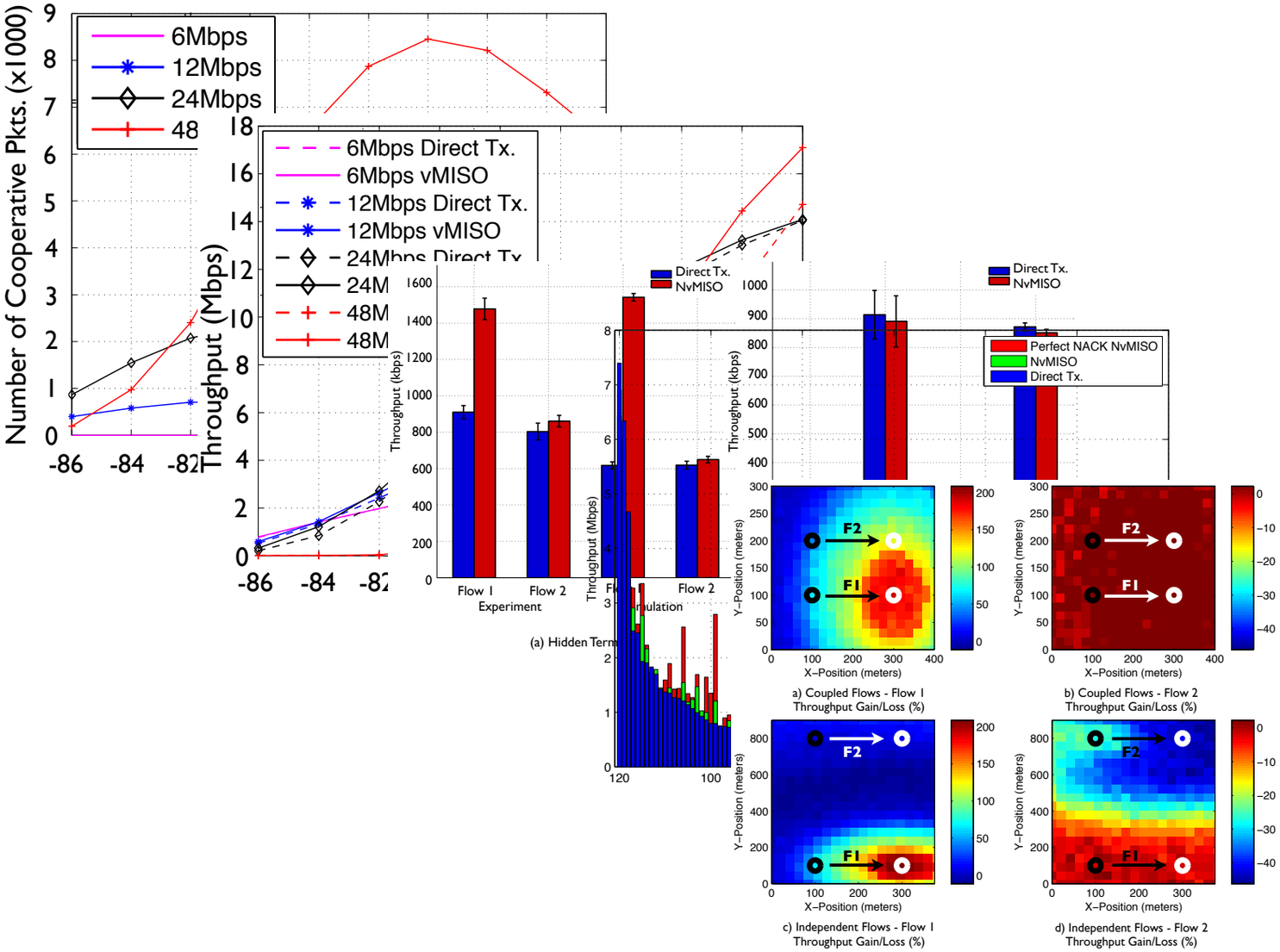
RICE

Evaluation Roadmap

- System Implementation
- Comprehensive vMISO Evaluation
  - Atomic Scenarios (Fundamental Small-Scale Topologies)
  - Large-Scale Topologies (up to 20 flows)



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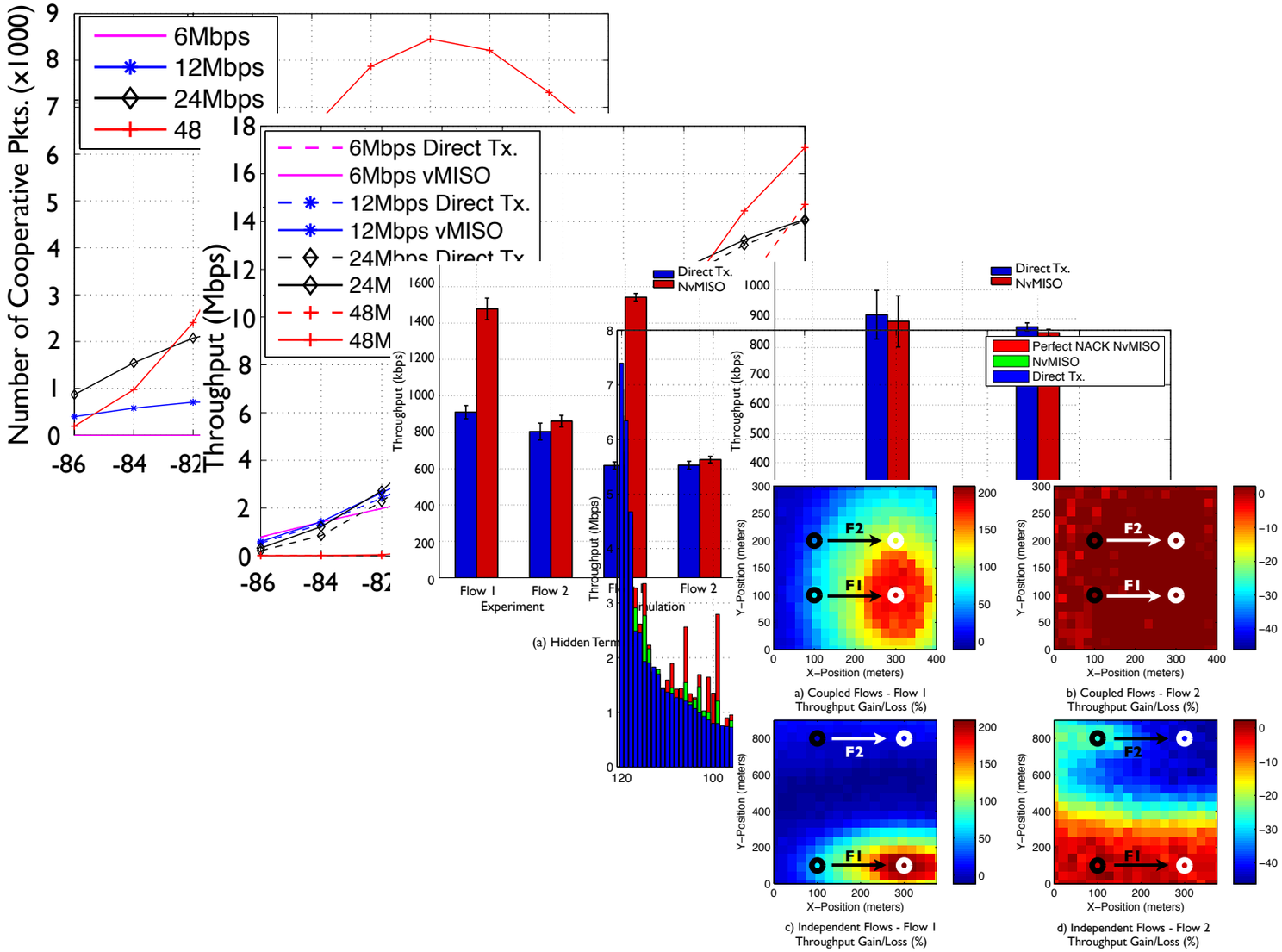
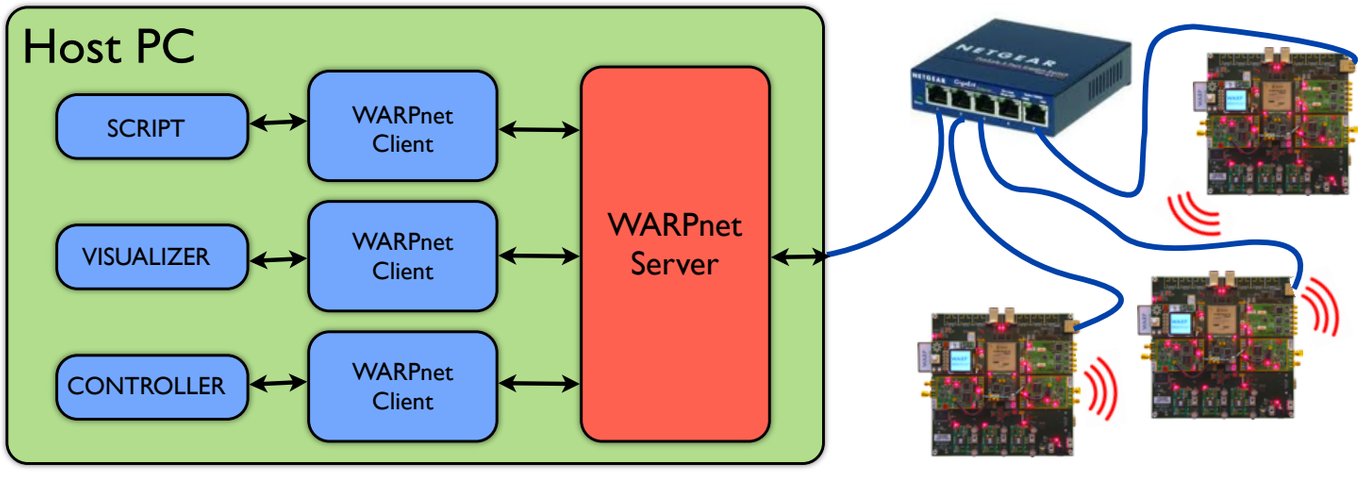
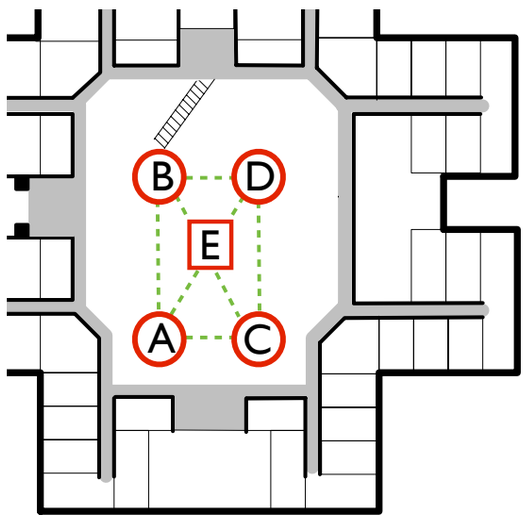
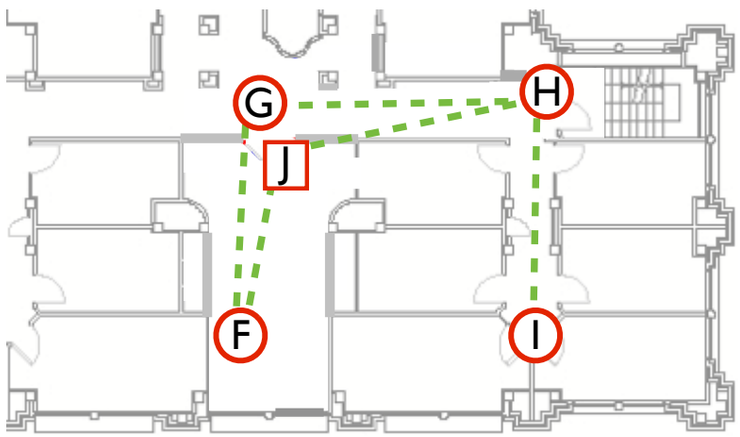


However, our evaluation explored networks of up to 120 flows

System Implementation





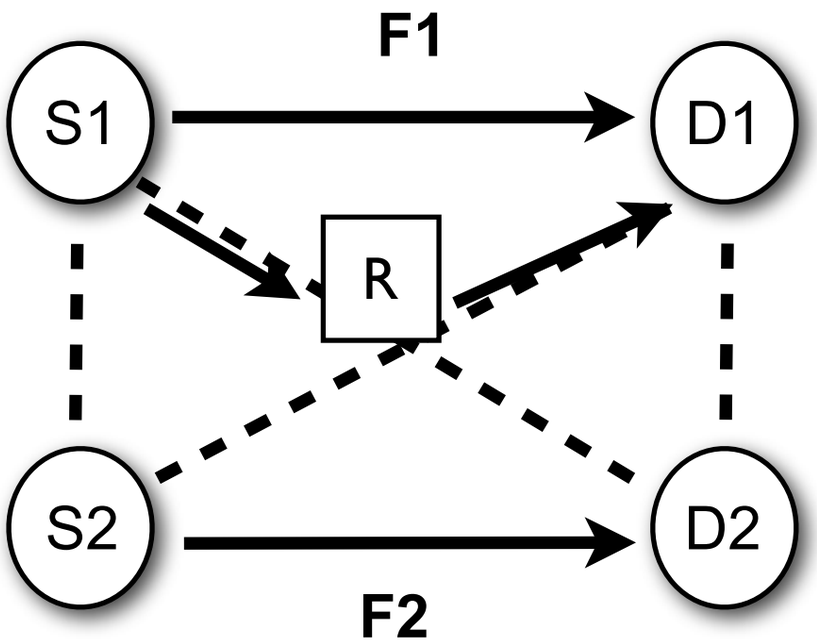


- Combination of over-the-air experiments (small topologies) and simulation (large topologies)
  - WARP Platform [1] and WARPnet - Clean slate MAC and PHY
  - Simulations in NS-2
- Performance Metric: Throughput (bps)
- Protocol Implementation: Idealized NACK-based (benchmarking) vs practical NACK-based scheme.

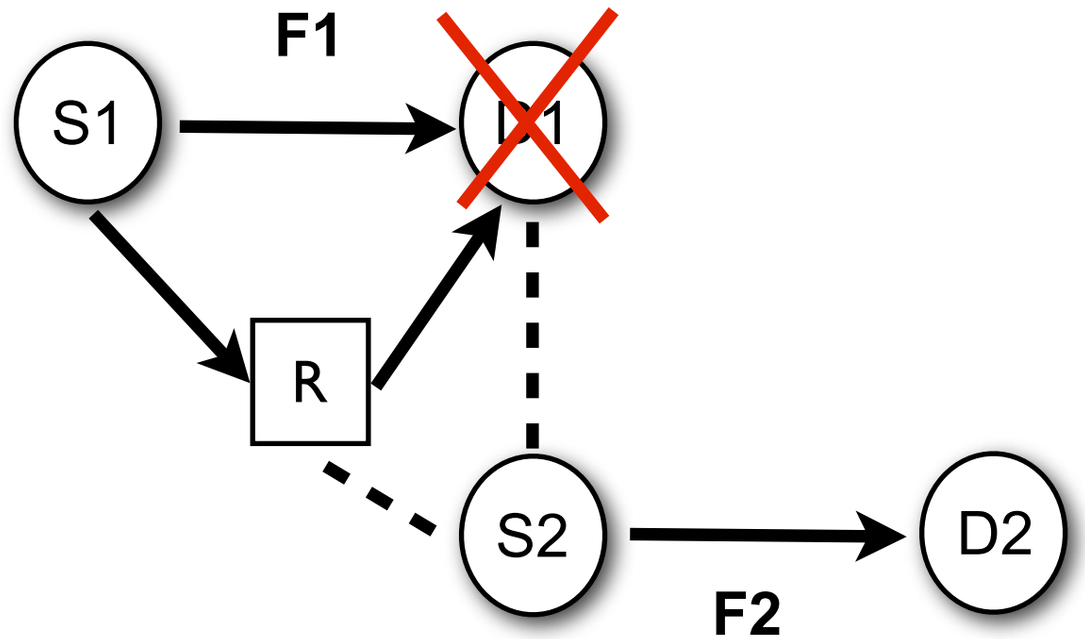
[1] http://warp.rice.edu/

vMISO in Atomic Scenarios

vMISO in Atomic Scenarios

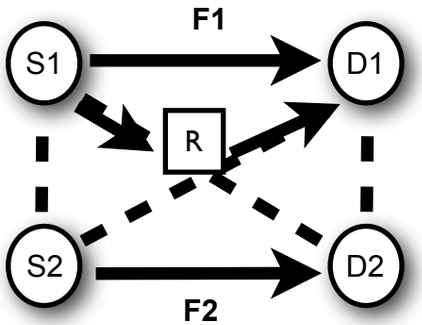


Fully Connected



Information Asymmetry

vMISO in Atomic Scenarios



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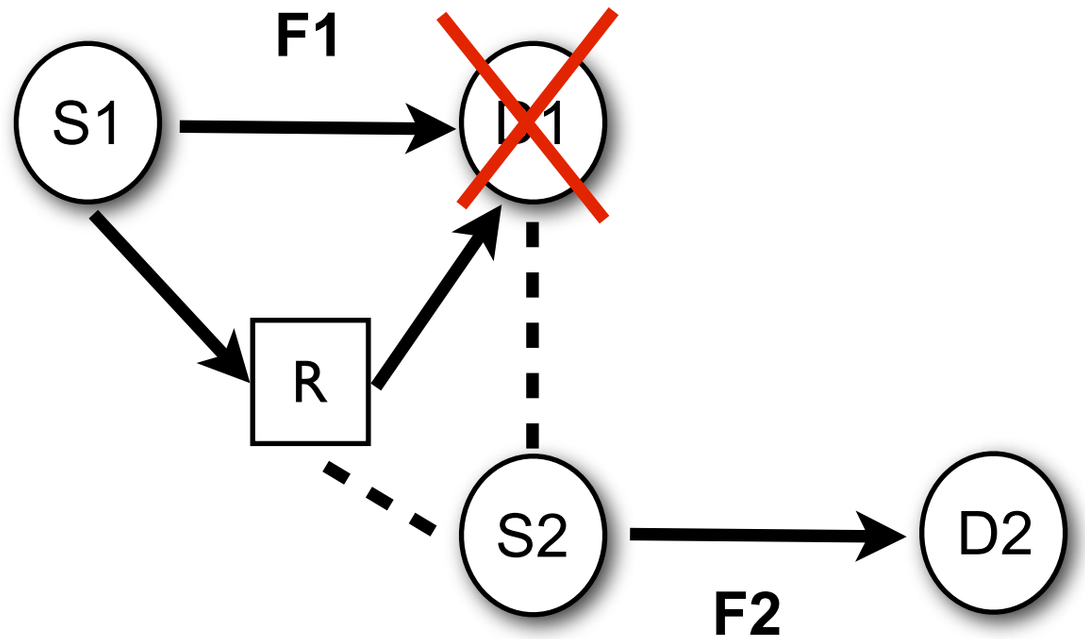

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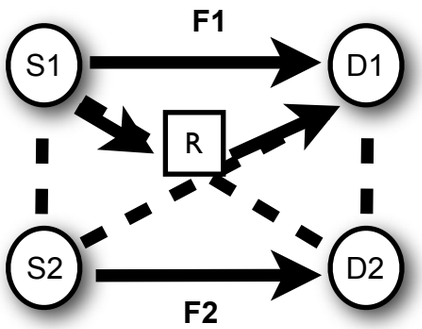

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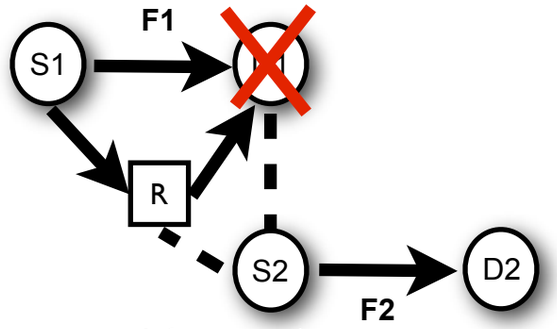

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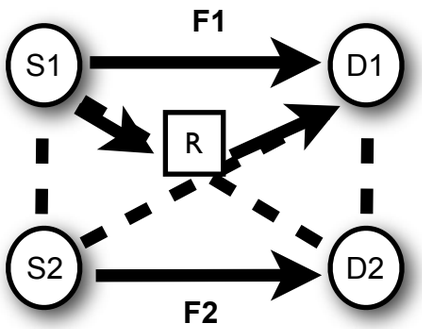
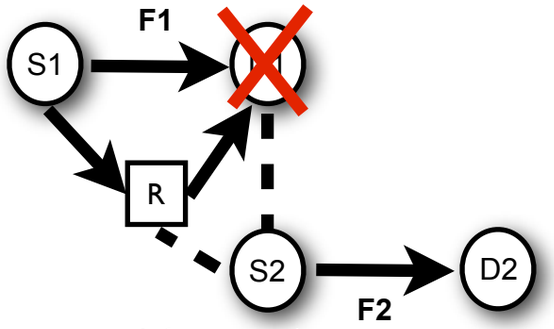


Fully Connected

Direct Tx
vMISO



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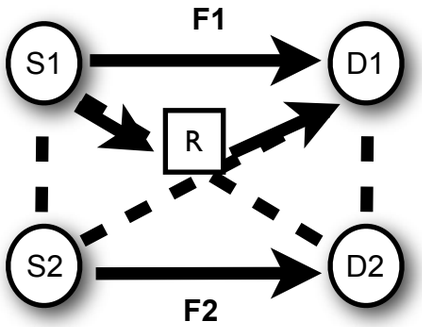

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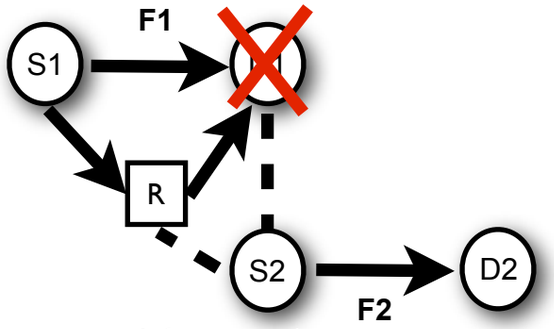

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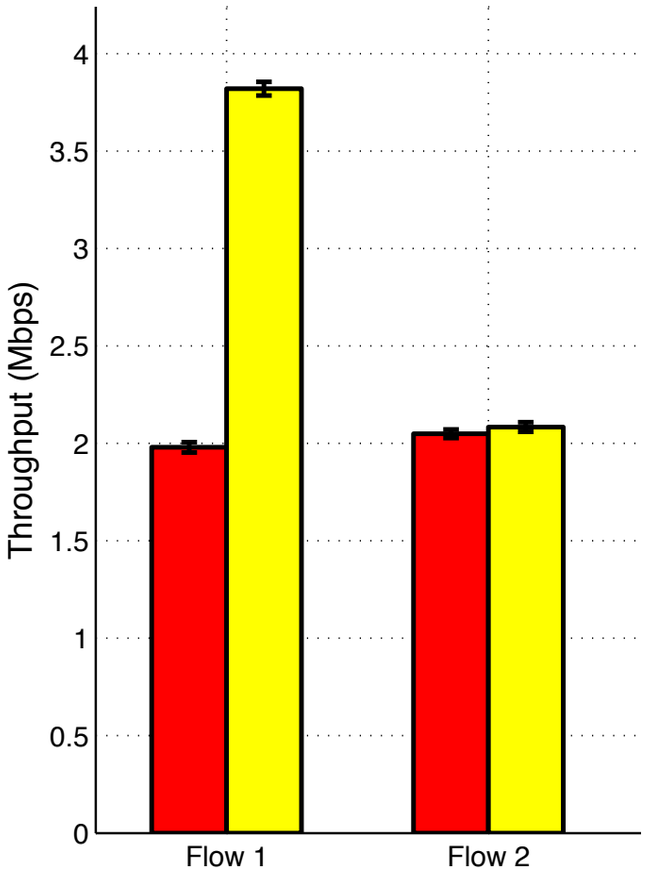

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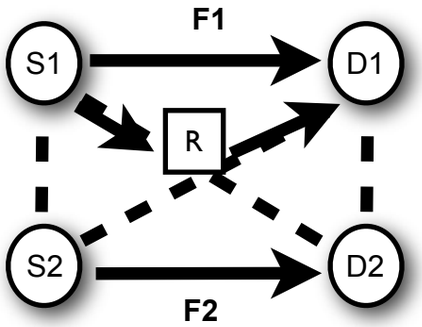
vMISO in Atomic Scenarios



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Direct Tx
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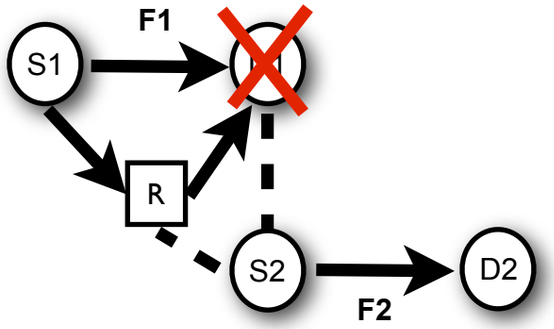

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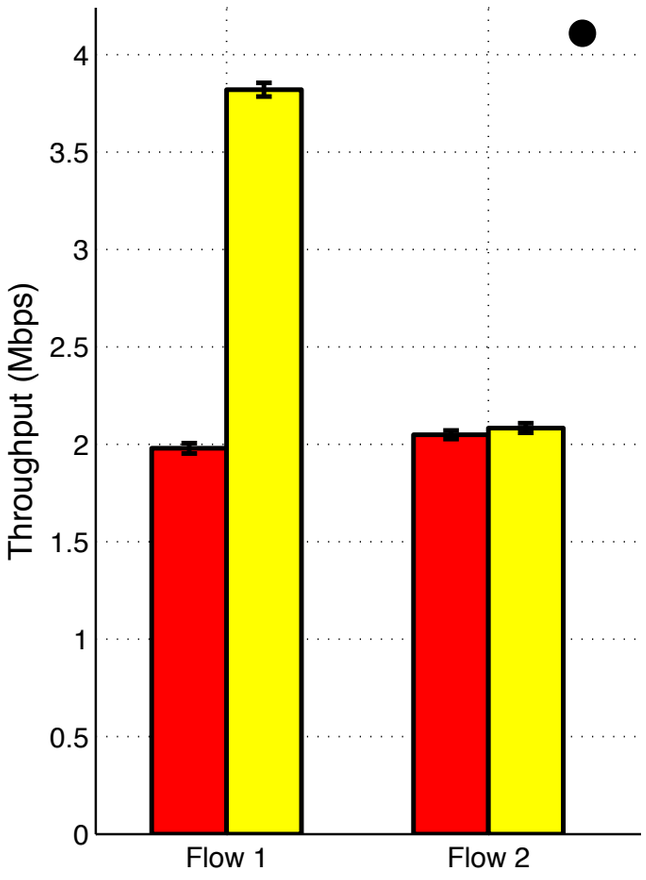
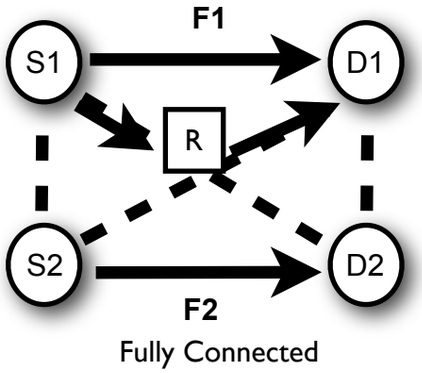


- Almost doubled throughput of flow 1

Fully Connected

vMISO in Atomic Scenarios



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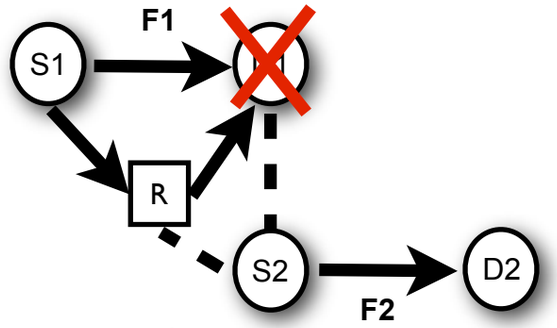

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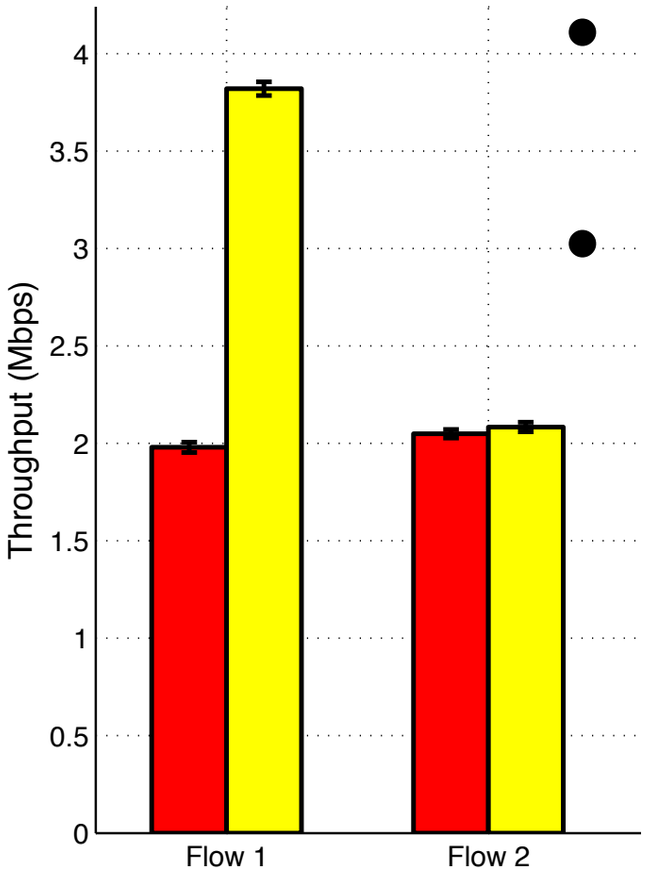
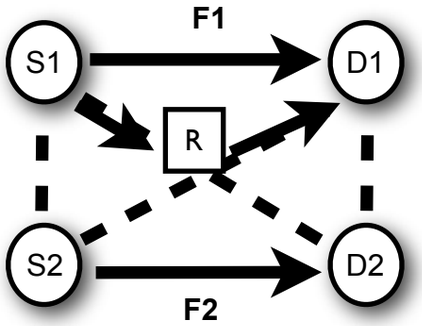


- Almost doubled throughput of flow 1
- No negative effect of the cooperator on competing flow:

Fully Connected

vMISO in Atomic Scenarios



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Direct Tx
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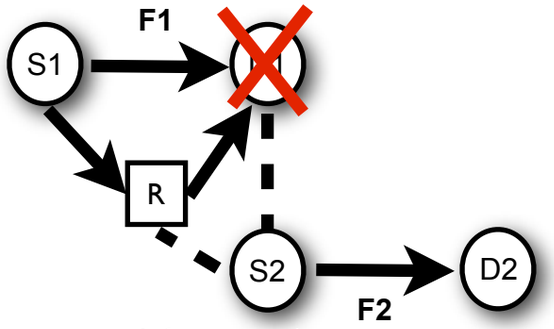

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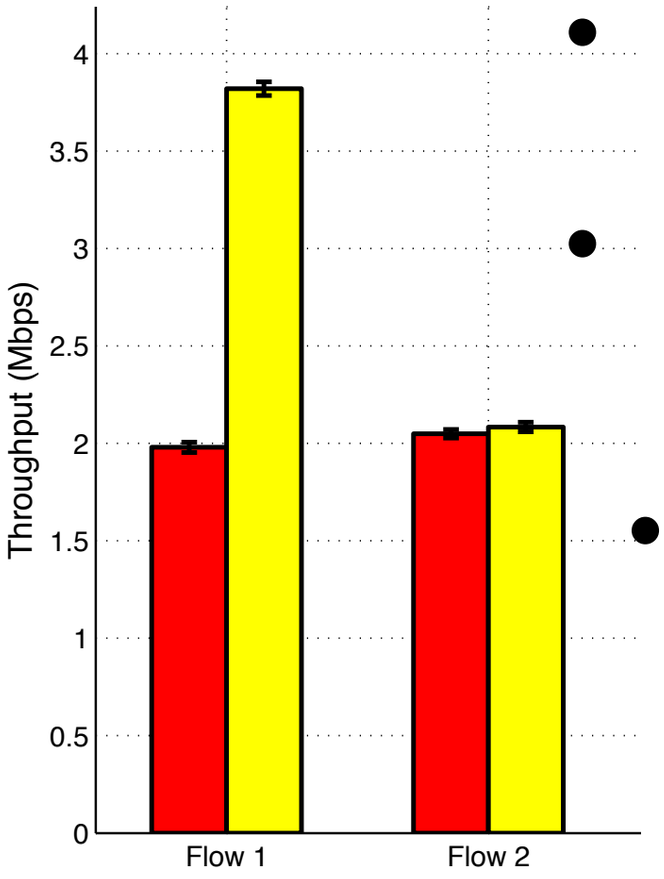

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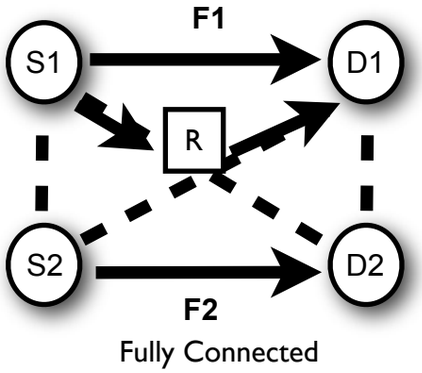

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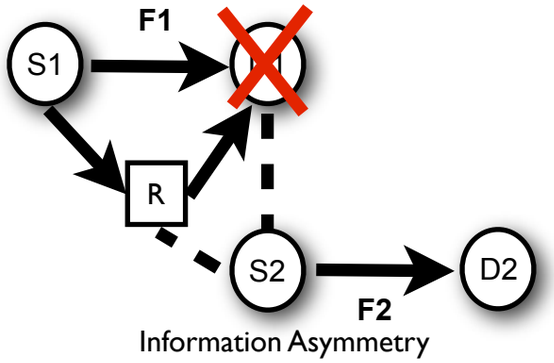

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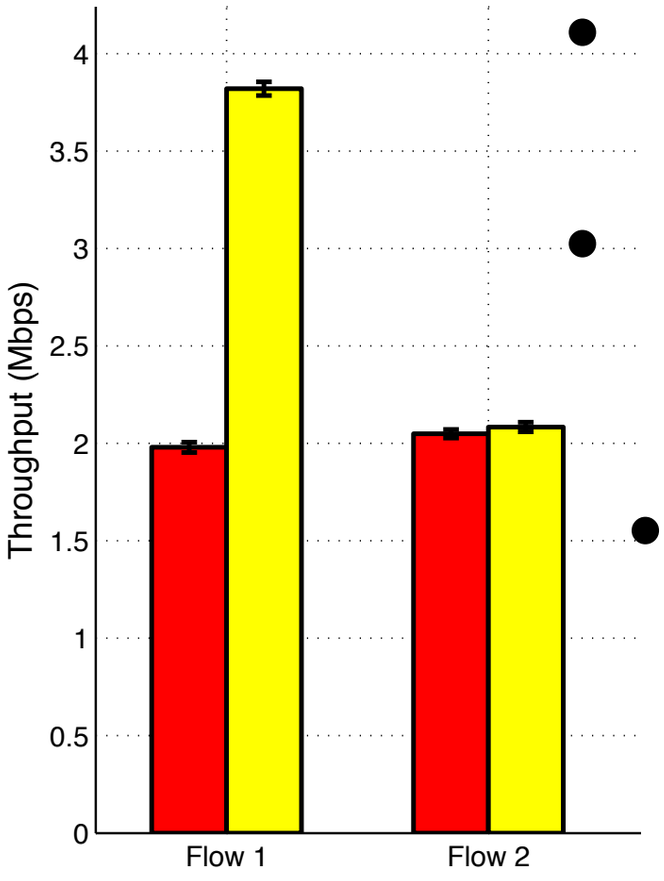

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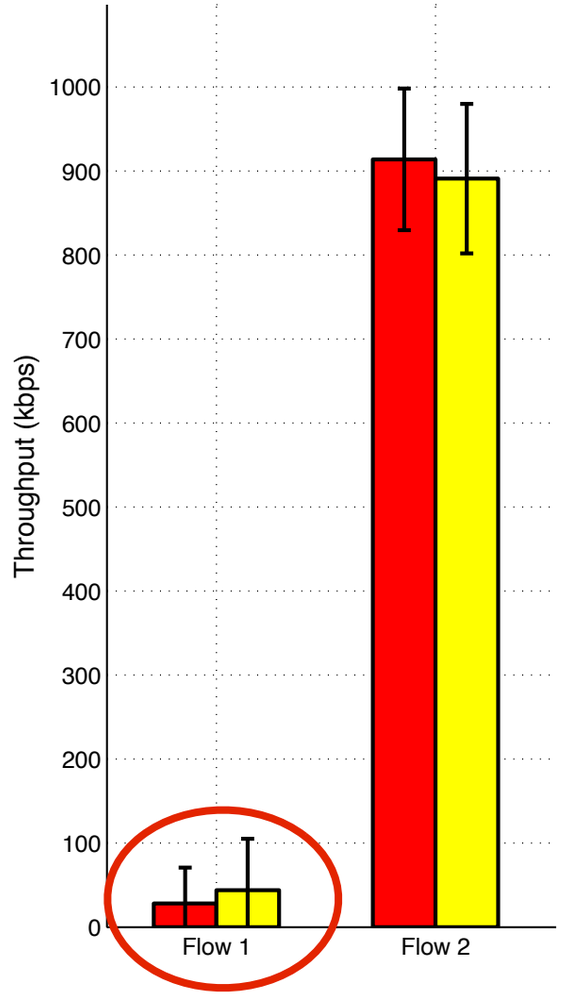

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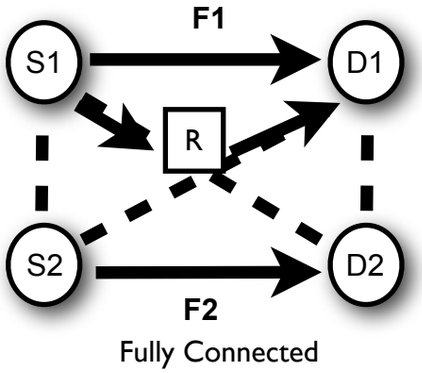

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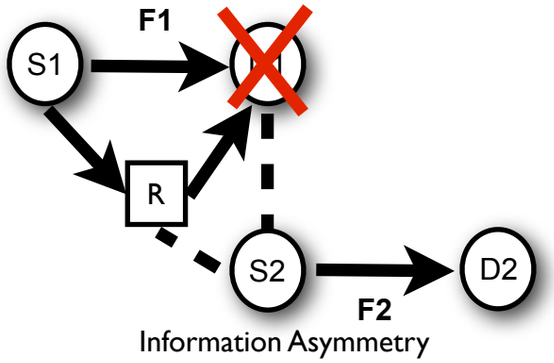

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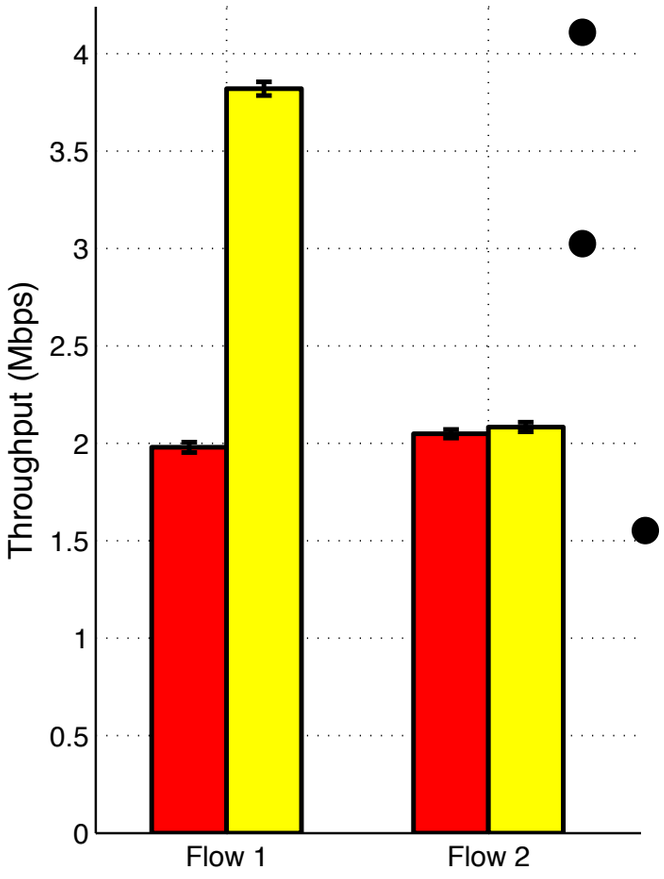

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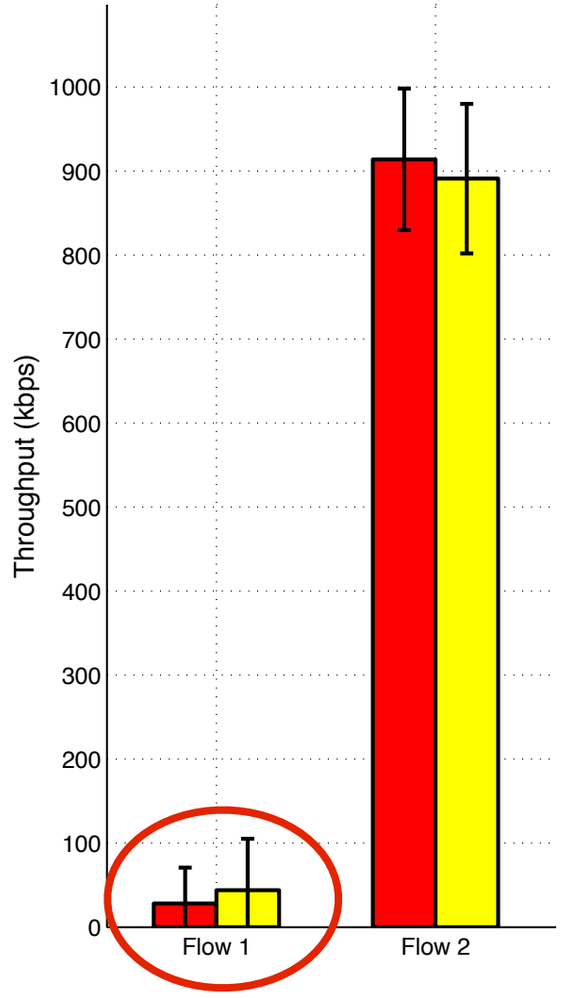

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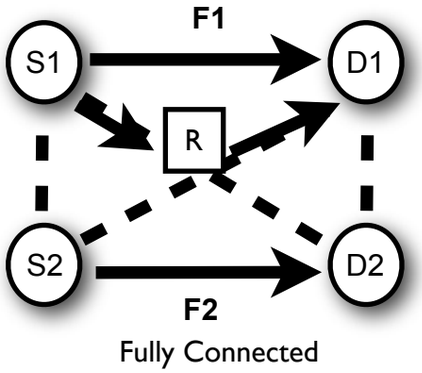

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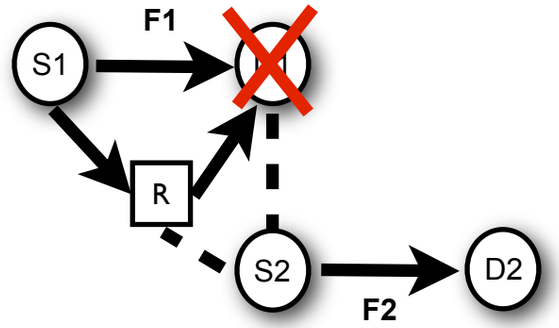

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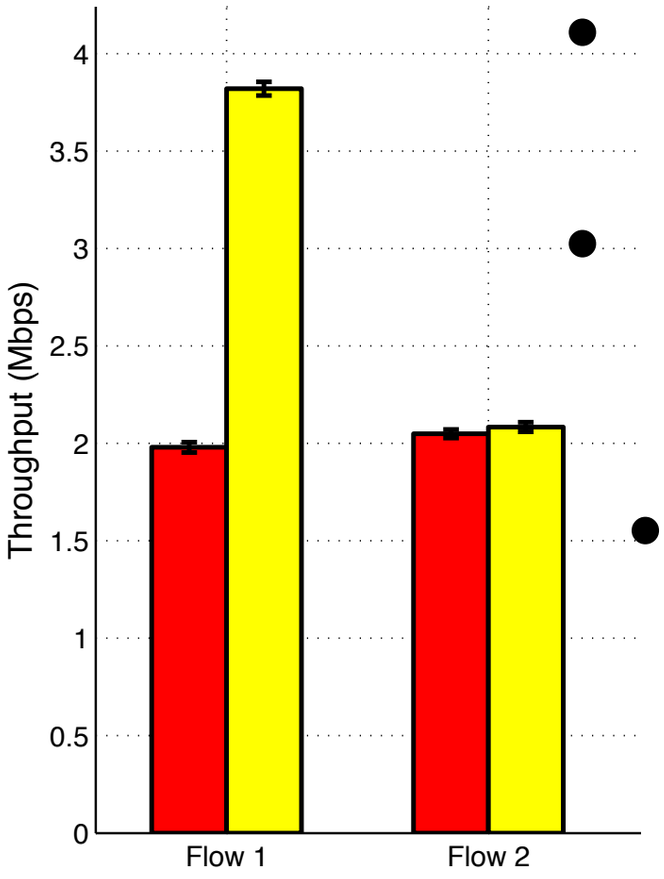

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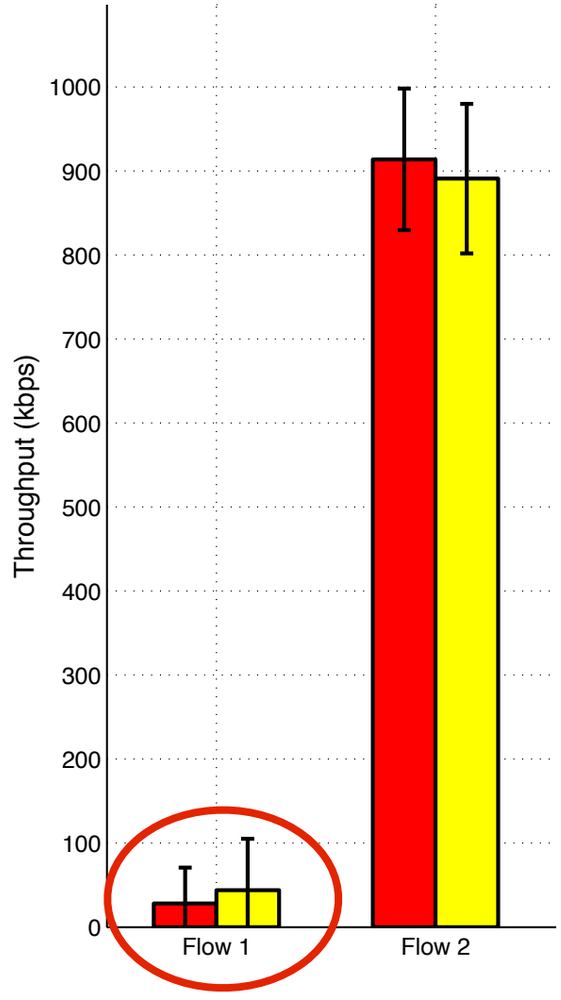

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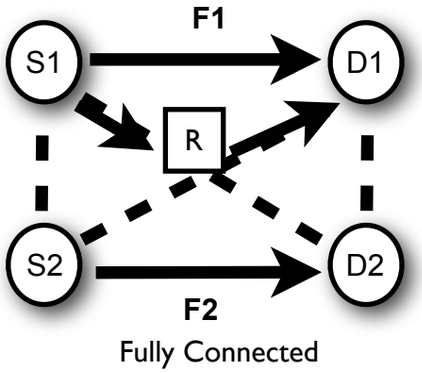

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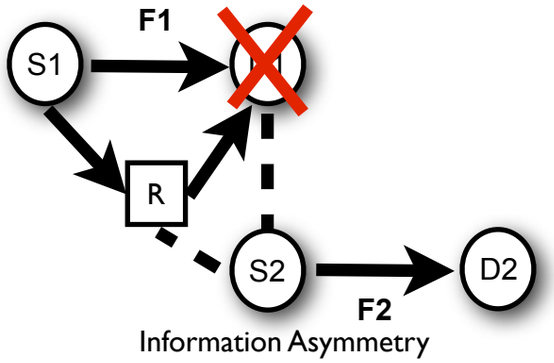

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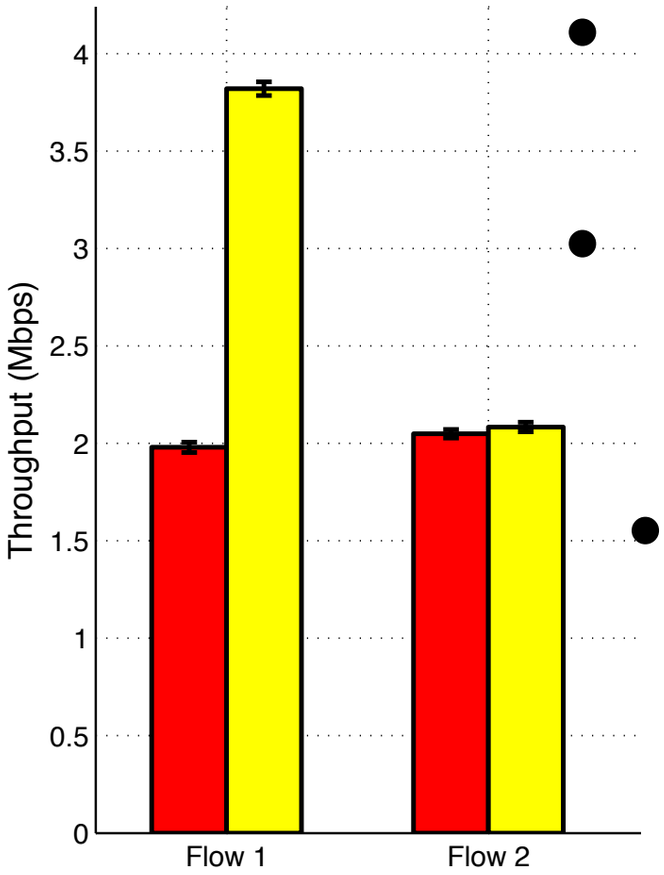

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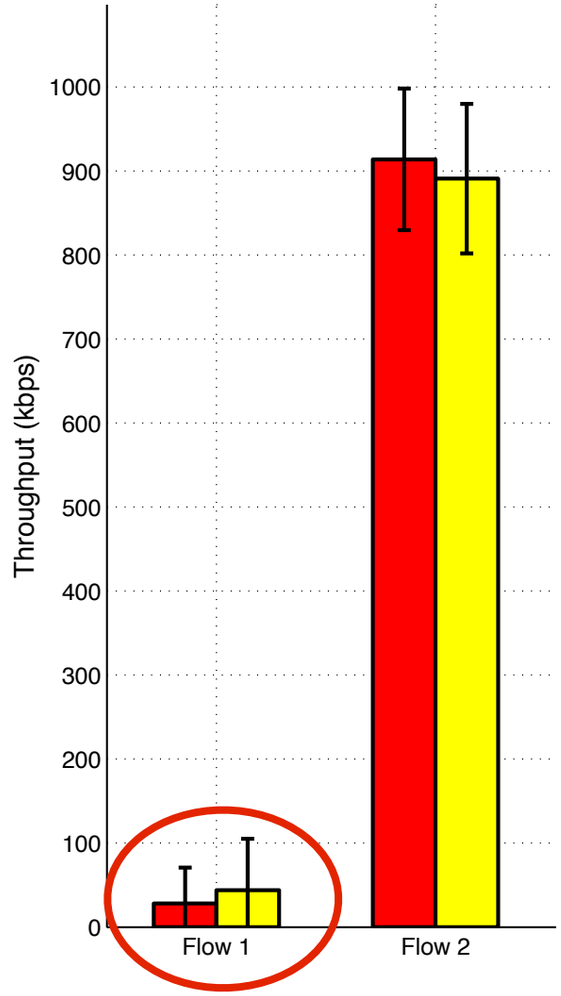

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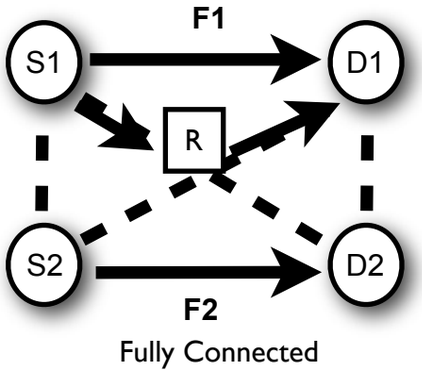

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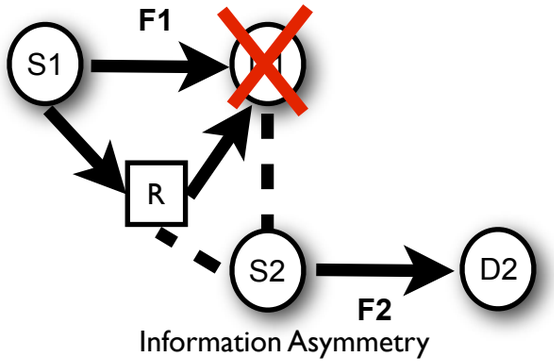

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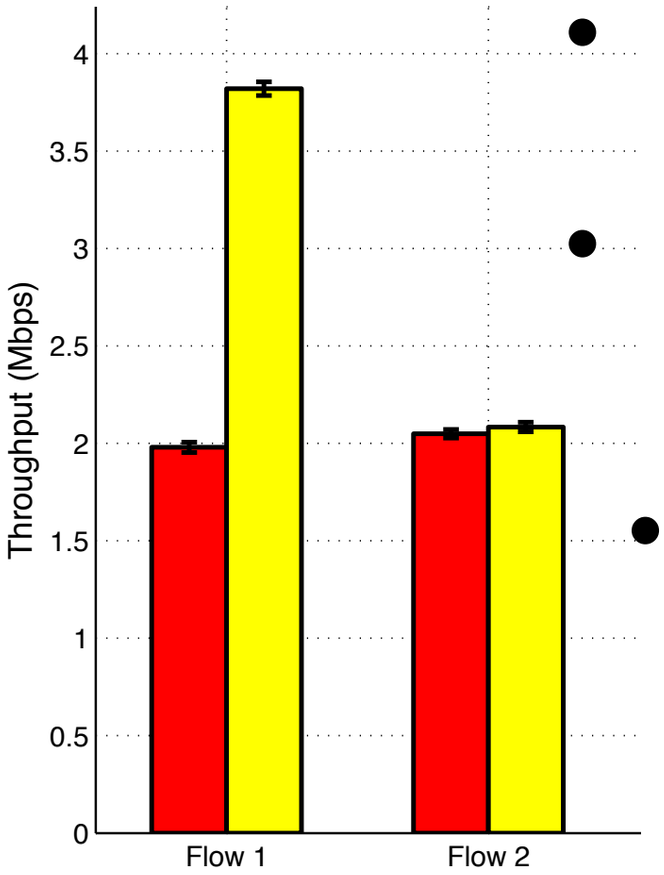

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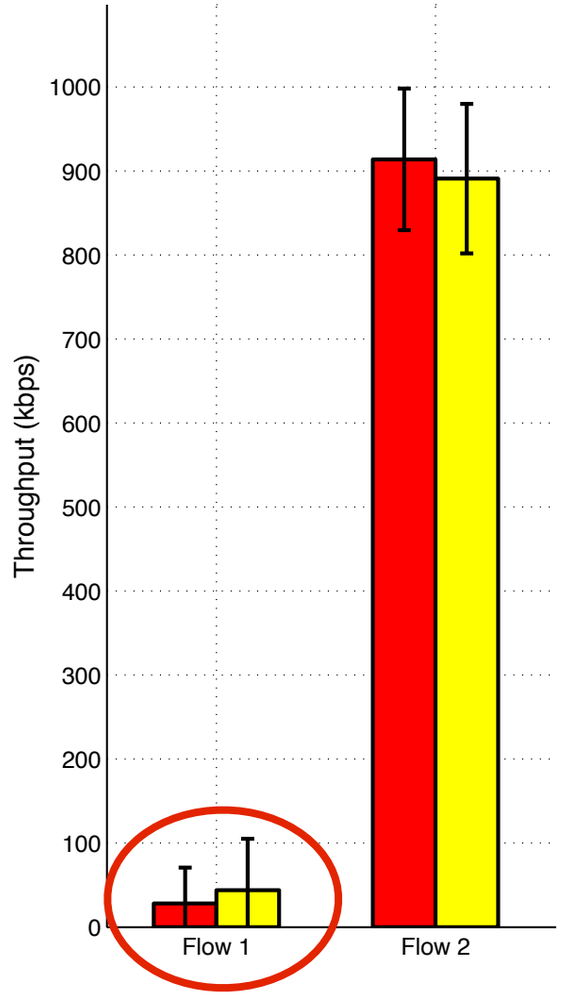

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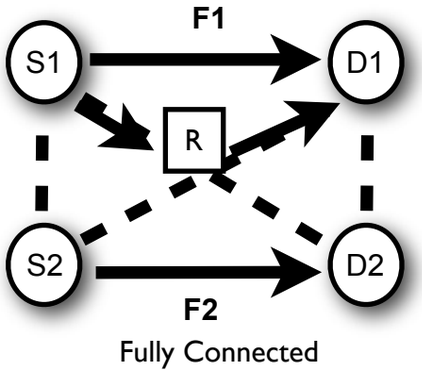

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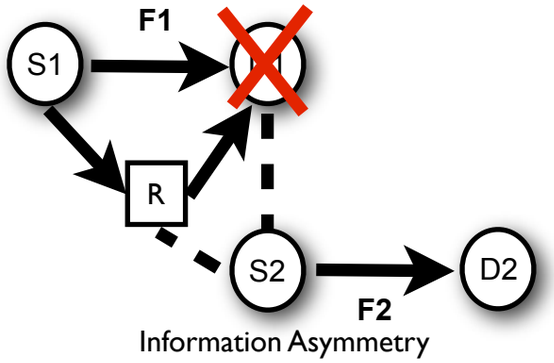

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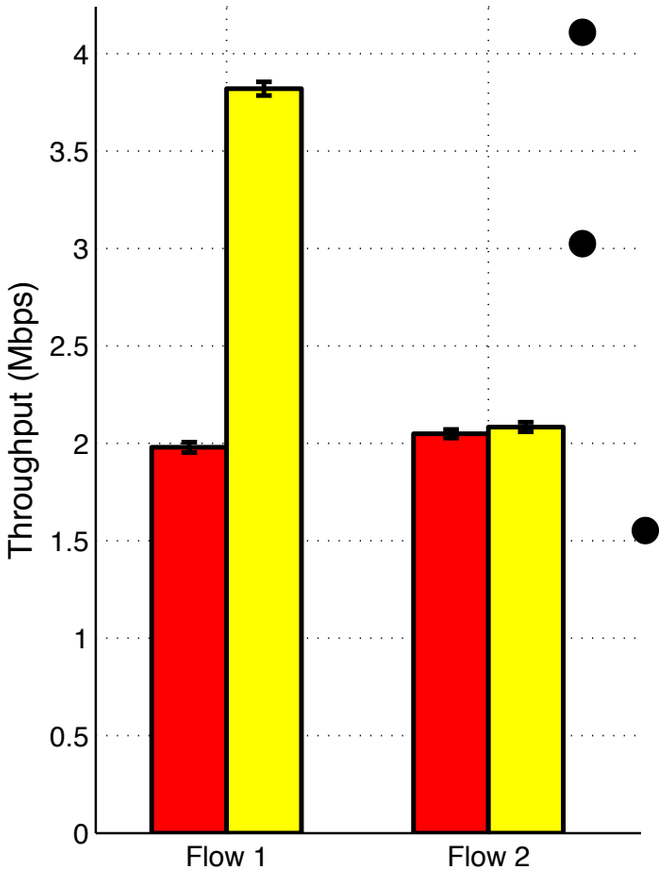

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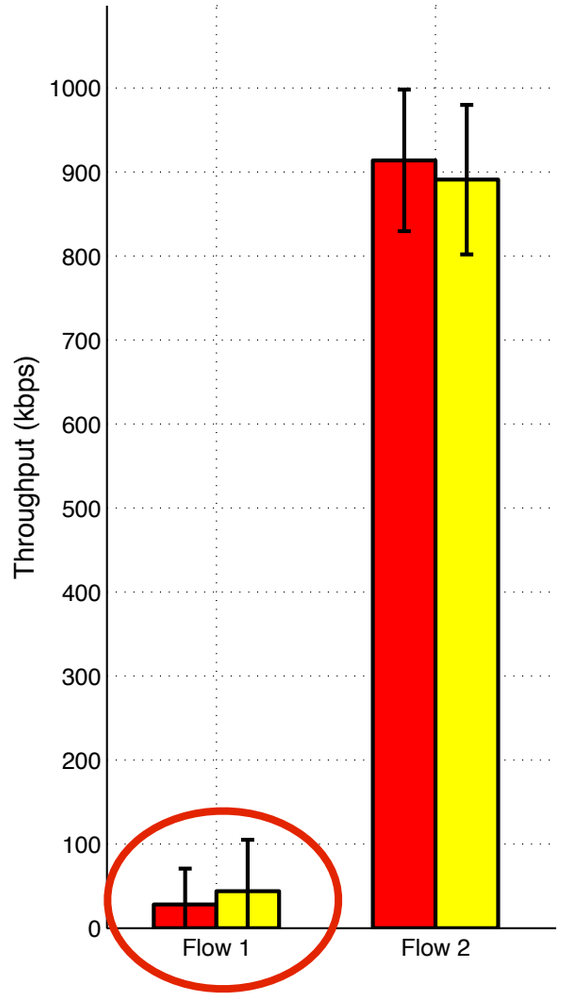
  - MAC behavior completely dominates the PHY behavior



Information Asymmetry

vMISO in Large-Scale Scenarios

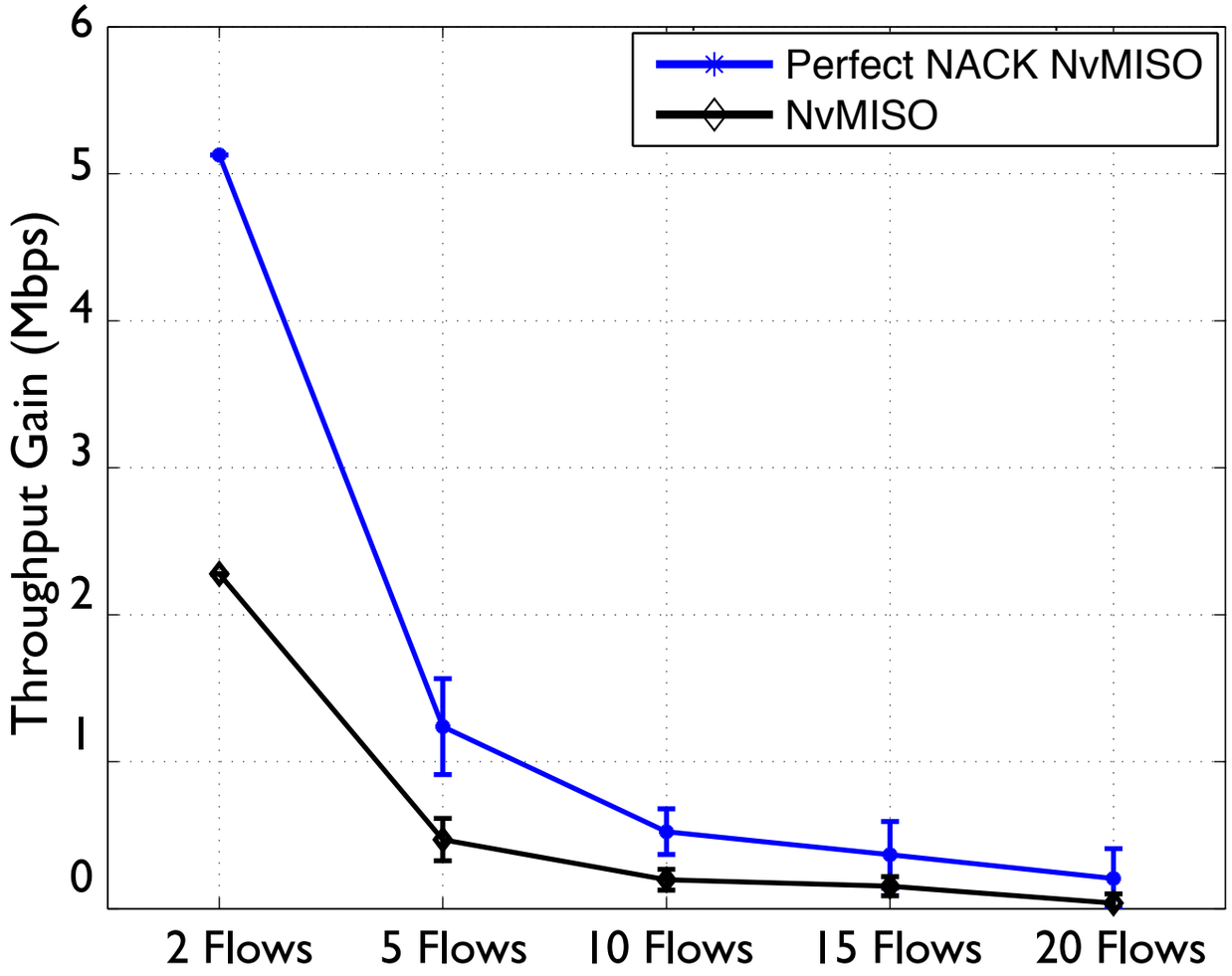
vMISO in Large-Scale Scenarios

1. Aggregate effects observed in atomic scenarios

2. Complex interactions between nodes (specially between cooperator and neighboring nodes/flows)

vMISO in Large-Scale Scenarios

- 2 to 20 flow networks, random position, static topology
- Aggregate effects due to the cooperator (*increased transmission footprint*) hinder gains attained by vMISO
- Gains decrease from 47% (2 flows) to approximately 0% (20 flows)



vMISO in Large-Scale Scenarios

How do we diminish negative effects of vMISO?

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Establish a Network Wide Trigger Policy

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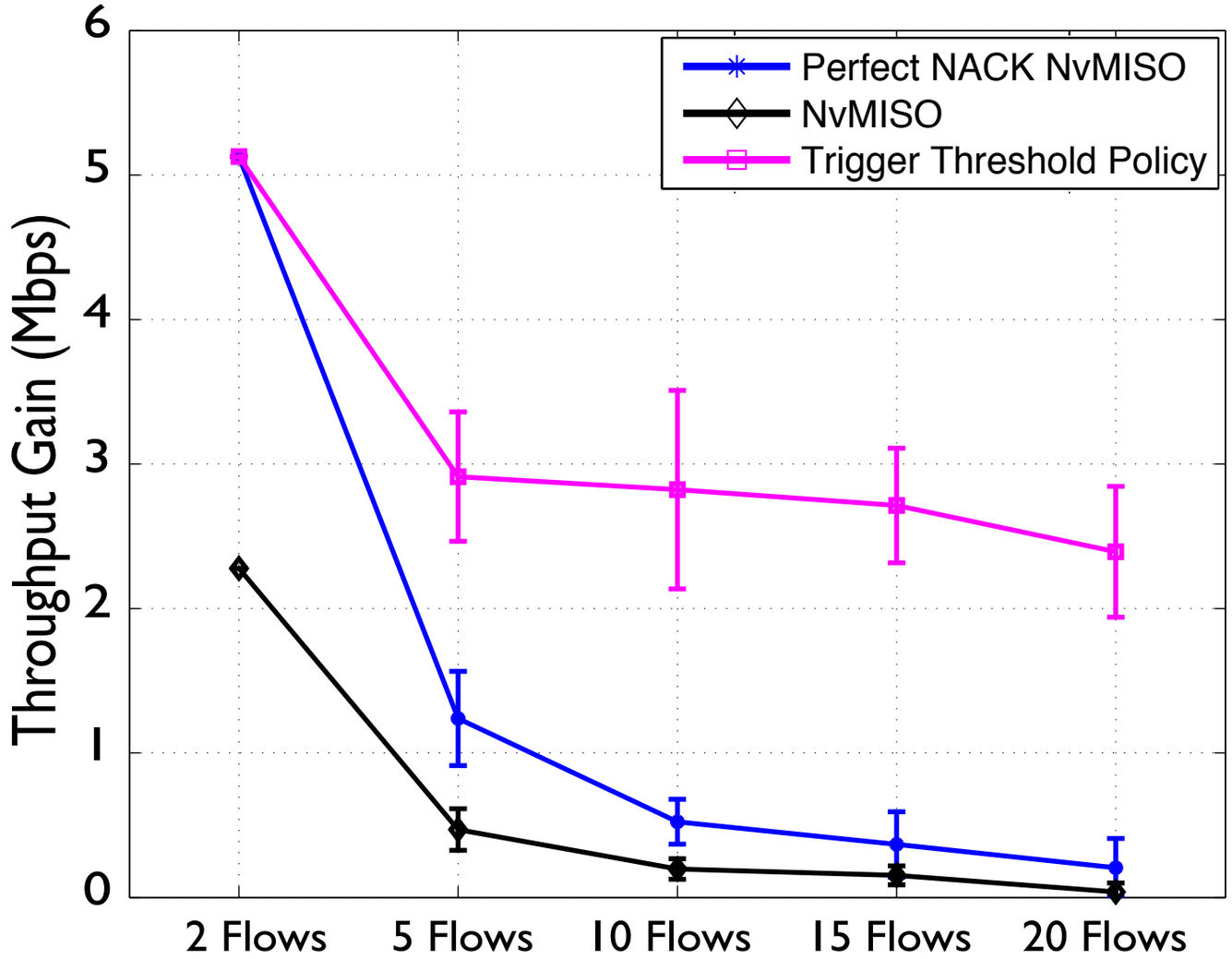
Establish a Network Wide Trigger Policy

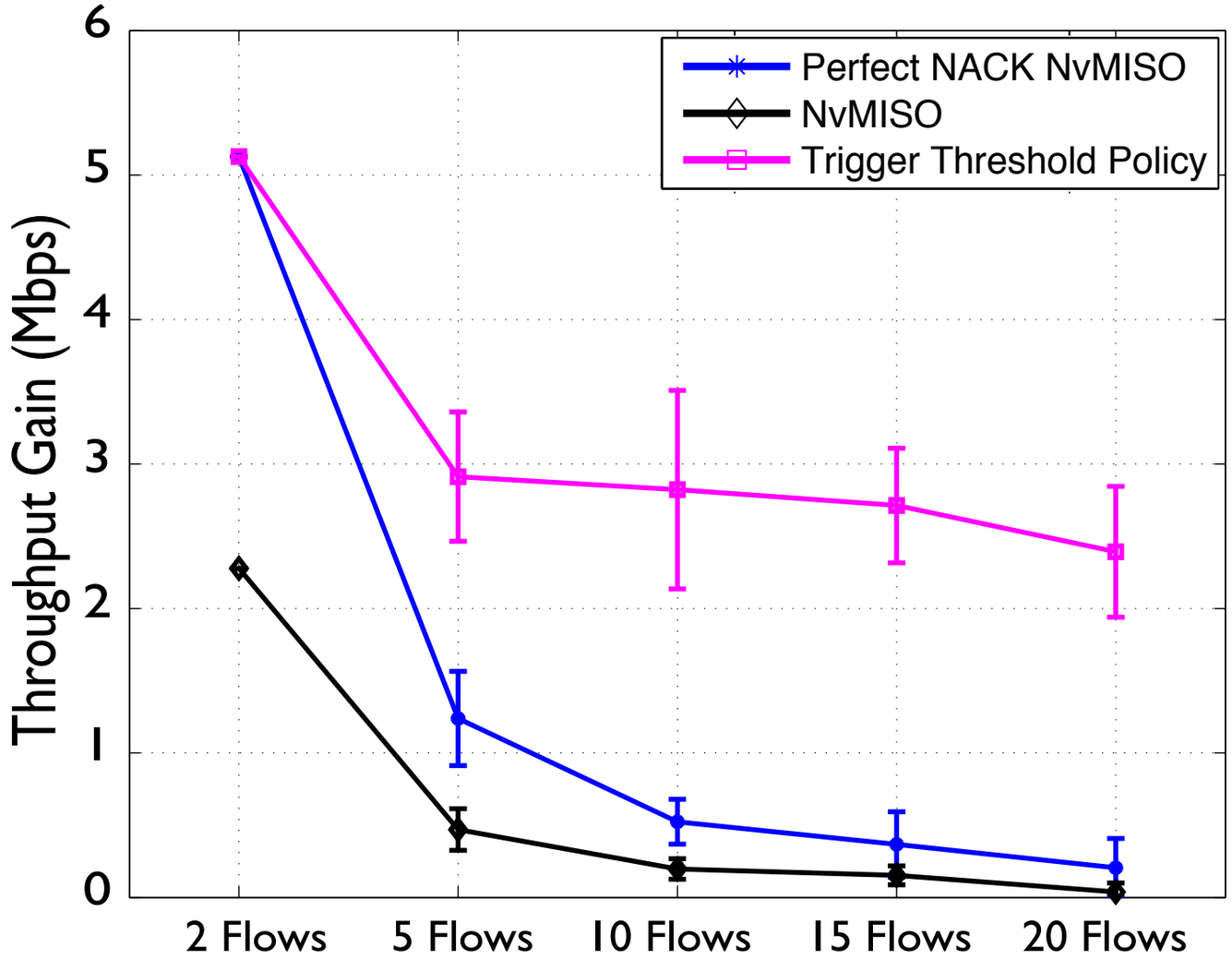
e.g., Local Approach: only flows achieving γ% gains allowed to trigger vMISO

vMISO in Large-Scale Scenarios



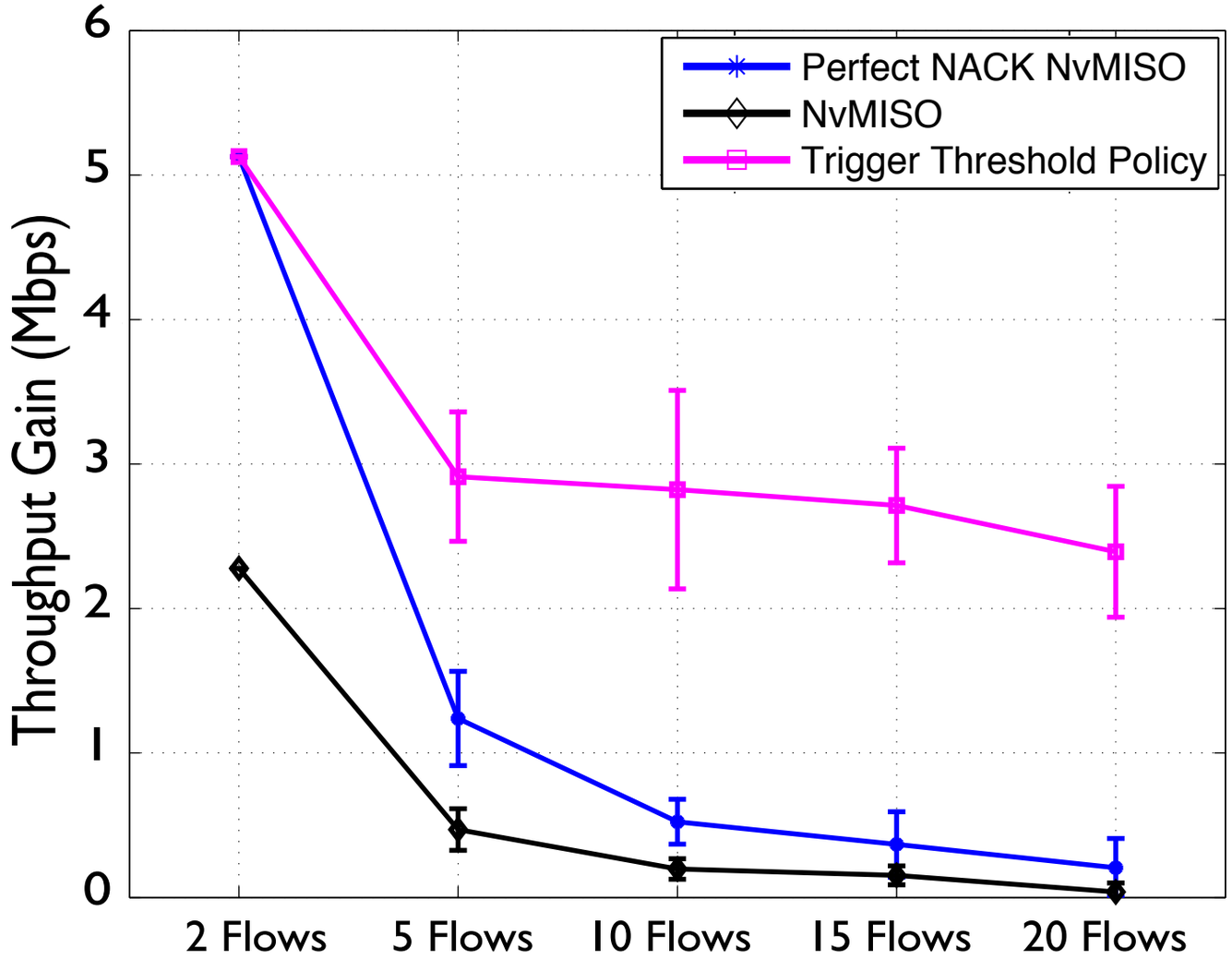
vMISO in Large-Scale Scenarios

- Network-wide trigger threshold policy:



vMISO in Large-Scale Scenarios

- Network-wide trigger threshold policy:
  - Local Decisions



vMISO in Large-Scale Scenarios

- Network-wide trigger threshold policy:
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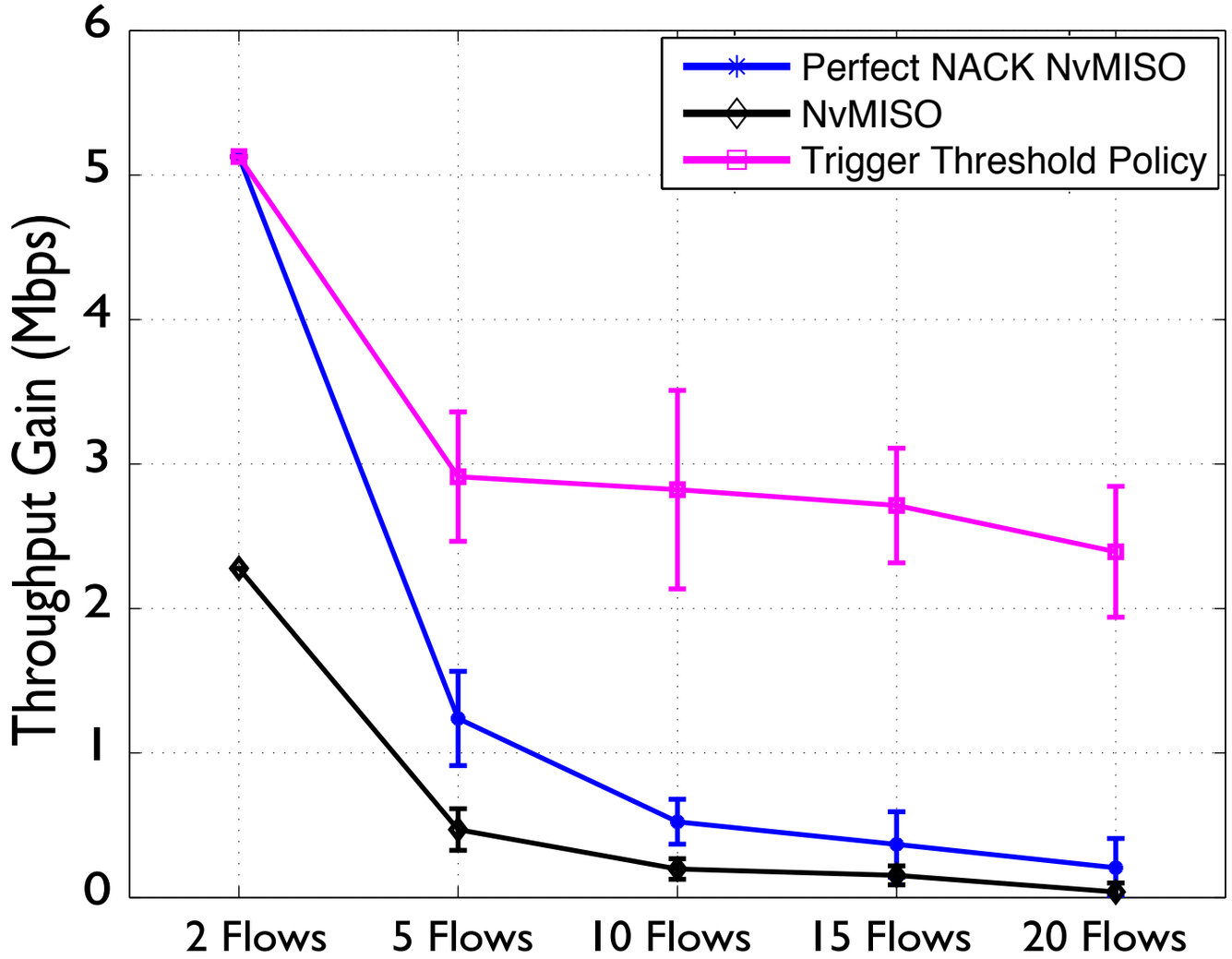

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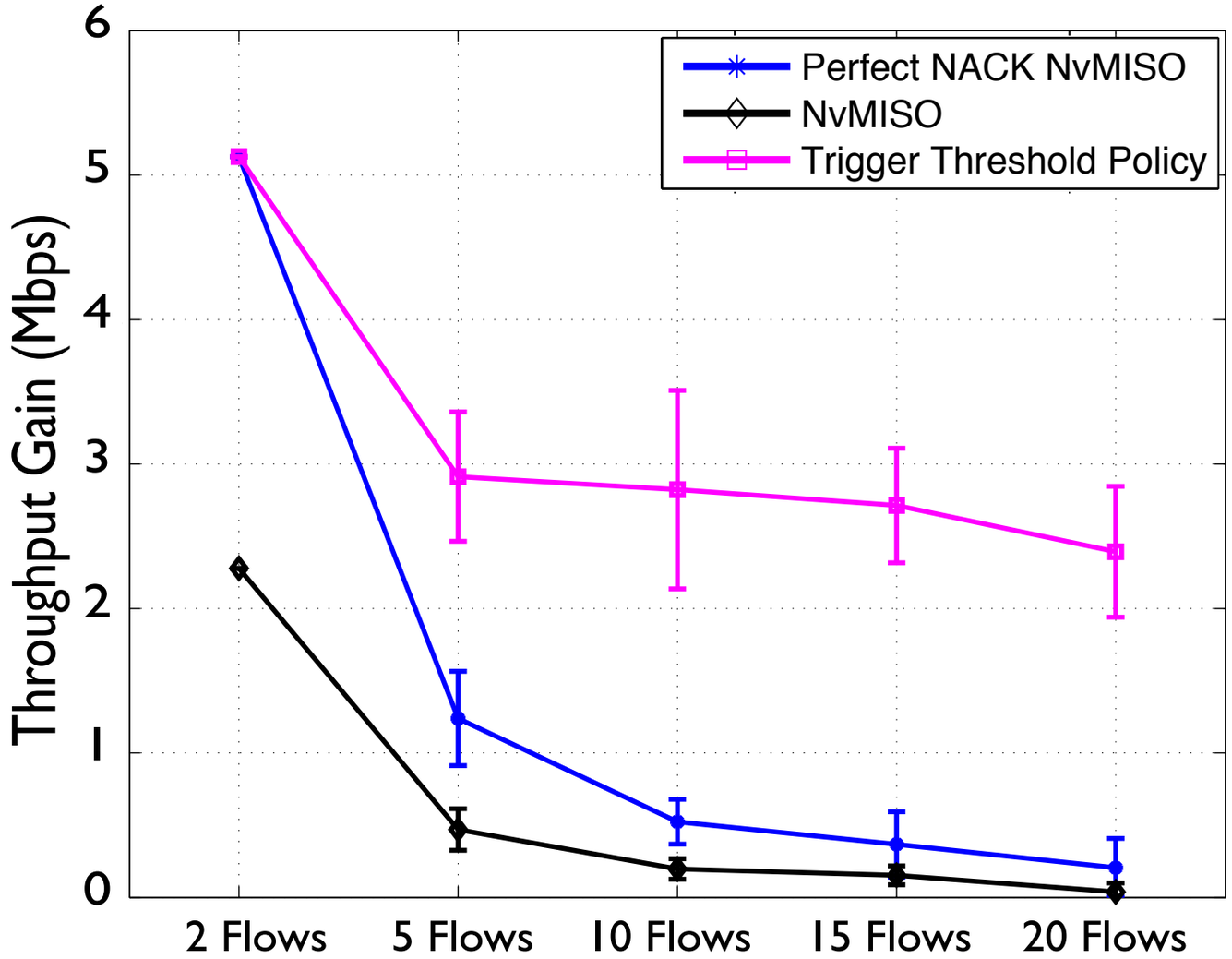

vMISO in Large-Scale Scenarios

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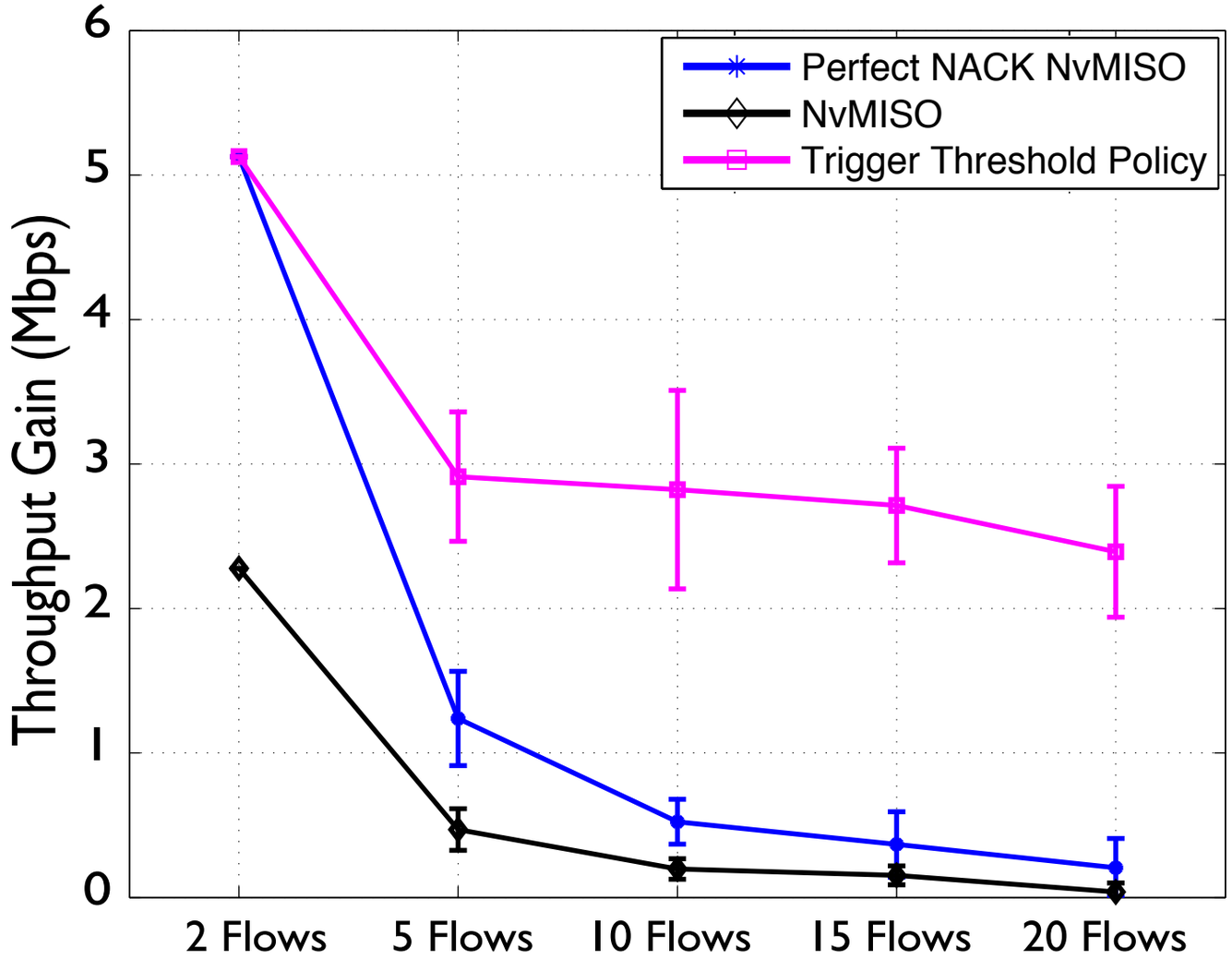

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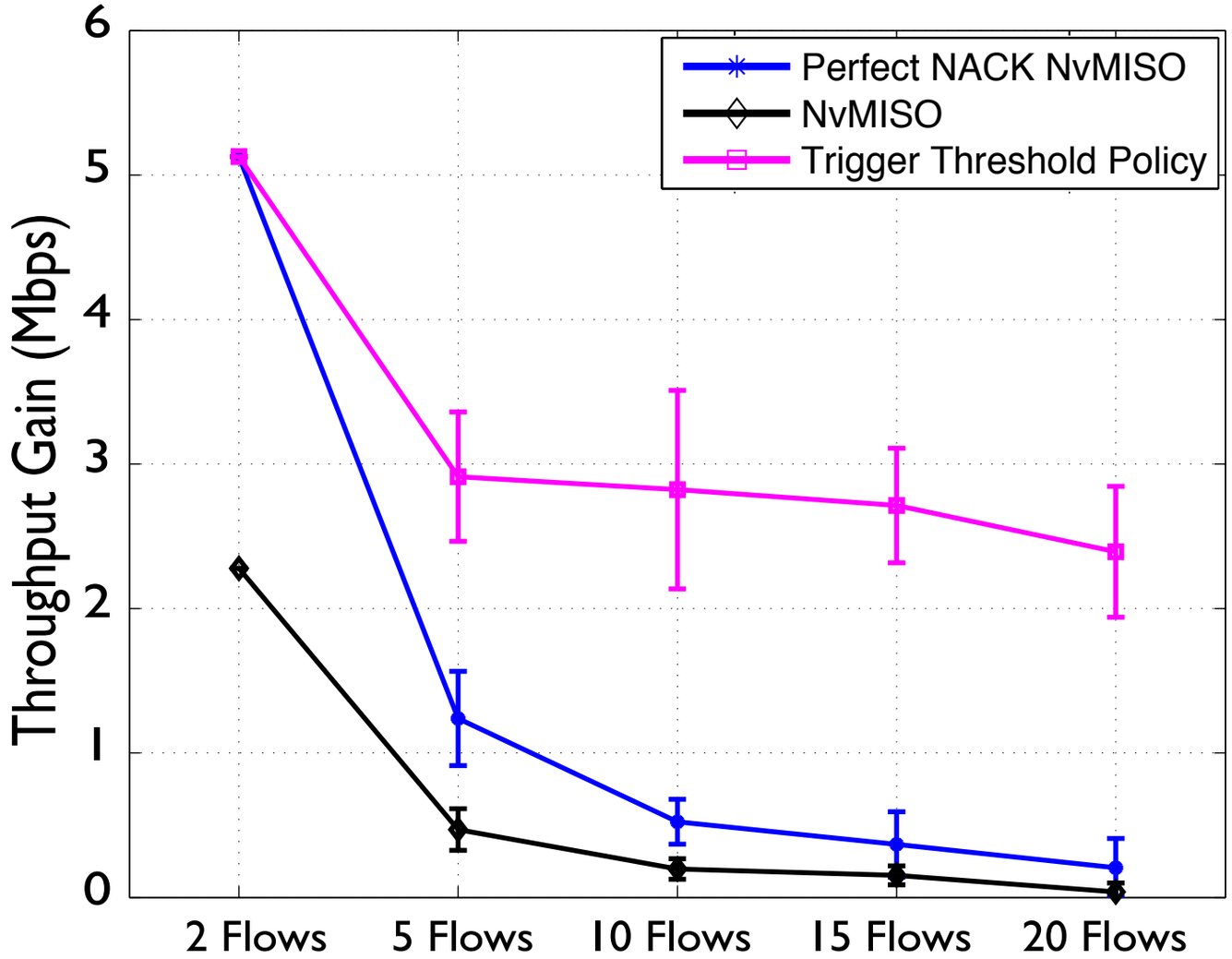

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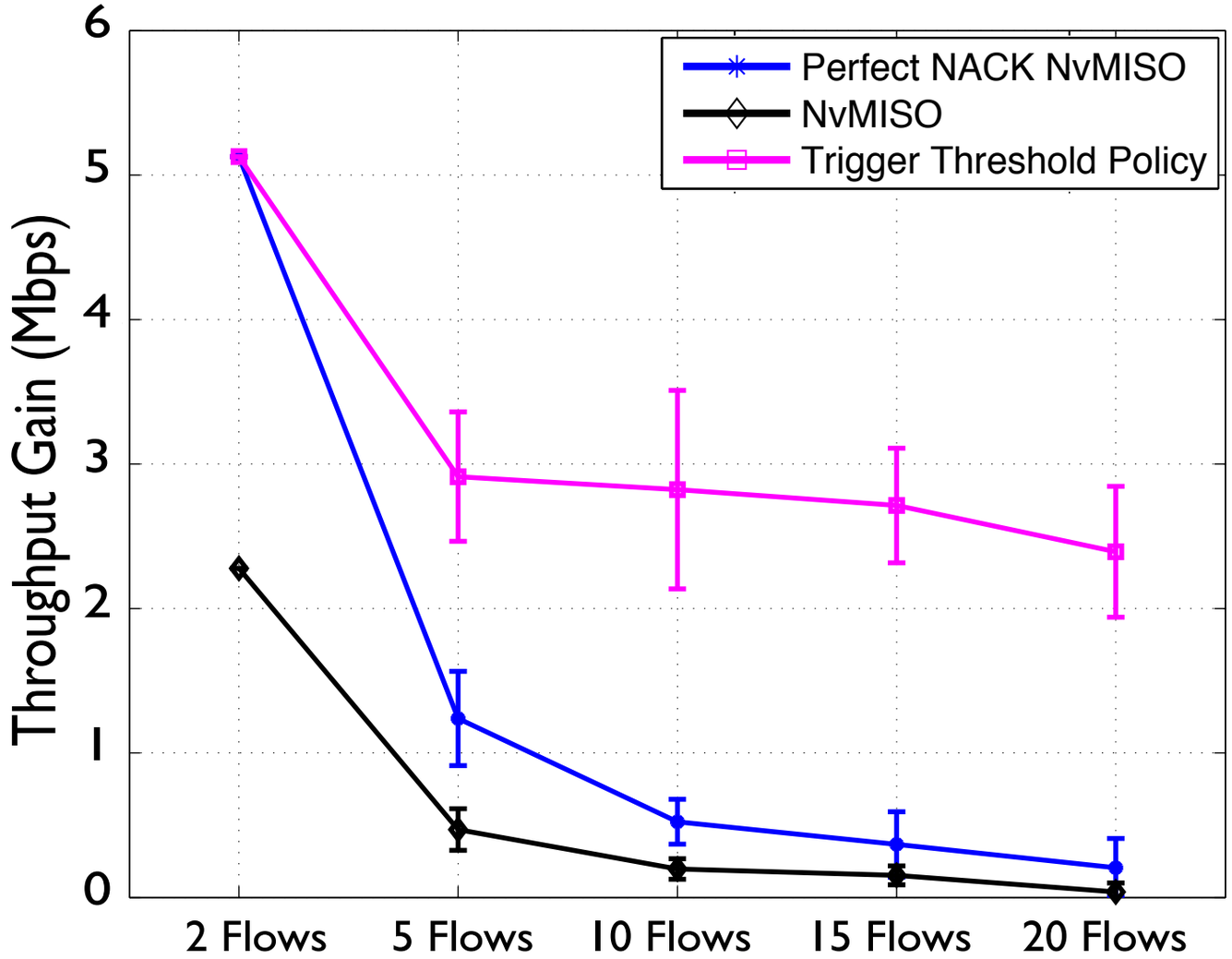

Even a simple policy can be highly efficient in large networks

RICE

Conclusion

- Objective: To develop a **comprehensive understanding of vMISO** in the context of WLANs that, leads to the design of ***trigger policies*** that maximize throughput performance gains
- Demonstrated that cooperation is able to achieve very high gains at atomic level scenarios
- However, the magnitude of these gains decrease at network-scale scenarios
- Nonetheless, simple trigger policies can have a significant positive impact on the performance of vMISO

RICE

Thank You!

Virtual MISO Triggers in Wi-Fi-like Networks

Oscar Bejarano
Edward W. Knightly