A MAC Interaction Aware Routing Metric in Wireless Networks

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ACM MSWiM, 2010

Introduction

Routing in *Multi-Hop Wireless Networks* (MHWN) is becoming increasingly important:

- Mesh networks, Relay Networks, ...

But, performance of routing is inefficient and unpredictable

- Complexity of wireless PHY and MAC
- Far below analytical limits

Motivation

There has been a vast number of routing metrics and protocols

- First generation: Hop-count based
- Second generation: Link-quality based (e.g., LQSR, ETT)

Current routing metrics

- Account for effect of interference at PHY layer
- At MAC layer? CSMA effects? Performance penalties?

CSMA protocols have many inefficiencies

- Different type of packet timeouts, exposed terminals, their impact . . .

Contribution

Recent studies:

- A new approach that quantifies effect of interference at MAC layer
- Extended to study performance of **chains**.

We propose a routing metric that accounts for detailed CSMA MAC effects

MAC interactions

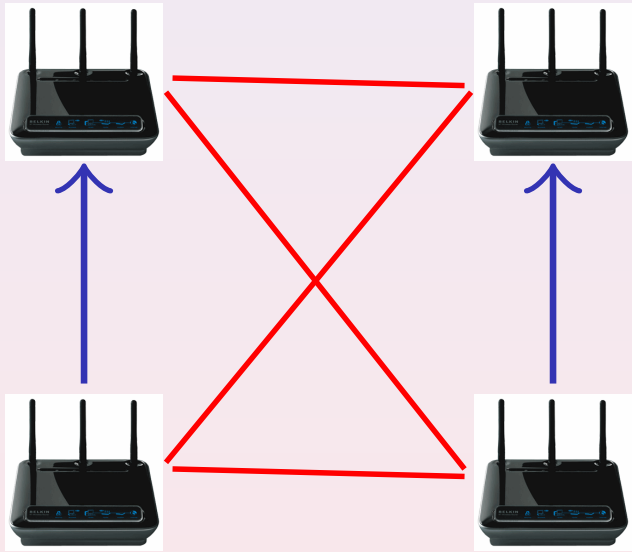
Two-flows under CSMA/CA

Discrete number of interaction patterns:

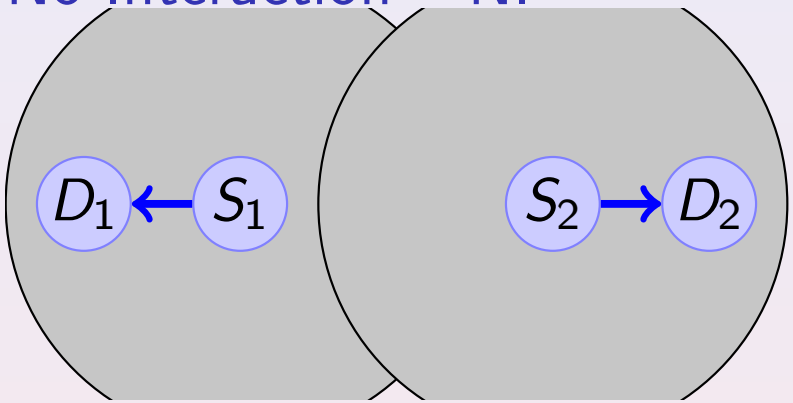
- 10 categories under SINR model

4 prominent categories:

- No Interaction
- Sender Connected
- Classical Hidden Terminal
- Capture Effect



No Interaction – NI

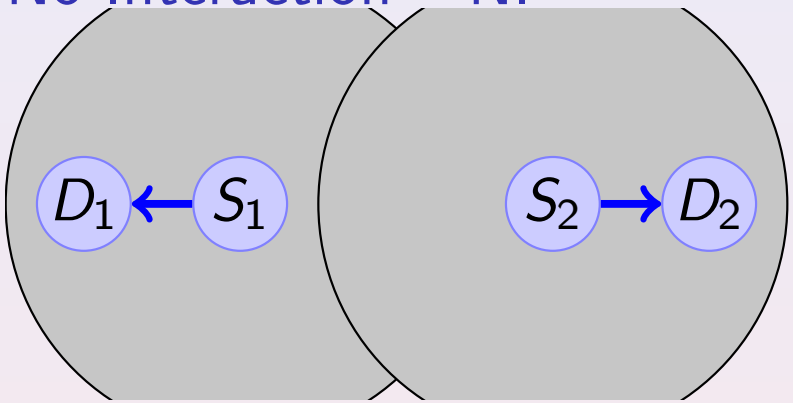


Sender Connected – SC

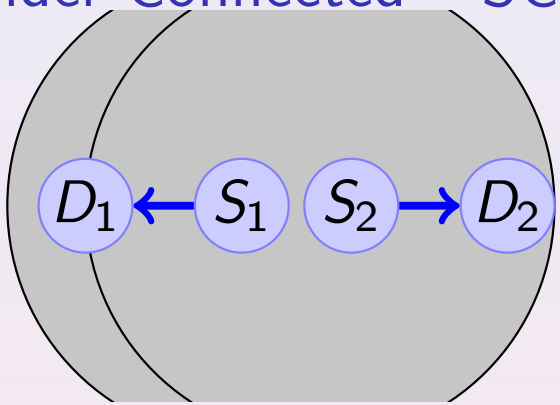
Hidden Terminal – HT (AIS)

HT with Capture – HTC

No Interaction – NI



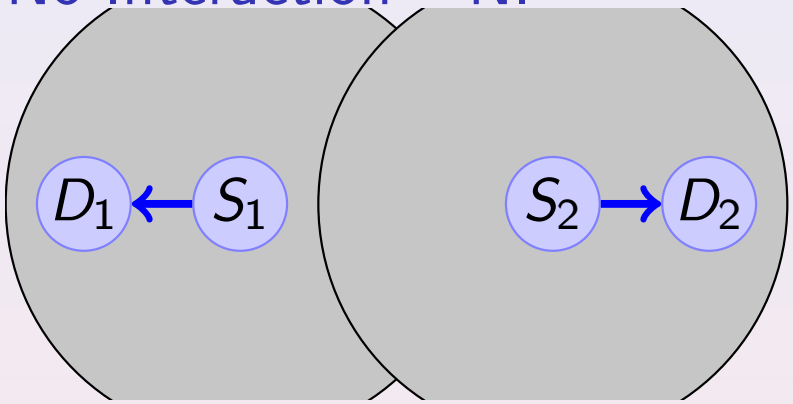
Sender Connected – SC



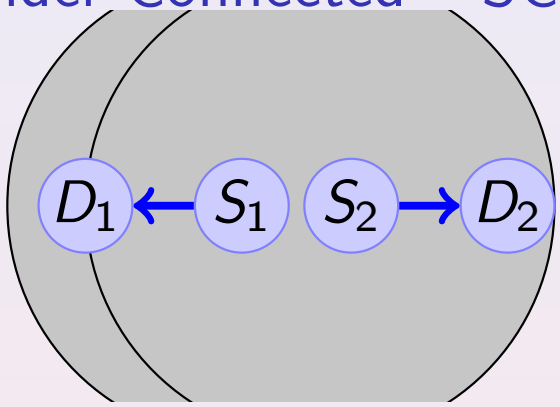
Hidden Terminal – HT (AIS)

HT with Capture – HTC

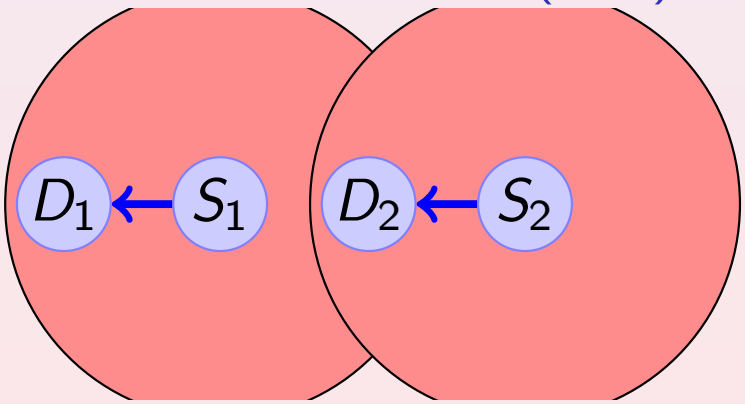
No Interaction – NI



Sender Connected – SC

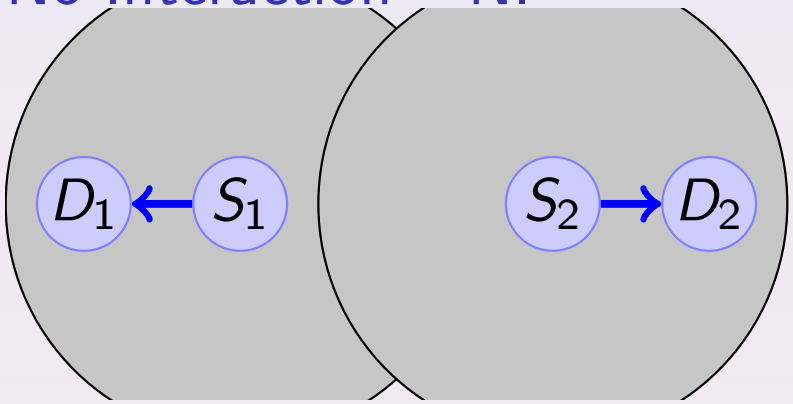


Hidden Terminal – HT (AIS)

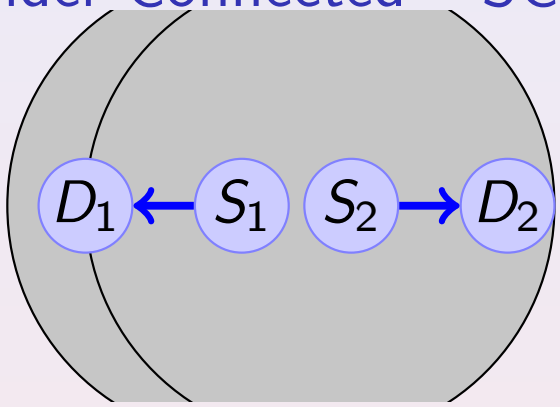


HT with Capture – HTC

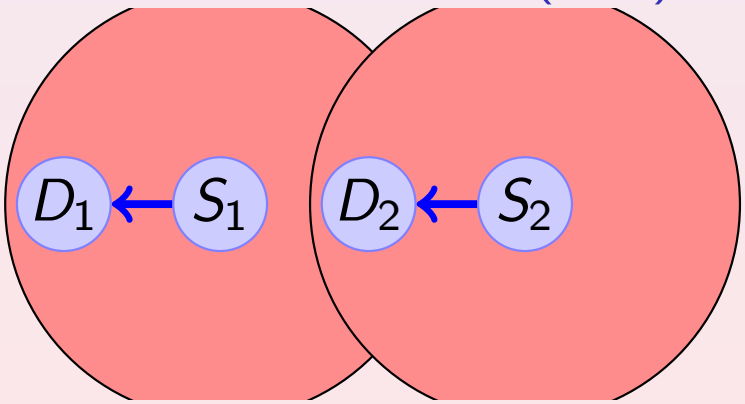
No Interaction – NI



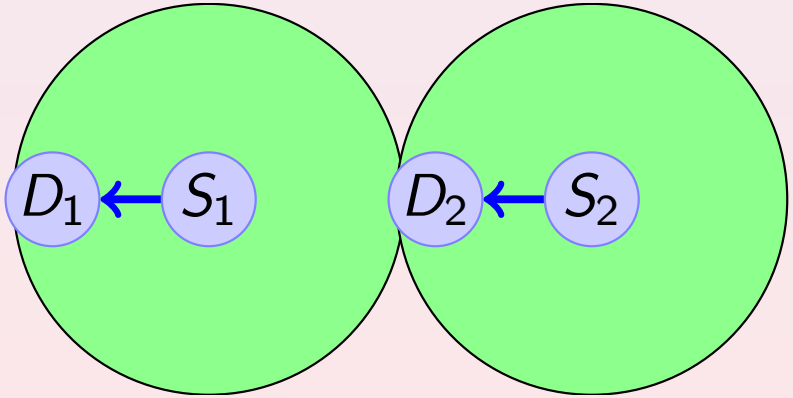
Sender Connected – SC



Hidden Terminal – HT (AIS)



HT with Capture – HTC



Interference in Chains

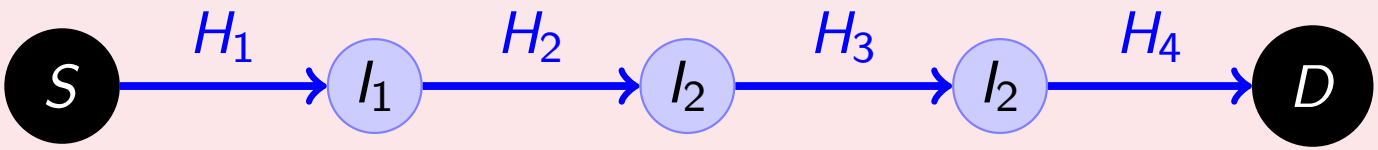
CSMA interactions affect chain performance

Self-interference

- End-throughput does NOT depend on the interactions
- Network efficiency depends on the interactions

Cross-chain interference

- Efficiency and vulnerability of a chain depends on
  - Type of interaction: NI $>$ SC $>$ HTC $>$ AIS
  - Location of interaction: Interactions nearer to sources matter the most



CSMA aware routing metrics

We propose two metrics

- MIAR-Self
  - Uses self-interference to assign weights
- MIAR-Cross
  - Considers interactions between all links in all chains

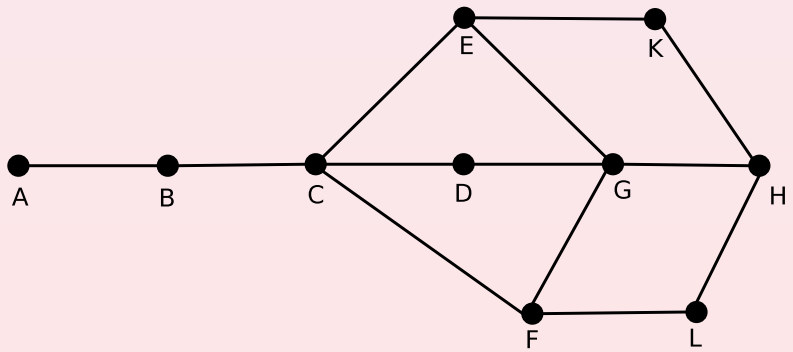
MIAR-Self

Recall: Chain efficiency depends on *(type, location)* of interactions

Idea: Assign route metric based on the type- and location- of its constituent links

Approach:

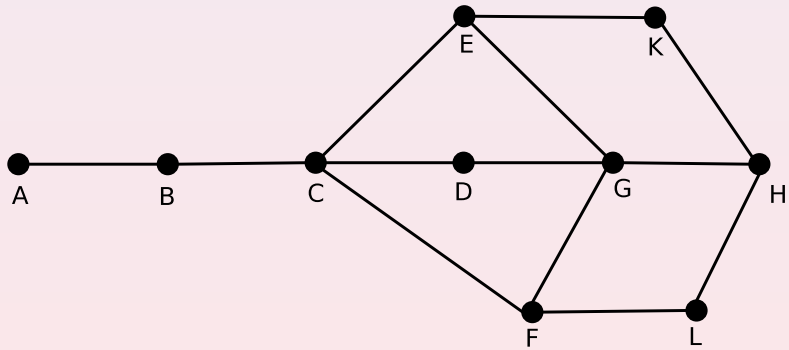
- Type-cost: NI=0; SC=0; HTC=1; AIS=1.25
- Location-cost: 1st hop=1, 2nd = $\frac{1}{2}$, 3rd=$\frac{1}{4}$, ...
- MIAR-Self(ABCD) = $T_{AB}L_{AB} + T_{BC}L_{BC} + T_{CD}L_{CD}$



MIAR-Self Protocol

A distributed approach to compute and propagate routing metric

$$\begin{aligned} \text{MIAR-Self}(\texttt{ABCD}) &= T_{AB}L_{AB} + T_{BC}L_{BC} + T_{CD}L_{CD} \\ &= T_{AB} + \frac{T_{BC}}{2} + \frac{T_{CD}}{4} \\ &= T_{AB} + \frac{\text{MIAR-Self}(\texttt{BCD})}{2} \end{aligned}$$

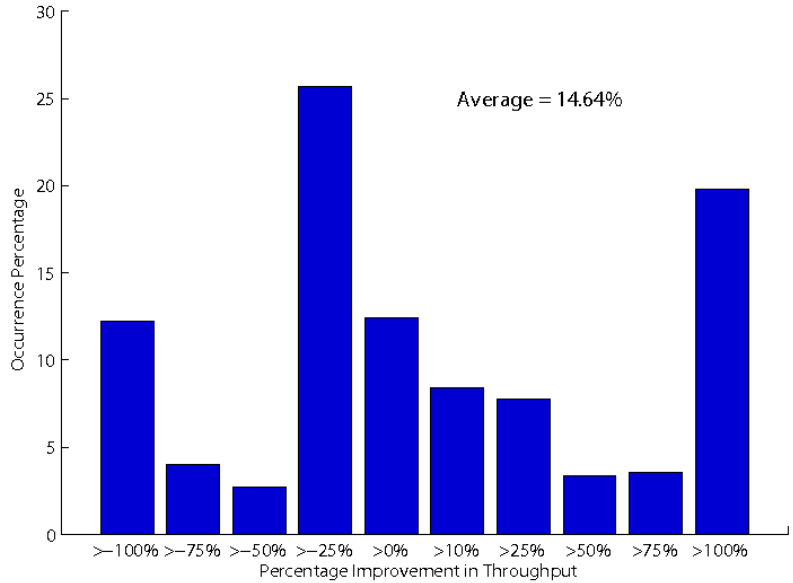


Propagate routing metric using traditional schemes (RREP, periodic broadcasts)

Performance of MIAR-Self

500 scenarios, 2-chains

- Average improvement=15%
- Network efficiency: Lesser network load in 80% of scenarios
- Self-interference is insufficient
  - Poor performance in 45% of scenarios
  - Cross-chain interactions



MIAR-Self

MIAR-Cross

Cross-chain interference has large impact

But, direct extension of MIAR-Self is not scalable

- Requires computing of *(type, location)* tuples for all link-pairs
- e.g., two 4-hop chains: 10^{16} combinations!

We empirically learn from simulating large number of scenarios

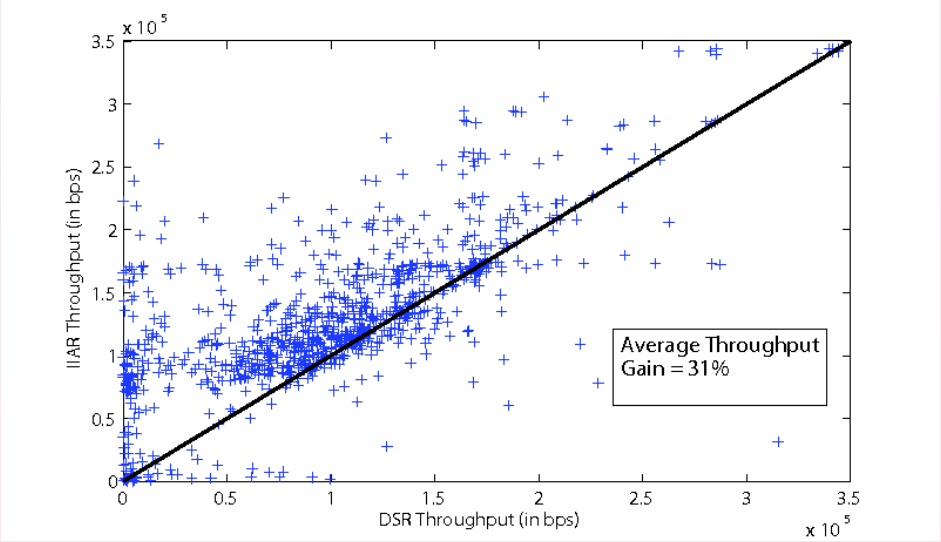
- Assign weight to each (type, location) tuple
- Map the weighted sum of each chain to throughput
- Solve the system of equations

Centralized MIAR-Cross

1. Assign random min-hop (ETX) route to each connection
2. Evaluate MIAR-Cross for one chain, assume others constant
3. Iterate step 2 until convergence

Performance of MIAR-Cross

- Two and four 4-hop chains
- Average improvement=31%
- Throughput improves in 80% of scenarios



Improvement of MIAR-Cross

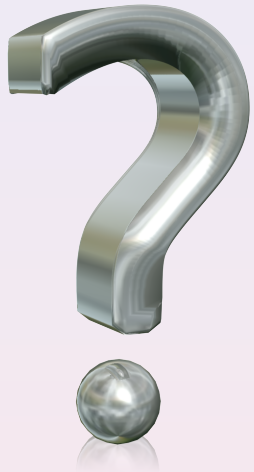
Conclusions and Future work

- Proposed two metrics that evaluate CSMA effectiveness in routes
  - Self-interference in a chain
  - Cross-chain interference
- Significantly improves throughput of weak chains

Future Work

Quantifying interference above MAC layer is complex, but important

- Statistical properties of metric that accounts for CSMA interactions
- Distributed MIAR-Cross protocol



Thank you.

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MIAR-Self in example chain

Node B		Node A	
Route	MIAR-Self	Route	MIAR-Self
BCEKH	1.25	ABCEKH	2.0
BCEGH	0.0	ABCEGH	1.25
BCDGH	0.0	ABCDGH	0.0
BCFGH	0.0	ABCFGH	1.0
BCFLH	1.25	ABCFLH	1.75

Table: Route metric at nodes B and A.

(AB, EK), (AB,EG), (BC,KH) and (BC,LH) have AIS interactions, and pairs (AB, FL) and (AB,FG) have HTC