Opportunistic Routing

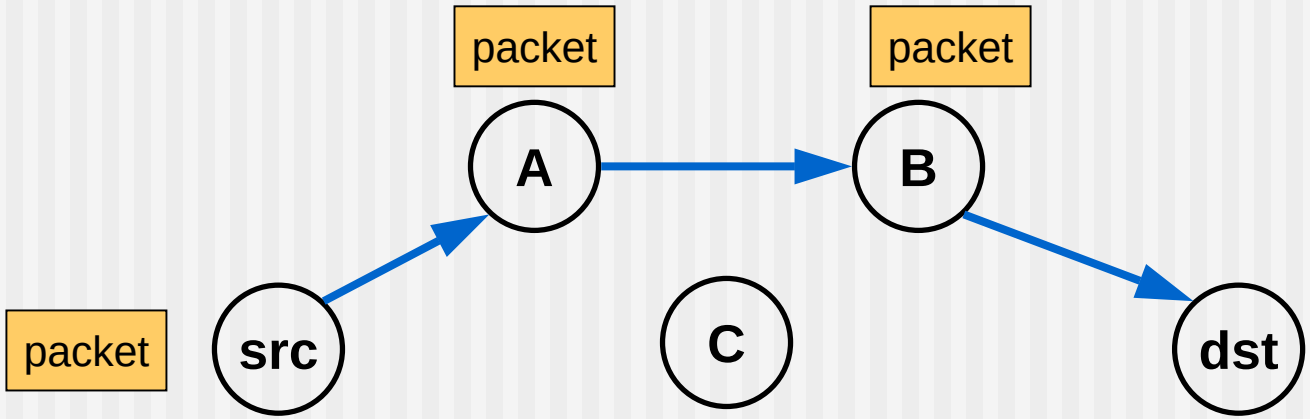
Robert Hilbrich
Robert@Hilbri.ch

ExOR – a new routing approach

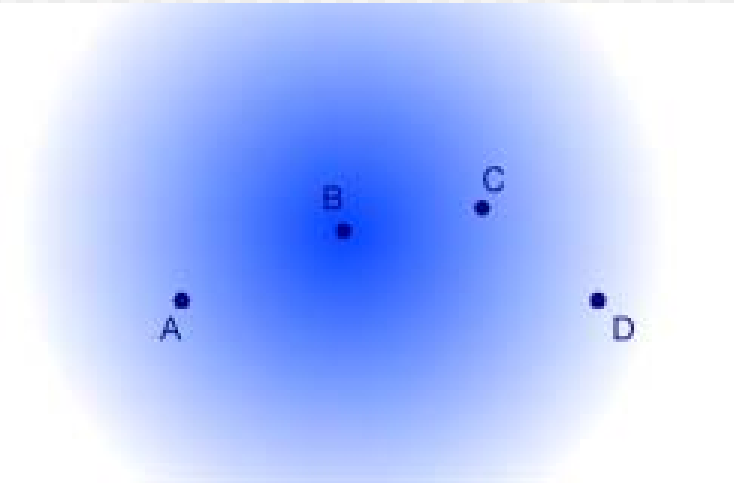
- dense 802.11 based mesh network
- Goal: high-throughput & capacity

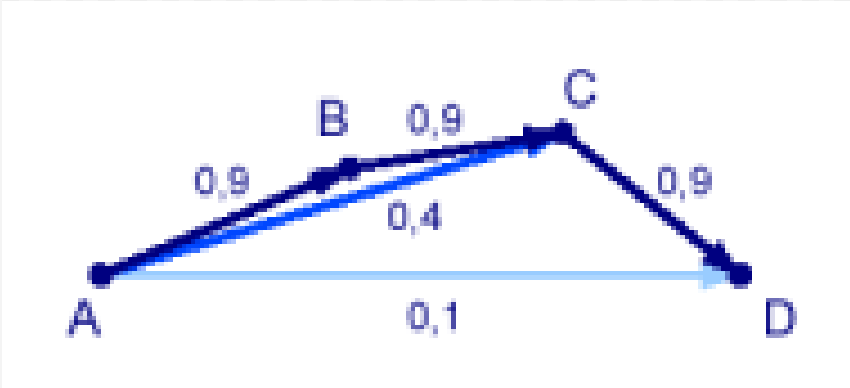
Traditional routing

- choose a static route before transmitting a packet
- treat wireless links like wired links



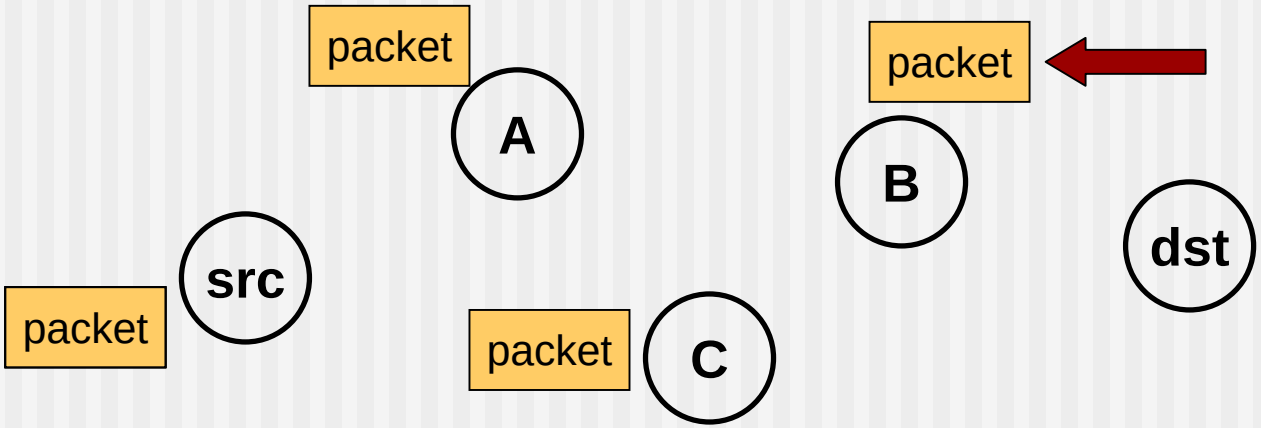
Reception is probalistic





- Goal:
  take advantage of wireless radio properties

Idea behind ExOR

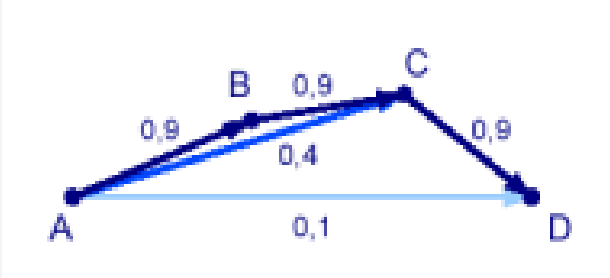


- Decide who forwards the packet after reception (no static route)
- Goal: only closest receiver should forward
- Challenge: agree efficiently and avoid duplicate transmissions

Outline

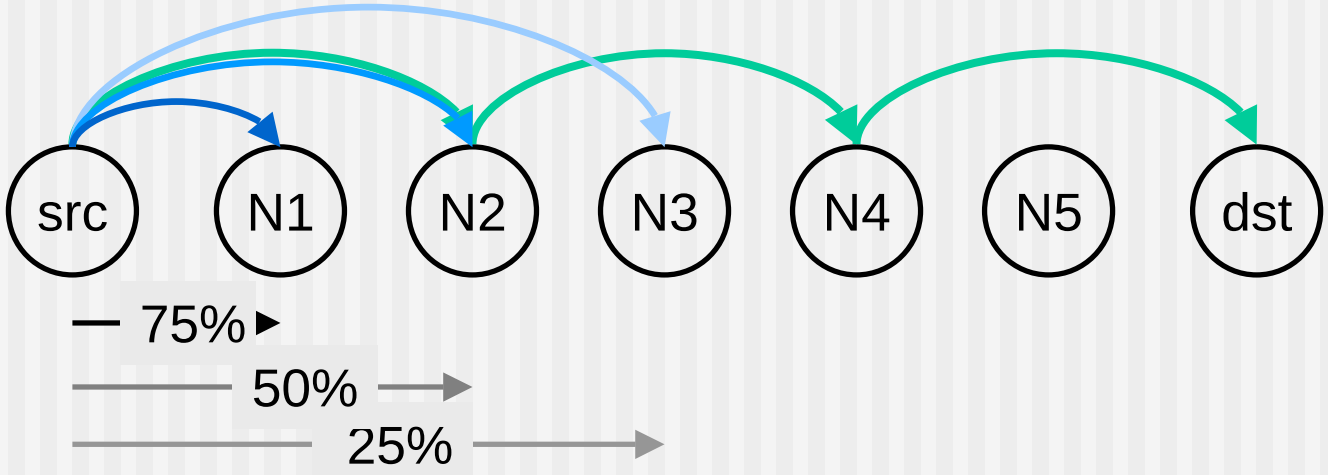
- Introduction - Idea behind ExOR
- Example Transmission
- Why ExOR increases throughput
- Protocol details
- Routing Performance
- References

Example Transmission



- Goal:
  Transmitting a packet from A to D
- 1) A-B-C-D = 3 Hops, most likely
- 2) A-D = 1 Hop, most unlikely
- lets take chances!

Why ExOR increases throughput



- Best traditional route over 50% hops: $3(1/0.5) = 6$ tx → Throughput $\cong 1/\#\ \text{transmissions}$
- ExOR exploits lucky long receptions: 4 Transmissions

Outline

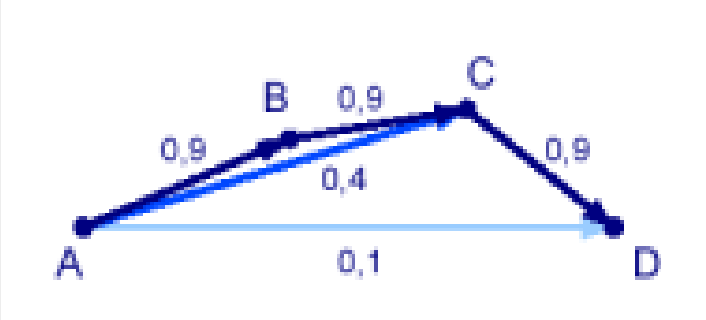
- Introduction - Idea behind ExOR
- Example Transmission
- Why ExOR increases throughput
- Protocol details
- Routing Performance
- References

Protocol details

- Forwarding decision resides on
  - ordered list of candidates
  - reception ack‘s
- Need a loss rate matrix and network layout (i.e. ETX + Dijkstra)
- Every packet includes a candidate set, ordered by distance to the destination

Step 1) Select Candidates

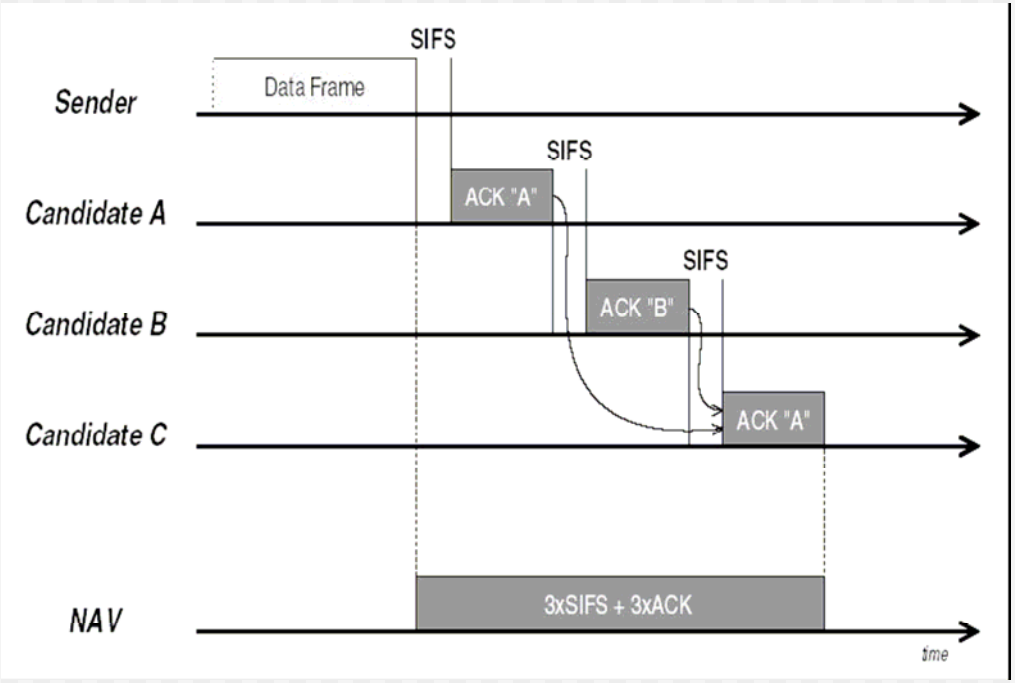
- Identify shortest path (using ETX)
- Use first node as best candidate
- Remove node from ETX matrix
- Repeat until candidate list is filled



Candidate set: D,C,B

Step 2) Ack‘s

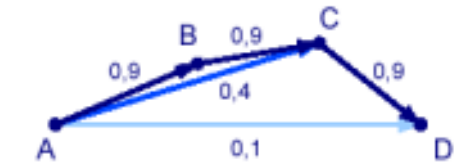
- Slotted ACK‘s based on senders priority in candidate list
- each ACK contains the highest recipient known
- all candidates listen to all ACKs before forwarding



Step 3) Forwarding?

- Rule:
  Forward if you have not seen a higher ID in any ACK received.

- Use packet ID caching and checking to reduce duplicates



Example Transmission

- Candidate Set: (D, C, B)
- Assumption: B and C receive, D does not
- ACK-slots:
  - 1.No ACK from D (since D didn't hear the transmission)
  - 2.ACK from C containing C's own node-id
  - 3.ACK from B containing C's node-id as well
- If all nodes registered the ACKs, C will become the forwarding node
- Even if A didn't receive C's ACK, it may have heard B's ACK

Outline

- Introduction - Idea behind ExOR
- Example Transmission
- Why ExOR increases throughput
- Protocol details
- Routing Performance
- References

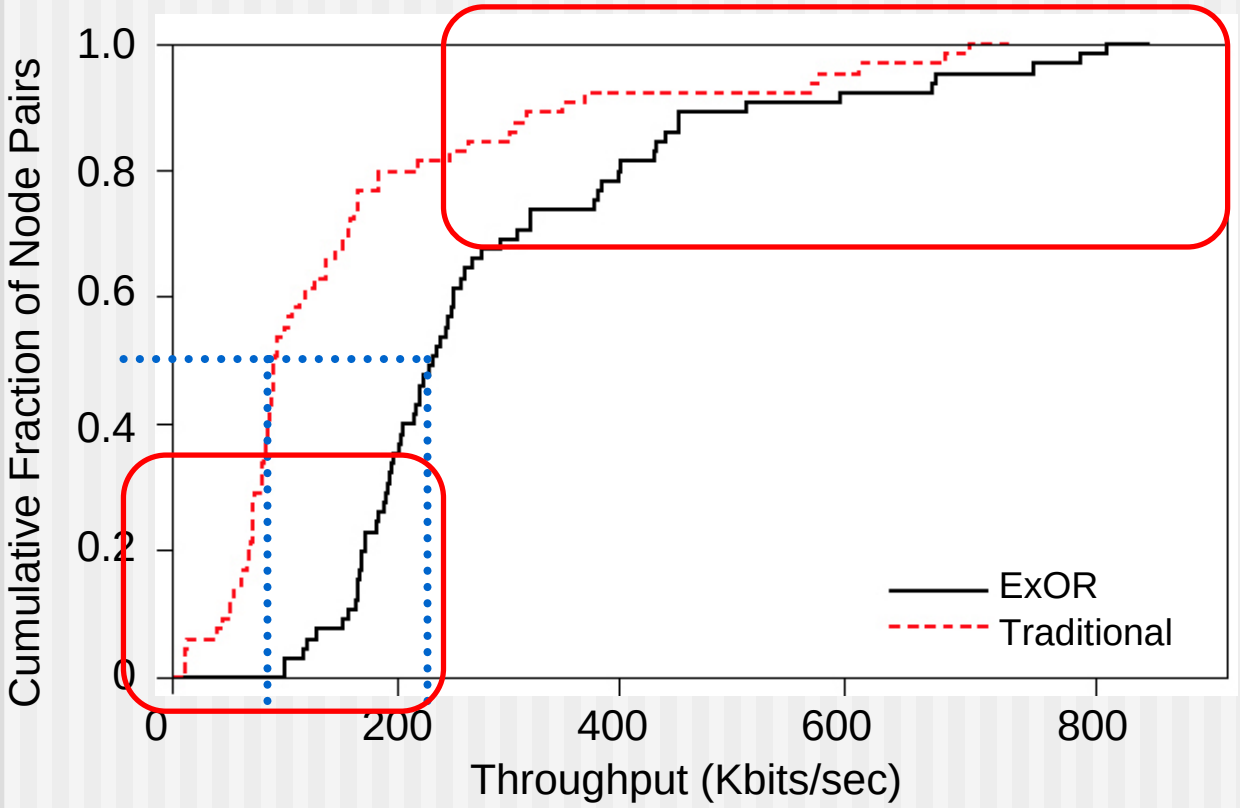
Routing performance

- 65 node pairs, 802.11 @ 1 MBit/s, 1KByte packets, 1MByte file transfer

Traditional Routing	ExOR
802.11 unicast with link-level retransmissions Hop-by-hop batching UDP, sending as MAC allows	802.11 broadcasts 100 packet batch size

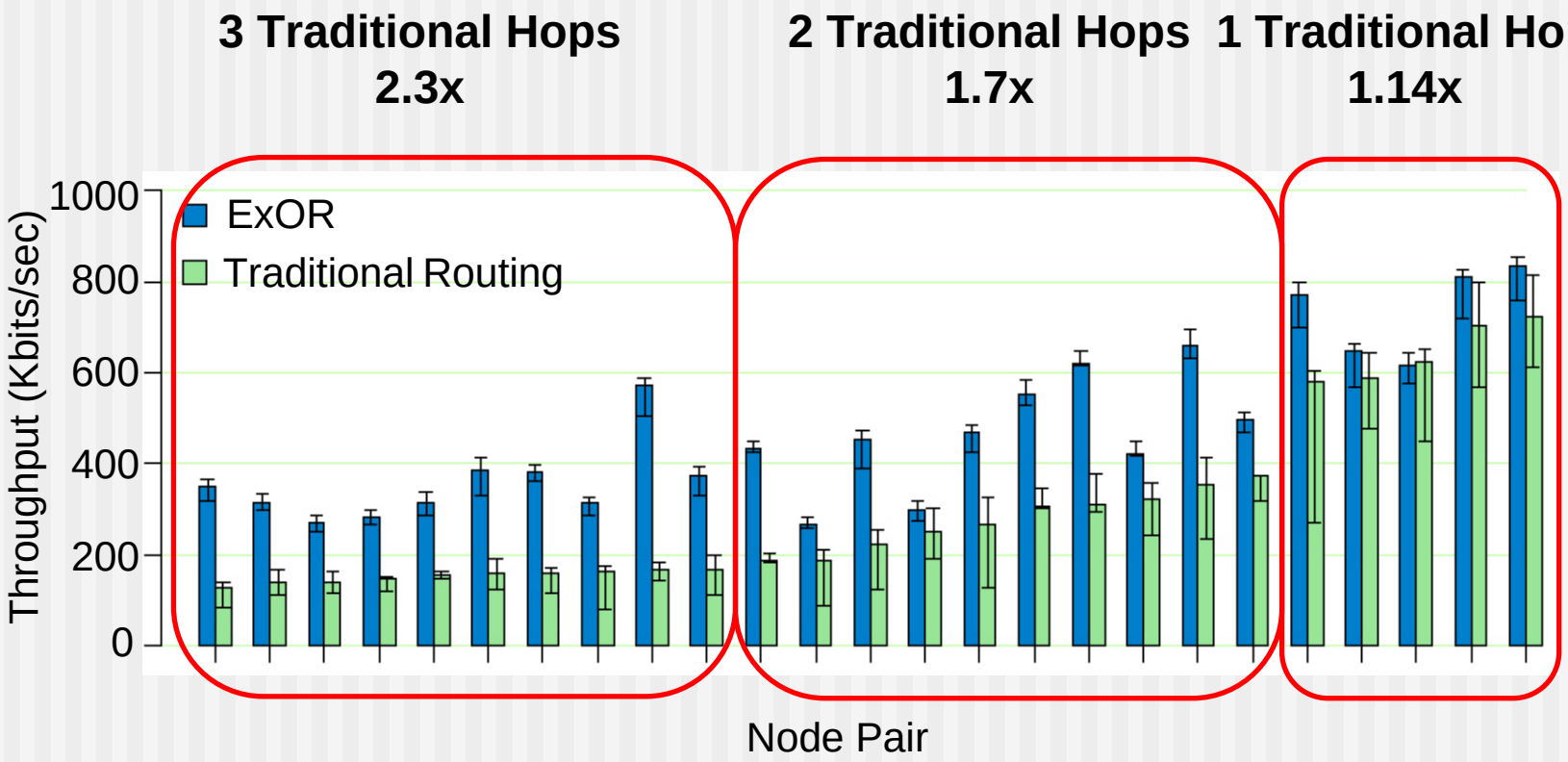
Routing performance

- ExOR: 2x overall improvement

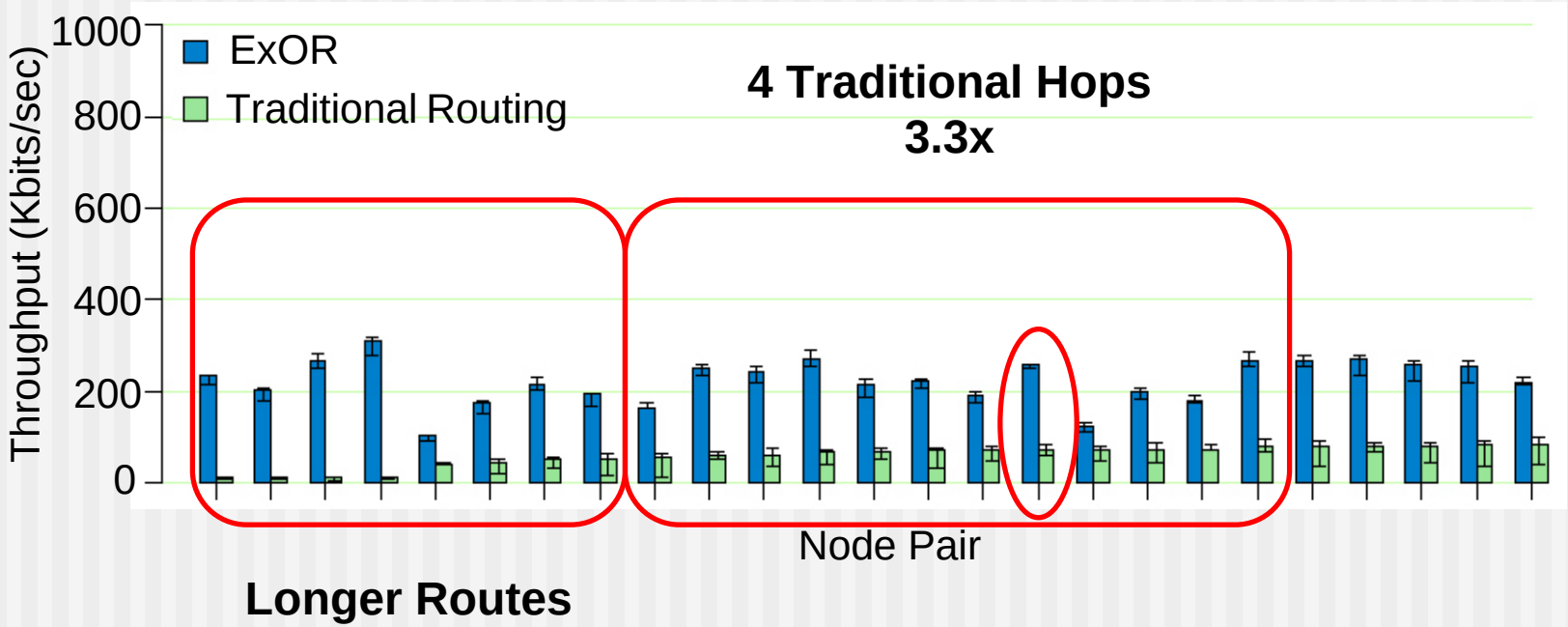


- ExOR: 240Kbits/s
- Traditional: 121Kbits/s

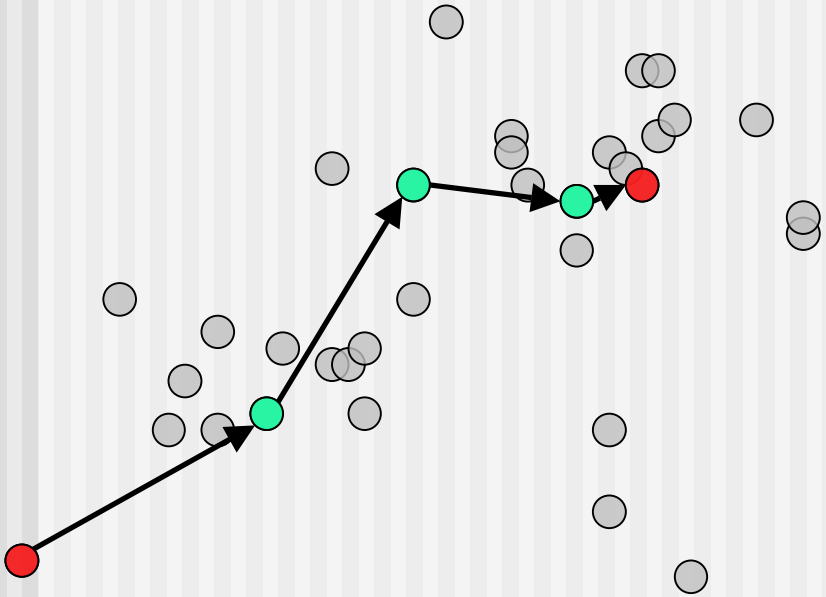
25 Highest throughput pairs



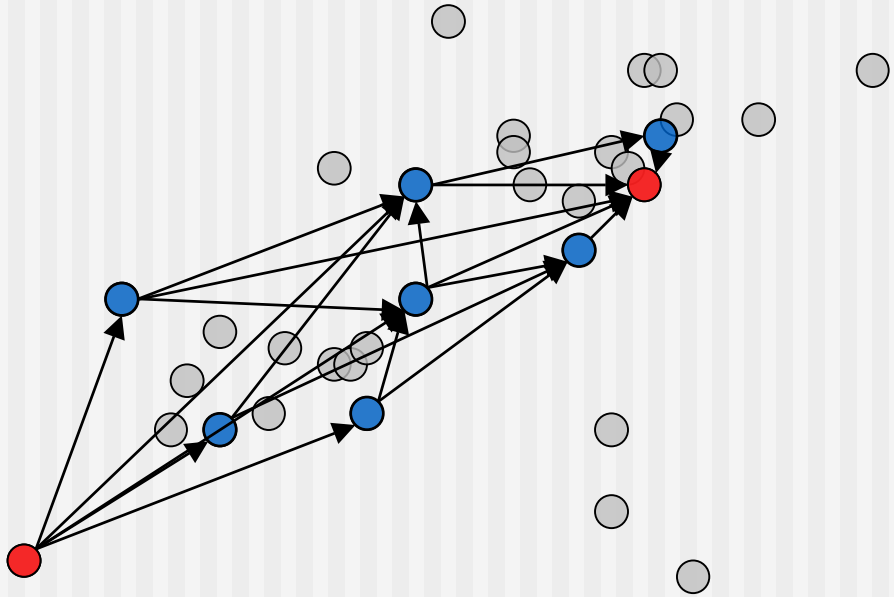
25 Lowest throughput pairs



ExOR uses links in parallel

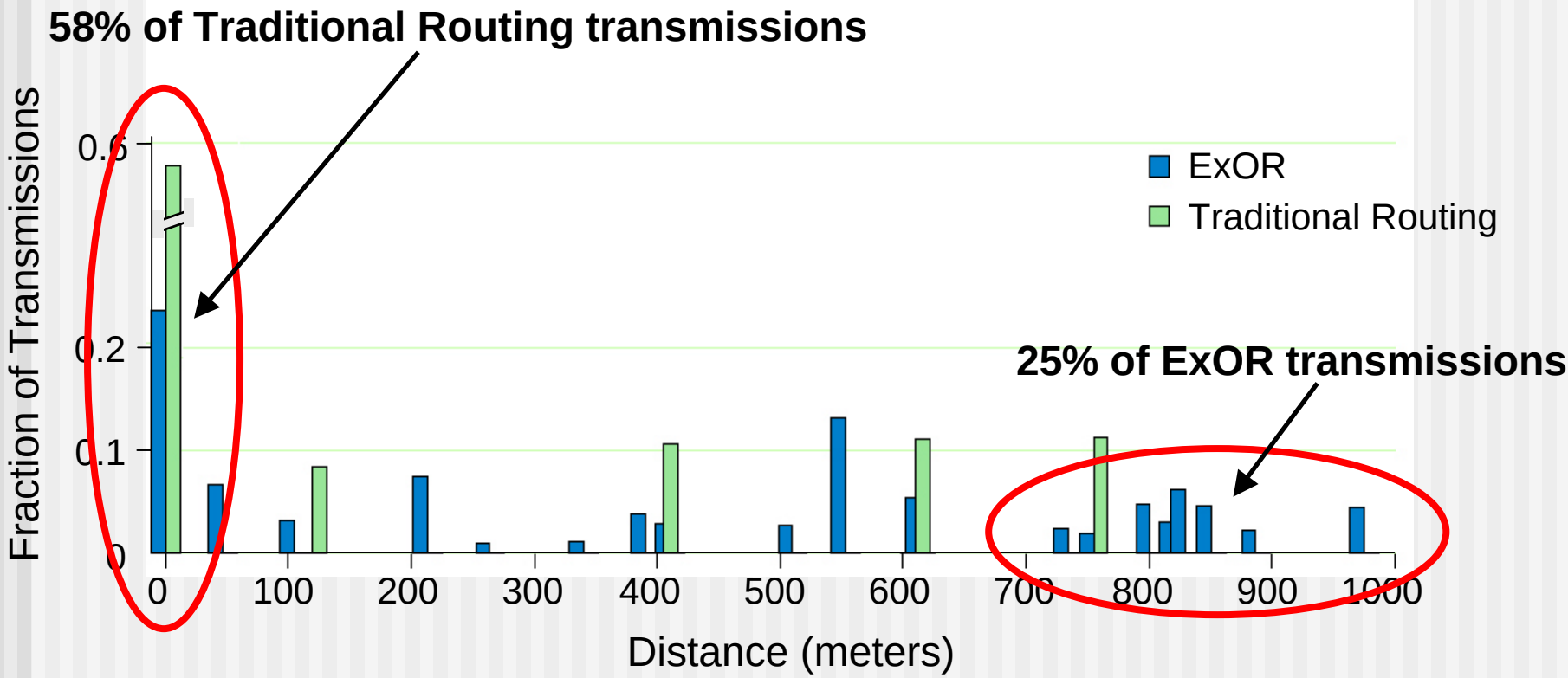


Traditional:
3 forwarders, 4 links



ExOR:
7 forwarders, 18 links

ExOR moves packets farther



ExOR: 422m/tx, Traditional: 205m/tx

Summary

- ExOR achieves 2x throughput improvement
- ExOR implemented on Roofnet (i.e. MIT)
- Exploits radio properties, instead of hiding them

References

- http://pdos.csail.mit.edu/roofnet/
- Opportunistic Routing in Multi-Hop Wireless Networks
  (Sanjit Biswas and Robert Morris, MIT, 2004)