Overview

• Most wireless routing protocols abstract wireless links as unreliable wireline links

• Are wireless links the same as wireline links except that they are less reliable?
Overview (Cont.)

• Difference between wireless and wireline links
  - Higher loss rate
  - Broadcast medium
  - Wireless interference
  - Highly dynamic and unpredictable
Traditional Routing

- Committed to a specific route before forwarding

- Problems: don’t fully exploit path diversity
  - Unpredictable wireless medium
  - Intermittent connectivity
  - High mobility
  - Routing attacks
Motivating Scenario I

- Assume independent loss
- Tradition routing has to follow one pre-committed route
Motivating Scenario II

- Assumes loss rate increases gradually with distance
- Tradition routing has to make comprise between progress and loss rate
Opportunistic Routing (ExOR)

- Don’t commit to a route before data forwarding
- Exploit wireless broadcast
- The source broadcasts the packet and then chooses a receiver to forward only after learning the set of nodes which actually received the packet.
- Goal: Among the nodes who receive the packet, the node closest to the destination should forward.
Main Challenge

• How to select the node that is closest to the destination that received the packet to forward it with low overhead?
Issues to Address

• What do we want?
• How often should ExOR run?
• Who should participate in the forwarding?
• When should each participant forward?
• What should each participant forward?
Issues to Address

• What we want: an effective protocol with low overhead
• How often should ExOR run?
  - Per packet is expensive
  - Use batches
Issues to Address

- What we want: an effective protocol with low overhead
- How often should ExOR run?
  - Per packet is expensive
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- Who should participate forwarding?
  - Too many participants cause large overhead
Who should participate?

- A background process collects ETX information via periodic link-state flooding.

- The source chooses the participants (forwarder list) using ETX-like metric.
  - Only consider forward delivery rate
    - Why?
  - The source runs a simulation and selects only the nodes which transmit at least 10% of the total transmission in a batch.
Issues to Address

• What we want: an effective protocol with low overhead
• How often should ExOR run?
  - Per packet is expensive
  - Use batches
• Who should participate the forwarding?
  - Too many participants cause large overhead
• When should each participant forward?
  - Avoid simultaneous transmissions
When should each participant forward?

- Forwarders are prioritized by ETX-like metric to the destination
- The highest priority forwarder transmits when the batch ends
- The remaining forwarders transmit in prioritized order
- Question: How does each forwarder know it is its turn to transmit?
  - Assume other higher priority nodes send for five packet durations if not hearing anything from them
Issues to Address

• What we want: an effective protocol with low overhead
• How often should ExOR run?
  – Per packet is expensive
  – Use batches
• Who should participate the forwarding?
  – Too many participants cause large overhead
• When should each participant forward?
  – Avoid simultaneous transmissions
• What should each participant forward?
  – Avoid duplicate transmissions
What should each participant forward?

- Packets it receives yet not received by higher priority forwarders
- Question: How does a node know the set of packets received by higher priority nodes?
  - Using batch map
Batch map

- Batch map indicates, for each packet in a batch, the highest-priority node known to have received a copy of that packet.

1st round Tx: 1, 2, 3, 4, 5, 6, 7, 8
Batch map: 13032012

Rx: 1, 2, 7, 8   Tx: 1, 7
Batch map: 13032012

2nd round Tx: 3, 6
Batch map: 13032012

N0

N1

N2

N3

Forwarder list: N3(dst), N2, N1, N0 (src)
Rx: 2, 5, 8   Tx: 5, 8
Batch map: 03032002

Rx: 2, 4   Tx: batch map only
Batch map: 03030000
Completion

- A node stops sending the remaining packets in the batch if its batch map indicates over 90% of this batch has been received by higher priority nodes.

- The remaining packets transferred with traditional routing.
Example

Forwarder list: N24(\text{dst}), N20, N18, N11, N8, N17, N13, N5(\text{src})
ExOR with TCP

- ExOR creates lots of packet reordering
- ExOR increase end-to-end delay
- Solution: Split web proxy
Evaluation - Network Description

- Performed on Roofnet, an outdoor roof-top 802.11 networks
- 38 nodes distributed over six square kilometers
- 65 Node pairs
- 1.0MByte file transfer
- 1 Mbit/s 802.11 bit rate
- 1 KByte packets
Evaluation - Throughput

Median throughputs:  2X overall improvement
Evaluation - 25 Highest Throughput Pairs
Evaluation – 25 Lowest Throughput Pairs

- ExOR
- Traditional Routing

Throughput (KB/Bytes/s)

5-7 Traditional Hops
4 Traditional Hops
3 Traditional Hops
Evaluation – Distance per Transmission
Evaluation - Batch Size
Comments?
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• Pros
  - Takes advantage of the probabilistic reception to increase the throughput
  - Does not require changes in the MAC layer
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• Pros
  - Takes advantage of the probabilistic reception to increase the throughput
  - Does not require changes in the MAC layer
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• Cons
  - Complicated: many corner cases to handle
  - Cannot take advantage of multiple data rates
  - Forwarders take turns to transmit and do not leverage spectral reuse
  - Does not explicitly support multiple flows or TCP traffic
  - Batches increase delay
  - Hard to scale to a large network
  - Trade-off between spatial reuse and opportunistic gain
  - ETX based forwarder selection does not yield least cost path
Follow up work

- SOAR
- SourceSync
- Routing metric under opportunistic routing
- Network coding