Making Friends with Broadcast

CMU 15-744

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Administrivia

- Midterm
  - Mean 66.5, Median 70, Stddev 13.7
  - Histo:
    - 35-39 37 38
    - 40-44
    - 45-49
    - 50-54 54 54 54
    - 55-59 56 57
    - 60-64 61 64 64
    - 65-69 69
    - 70-74 71 73 73 73
    - 75-79 75 76 76 79
    - 80-84 83
    - 85-89 86
    - 90-95 90
- Correlation with PS1 scores: 0.7
- This is a grad class. Expect As and Bs in the "normal" curve (stddev)
- If outlier, might want to talk with dga.

Feedback Feedback

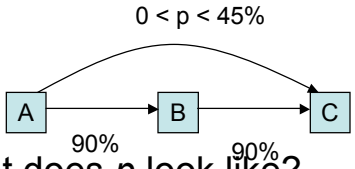
- #1 complaint: Post lecture notes earlier
  - Answer: Okay!
- Second popularity group:
  - Req. security topics
    - Yes! Already planned; if suggestions, drop me a note.
      - Security overview (problems, causes, challenges, definitions, packet floods, SYN floods, botnets, some defenses)
      - DDoS control and traceback
      - Worms
  - Slides are sometimes hard to understand
    - Will work on that. Many of them are brand new this semester
  - Less "un-important" topics
    - Need to clarify my emphasis. Every topic so far is important *either* because of practical impact, or because it's intellectually important in terms of methods or the things that came from it, or because it illustrates open problems
      - But very true that not everything is *practical*. ☺
- Thank you for the feedback!

Back to Ad Hoc Networks

- Recall that
  - Transmissions interfere with many nodes, which constrains capacity of ad hoc nets
  - Multiple receivers hear every transmission
  - Delivery is probabilistic b/c of multipath interference [Roofnet sigcomm2005]
- Today's papers: Past the cutting edge of what's commonly used in wireless nets
  - Will they be? We'll see.

1) "Hop-over" overhearing

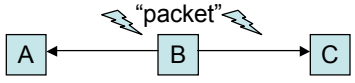
- Observation 1: Best ETX/ETT path may have "overhearing":



  - What does *p* look like?
  - If *p > 0*, can we take advantage of it when overhearing happens instead of having it interfere with C's ability to talk concurrently?

2) Bidirectional Reception

- Observation 2: When you Tx in a line, both sides can hear you:

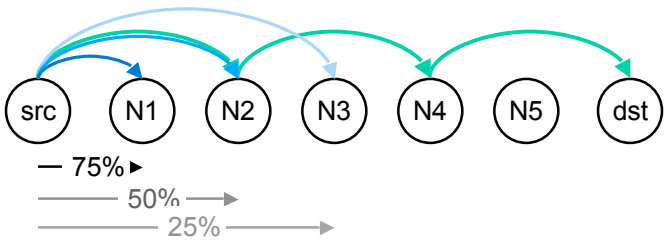


  - If sending from A → B → C
    - A hearing (B→C) is unwanted interference
    - But we can turn it to our advantage

ExOR

- Let's take advantage of the first observation, with an extra twist:
  - Packets may hop over in a line
  - Or may hop "sideways" as well
  - Want to use the best route even if it goes off the "expected" best path

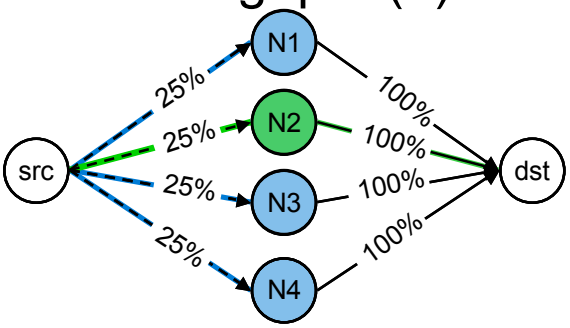
Why ExOR might increase throughput (1)



- Best traditional route over 50% hops: $3(1/0.5) = 6$ tx
- Throughput $\cong 1/\#\text{ transmissions}$
- ExOR exploits lucky long receptions: 4 transmissions
- Assumes probability falls off gradually with distance

Slide Credit: Biswas & Morris

Why ExOR might increase throughput (2)



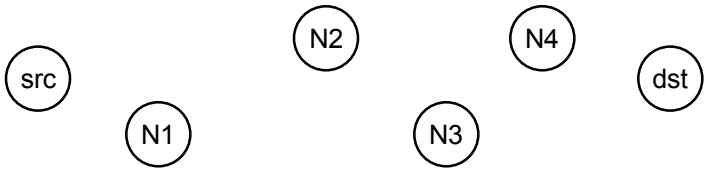
- Traditional routing: $^{1}/_{0.25}$ + 1 = 5 tx
- ExOR: $^{1}/_{(1 - (1 - 0.25)^4)}$ + 1 = 2.5 transmissions
- Assumes independent losses

Slide Credit: Biswas & Morris

Design Choice

- ExOR makes routing decision *after* packets have been received
  - Lets you decide route based upon actual success instead of probability
  - Requires a way of communicating to other nodes who actually received packet

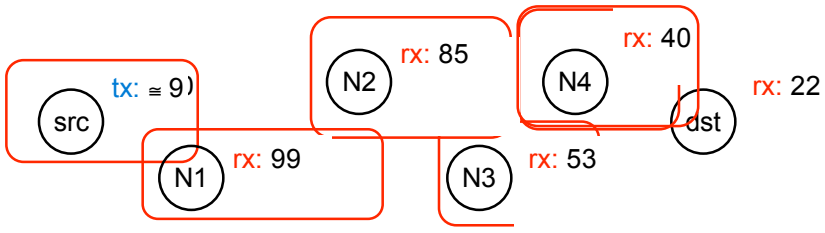
Priority ordering



- Goal: nodes “closest” to the destination send first
- Sort by ETX metric to dst
  - Nodes periodically flood ETX “link state” measurements
  - Path ETX is weighted shortest path (Dijkstra’s algorithm)
- Source sorts, includes list in ExOR header

Slide Credit: Biswas & Morris

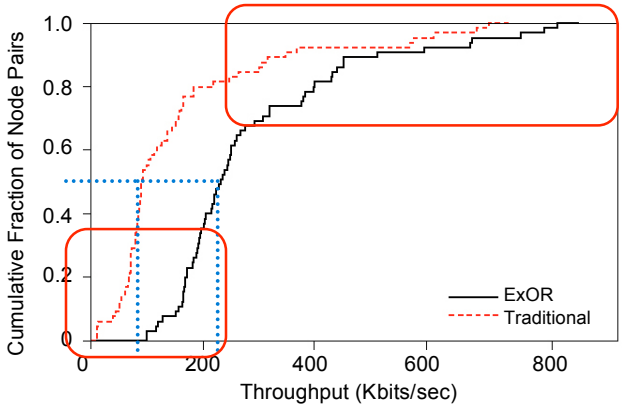
ExOR batching



- Challenge: finding the closest node to have rx’d
- Send batches of packets for efficiency
- Node closest to the dst sends first
  - Other nodes listen, send remaining packets in turn
- Repeat schedule until dst has whole batch

Slide Credit: Biswas & Morris

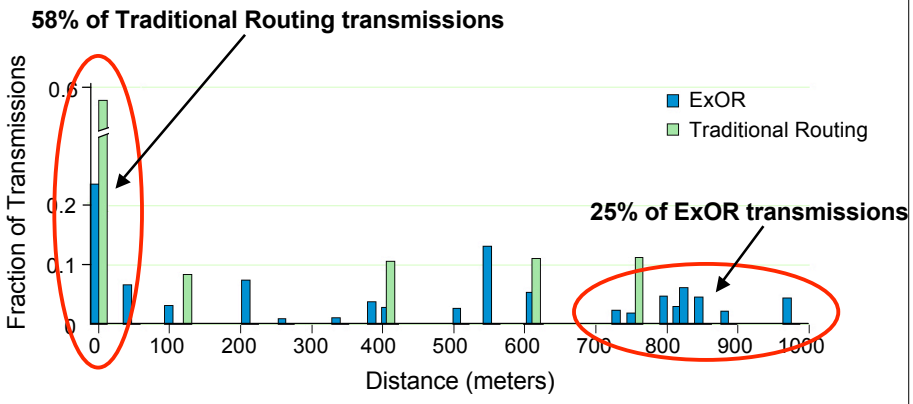
ExOR: 2x overall improvement



- Median throughputs: 240 Kbits/sec for ExOR,
  121 Kbits/sec for Traditional

Slide Credit: Biswas & Morris

ExOR moves packets farther



- ExOR average: 422 meters/transmission
- Traditional Routing average: 205 meters/tx

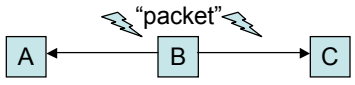
Slide Credit: Biswas & Morris

ExOR discussion

- 2x improvement: Awesome!
- The cost? Look at Figure 6 in the paper.
  - What's the range of RTTs from src->N24?
    - Up to 3.5 *seconds*. Ouch!
  - Batching: Requires many pkts from src→dst
    - Increases delay
    - Interacts *very* poorly with TCP. (Translation: probably *slower*!)
    - Solution: Proxy at edge, custom transport protocol across wireless network
    - Awesome performance and nice design, but some serious deployment challenges

Back to Bidirectional

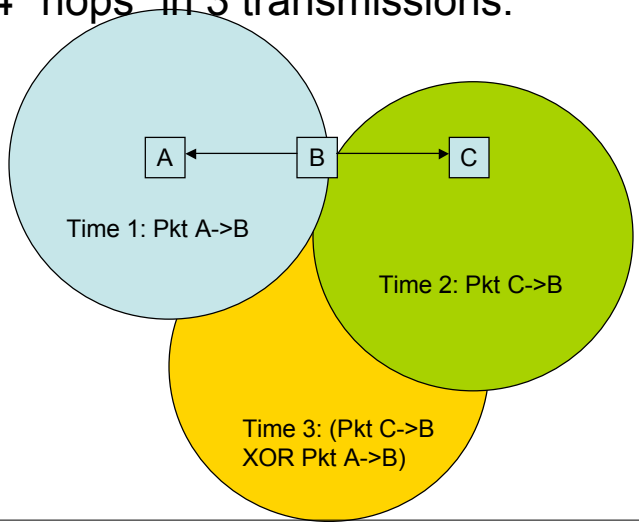
- When you Tx in a line, both sides can hear you:



- How do we make this work *for* us?

Coding with Bidirectional *traffic*

- 4 “hops” in 3 transmissions:



Building it: COPE

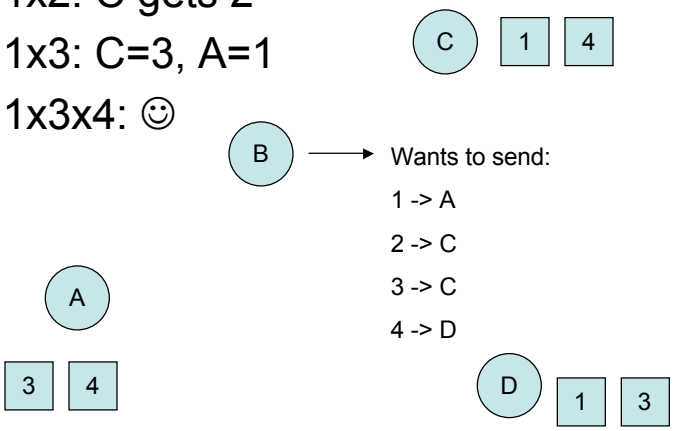
- Opportunistic listening (common to ExOR)
  - Nodes listen all the time to all Tx
    - (n.b. – would consume more power; assumption here is that you really want throughput)
- Periodic “reception reports”
  - Tells neighbors what it’s heard
  - Usually piggybacked on data
- Can also guess about reception using ETX

What packets to code??

- Node has some packets in Tx queue
  - Which of them should it XOR together?
- Goal:
  - max # of real packets delivered
  - S.t. each nexthop can decode the real packet
- Let's walk through an example…

COPE-ing

- 1x2: C gets 2
- 1x3: C=3, A=1
- 1x3x4: ☺



Gain: Theory and Practice

- Depends on topology. An "X": middle node can xor 4 packets
  - Each edge sends once
  - Middle sends once = 8 pkts in 5 tx = 1.6 gain
- Max: ~2
- But
  - Overhead, loss, etc.

Quirk: Coding+MAC gain

- Consider A-B-C topology
  - w/out COPE: middle must send 2x as many packets
  - If MAC is "fair", middle only gets 1/3 of transmit time
  - So packets build up and get lost
- BUT:
  - TCP prevents too much packet buildup
  - So this is achievable with UDP flows

Can We COPE With It?

- Overall:
  - With symmetric, same-size UDP flows, COPE gain very nice
  - With symmetric TCP, maybe 30%, but:
    - COPE works best in a highly-loaded network (increases *capacity*)
    - TCP performs very poorly with high loss rates!
  - Requires lots of work to get TCP to work well over cope
    - Fundamental and cool results, but may also need custom transport protocols to really use
    - Could be great for software/multimedia/etc., dist over mesh network…

If time permits

- TCP performance and wireless discussion
  - Interesting RTS/CTS positive notes in COPE paper
- Application of cope and ExOR
- RTS-id

Credits

- Several of the ExOR slides (the pretty ones) are from “Opportunistic Routing in Multi-hop Wireless Networks”, Sanjit Biswas and Robert Morris, talk at SIGCOMM 2005.
  - Aside: The Roofnet guys have a startup, Meraki (http://meraki.net/), doing mesh networks. They make cool little low-power mesh radios that implement many of the things we’ve read about in class. Fun stuff.