CS 525M – Mobile and Ubiquitous Computing Seminar

Ted Goodwin

Mitigating Routing Misbehavior in Mobile Ad Hoc Networks

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Contents

Introduction

- Ad Hoc Networks
  - Ideal for when network is too transient or infrastructure is destroyed.
  - Maximize throughput by using all nodes for routing and forwarding.
  - Misbehaving nodes cause problems.
    - Overloaded – lacks cpu cycles, buffer space, or network bandwidth to forward packets.
    - Selfish – unwilling to spend battery life, CPU cycles, or network bandwidth.
    - Malicious – drops packets for denial of service attack.
    - Broken – software fault keeps from forwarding packets.

Introduction (cont.)

- Solution to misbehaving nodes
  - Priori trust relationship: separate relationship outside of network
    - Problems:
      - Requires key distribution.
      - Trusted nodes overloaded.
      - Trusted nodes can be compromised.
      - Untrusted nodes may be well behaved.
  - Isolate or forestall misbehaving nodes
    - Problems:
      - Complexity added to well defined protocols.
  - Many existing ad Hoc networks admit misbehavior.

Introduction (cont.)

- Solutions to misbehaving nodes:
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  - Isolate or forestall misbehaving nodes
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  - Many existing ad Hoc networks admit misbehavior.

Introduction (concl.)

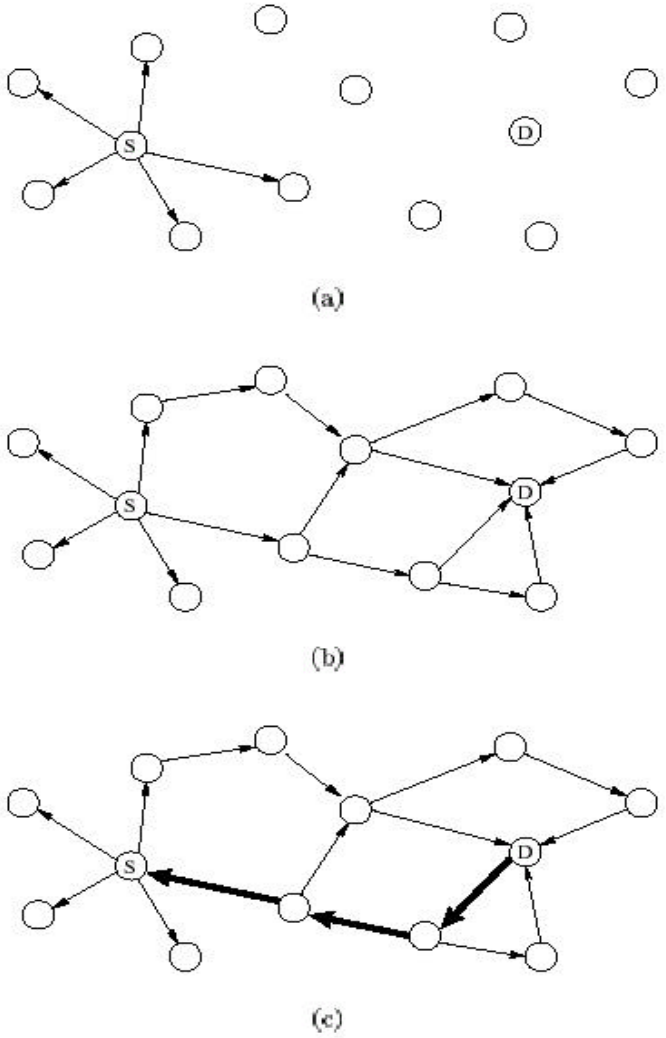
- Paper's solution – Watchdog and Pathrater added to network.
  - Watchdog – identifies misbehaving nodes.
    - Node A sends a packet to Node B.
    - Node A Watchdog listens promiscuously to Node B to ensure it forwards the packet.
    - If Node B does not, Watchdog identifies it as misbehaving.
  - Pathrater – avoids routing packets through misbehaving nodes.

Assumptions and Background

- Definitions
  - neighbor – node within wireless transition of another node
  - neighborhood – all nodes that are within wireless transmission range of a node
- Physical Layer Characteristics
  - Bidirectional links between all nodes (Watchdog relies on bidirectional links).
  - Promiscuous mode supported by all nodes.
- Dynamic Source Routing (DSR) – On-demand source routing protocol
  - Route path – each packet has the addresses of nodes agreed to participate in routing packet.
  - “On demand” – route paths are discovered when there is no path to a destination.

Assumptions and Background (cont.)

- DSR – route discovery
- From S (source) to D (destination)
- S sends Route Request
- Request is forwarded, adding their address building a route.
- D returns Route Reply using a route in a Route Request packet or do its own route discovery back.
- S caches multiple paths from destination for later.

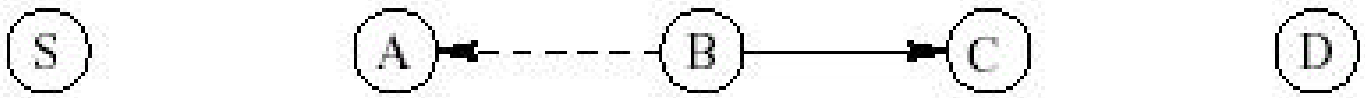


Assumptions and Background (concl.)

- DSR – route maintenance
  - Link breaks – Two nodes are no longer in transmission range of each other.
  - If an intermediate node detects a link break during forwarding, it notifies source.
  - Source either tries another path or does a route discovery.

Watchdog and Pathrater

- Watchdog – checks for misbehaving nodes.
- Below, A sends a packet to B to be forwarded to C.
- A then listens to B to make sure it forwards the packet to C.
- If packets are not encrypted individually, can check for tampering.



Watchdog and Pathrater (cont.)

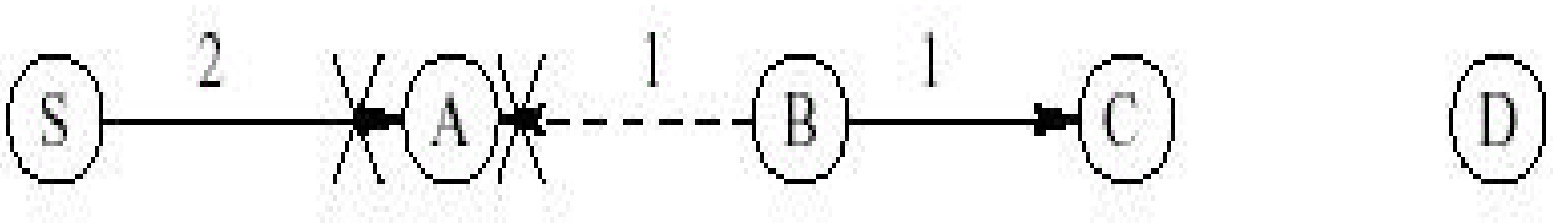
- Watchdog
  - Maintains a buffer of recently sent packets.
  - Compares each overheard packet with the buffer.
  - If overheard packet is in buffer, remove it.
  - If not, wait for a timeout, then increase tally for that node.
  - If that node's tally reaches a certain threshold, mark it as misbehaving.
  - If misbehaving, notify the source of the misbehaving node.

Watchdog and Pathrater (cont.)

- Watchdog (cont.)
  - Advantages:
    - Detects errors at the forwarding level, not just the link level.
  - Disadvantages:
    - May not detect misbehaving nodes when:
      - Ambiguous collisions
      - Receiver collisions
      - Limited Transmission power
      - False misbehavior
      - Collusion
      - Partial dropping

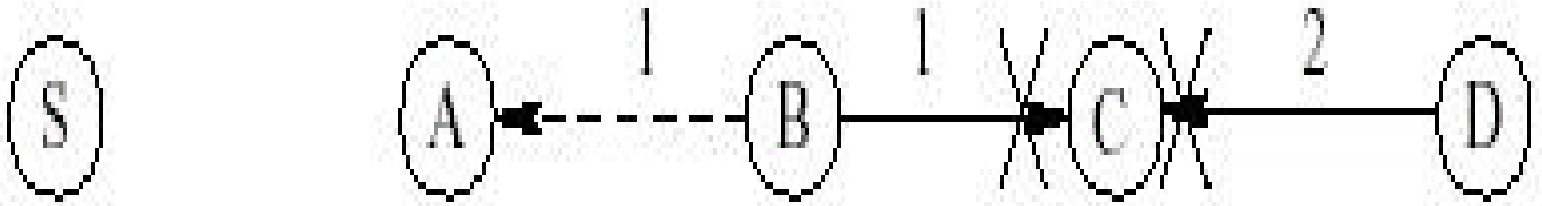
Watchdog and Pathrater (cont.)

- Watchdog – Disadvantages
  - Ambiguous collisions
    - Node A listens for Node B to forward packet 1 to Node C.
    - Packet 1 from Node B and packet 2 from Node S collide at Node A.
    - Node A cannot tell in this instance if B is misbehaving or not.
    - Keep listening to Node B to see if it is misbehaving.



Watchdog and Pathrater (cont.)

- Watchdog – Disadvantages (cont.)
  - Receiver collisions
    - Node A knows Node B forwarded the packet, but does not know if Node C receives it.
    - Node B could refuse to resend the packet to Node C, because it does not want to waste resources to resend.
    - Node B could also wait until Node C is sending to cause a collision. This would be malicious behavior.



Watchdog and Pathrater (cont.)

- Watchdog – Disadvantages (cont.)
  - Falsely misbehaving
    - If nodes falsely accuse the node they forwarded the packet to as misbehaving.
    - Should be caught, because the source will receive packets back from the destination.
    - If the accusing nodes start dropping the return nodes, the accused would inform the destination and it would reroute.

Watchdog and Pathrater (cont.)

- Watchdog – Disadvantages (cont.)
  - Limited transmission power
    - Signal strength is manipulated
      - Previous node can hear forward.
      - Next node can not hear forward.
    - The node must know the signal power to reach the others.
    - (Directional transmission could cause the same problem.)

Watchdog and Pathrater (cont.)

- Watchdog – Disadvantages (cont.)
  - Collusion
    - If two nodes in a row collude, you can fool Watchdog.
      - Node A sends a packet to colluding Node B.
      - Node B forwards the packet to other colluding Node C.
      - Node C drops the packet and Node B does not report it.
    - Do not have two untrusted nodes in a row in a path.
    - This paper assumes nodes act by themselves.

Watchdog and Pathrater (cont.)

- Watchdog – Disadvantages (concl.)
  - Partial droppings
    - Node keeps its tally just below the threshold.
    - Never is labeled as misbehaving.
  - Replay attacks
    - Ineffective dealing with replay attacks.
    - Too much state information at each node.
    - Retransmits could be seen as replay attacks.

Watchdog and Pathrater (cont.)

- Pathrater
  - Run by each node.
  - Misbehaving nodes + link reliability data to pick route.
  - Each node keeps a metric for each node it knows about.
  - Path is chosen by averaging the metric for each node.
  - Highest average metric is chosen.

Watchdog and Pathrater (concl.)

- Pathrater – Assigning Ratings to other nodes
  - Starts with neutral rating (0.5) at discovery.
  - At periodic intervals (200 ms), increment nodes on active paths (0.01).
  - Decrement the rating when link breaks occur.
  - Misbehaving nodes set to -100.
  - If a node on a path misbehaves and there no other paths, sends a Route Request.

Methodology

- The paper used Berkeley's Network Simulator with CMUs Monarch project plugin, and CMU's ad-hockey to visualize the network data.
- The simulation was of 50 wireless nodes in a flat space measuring 670 x 670 meters.

Methodology (cont.)

- Movement and Communication Patterns
  - 10 constant Bit rate connections.
    - 4 nodes source 2 connections.
    - 2 nodes source 1 connection.
    - 8 nodes destination 1 connection.
    - The last is a destination for 2 connections.

Methodology (cont.)

- Movement and Communication Patterns (concl.)
  - Random waypoint model
    - Pick destination and move in straight line.
    - Move at constant rate of 0 or a maximum speed.
  - Pause time of 0 or 60 seconds.
  - Gives 4 mobility scenarios.

Methodology (cont.)

- Misbehaving Nodes
  - Agree to participate in forwarding packets.
  - Drops all data routed through it.
  - Percentage of the network
    - Between 0 and 40 percent by 5 percent increments.
    - Picked pseudo randomly.

Methodology (concl.)

- Metrics
  - Throughput – Percentage of sent data received.
  - Overhead – Ratio of routing related transmissions to data transmissions.
  - Effects of Watchdog false positives on throughput.

Simulation Results

- Network Throughput
  - Watchdog, Pathrater, and SRR enabled.
  - Everything disabled.
  - Watchdog and Pathrater enabled.
  - Only Pathrater enabled.
  - Watchdog and SRR will not work without Pathrater to use the information.

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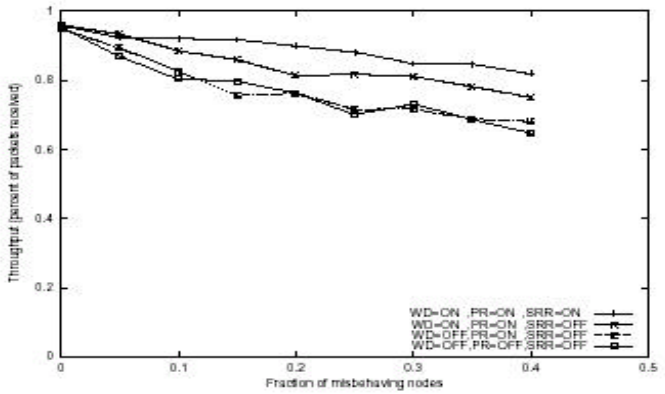
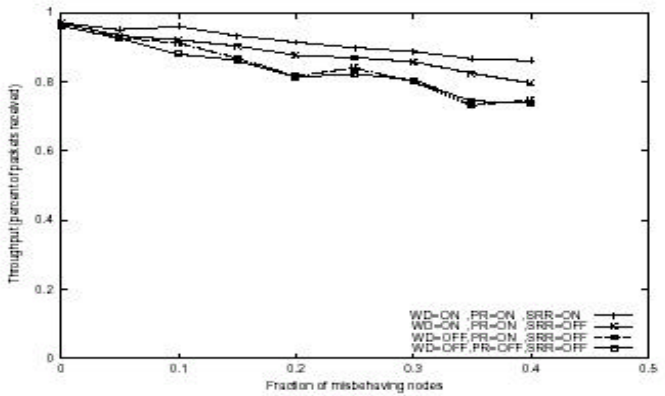
Simulation Results (cont.)

Network Throughput (concl.)

- Fraction of data generated received versus Fraction of misbehaving Nodes.
- 0% Misbehaving all were 95% throughput.
- Up to 27% increase compared to basic protocol.
- Subset of extensions do not improve as much.



(a) 0 second pause time



(b) 60 second pause time

Simulation Results (cont.)

- Routing Overhead
  - Everything enabled.
  - Pathrater and Watchdog enabled.
  - Watchdog enabled.
  - Everything disabled.

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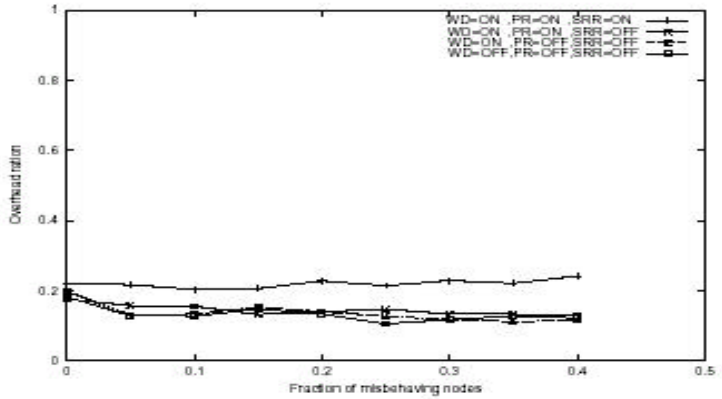
Simulation Results (cont.)

Routing Overhead (concl.)

- Ratio of routing to data packets versus fraction of misbehaving nodes.
- 40% misbehaving overhead rises from12 to 24% with SRR.
- Watchdog has very little overhead.



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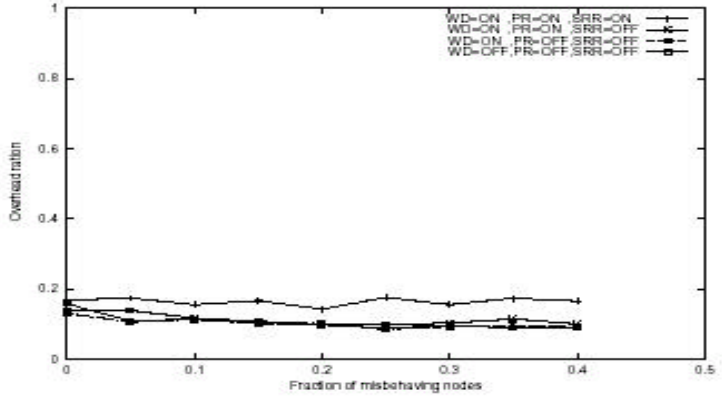
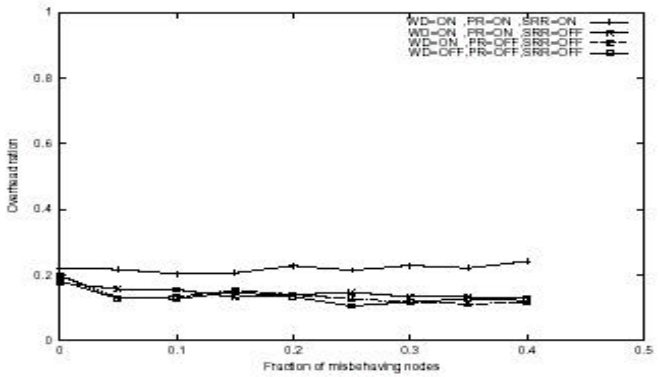


(b) 60 second pause time

Simulation Results (concl.)

Effects of False Detection

- Network throughput of Regular Watchdog versus a Watchdog no false positives.
- False positives have no effect on throughput.
- Misbehaving nodes could have moved out of range.
- Increased false positives increase suspect nodes, so it evens out.



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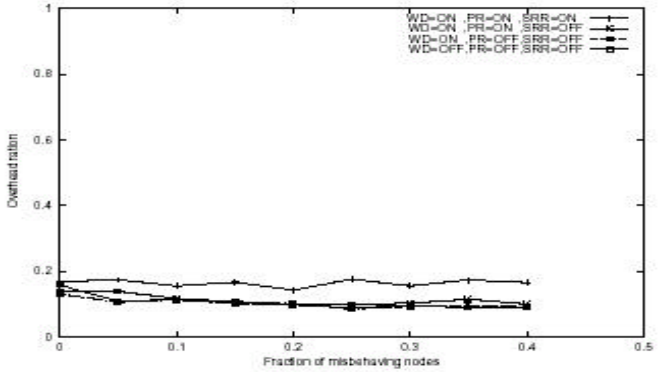

(b) 60 second pause time

Future Work

- Determine optimal value for parameters to extensions (watchdog thresholds and Pathrater's in/decrement amounts).
- Evaluate routing extensions using trusted node lists.
- Replace watchdog with a reliable transport layer.
- Test extensions using reliable data transfer (i.e., ftp transfer).
- Test extensions for latency as opposed to throughput.

Conclusion

- Pathrater and Watchdog extend DST
  - To increase throughput by 17% and overhead from 9% to 17% with moderate mobility.
  - To increase throughput by 27% and overhead from 12% to 24% with extreme mobility.
- Shows we can add routing nodes while minimizing misbehaving nodes' effect.

Questions?