Adaptive Topology Discovery in Hybrid Wireless Networks

Ranveer Chandra
Cornell University

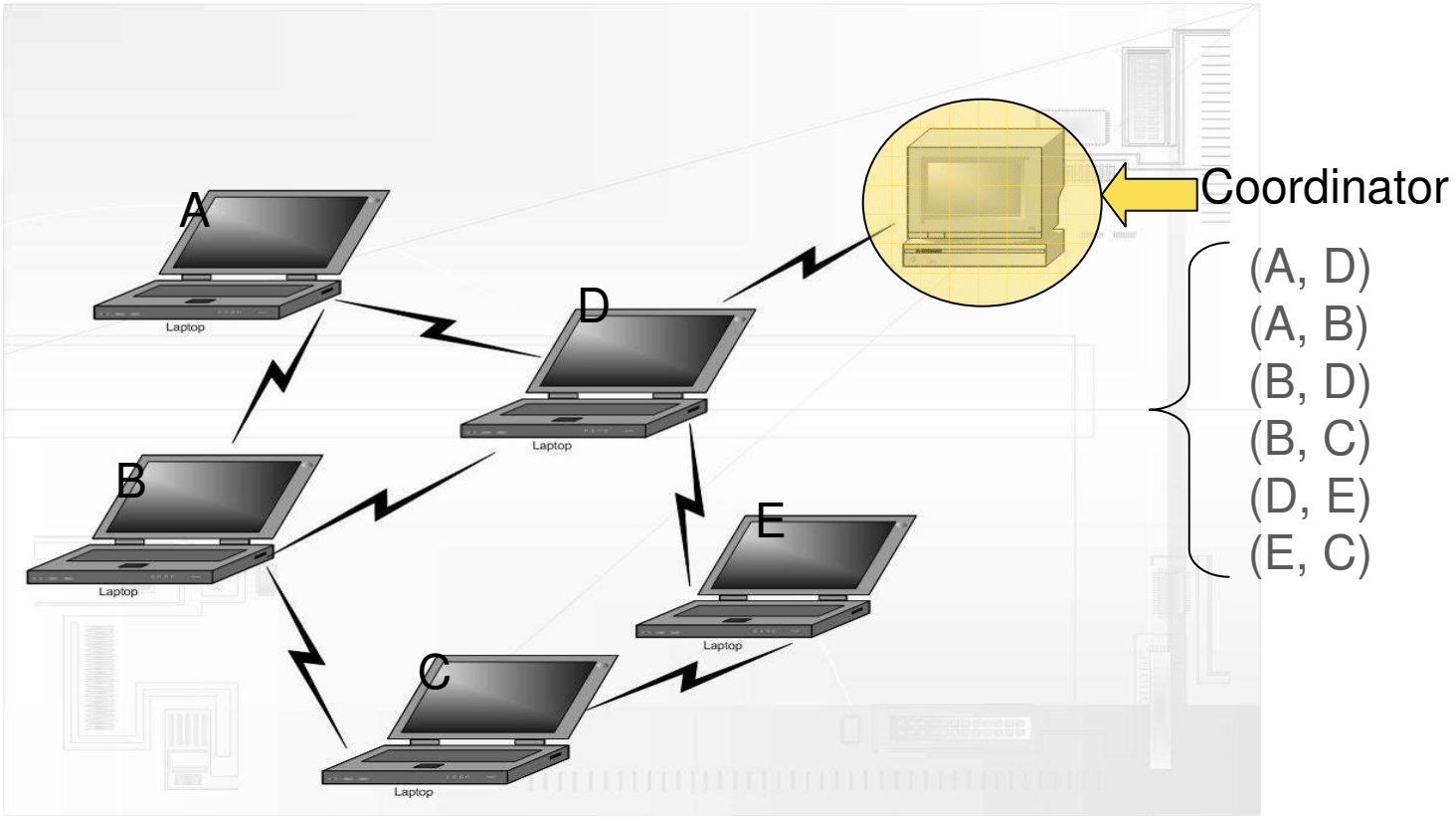
Joint work with **Christof Fetzer** *and* **Karin Högstedt**
AT&T Labs-Research

Problem Description

- Hybrid Wireless Network:
  - Ad hoc network with slow moving nodes
  - Presence of at least one relatively static node
- Nearly all the links are bidirectional
- A coordinator wants to know the topology of the network.
  - All the nodes
  - All the links

Hybrid Wireless Network

- Applications: Home, office networks, mesh networking



Issues In Ad Hoc Networks

- Communication is expensive
- Unreliable links
- No a priori knowledge of neighbors
- Possibility of unidirectional links
- Links could become stale due to mobility

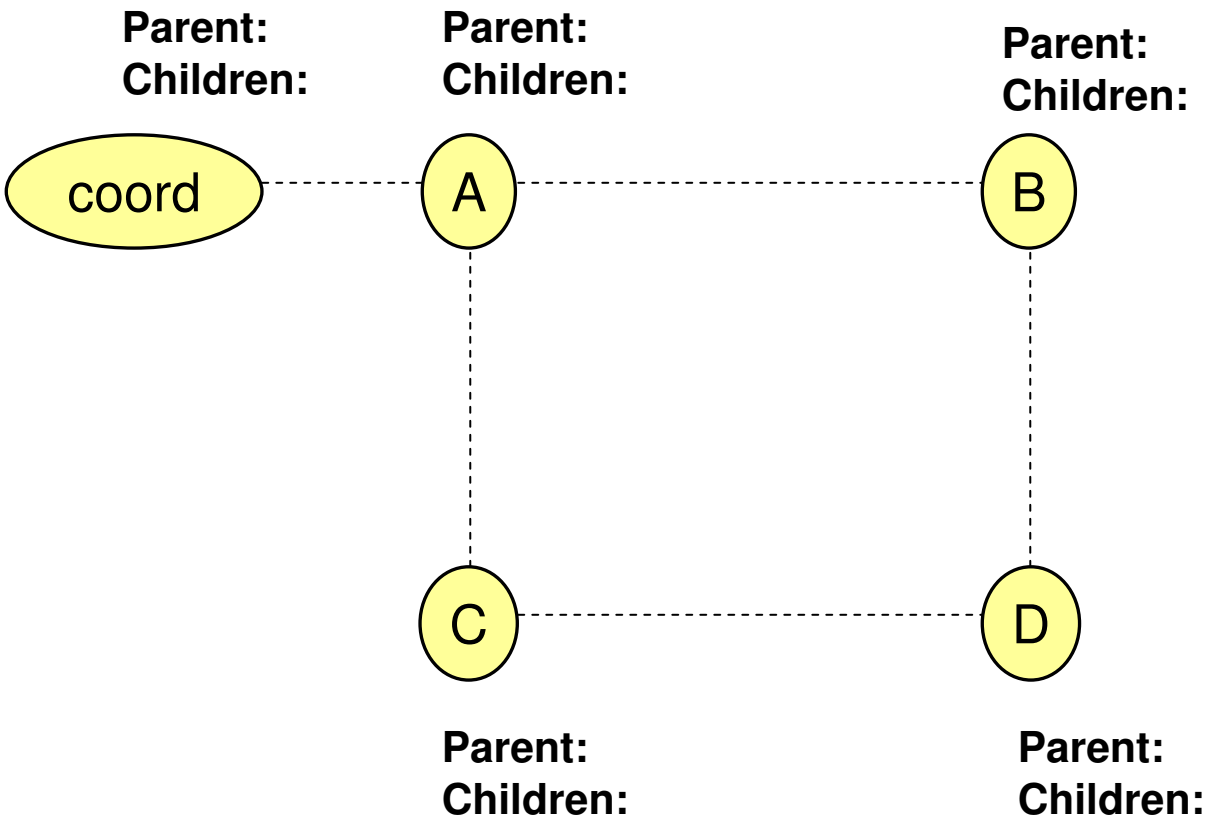
Outline of the Talk

- Introduction
- Basic protocol
- Enhancements for:
  - Unreliable broadcasts
  - Low mobility (low overhead)
  - High mobility (overhead depends on mobility)
- Performance
- Conclusion

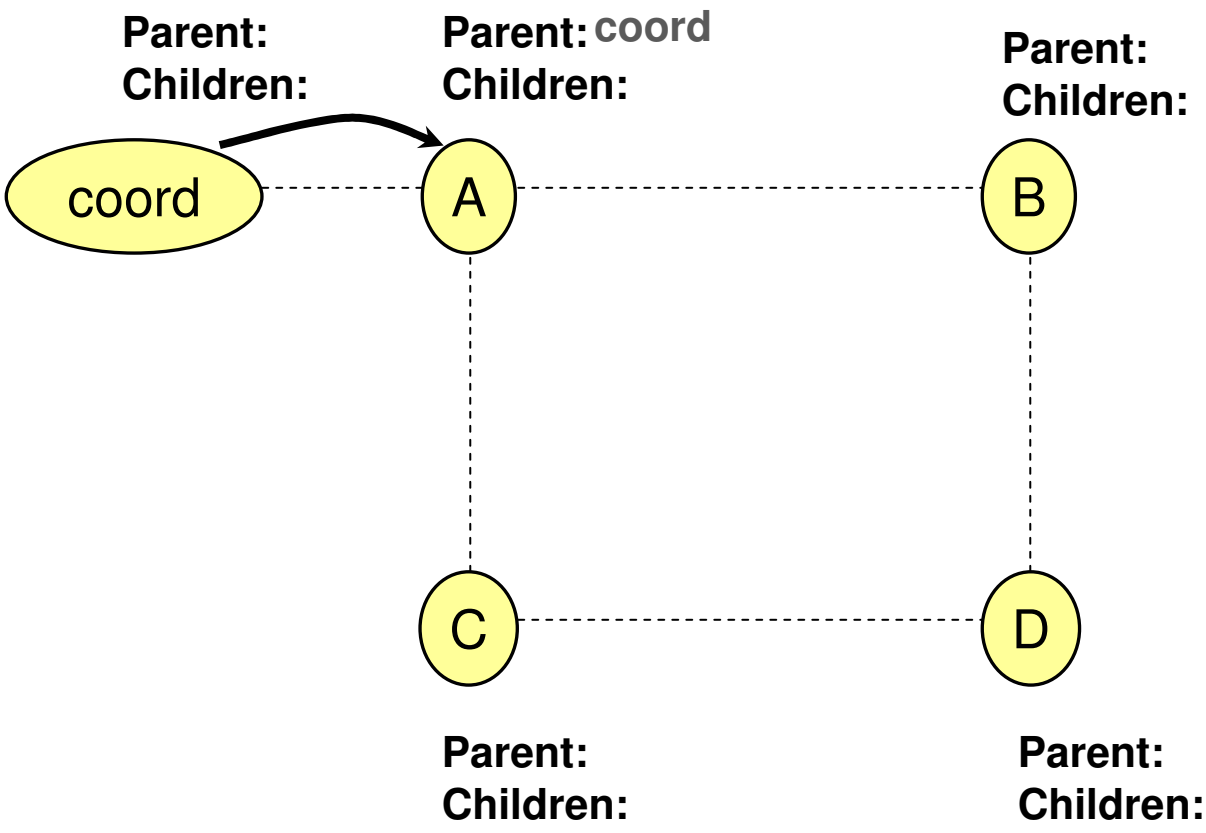
Protocol Overview

- Diffusion Phase
  - Propagates request through network
  - Establishes neighborhood information
  - Builds tree structure
- Gathering Phase
  - Propagates neighborhood information back along tree structure

Diffusion Phase



Diffusion Phase



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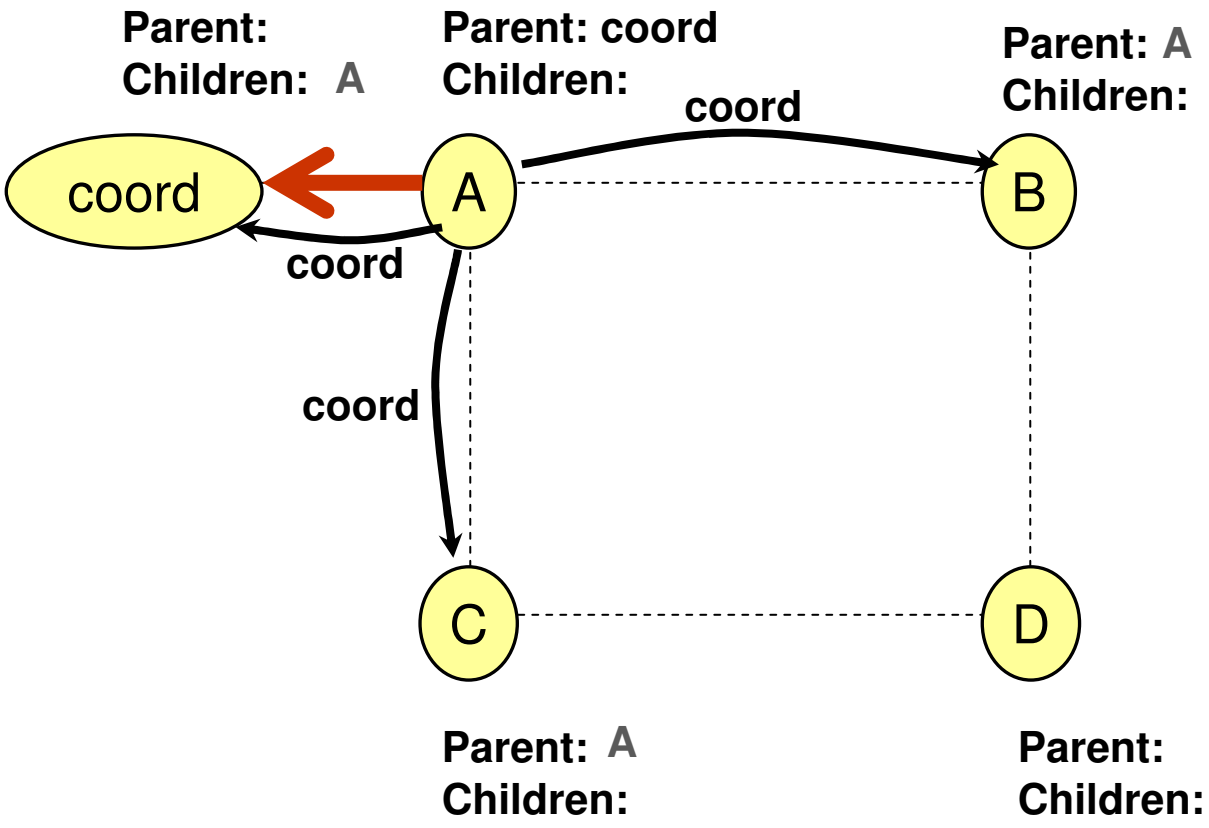

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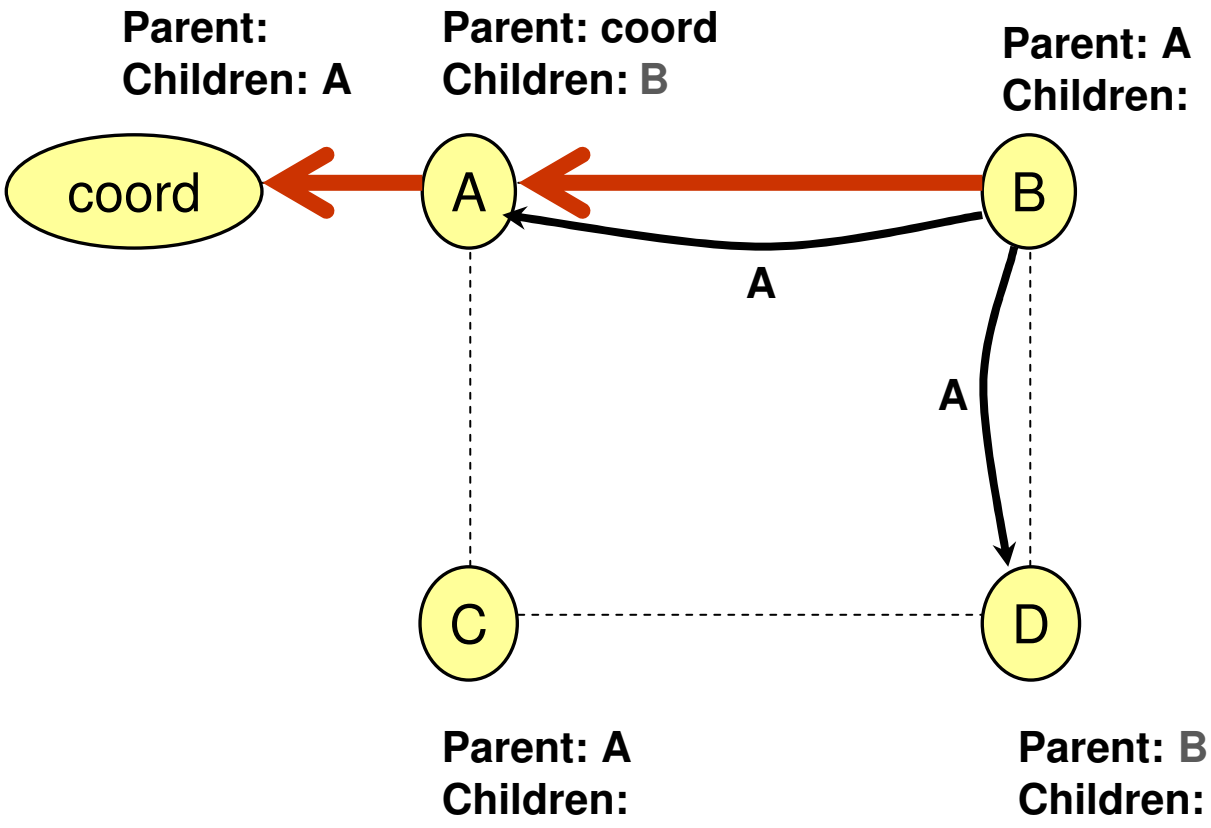

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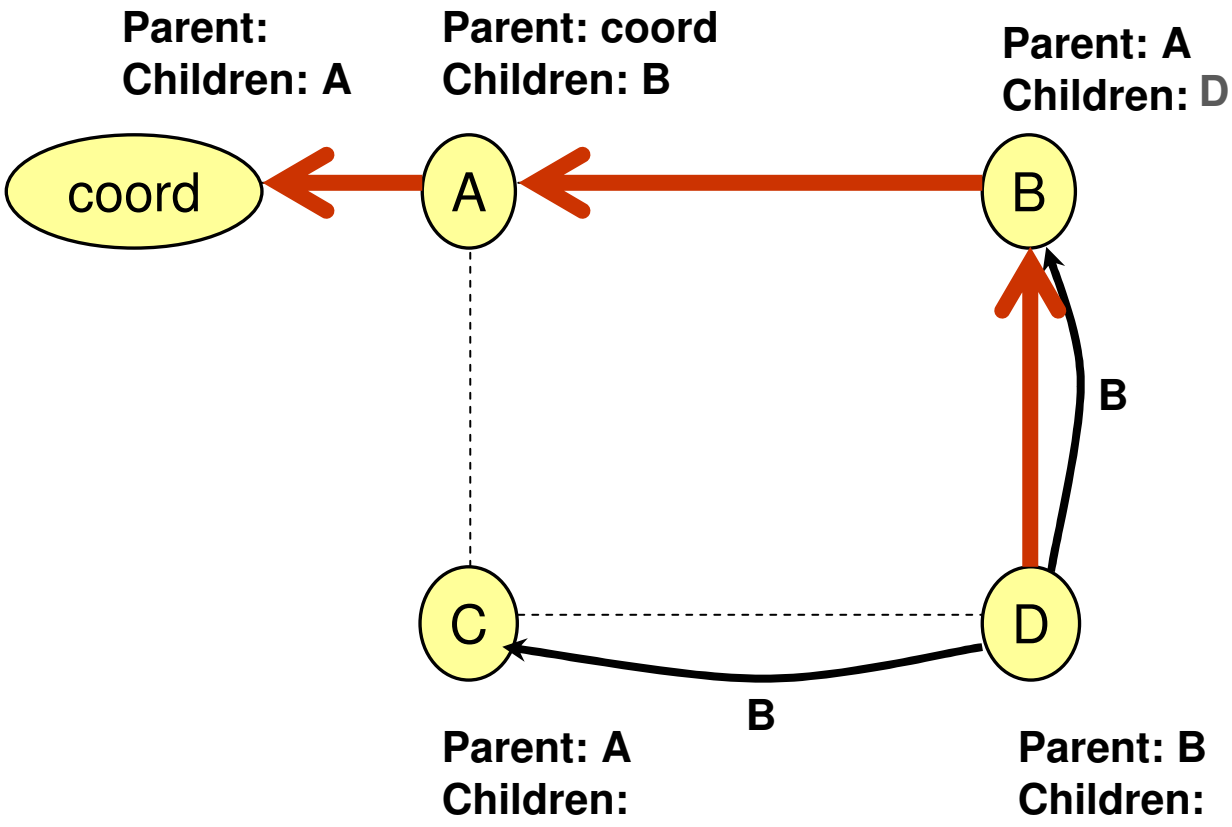

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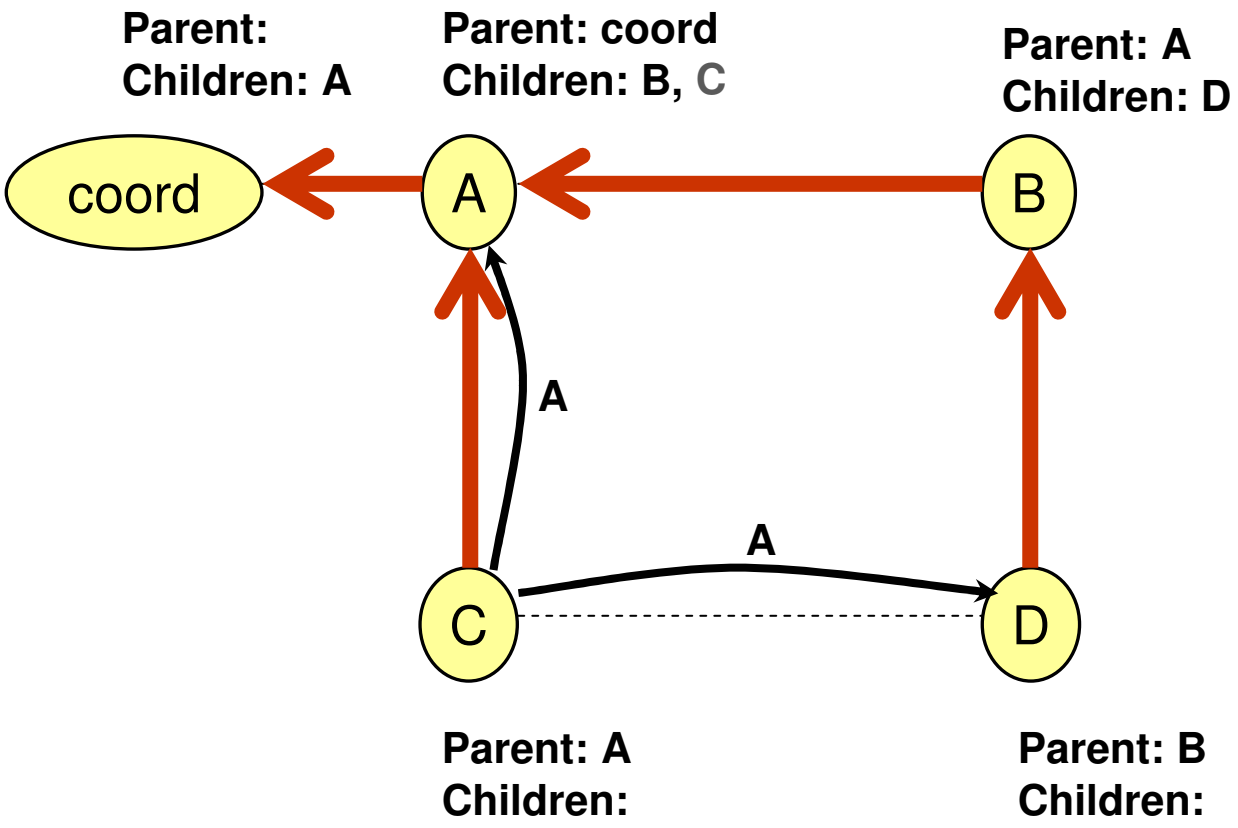
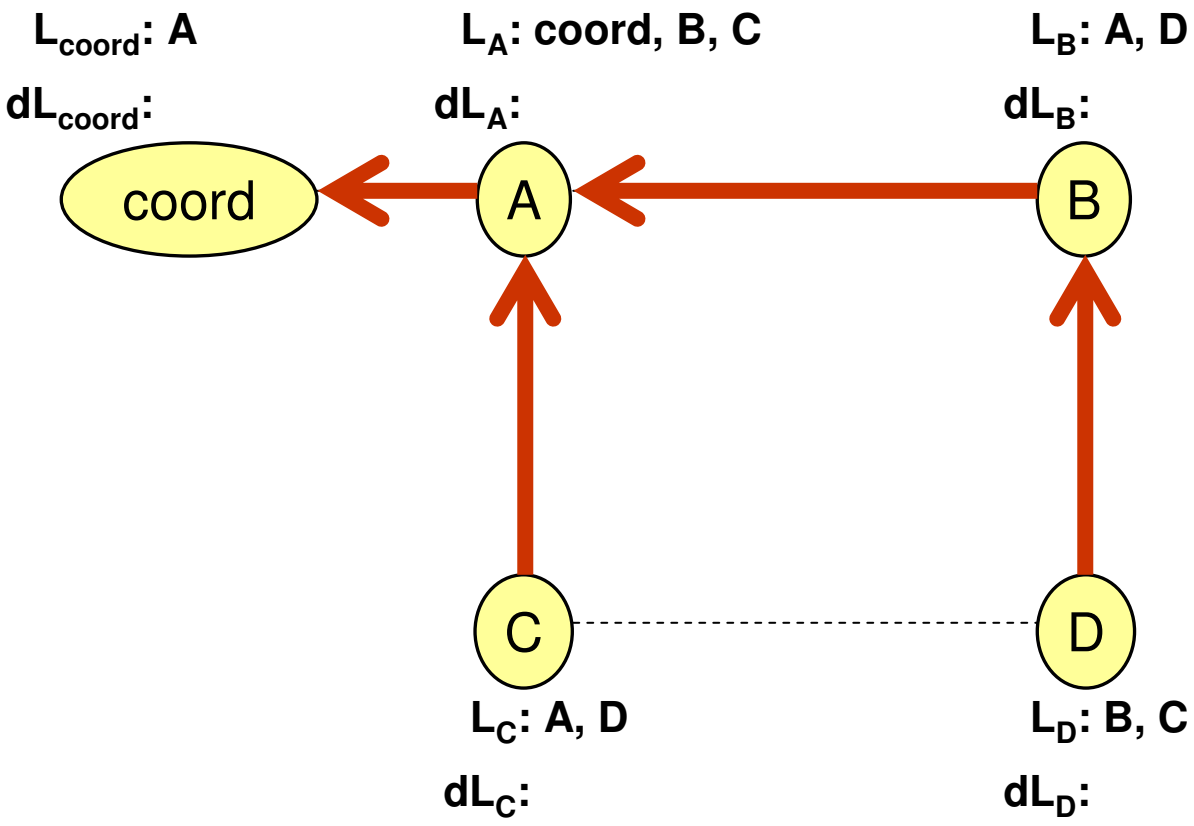


Gathering Phase



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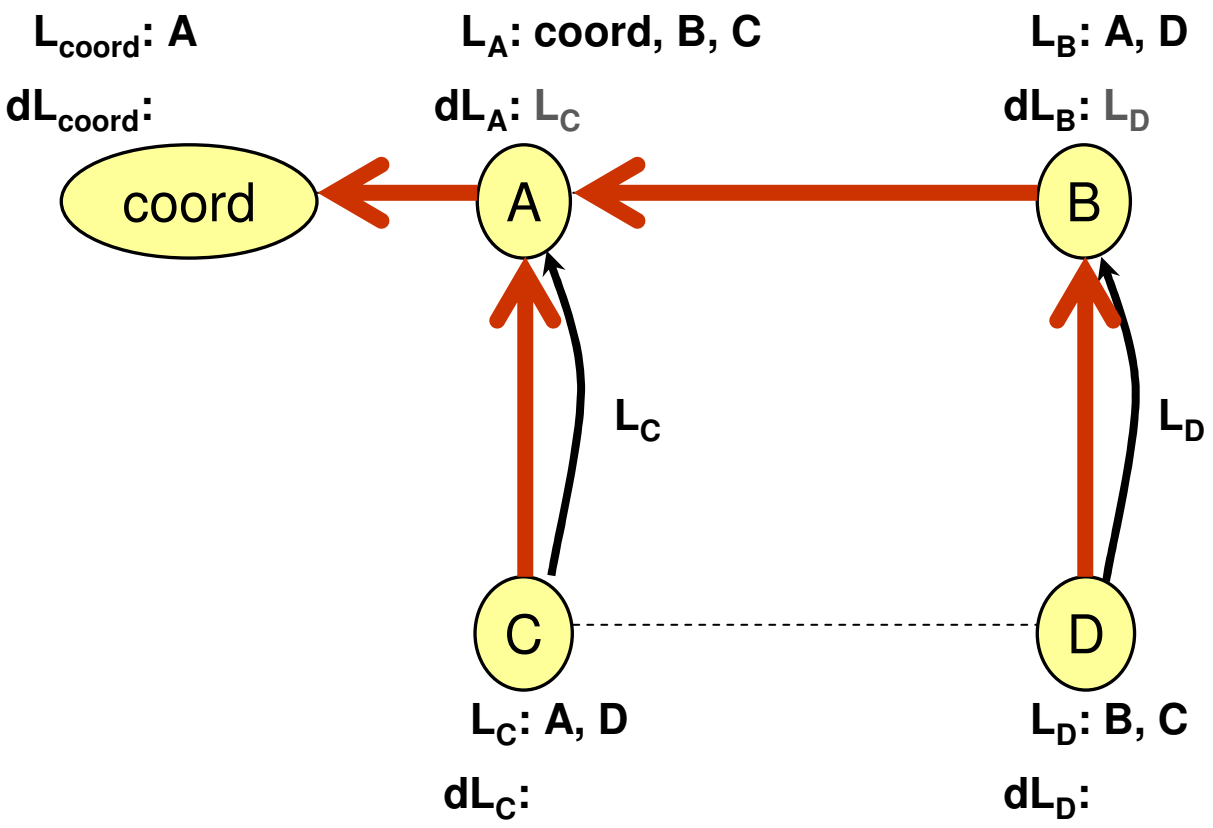

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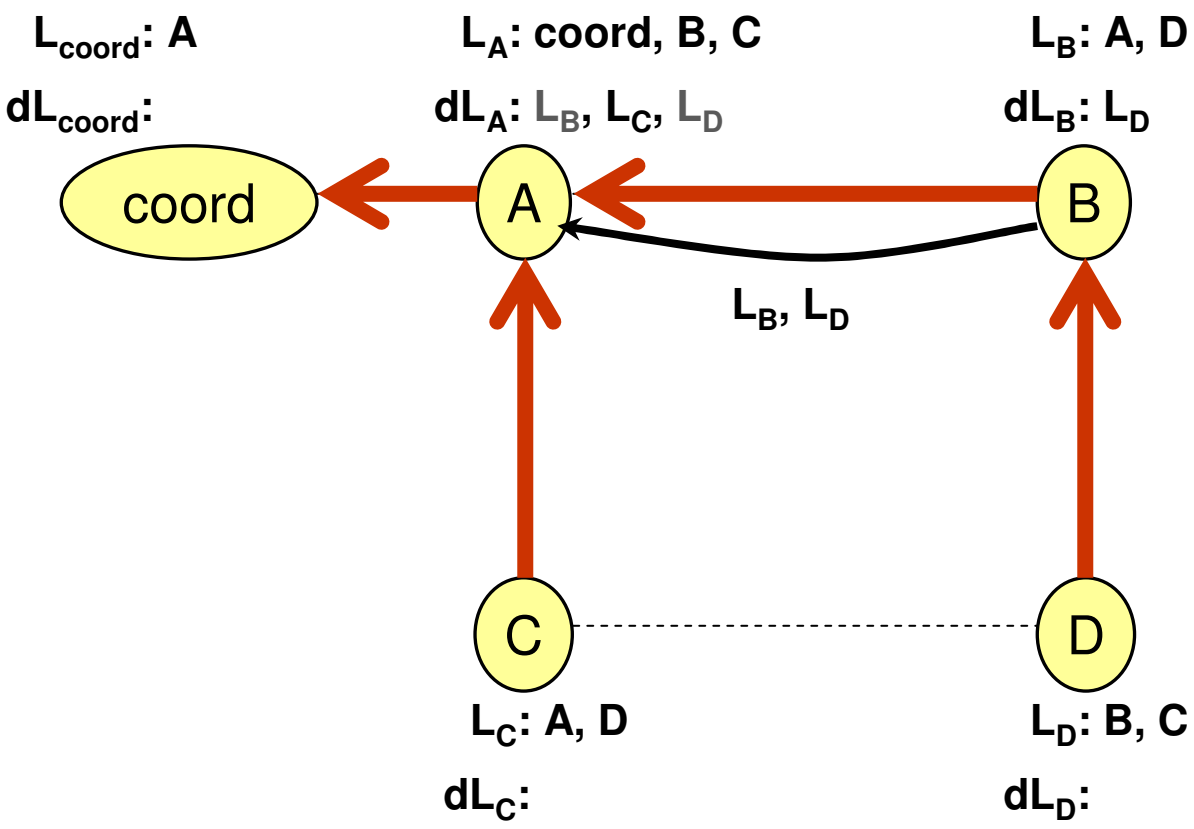

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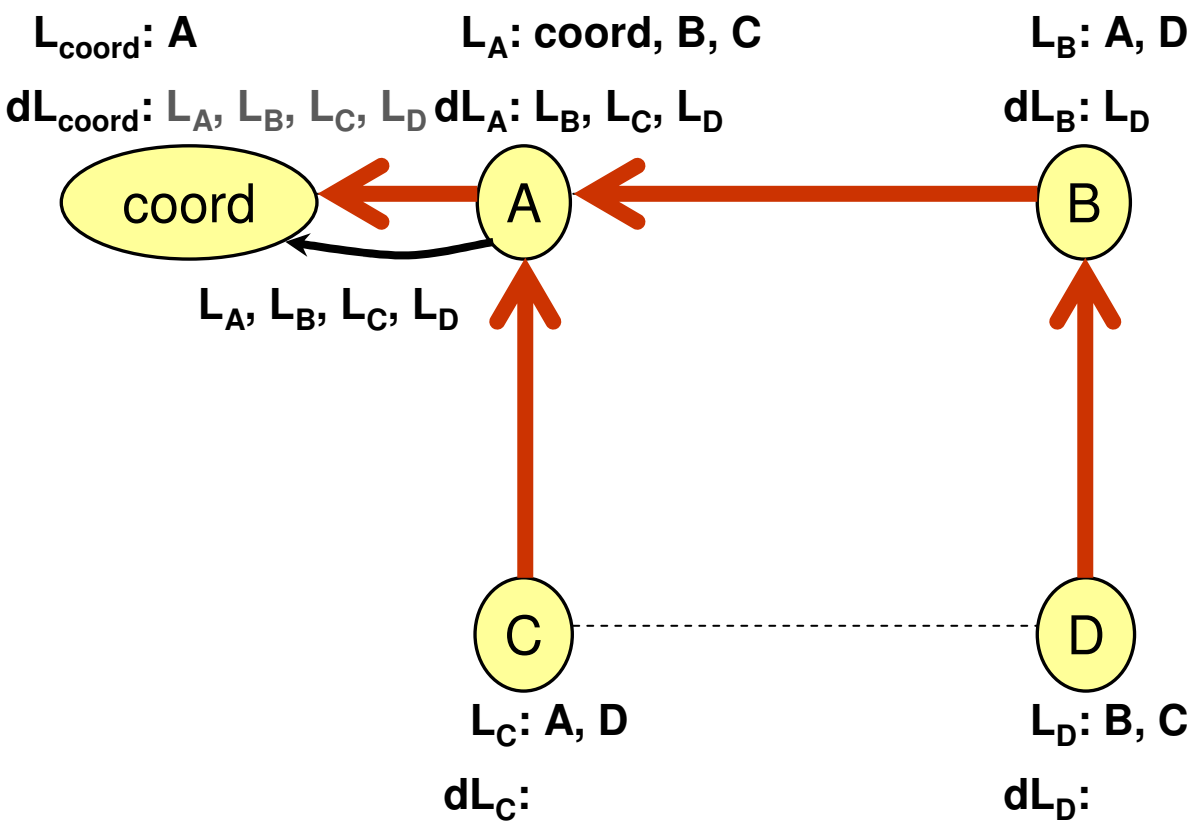

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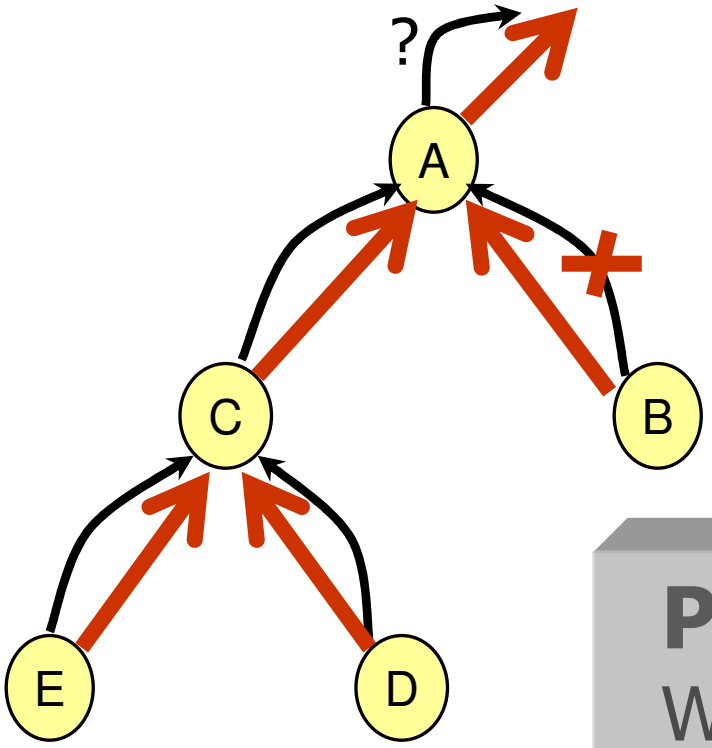


Problem:
What if node B fails?
How long should A wait?

Node Or Link Failures

- Node sends its response if:
  - it is a child, or
  - all its children have replied, or
  - it waited for (height - depth)*(b_time + u_time) amount of time.

    (height is the total height of the tree,

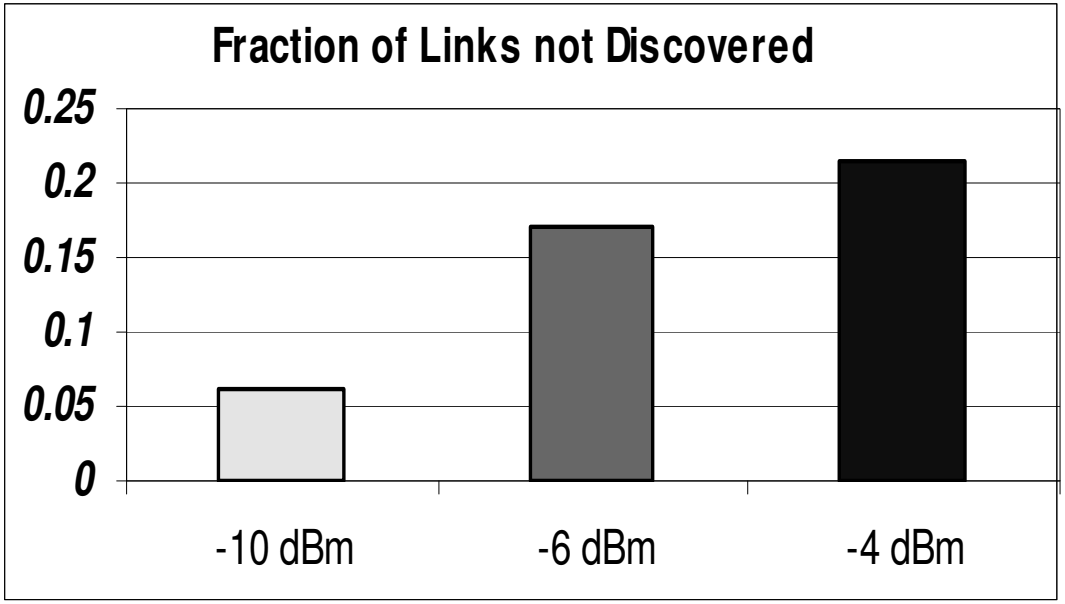
    depth is the current distance to the root

    b_time is the time to bcast a message to a nbr

    u_time is the time to unicast a message to a nbr)

Bad Performance

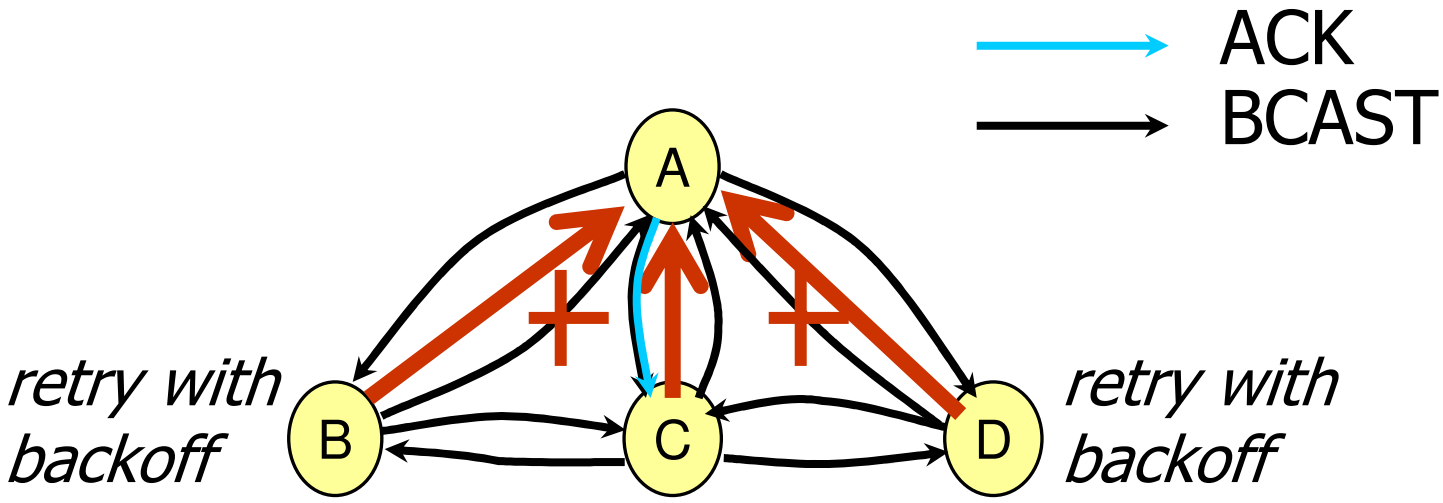
Using GloMoSim:
- 200m x 200m
- 50 nodes
- stationary



$\Rightarrow$ Broadcasts in 802.11 are unreliable

Robust Broadcast

- Modified RTS/CTS scheme for broadcasts
- Retry with back-off until parent ACKed



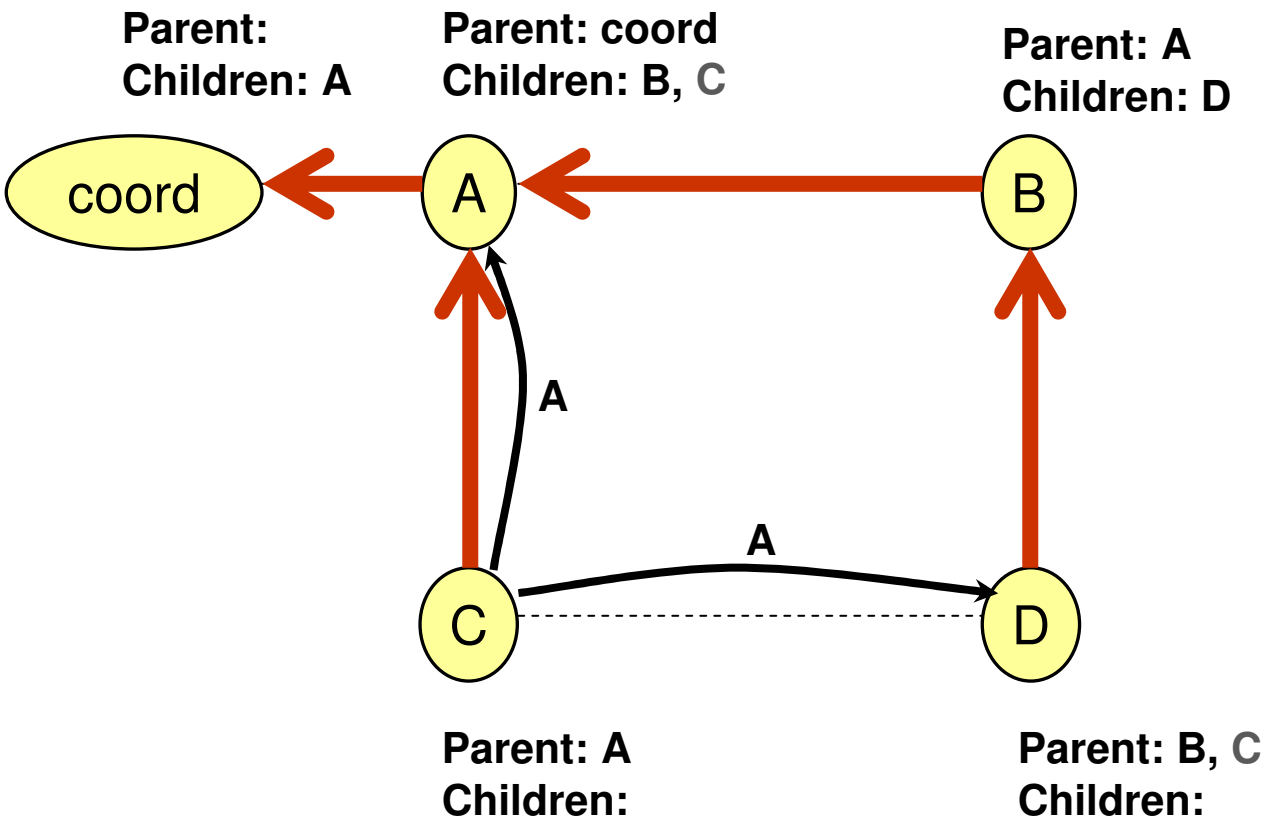
Bad Performance In Mobile Networks

- ✓ Discovers nearly all links when nodes are stationary
- ✗ Performance suffers in a mobile network

Building A Mesh

- Use the robustness of a mesh
  - A node can have multiple parents, max ‘k’
- Modified Algorithm:
  - On receiving the the first ‘k’ distinct broadcasts, mark them as parents
  - Use distance from coordinator to avoid loops
  - A node sends ‘k’ broadcasts if it has ‘k’ parents $\Rightarrow$ robustness

Diffusion Phase



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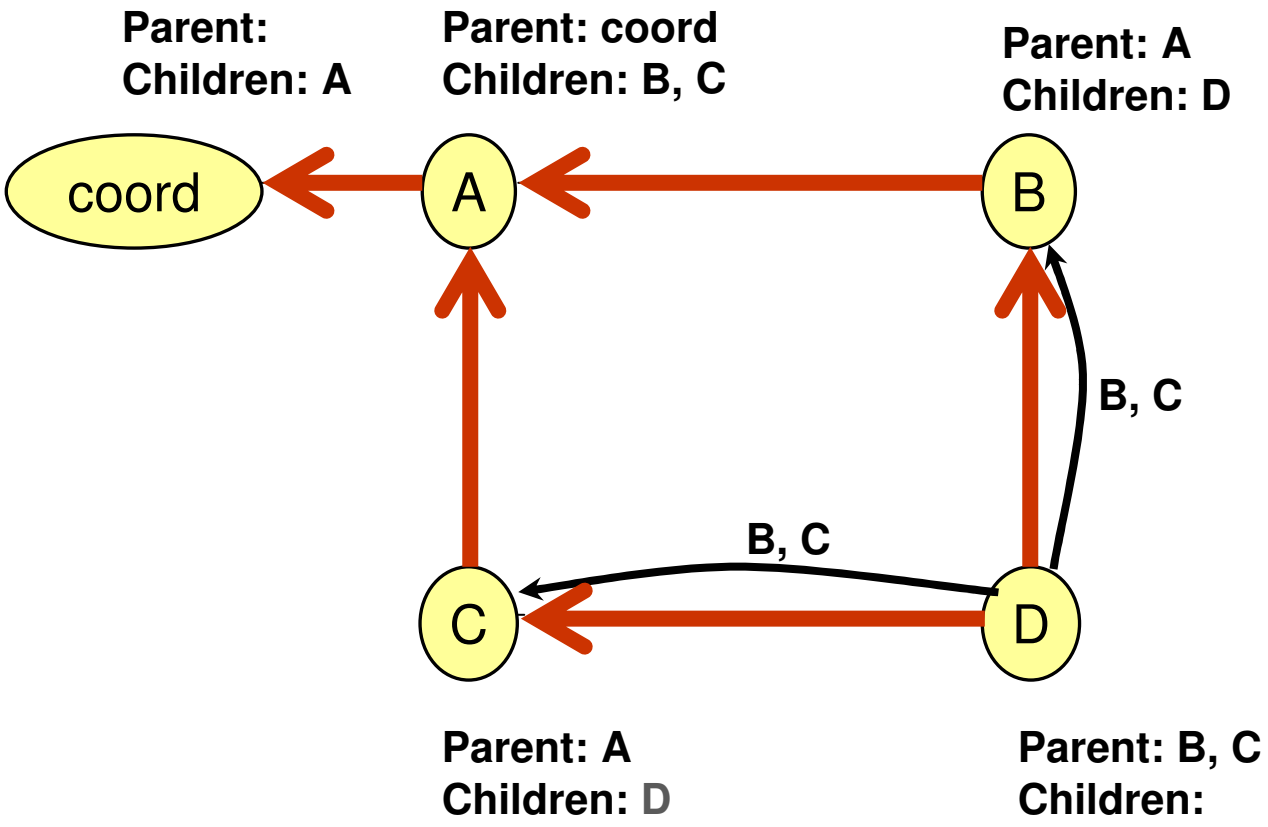
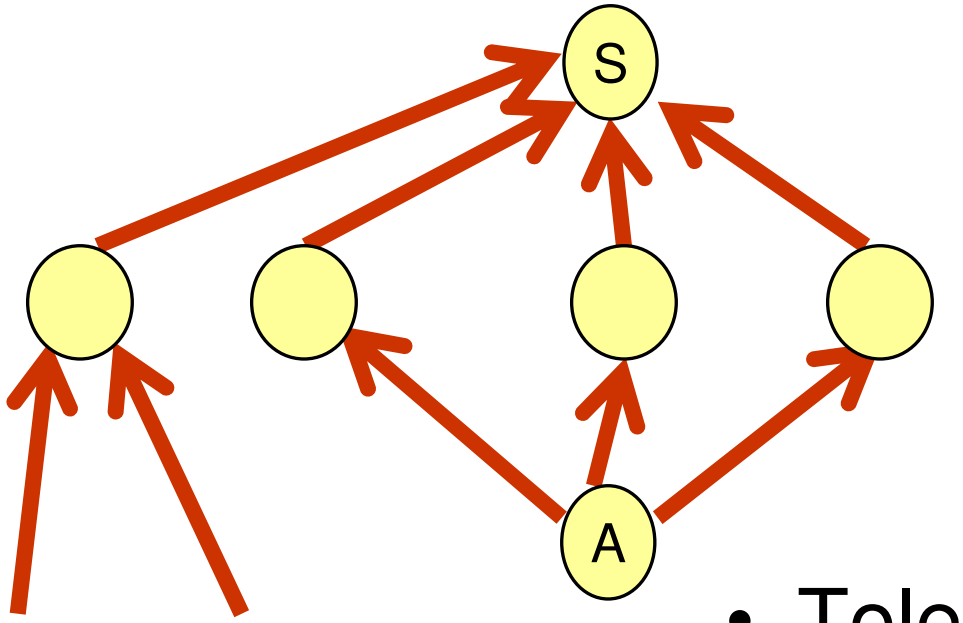


Mesh Advantages



A message from ‘A’ reaches ‘S’ through 3 different routes

- Tolerates lossy links
- Tolerates unreliable nodes
- Handles mobility

Mesh Failures

What if links to all parents fail?

$\Rightarrow$ Send information along alternate paths

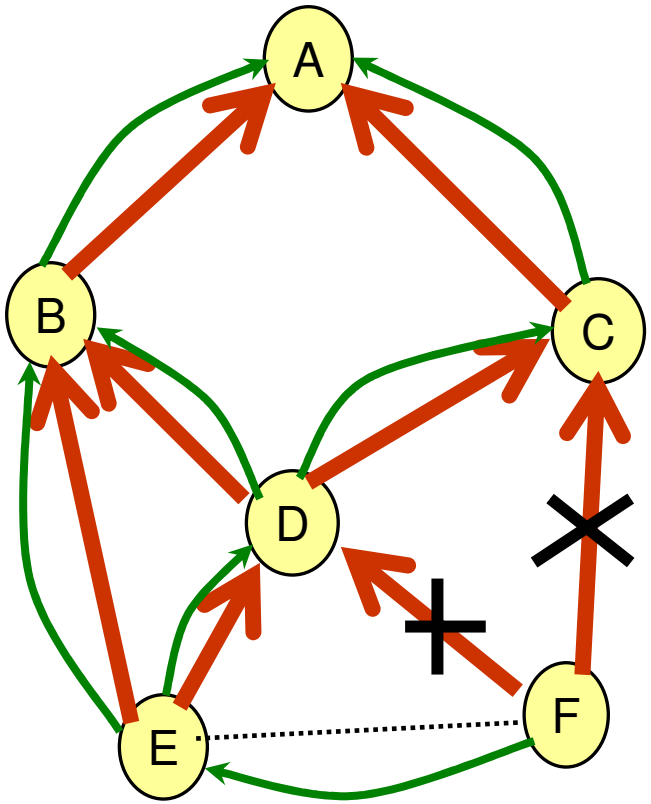
- If a node is unable to send to any parents, it enters Panic mode and broadcasts its message to all its nbrs.

Panic Mode

When a node receives a bcast from a node in panic mode,

- it removes sender from its list of parents, and
- if message gives new information, and
  - if its parent list is non-empty,
    - it proceeds as before
  - if its parent list is empty,
    - it enters “Panic Mode” and bcasts to all nbrs

Panic Mode: Example



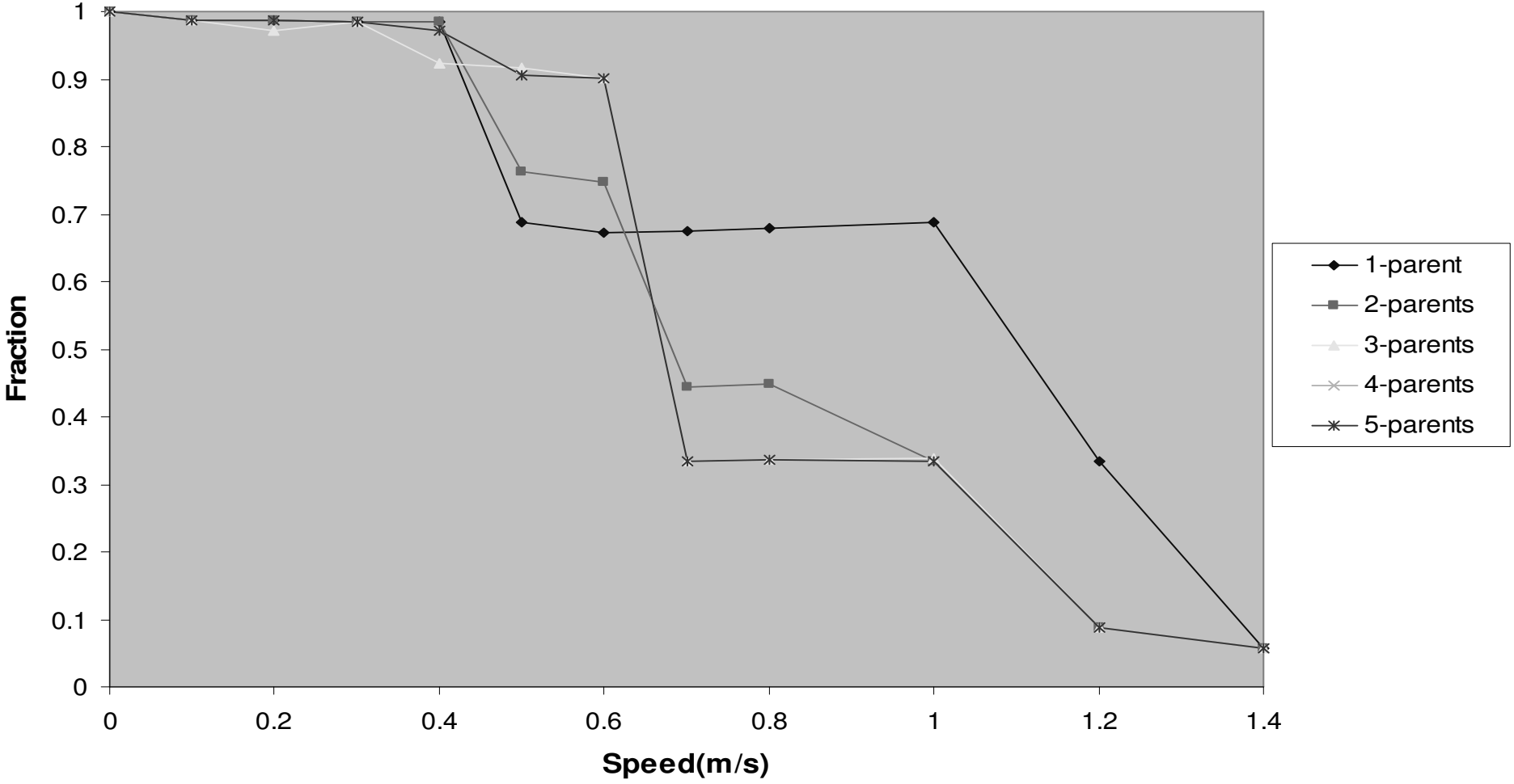
Note:
B does not resend info from D if it already received it from E.

Optimized Algorithm: Performance

- Simulation Environment : GloMoSim
  - 200m x 200m area
  - 50 nodes
  - Random waypoint mobility model
  - 802.11 MAC protocol
  - Varying speeds and power of nodes
  - Assume bidirectional links

Links Discovered: -10dBm

Without Panic Mode



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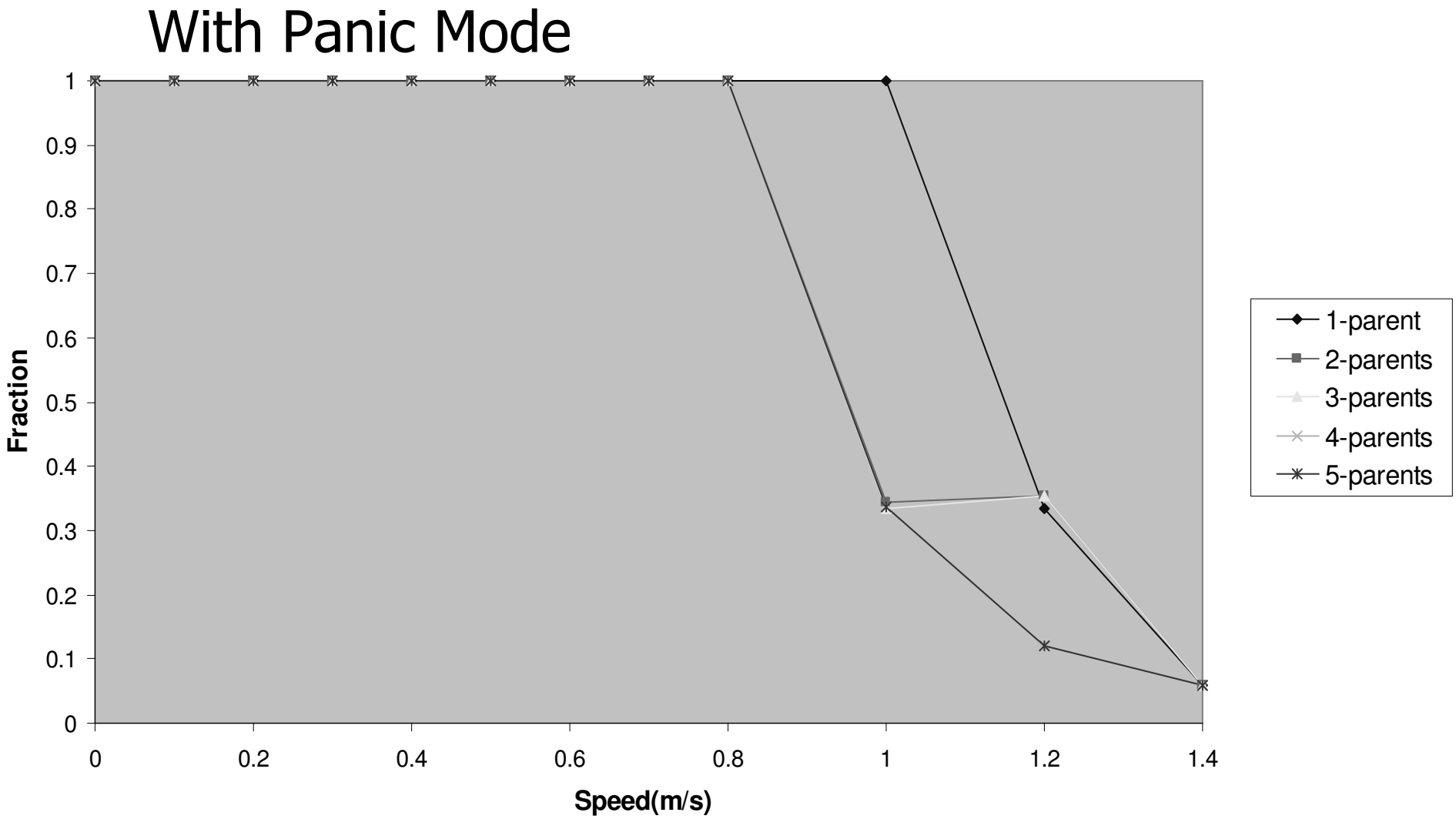
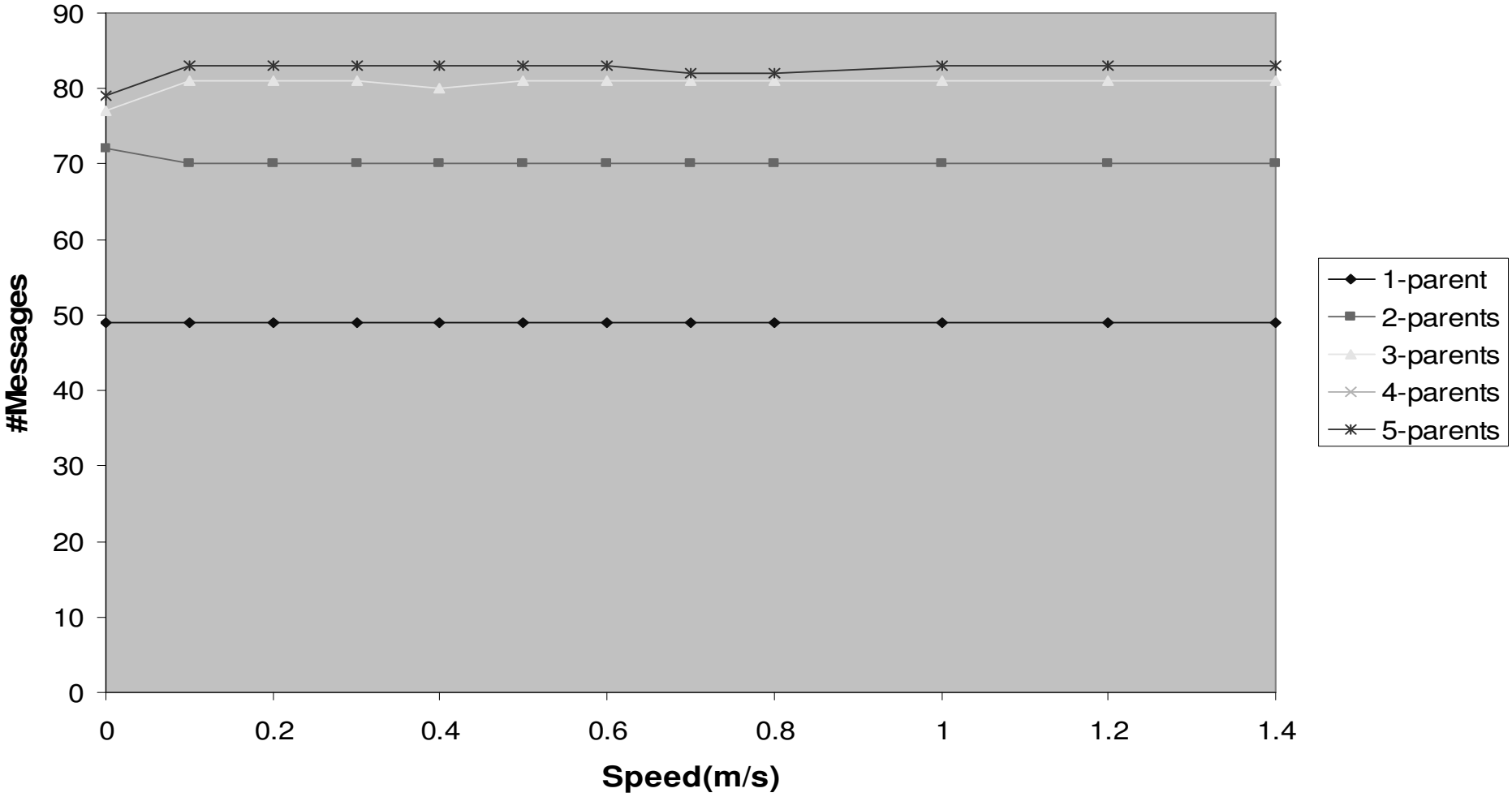


Message Overhead: -10dBm

Without Panic



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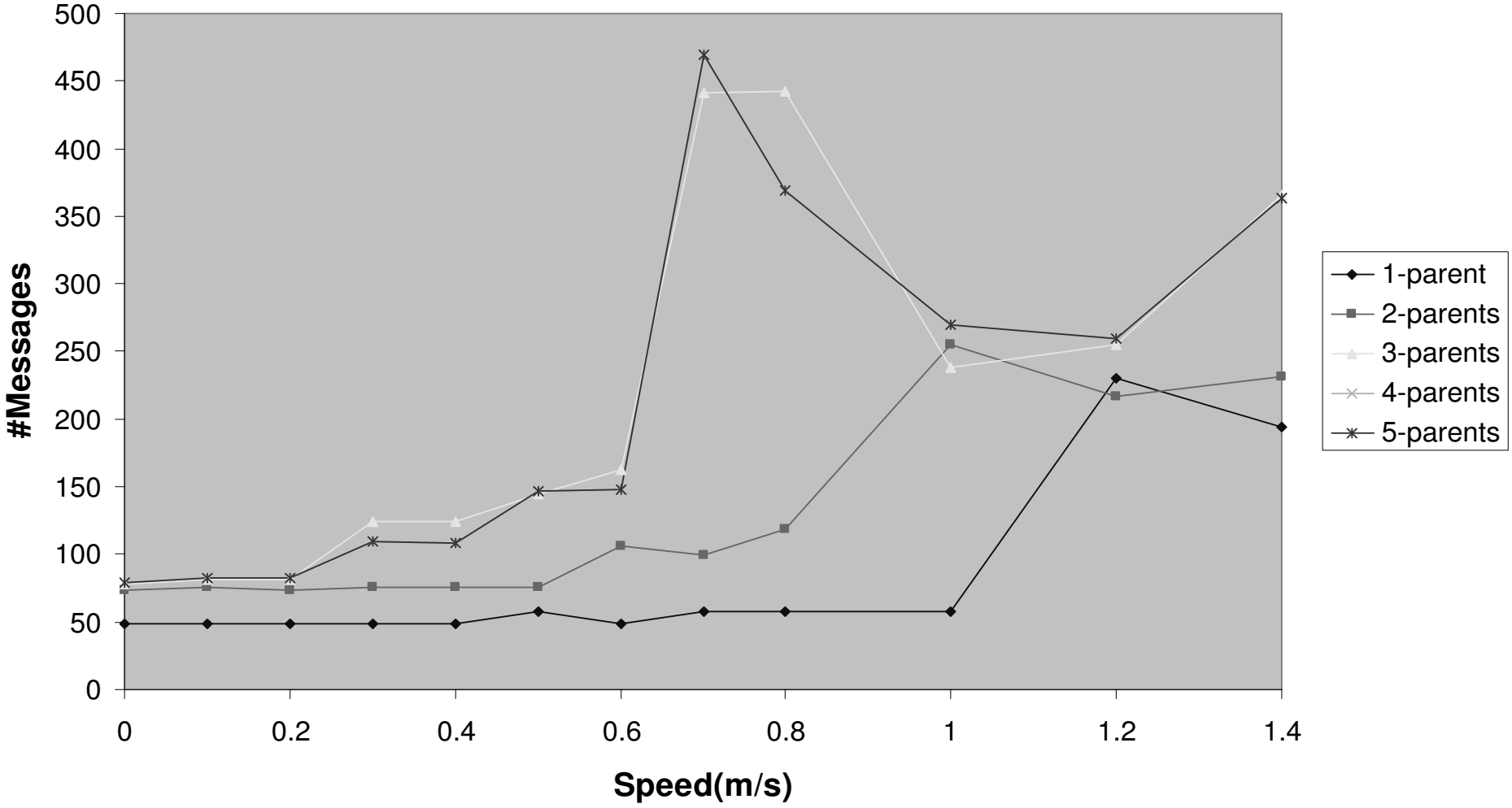
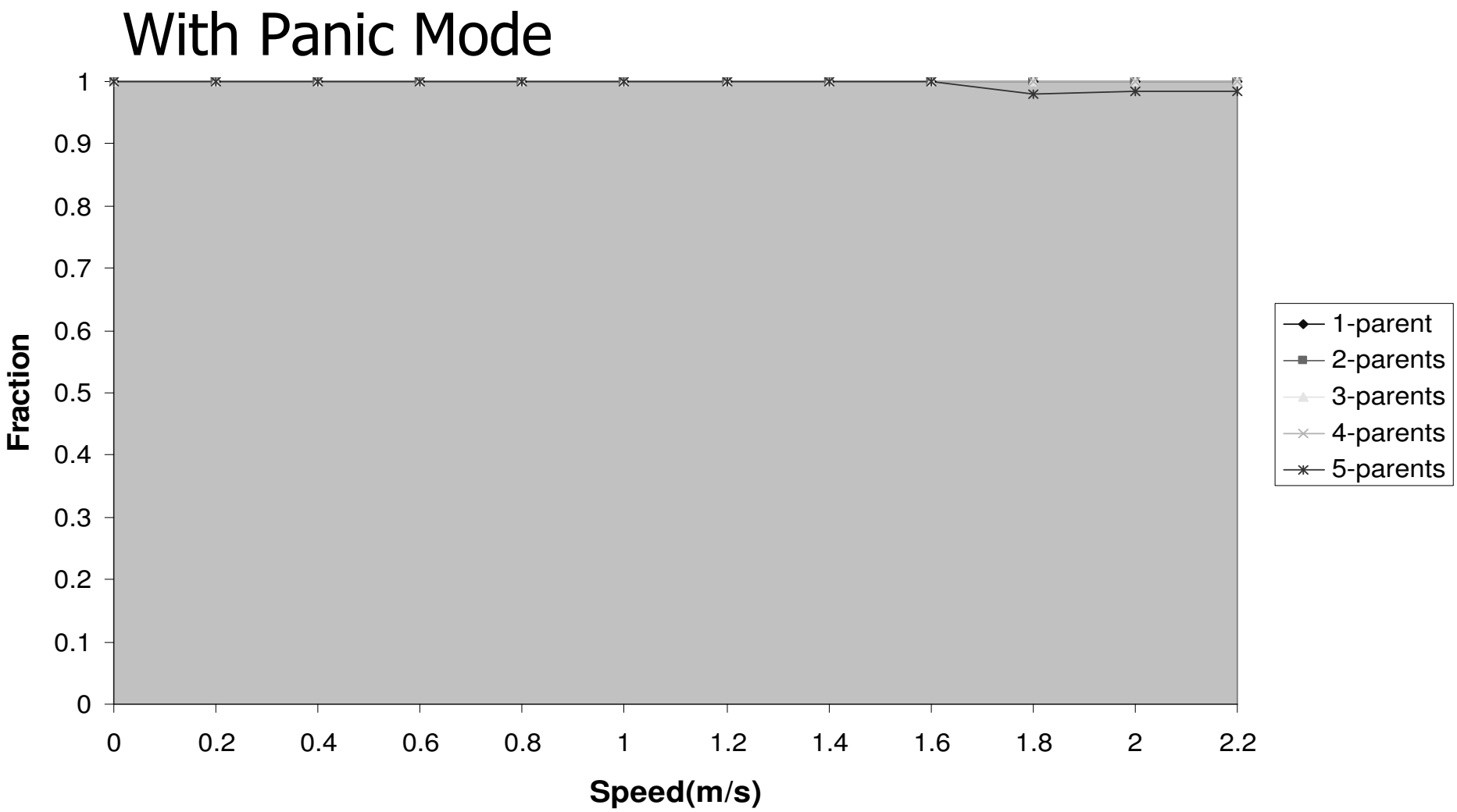
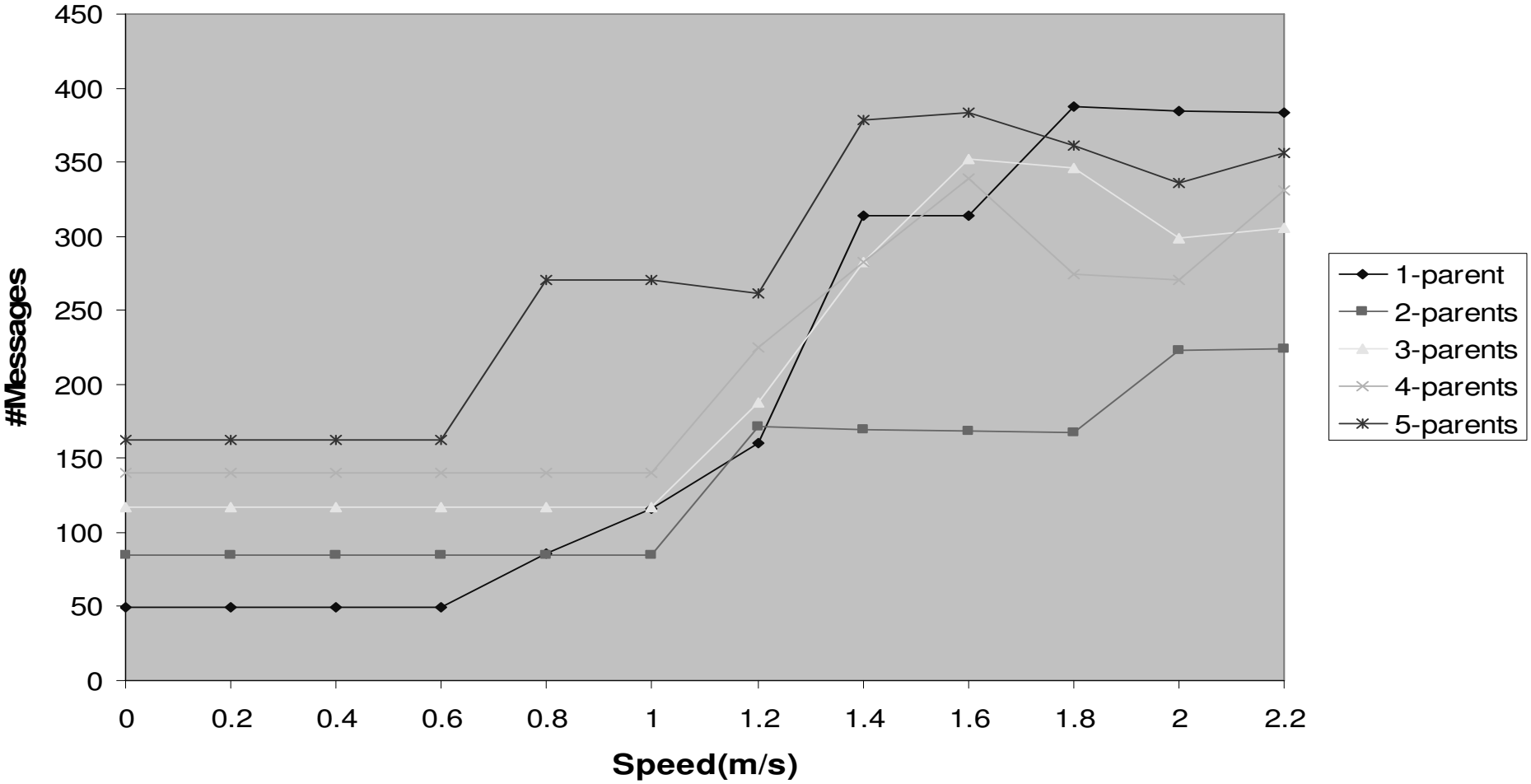


Links Discovered: -4dBm



Message Overhead: -4dBm

With Panic Mode



Conclusions

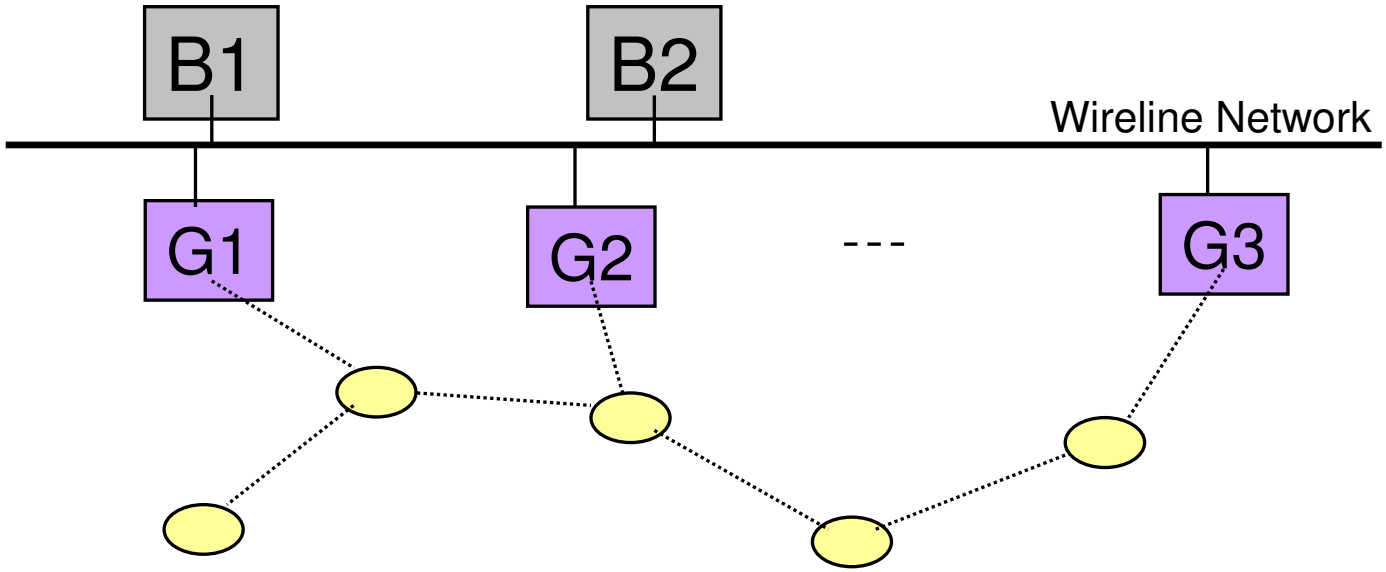
- Algorithm
  - Discovers all links & nodes in most slow moving networks
  - O(N) message complexity in such networks
  - Adaptive: The robustness of the mesh is a parameter of the algorithm
- Target scenario:
  - Not all nodes are moving… Some moving slowly, most of them stationary $\Rightarrow$ O(N)

Questions?

Backup Slides

Hybrid Wireless Network

- Applications: Home, office networks, mesh networking



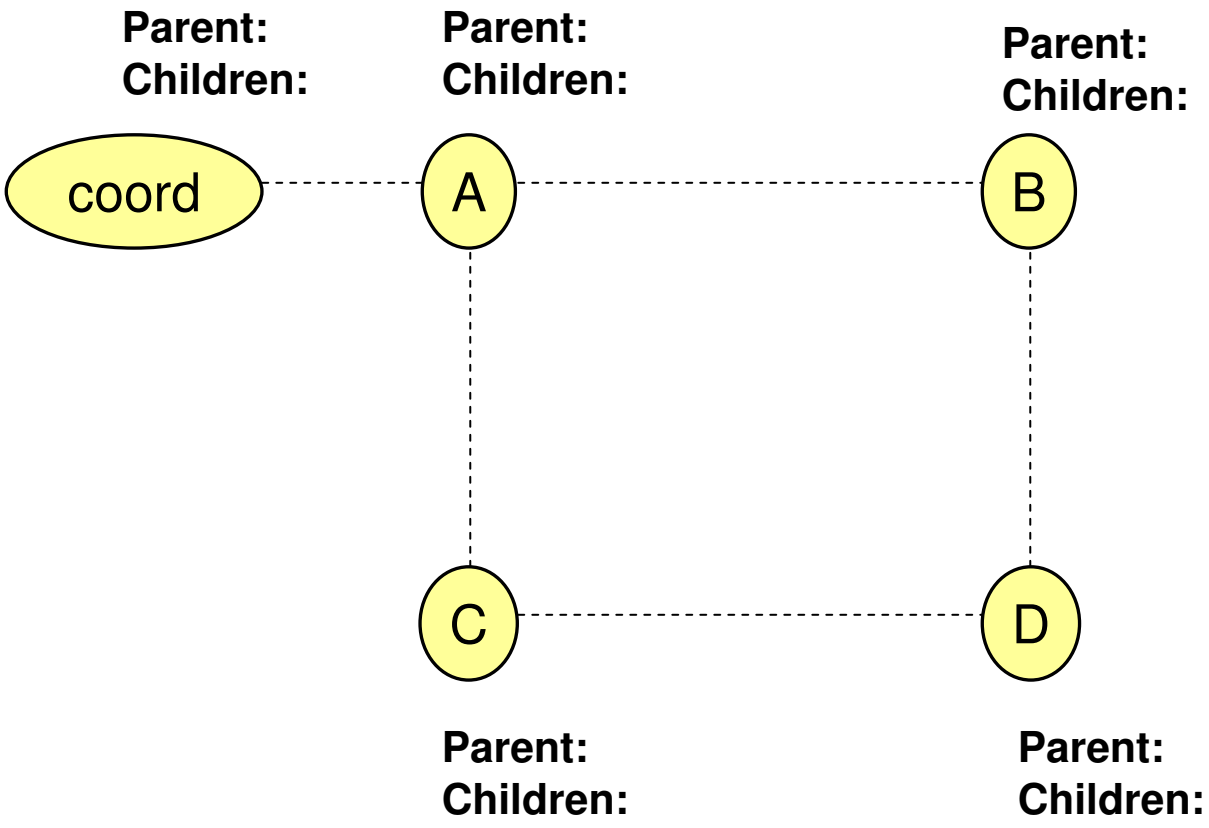
Stability properties

- *Stable link*
  - Present throughout running time of algo
- *Semi-stable mesh*
  - All nodes reachable via stable links in mesh
- *Semi-stable network*
  - All nodes reachable via stable links

Algorithm Properties

- Performance:
  - Semi-stable network: All links & nodes discovered
- Message complexity:
  - Semi-stable mesh: O(N) messages
  - Worst case: $O(DN^2)$ messages
- Adaptive Algorithm:
  - Performance degrades slowly as the number of nodes downstream of a mesh breakage increases.

Diffusion Phase



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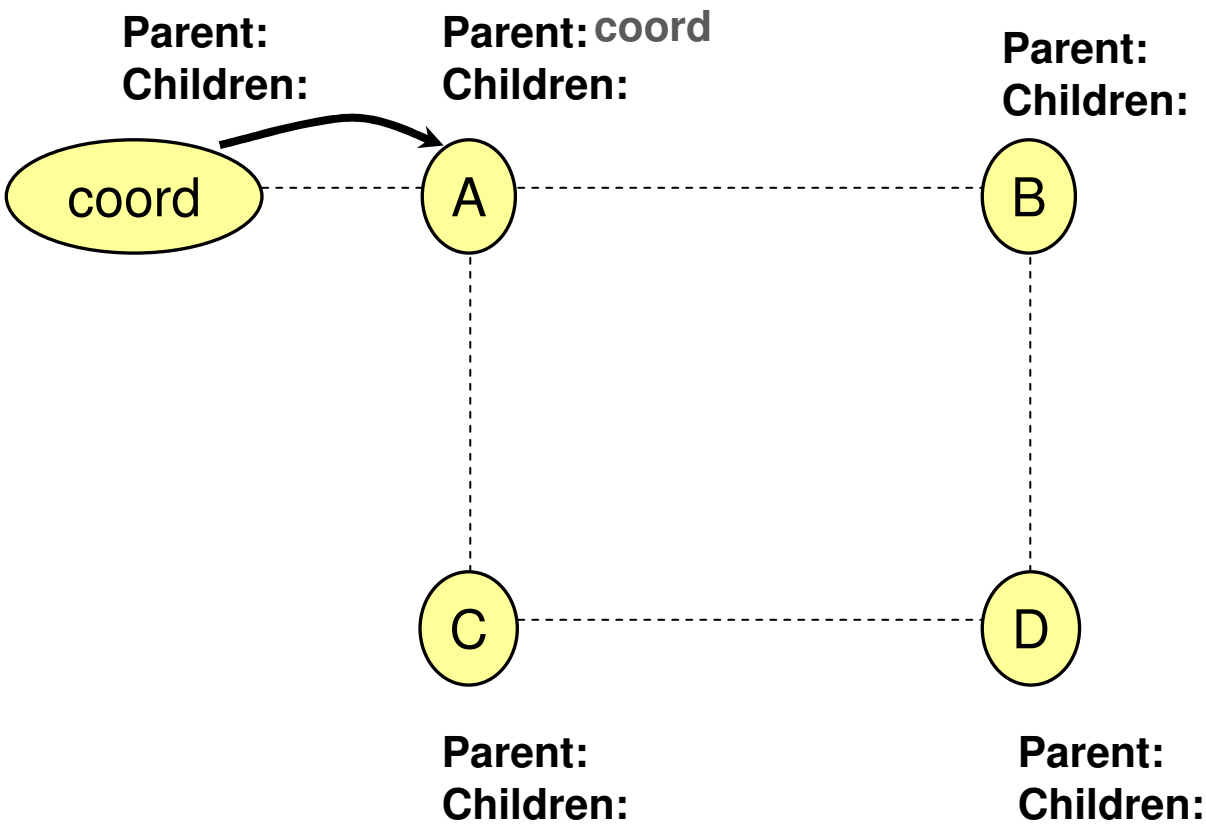

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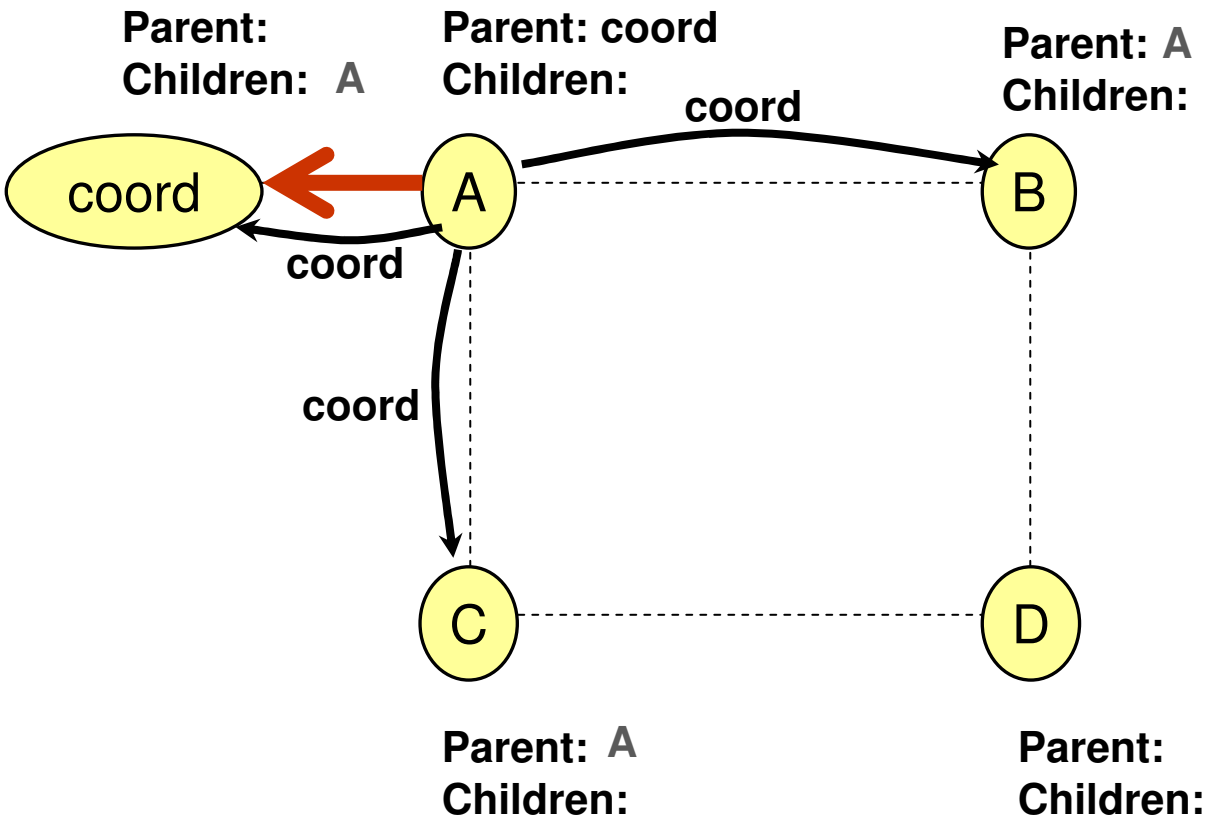

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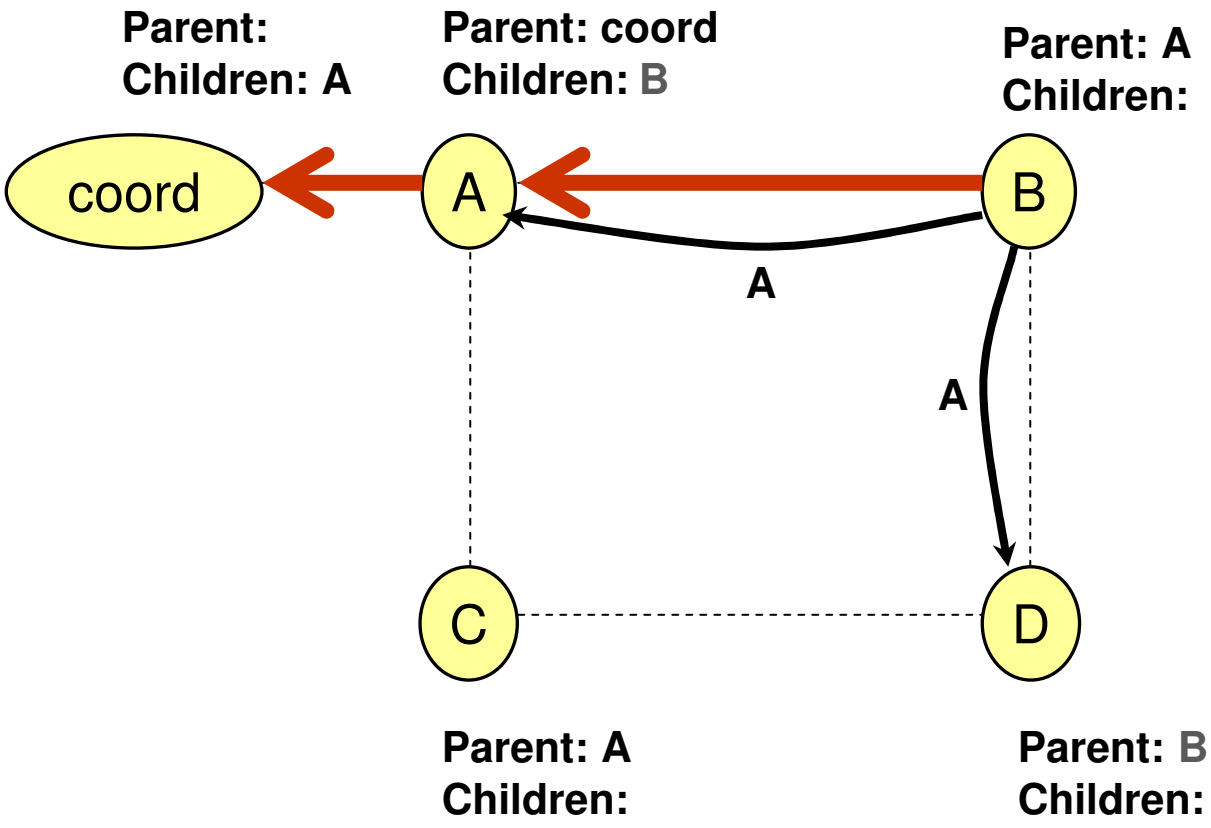

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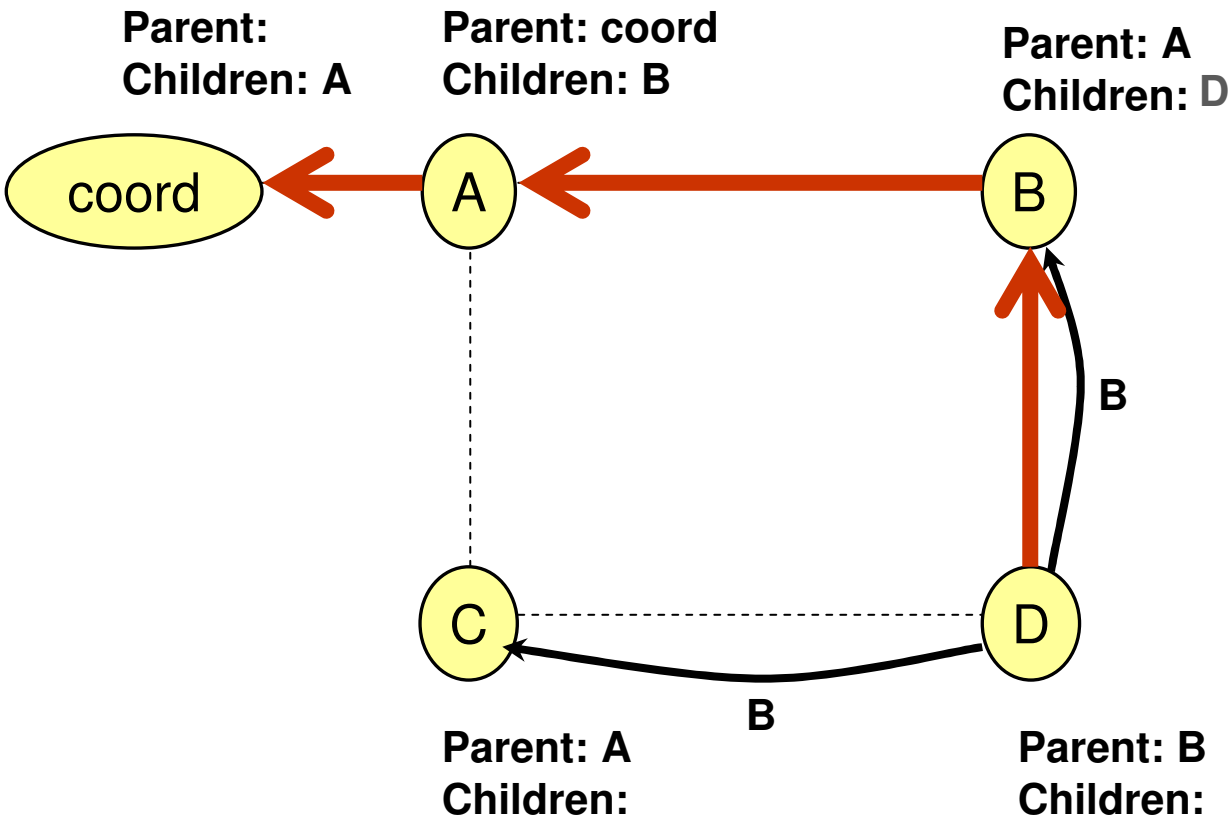
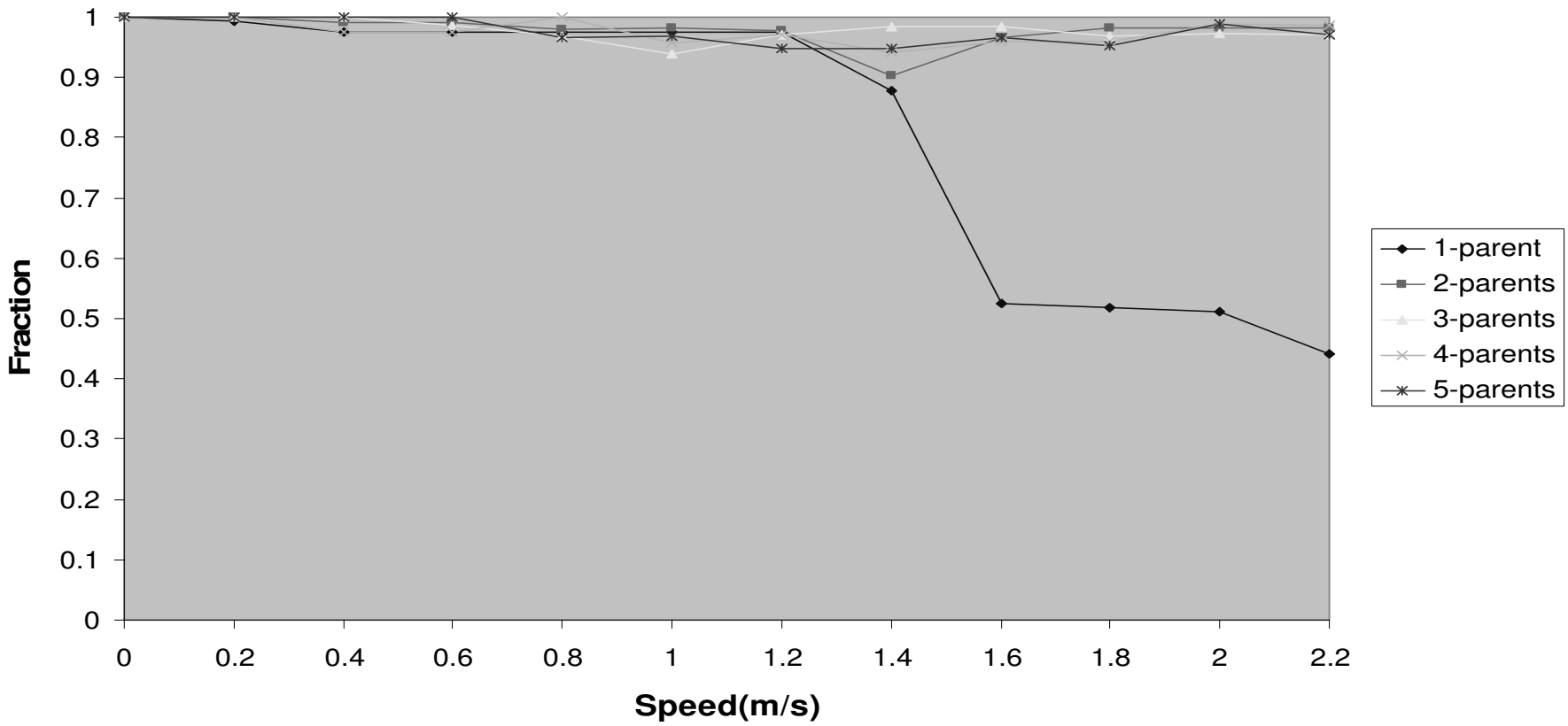


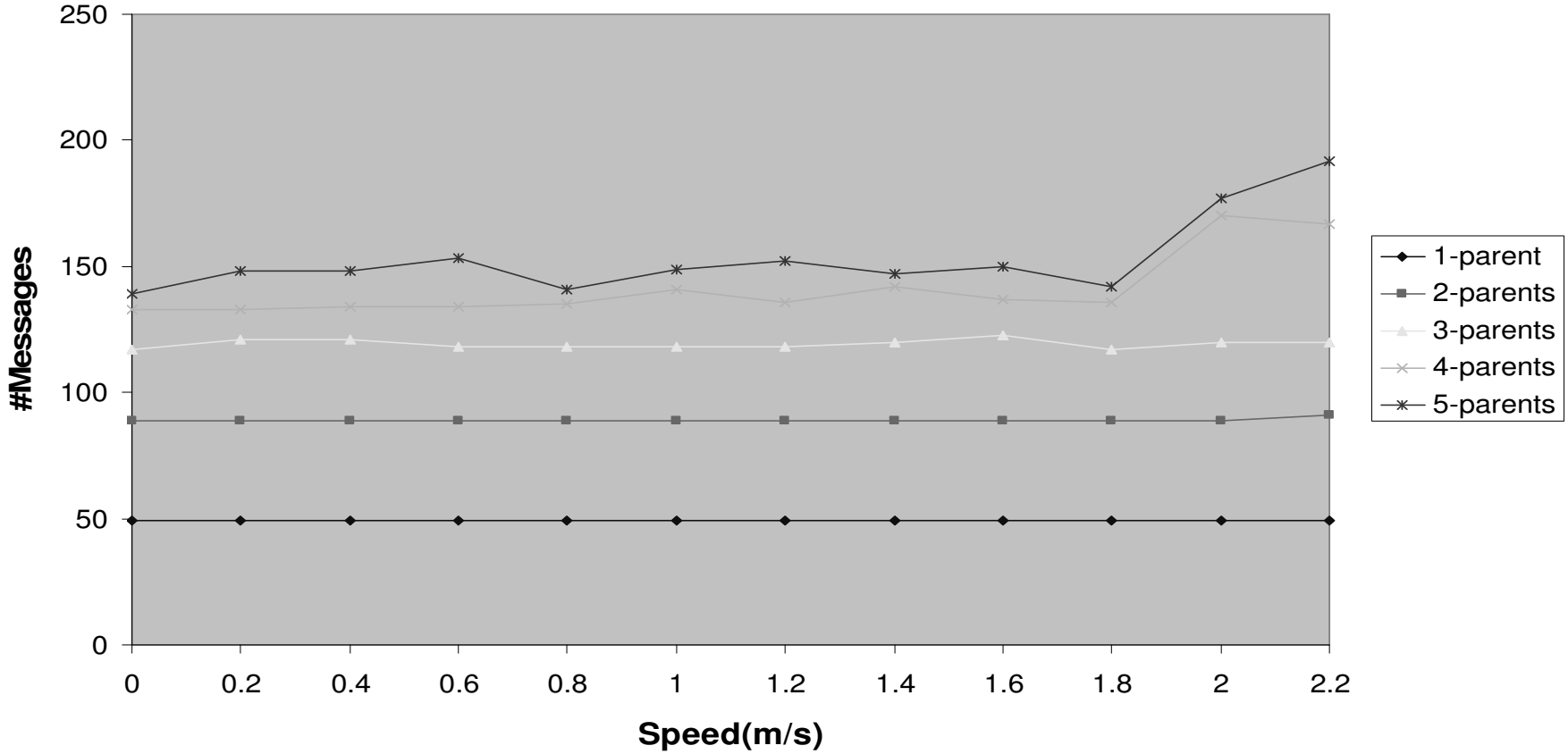
Links Discovered: -6dBm

Without Panic Mode



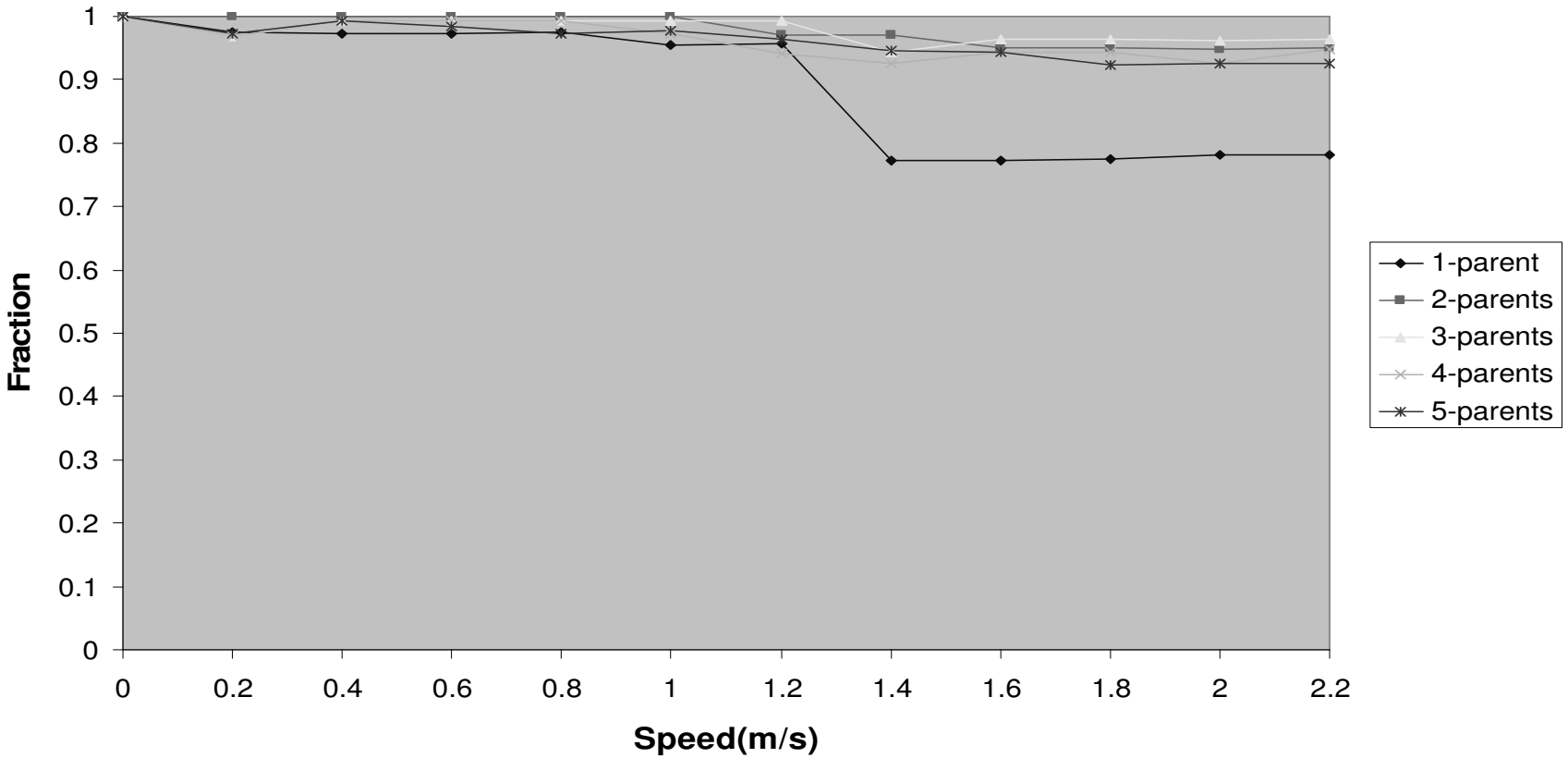
Message Overhead: -6dBm

Without Panic



Links Discovered: -4dBm

Without Panic Mode



Links Discovered: -6dBm

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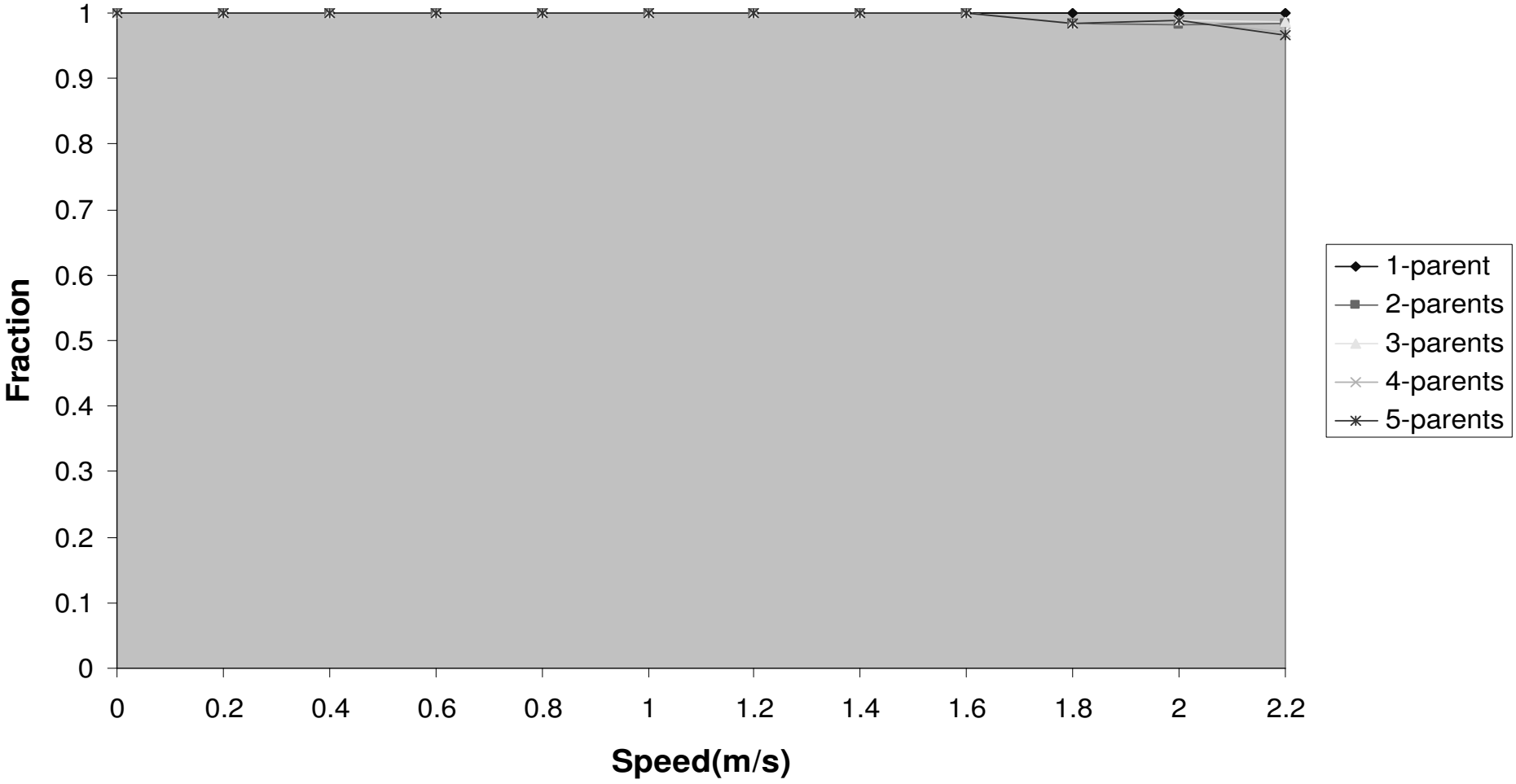

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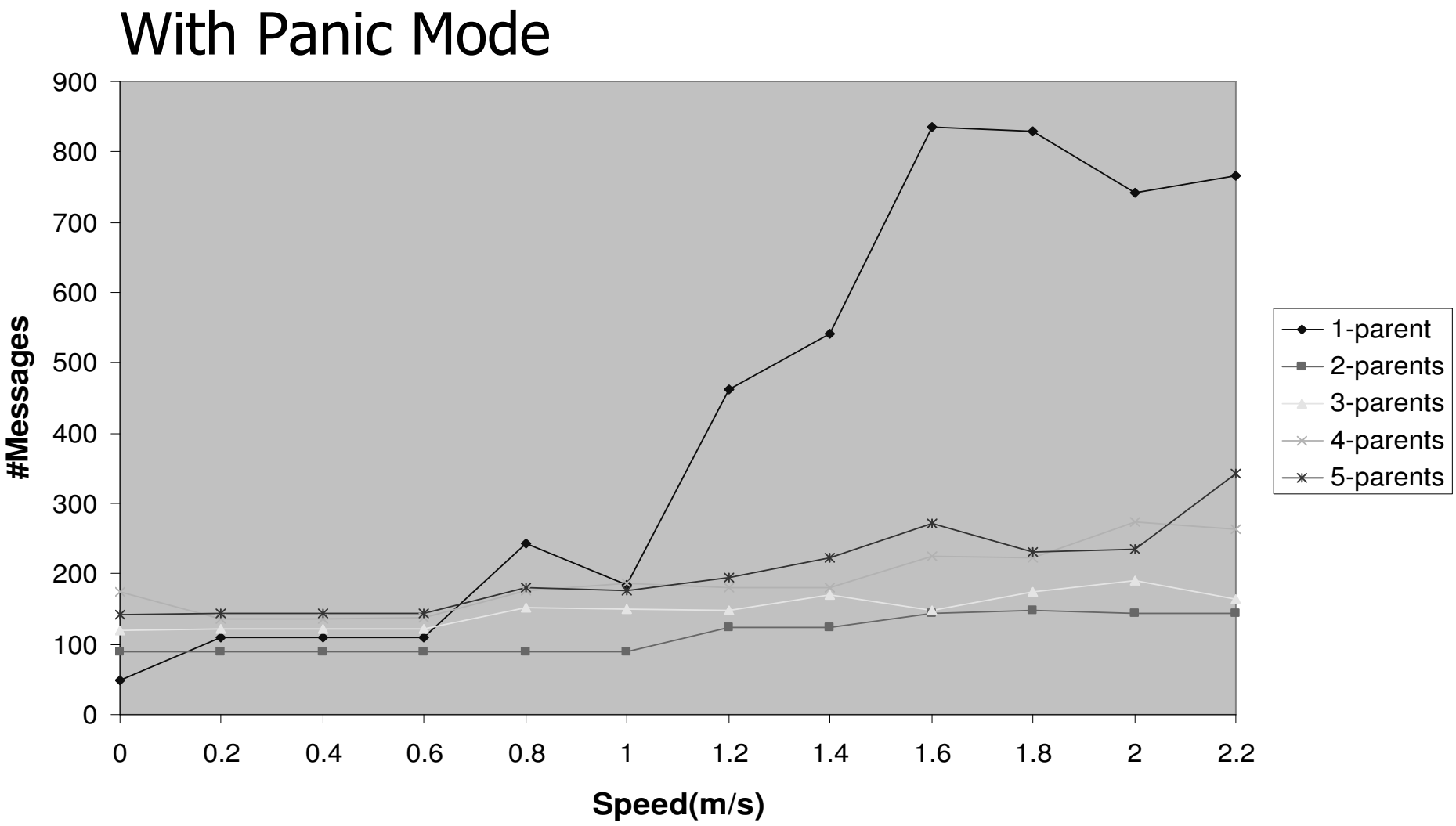

Message Overhead: -4dBm

Without Panic