Directed Diffusion: A Scalable and Robust Communication Paradigm for Sensor Networks

Chalermek Intanagonwiwat and Ramesh Govindan and Deborah Estrin

USC/Information Sciences Institute

May 1, 2007

Slides By John McCullough

Introduction

Sensor Networks:

- 'How many cows are in the north pasture?'
- 'How much is the volcano vibrating?'
- etc

Typical Sensor Networks:

- Stream time series data to collection point
- Static-ish

Directed Diffusion

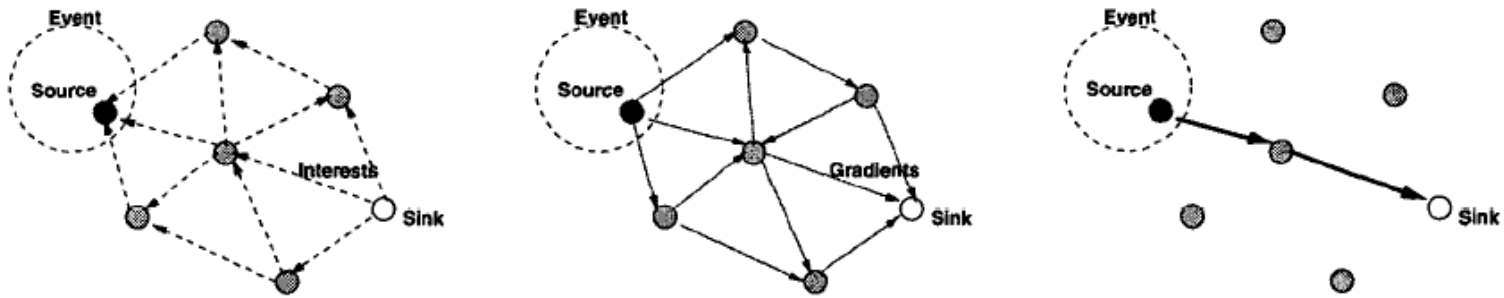
- Data-Centric
- Issue queries to the network
- Network returns aggregate data

Why not IP?

- Maintaining global knowledge of the network is expensive and unnecessary
- The network is task-specific
- Different primitives can be used

Big Idea

- Distribute Sensing Task ('Interest') to Network
  - type: four-legged animal
  - interval: 20ms
  - duration: 10s
  - rect: [-100,100,200,400]
- 'Draw' data back to a sink(s)



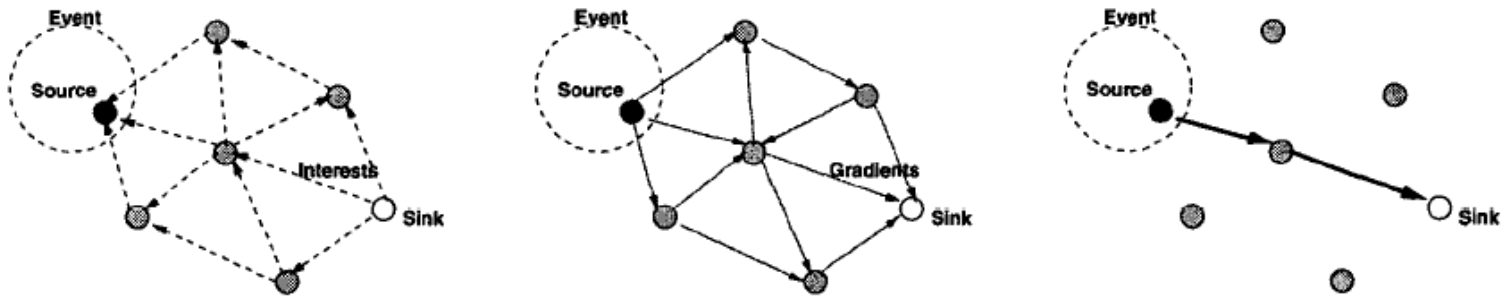
(a) Interest propagation

(b) Initial gradients set up

(c) Data delivery along reinforced path

Figure 1: A simplified schematic for directed diffusion.

Building Gradients



(a) Interest propagation

(b) Initial gradients set up

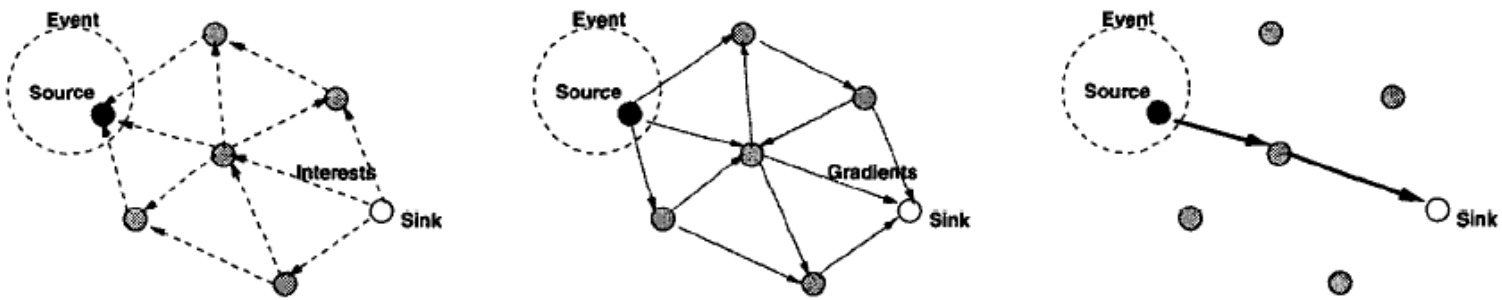
(c) Data delivery along reinforced path

Figure 1: A simplified schematic for directed diffusion.

- Initial Exploratory Period
  - broadcast with low data interval
  - update timestamp
  - Nodes cache interests
    - Distinct in (type, interval, rect)
    - timestamp
    - expiration
  - Nodes cache 'gradients' for each interest
    - address and timestamp for interest senders

Data Propagation

- Nodes that can provide for the interest generate data at highest requested rate
- Send data along all gradients
- Specific use of gradients is up to interpretation
- Data Caching $\longrightarrow$ In-path rate-limiting, rate-expanding, or aggregation possible.



(a) Interest propagation

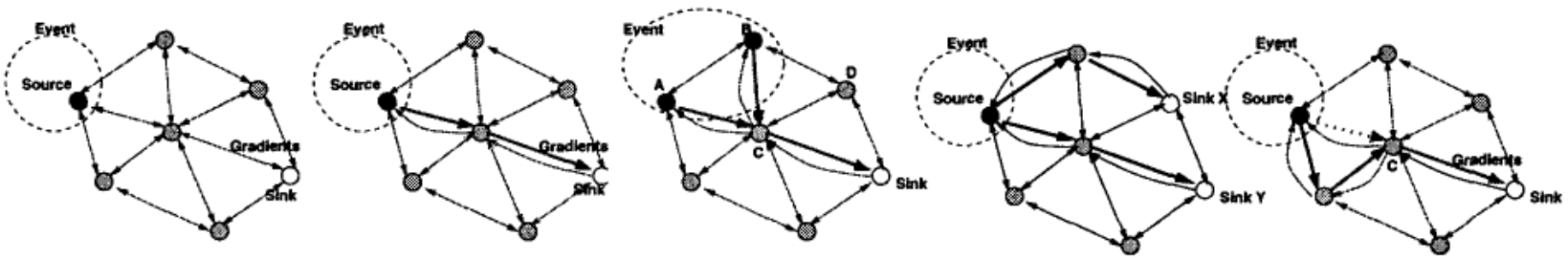
(b) Initial gradients set up

(c) Data delivery along reinforced path

Figure 1: A simplified schematic for directed diffusion.

Reinforcement

- Increase Data Rate after exploratory period
- Reinforce good neighbor
- Neighbor must reinforce it's neighbors to reach the update interval.

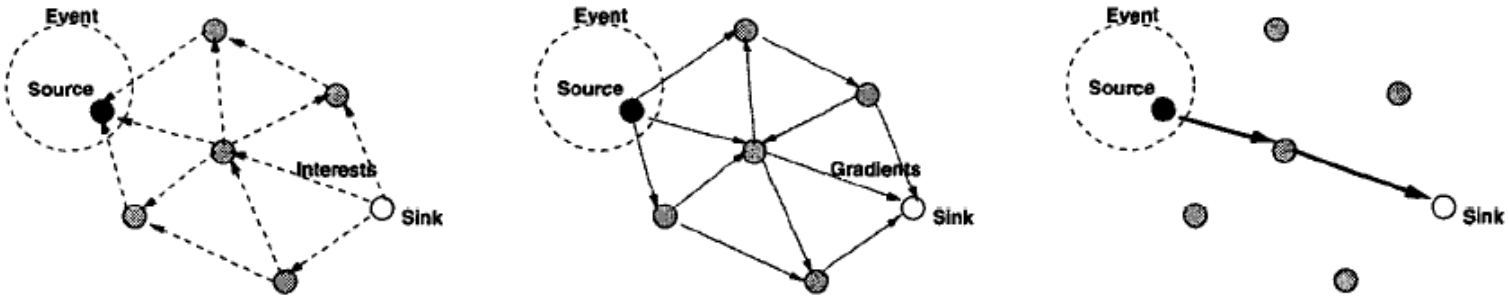


(a) Gradient establishment (b) Reinforcement (c) Multiple sources (d) Multiple sinks (e) Repair

Figure 2: Illustrating different aspects of diffusion.

Negative Reinforcement

- Exploratory = everyone has a gradient.
- Time out gradients w/o reinforcement
- Explicitly downgrade nodes intervals.



(a) Interest propagation

(b) Initial gradients set up

(c) Data delivery along reinforced path

Figure 1: A simplified schematic for directed diffusion.

Evaluation

Metrics:

- Average Dissipated Energy
- Average Delay
- Event Delivery Ratio

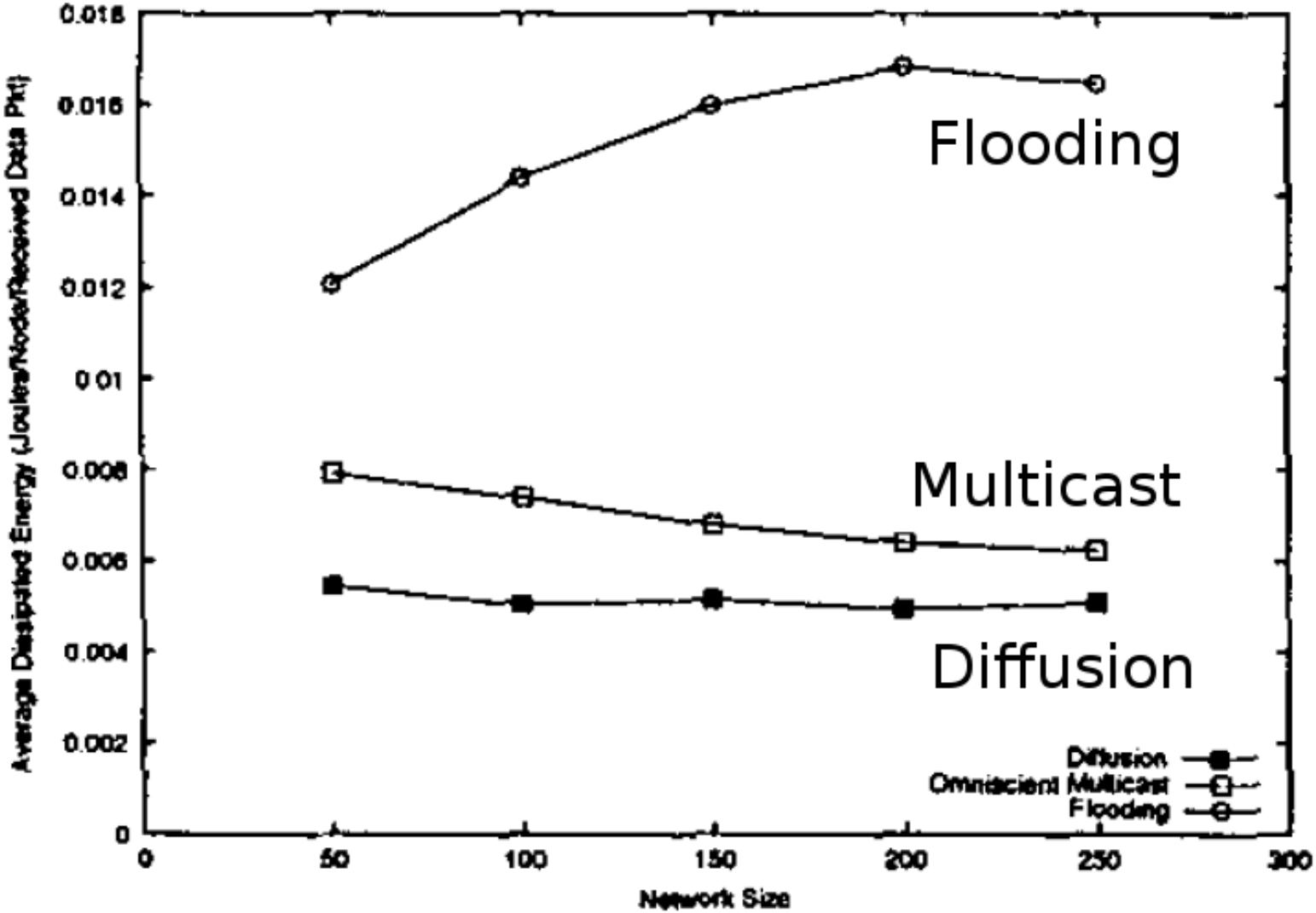
Comparisons:

- Flooding
- Omniscient Multicast
- Duplicate observations suppressed by diffusion.

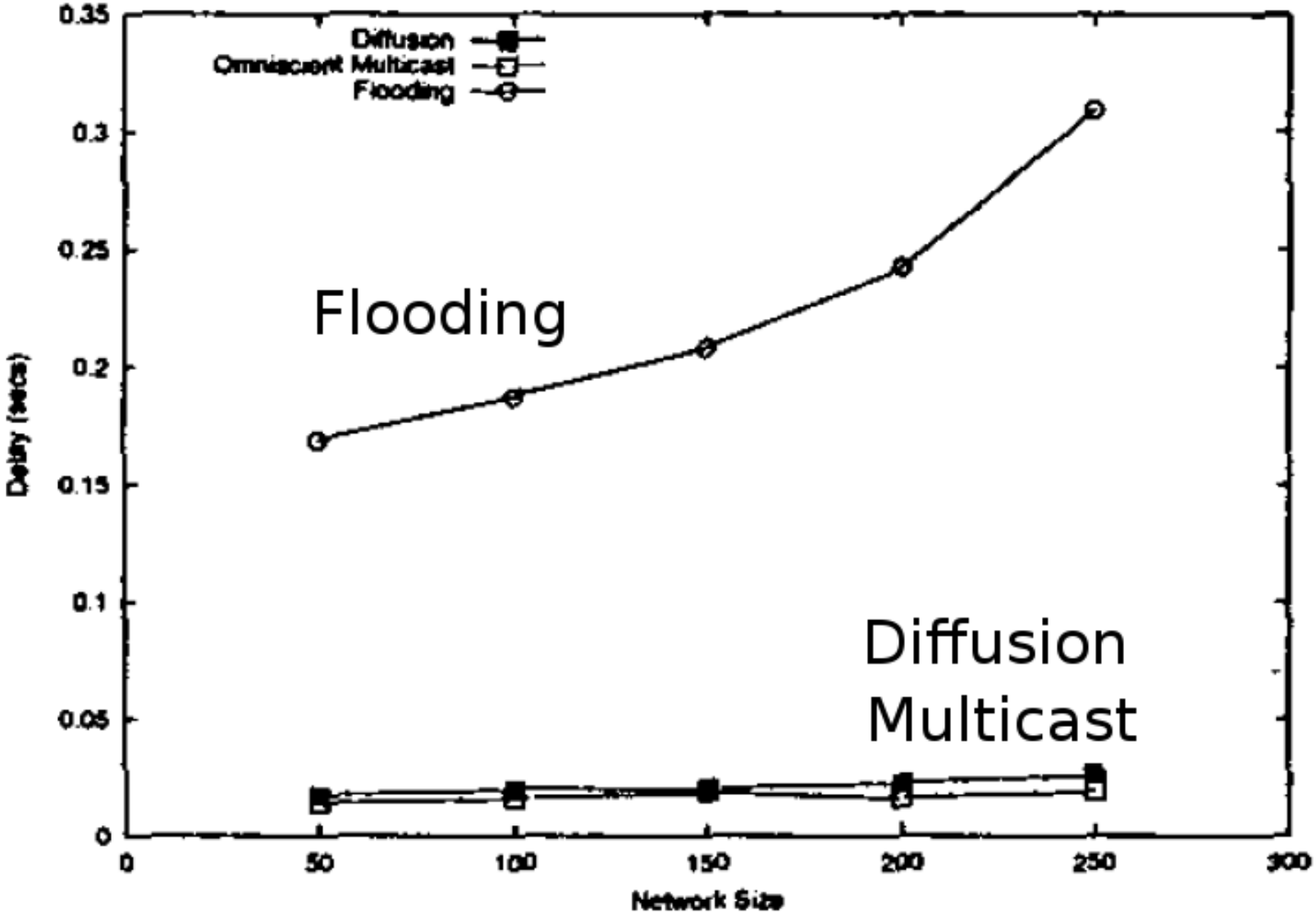
Setup:

- ns2
- Far from overload
- Random placement on area with fixed radio density.
- Radio w/diminished idle consumption to mimic sensor radios
- fixed workload w/five sinks (random), five sources (in 70m square, 2 events/s).
- Doesn't specify how events are generated?

Joules/Node/Received Packet



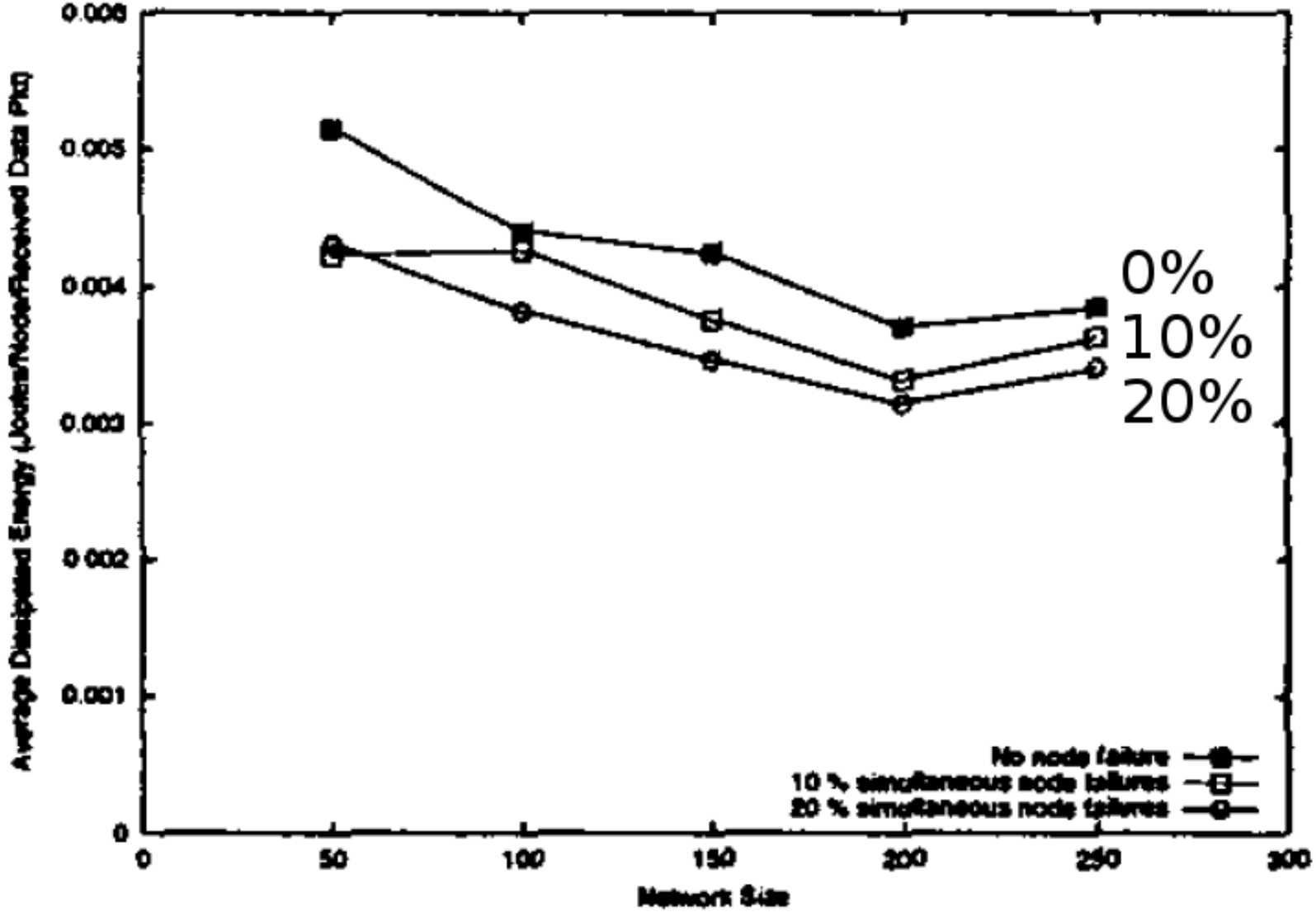
Average Delay



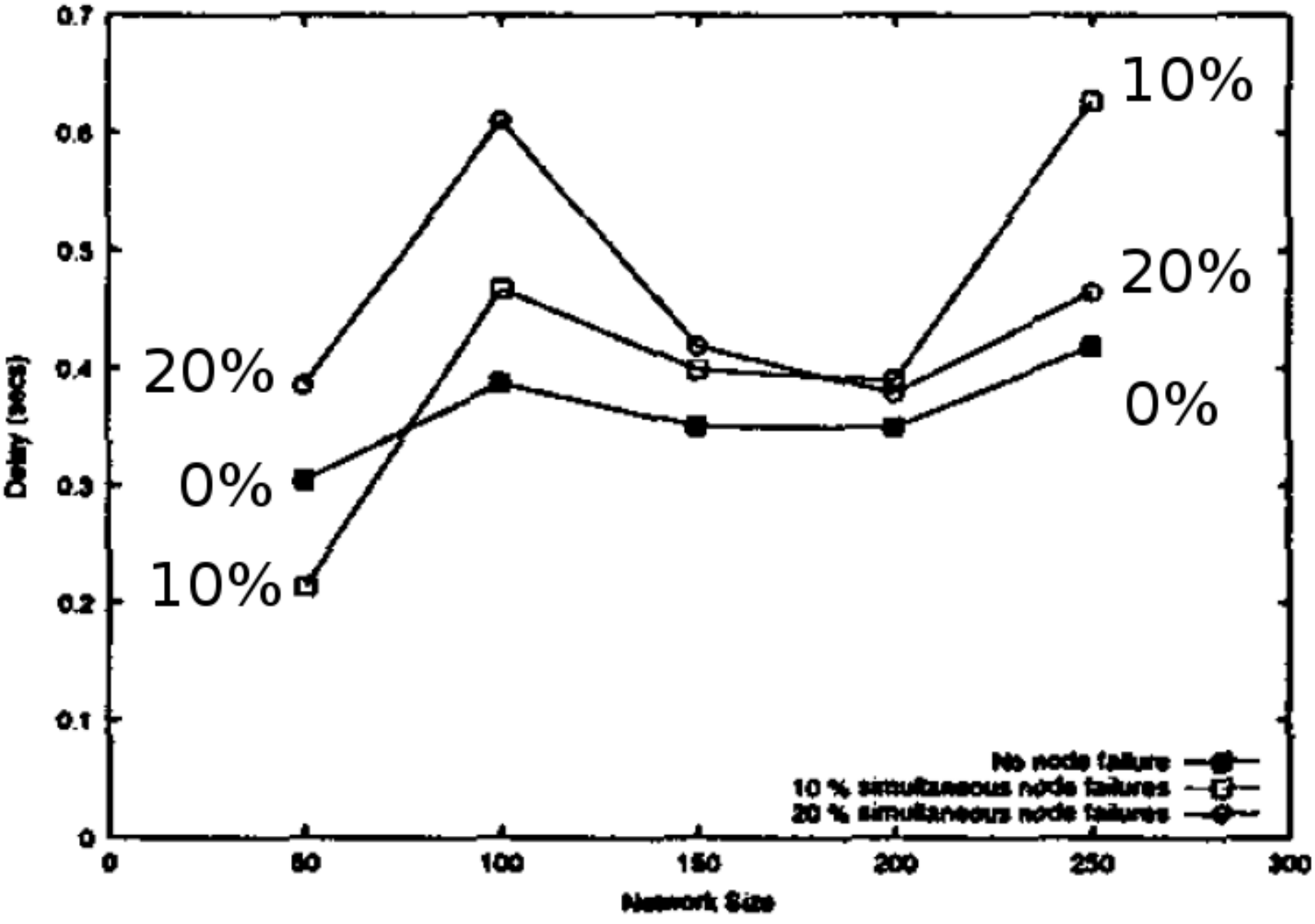
Dynamics

- Turned off a fixed fraction of nodes for 30s
- No overlap for suppressing duplicate observations.

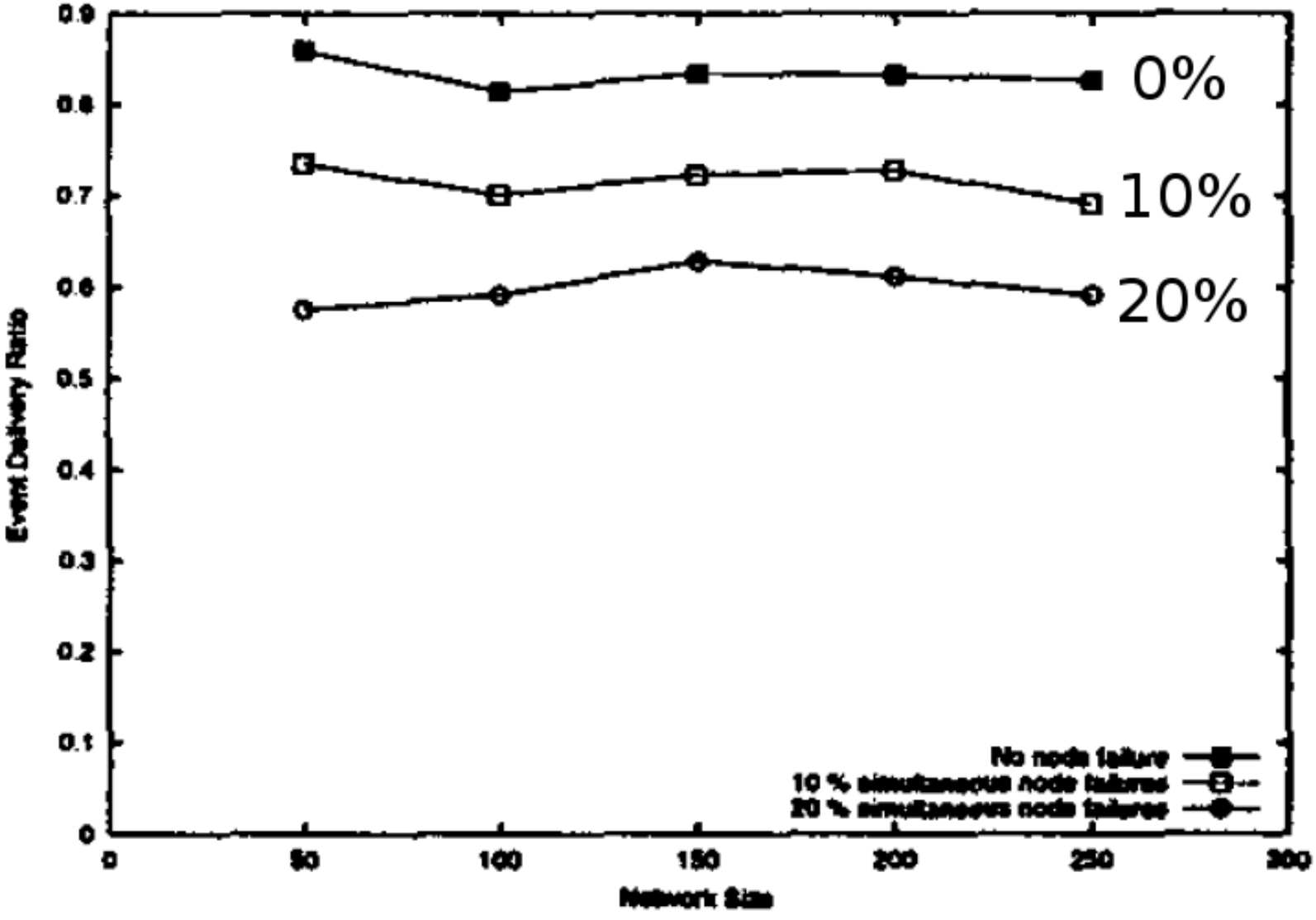
Energy with Loss (Does this make sense?)



Average Delay with Loss (Does this make sense?)

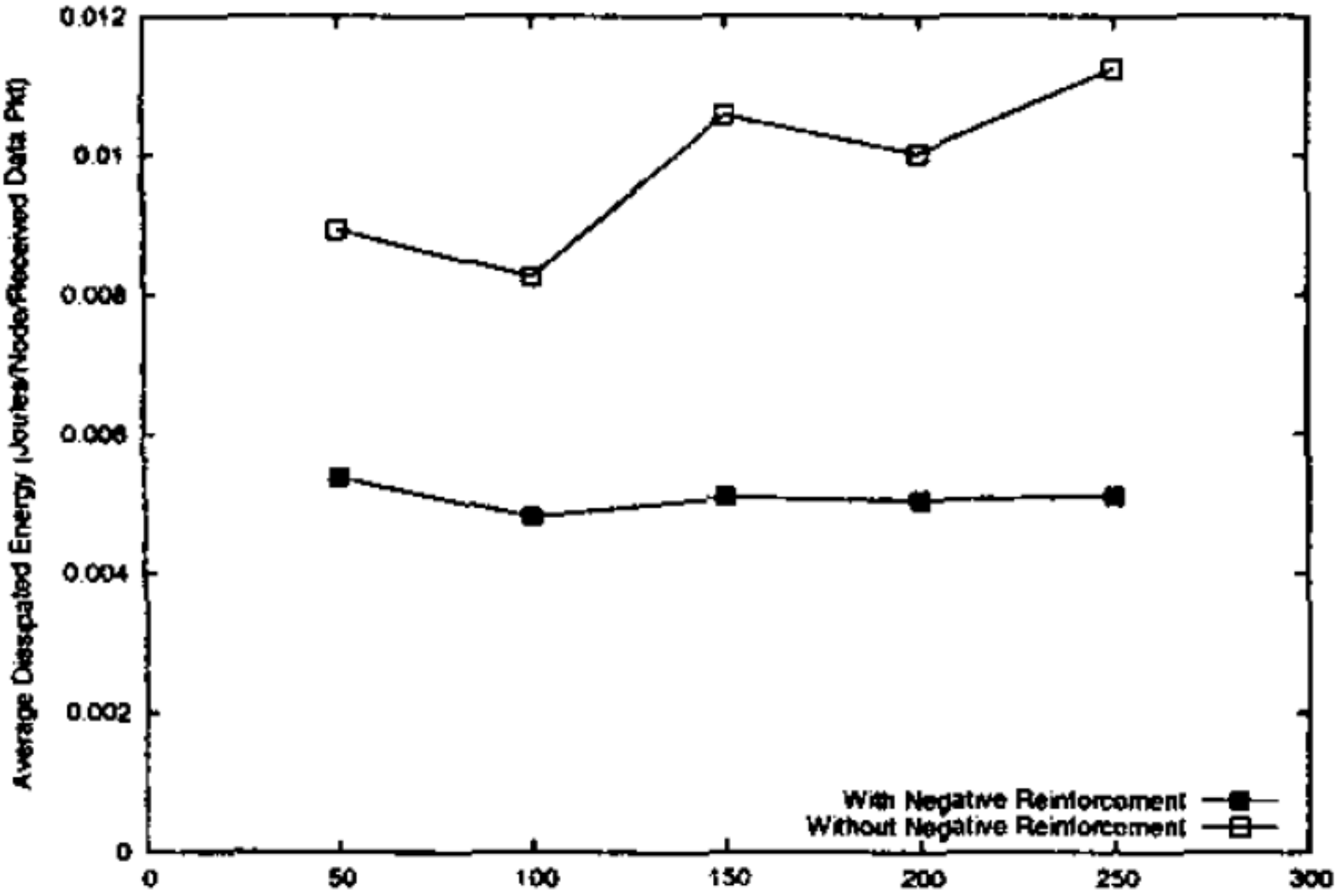


Event Delivery Ratio with Loss

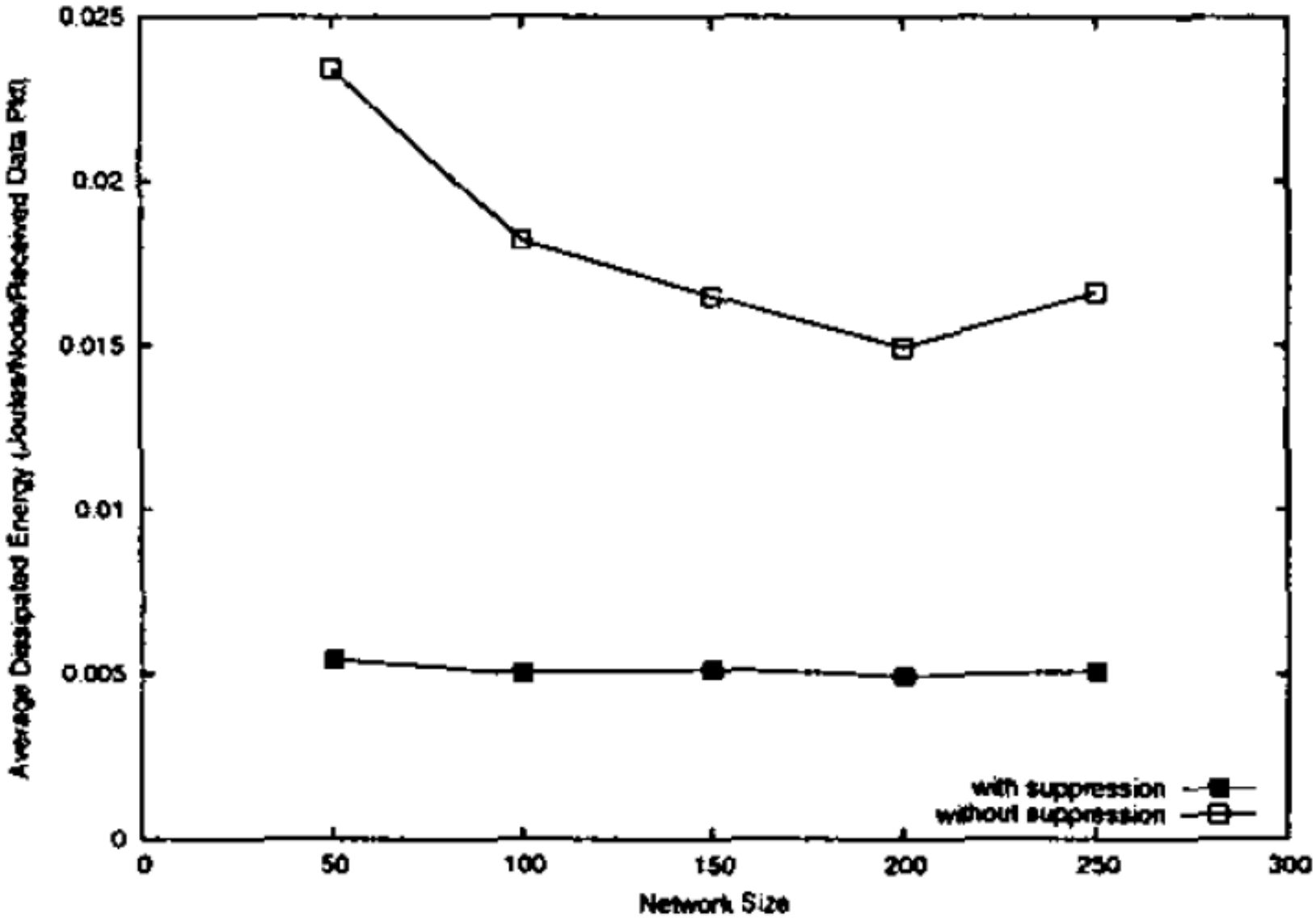


Impact of Negative Reinforcement

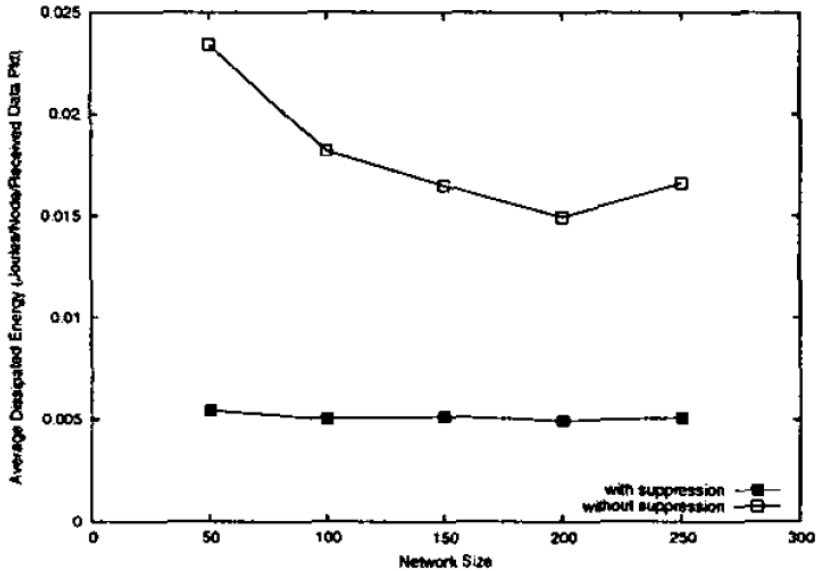
- Negative Re-enforcement more effective in larger networks (more alternate paths)
- Selects low latency paths

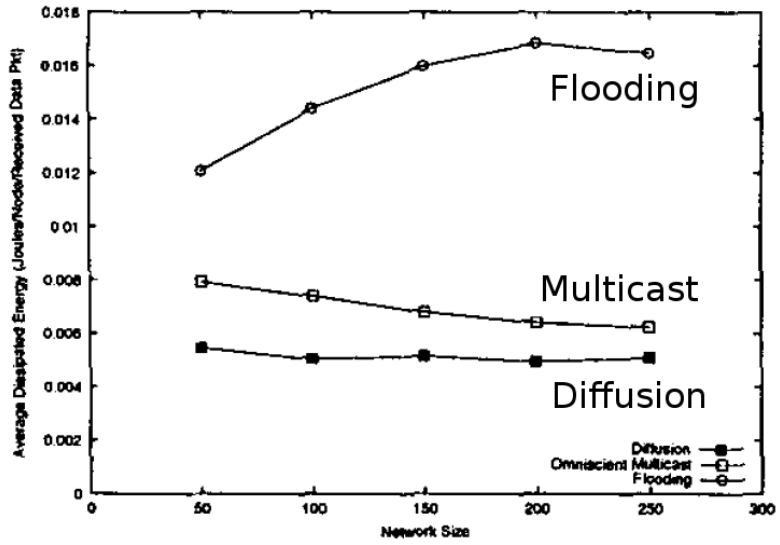


Impact of Duplicate Suppression



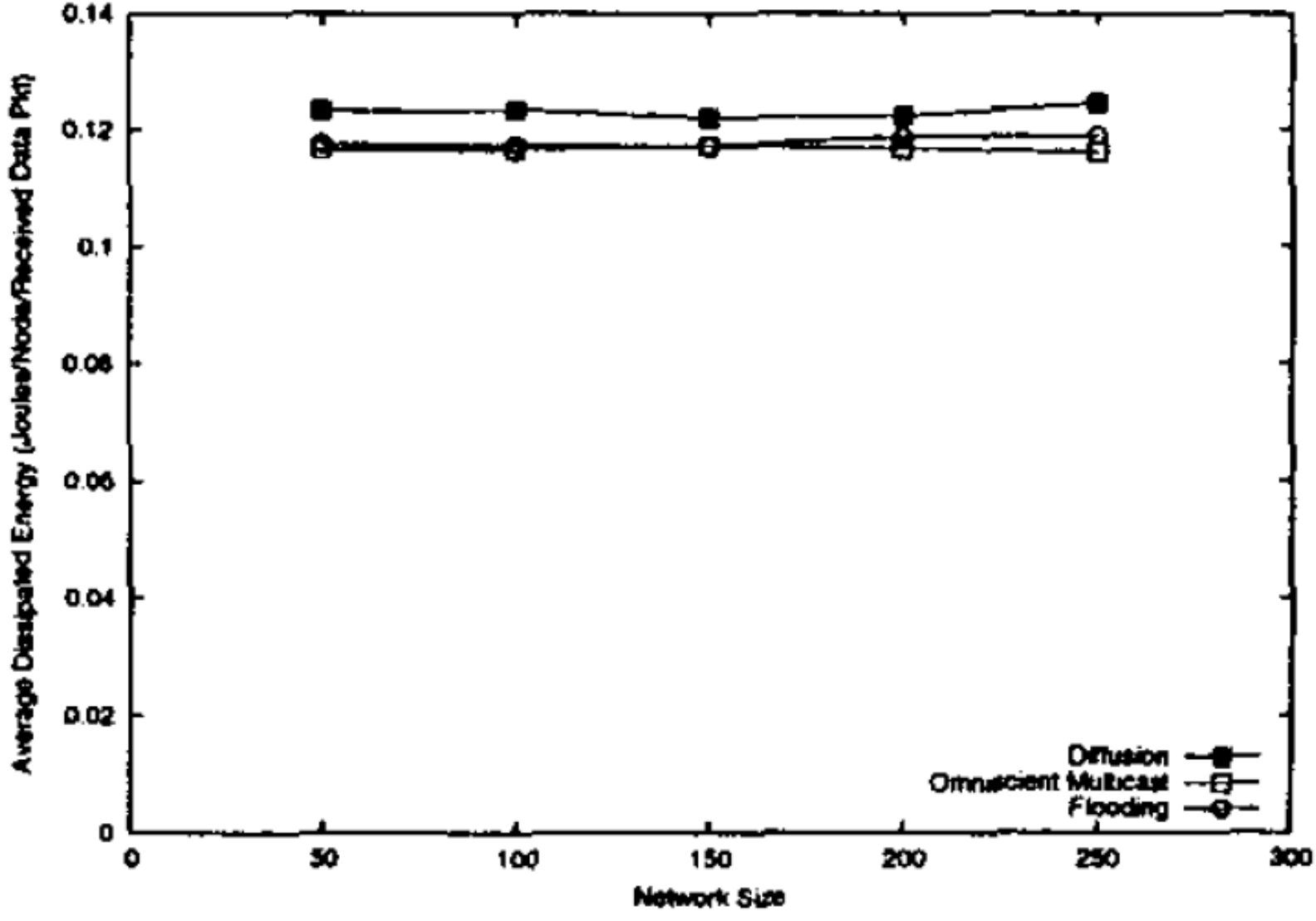
For Comparison





Impact of Radio Power

If 802.11 idle power used, no gains:



Paper's Conclusions

- Potential to reduce energy usage with good MAC layer.
- Data-centric dissemination is neat.

Questions

- How feasible is duplicate suppression?
- What is the energy cost of extra computation?
- Better path reinforcement methods?