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

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Problem Addressed

- In a Distributed Sensor Network System, how do you query the system for events of interest??
  - Two Parts
    - Query Propagation
    - Data Propagation

Core Idea

- Directed Diffusion is a data-centric approach.
  - Set up interests for named data in the network
  - Interested data is drawn towards the node through gradients
  - Intermediate nodes can cache, perform transformations etc for better utilization

Query Propagation

- User query is transformed into "interest" for named data.
- Data Naming
  - Attribute-Value pairs

type = four-legged animal //detect animal location
interval = 20 ms //send back event every 20 ms
duration = 10 seconds //for the next 10 s
rect = [-100, i00, 200, 400] //from sensors within rectangle

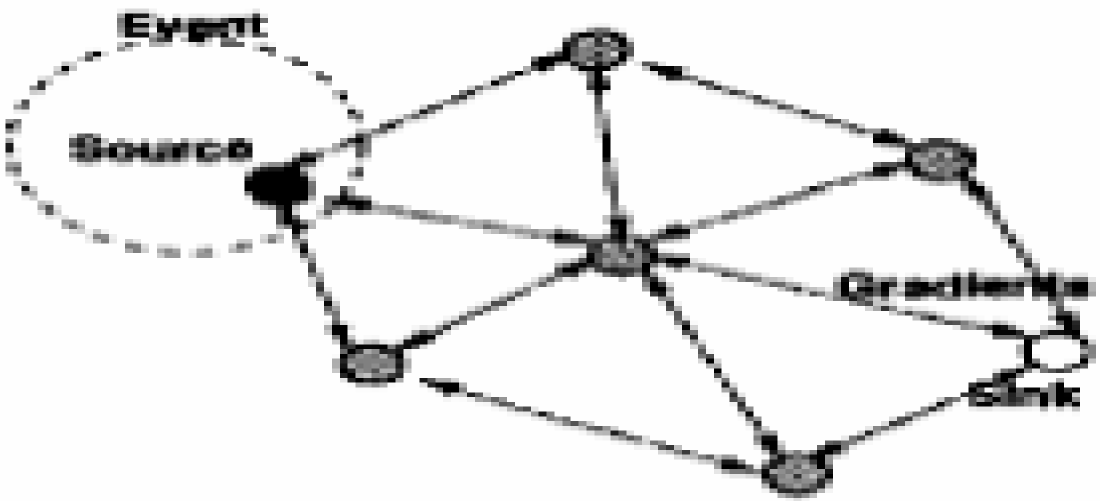
Basic Working

- Disseminate interest for named data
- Dissemination sets up gradients in network to draw events i.e. data matching the interest
- Events flow towards originator among multiple paths
- Network reinforces one or a small number of paths

Interest Propagation and Gradient Setup

- Sink periodically broadcasts interest to neighbors
  - Exploratory Phase
  - Broadcast Interest with low event rate
    - Goal is to discover routes between source and sink.
- Neighbors update interest-cache and forward interest
- Gradient set up to node from which interest was received

Interest Propagation and Gradient Setup



(a) Gradient establishment

- Bidirectional gradients due to local interactions
- Gradient specifies direction and value

Data Propagation

- When a source detects a target
  - Search interest cache
  - Generate samples at the highest event rate of all its outgoing gradients for this interest entry
  - Forward Event description to each neighbor that it has a gradient

Data Propagation

- When a node obtains a data message
  - Search data cache
    - Loop prevention
  - Search interest cache
  - Depending on gradient in interest entry forward data to neighbors
    - Nodes can perform down rate conversion, interpolation to improve utilization.

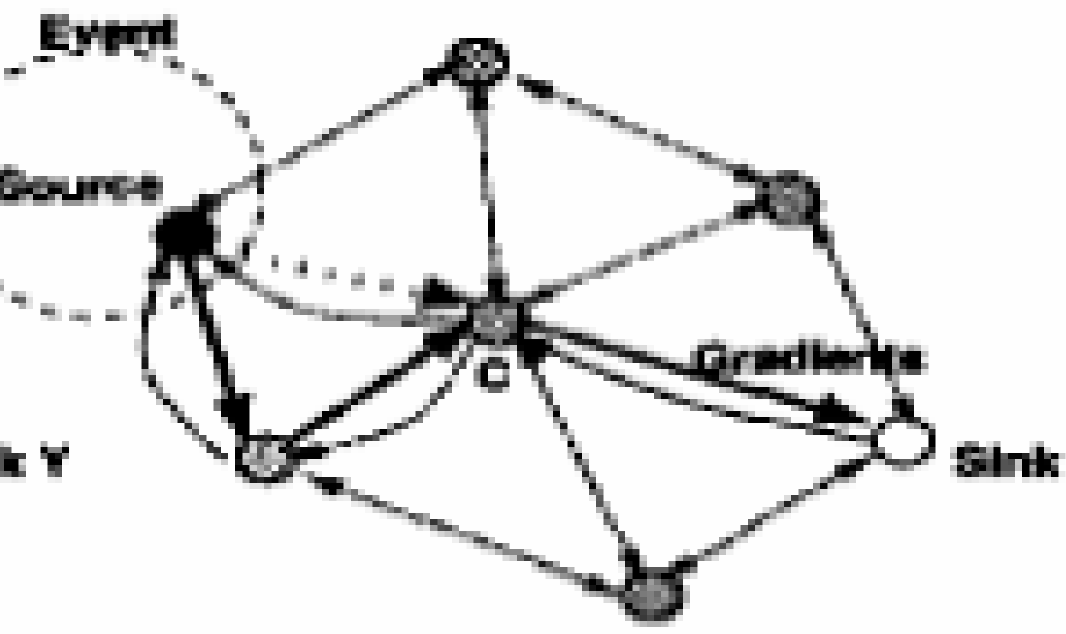
Reinforcement

- Source sends low-rate events to sink across multiple paths
- Sink then reinforces one particular neighbor to draw down high quality/data rate events
  - Choose neighbor based on data driven rules
  - Use data cache
- Results in high data rate path between source and sink

Negative Reinforcement

- How to prevent multiple paths from being reinforced??
- Idea is to negatively reinforce paths
  - Time out high data rate gradients
  - Explicitly resend interest with low data rate
- Choosing neighbor
  - Neighbor from which no new events have come in the last T seconds.

Repair



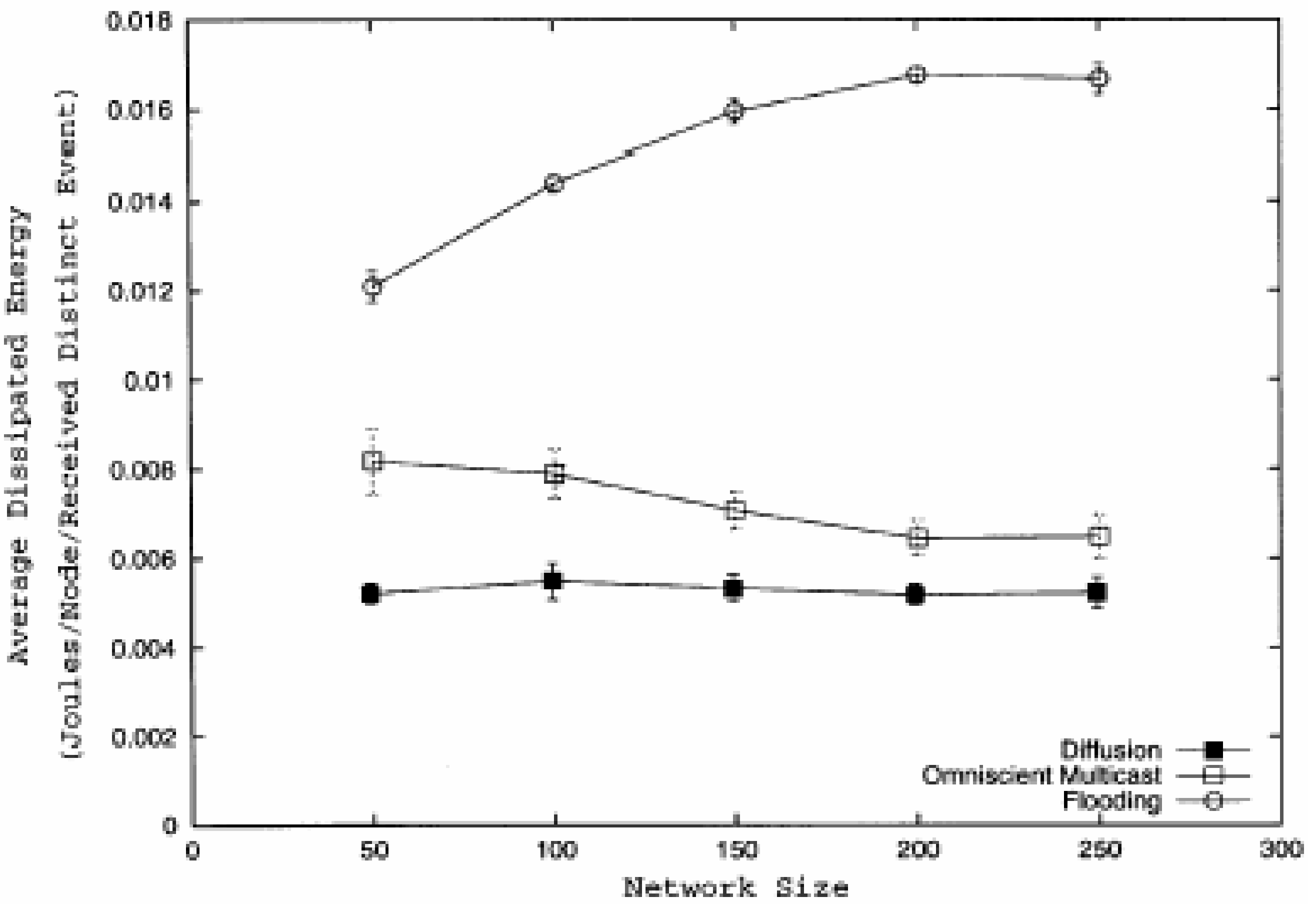
(e) Repair

- Initiated by intermediate nodes on a reinforced path
- Reinforce alternate path and negatively reinforce degraded path
- Intermediate nodes may need to interpolate data to prevent all downstream nodes from initiating reinforcement

Performance Evaluation

- ns-2 simulations , 50 nodes in 160*160 square sqm, 802.11 MAC
  - n/w size up to 250 nodes
  - Constant network density
- Metrics
  - Average Dissipated Energy
  - Average Delay
  - Event Delivery Ratio

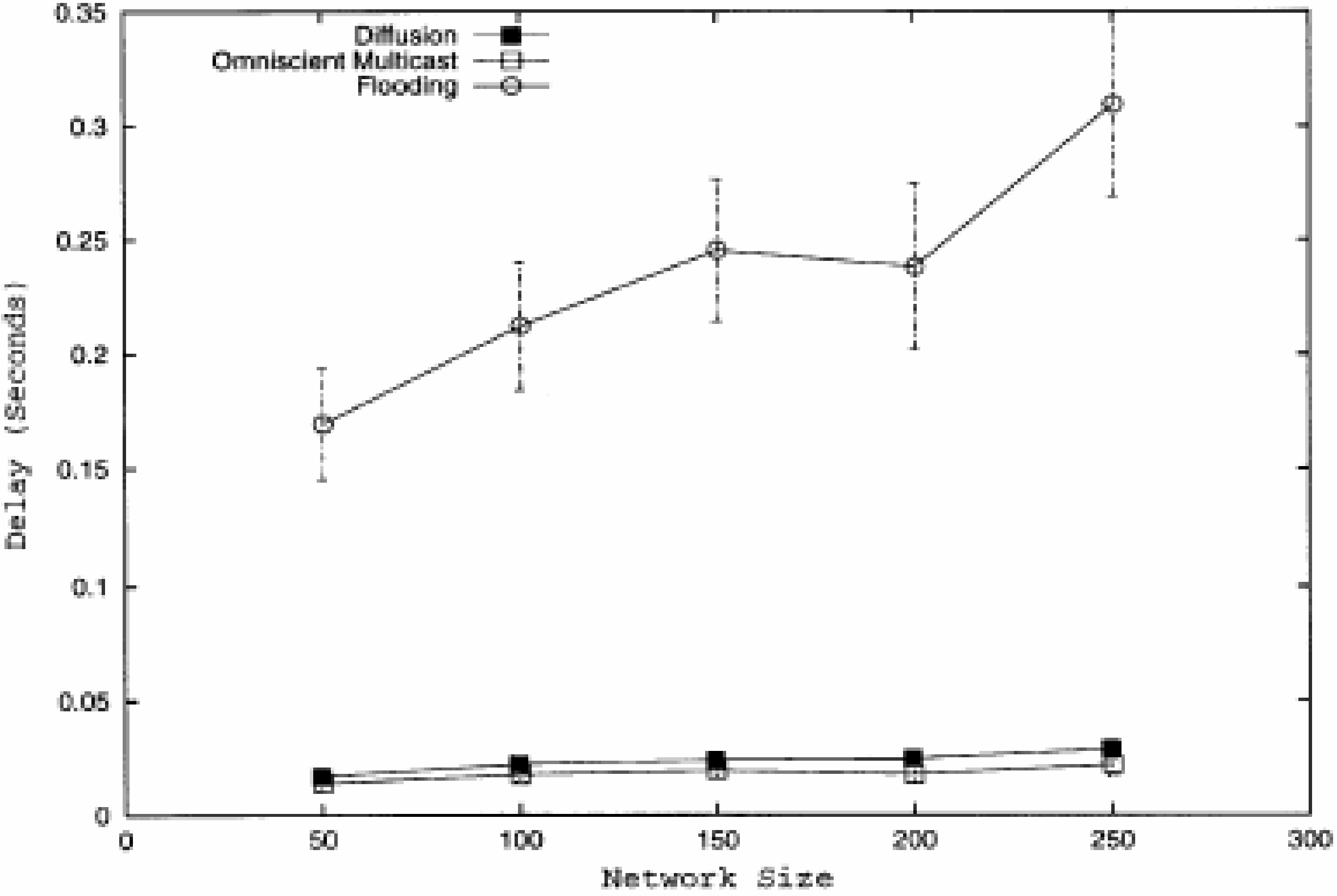
Average Dissipated Energy



DD achieves better performance by

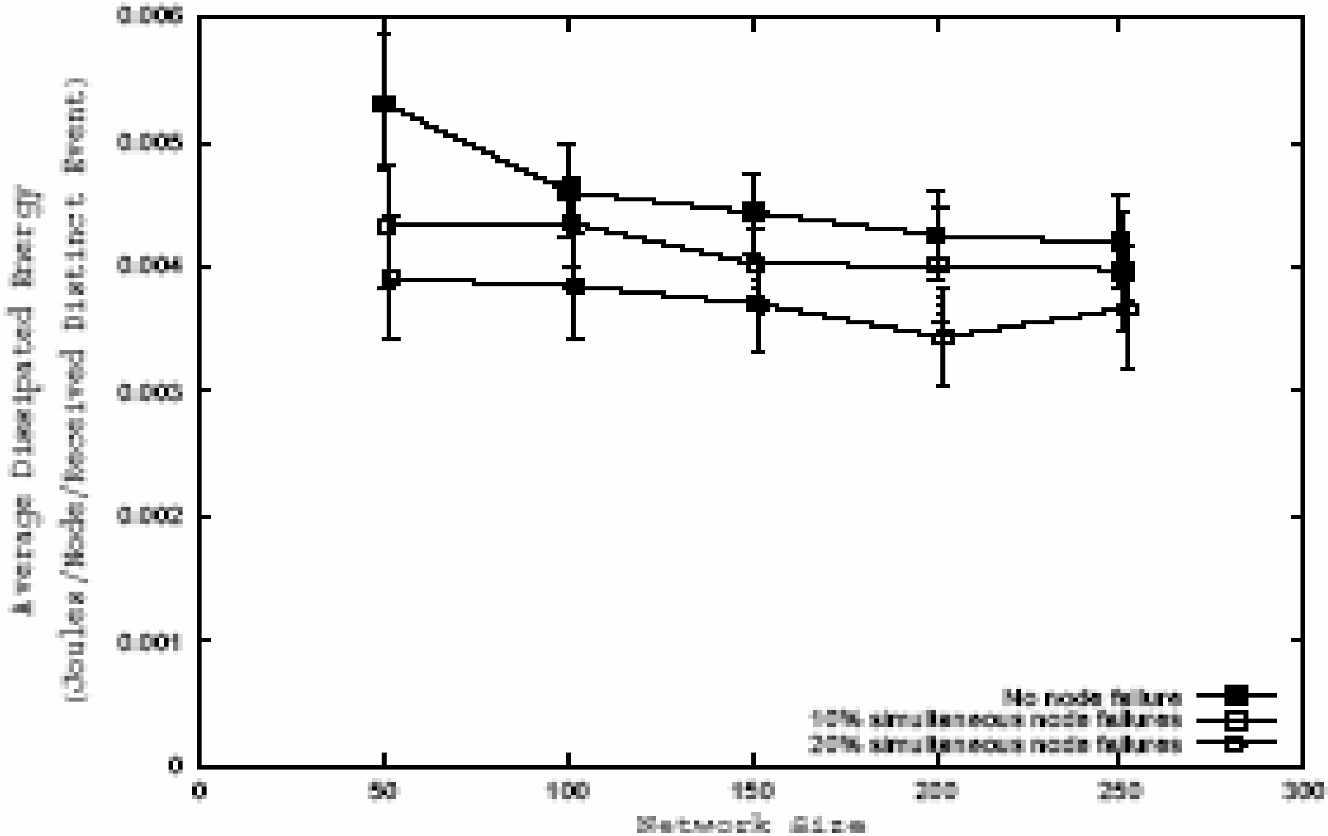
- **Reducing redundant data**
- **In-network aggregation**

Average Delay



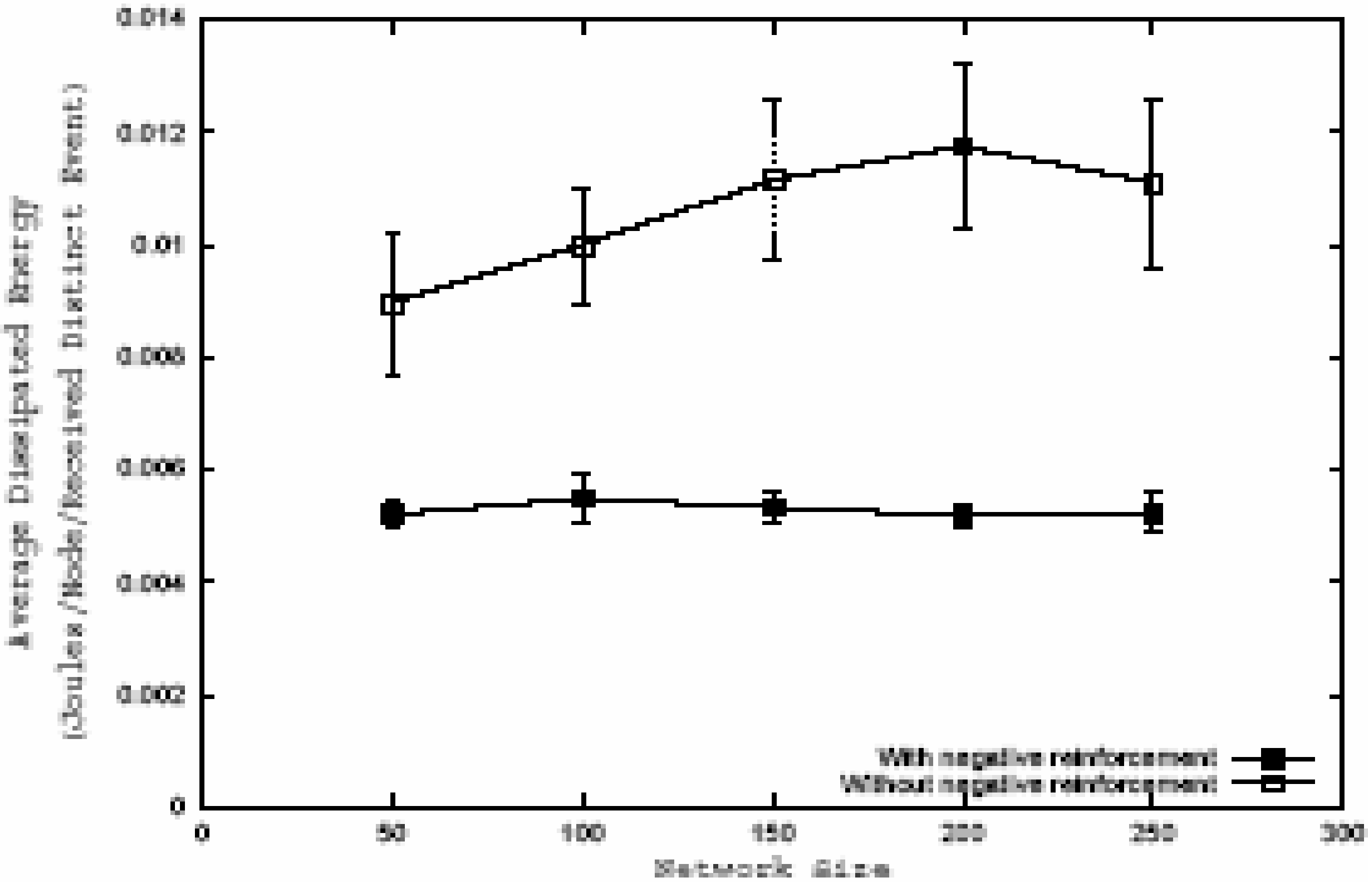
- DD finds least delay paths as Omniscient Multicast

Average Dissipated Energy in the presence of node failures



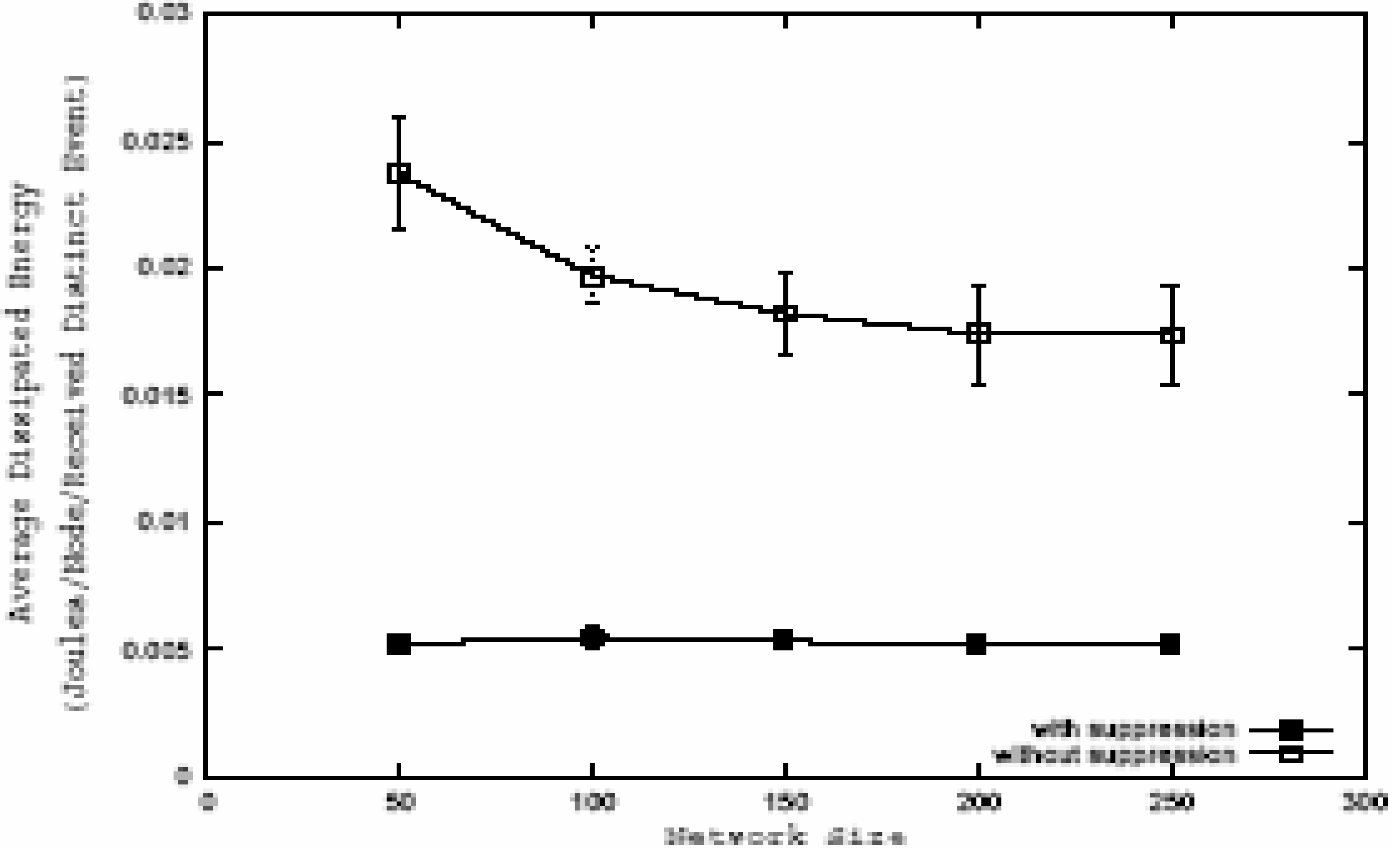
- ❑**Counter-Intuitive**
- ❑**Energy efficiency improves due to the negative reinforcement pruning paths**

Average Dissipated Energy with and without negative reinforcement



- **Energy dissipation without NR is twice that with NR**

Average Dissipated Energy with and without duplicate suppression



- Energy dissipation without suppression is between twice and 5 times that with suppression

Related Work

- Distributed Sensor Networks
  - WINS and Piconet consider networking and communication issues
- Sensor network protocols with application awareness
  - SPIN for energy efficiency
- Principles of reactive ad hoc routing protocols
  - Route salvaging

Conclusion

- Proposed Directed Diffusion as a new communication paradigm
- Application awareness
- Data centric, reinforced adaptation and in network aggregation and caching
  - Achieves better energy efficiency

Questions????????????

References

[1] C. Intanagonwiwat, R. Govindan, and D. Estrin, "Directed Diffusion: A Scalable and Robust Communication Paradigm for Sensor Networks," *in the Proceedings of the Sixth Annual International Conference on Mobile Computing and Networks (MobiCom'00)*, August 2000.

[2] http://www.isi.edu/~johnh/PAPERS/Intanagonwiwat02b.pdf