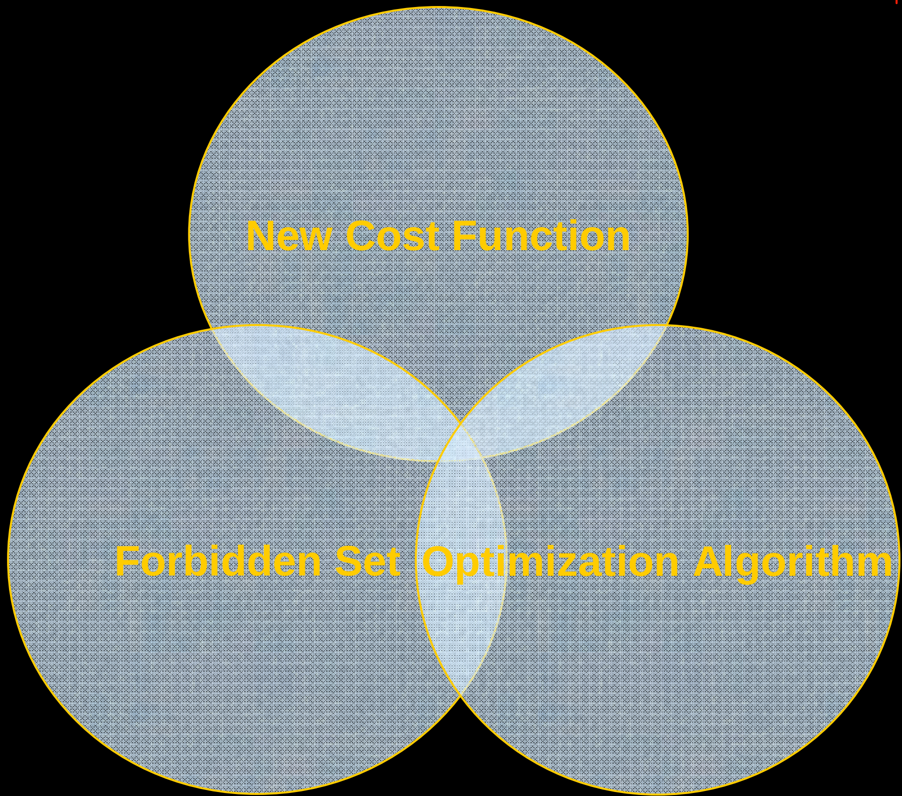
Broadcast Routing Algorithm Based on Minimum Cost Spanning Tree for Ad-Hoc Networks



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Outline

- Introduction
- Related Work
- Proposed Routing Algorithms
- Comparison of Broadcast Algorithms
- Simulation and Analysis
- Conclusion

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Features of Ad-Hoc Networks

- Power is mainly provided by a battery
- Performance is restricted by memory size, computing capability of mobile devices and battery energy
- Transmission range and lifetime of each node are restricted by limited battery energy
- Broadcast is needed for information sharing

Research Focus of Broadcast in ADN

- Reduction of power consumption
- Extension of network lifetime
- Improvement of network stability
- Reduction of latency

Motivation and Goals

- Motivation
  - Wireless transmission path is unstable
  - Traditional ad hoc broadcast routing protocols select path by the criterion of transmission power
- Goals
  - Achieve Energy-efficiency
  - Extend network lifetime
  - Improve network stability

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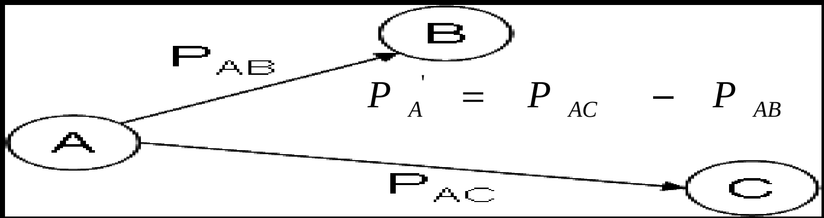
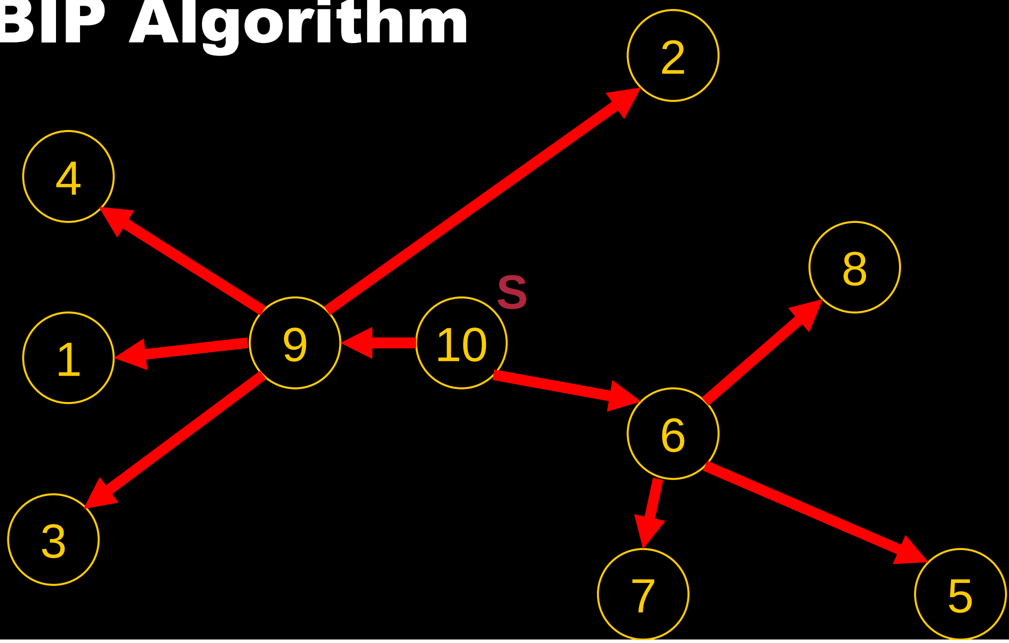
BIP (Broadcast Incremental Power)

- Similar to Prim algorithm
- BIP builds a tree according to **incremental power**
- Incremental power is the increment in transmission power for a node to cover a longer range



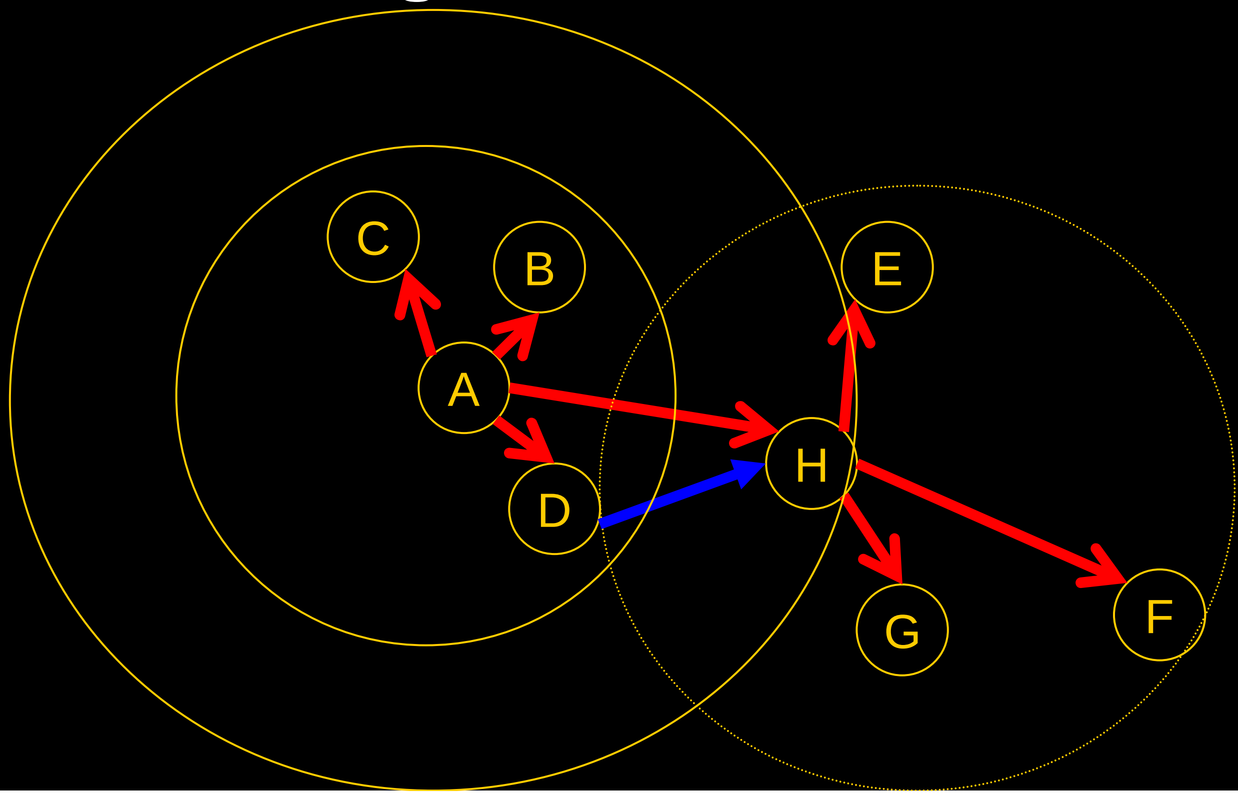
Example of BIP Algorithm



MLE (Minimum Longest Edge)

- MLE use MCST to reduce power consumption
- The link with the highest cost is removed to balance the power consumption of the nodes
- The transmission power of each node is adjusted to reduce overall power consumption.

Example of MLE Algorithm

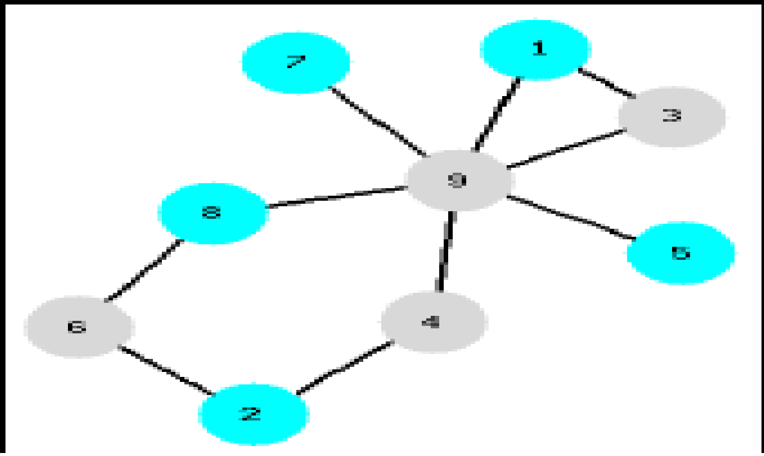


MWIS (Maximum Weighted Independent Set)

- Scheduling algorithm based on MWIS
- MWIS is able to find the optimal selection of forwarders without causing collision
- Two simple greedy algorithms called MAX and MIN find the MWIS in the conflict graph
- The goal is collision-free and reducing network latency

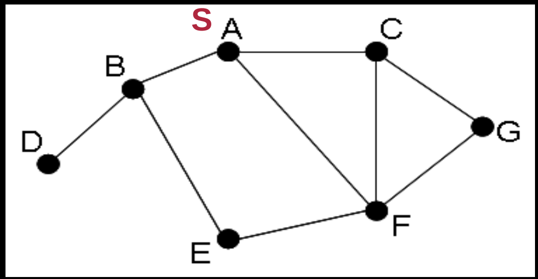
Independent Set

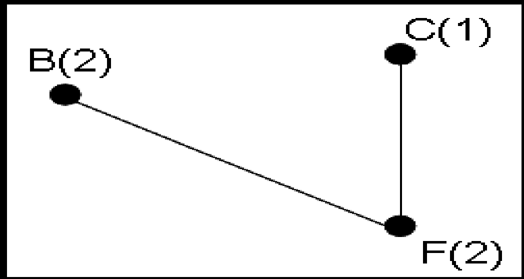
- Independent set induced by these vertices contains no edges, only isolated vertices.



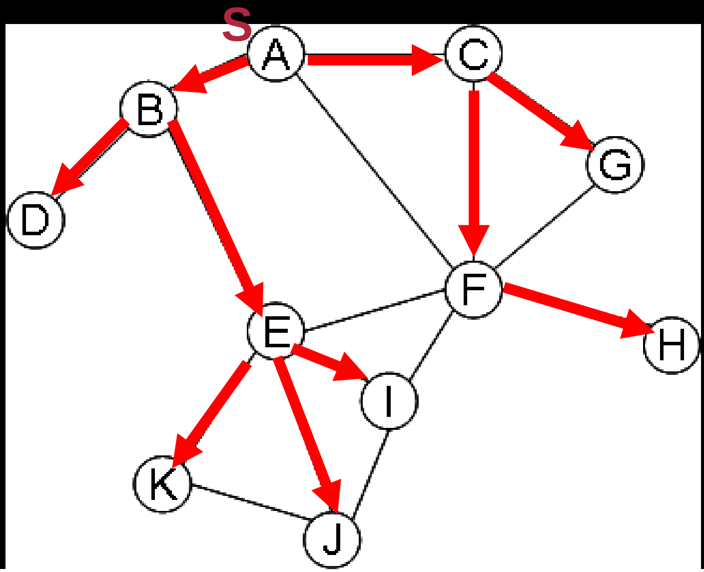
GWMIN2

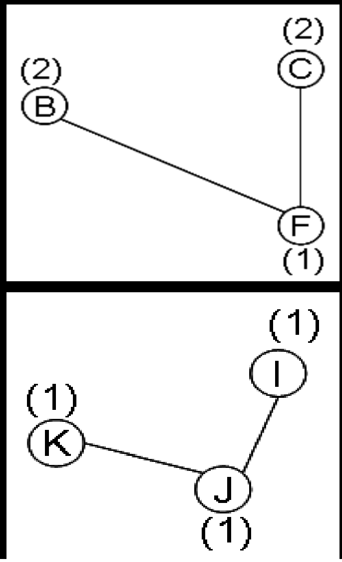
- Selects a vertex of minimum degree, removes it and its neighbors from the graph, and iterates this process on the remaining graph until no vertex remains.





Example of MWIS Algorithm

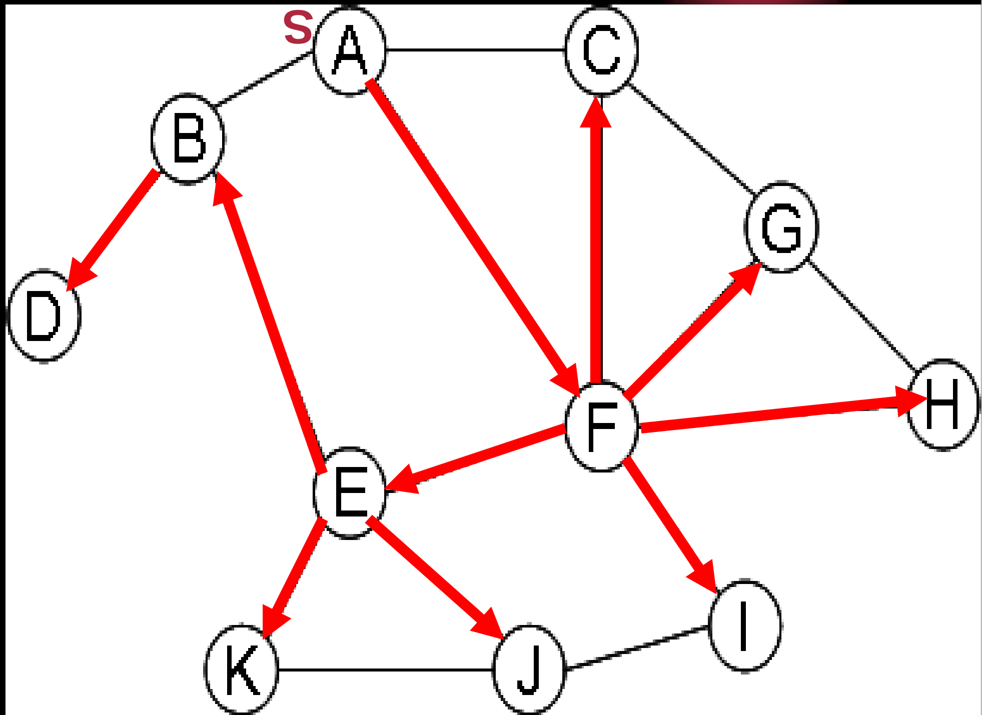




MCDS (Minimum Connection Dominating Set)

- Employs MCDS to reduce the broadcast latency
- Aims to find a small set of vertices with the domination property.
- Finding minimum connected dominating sets is equivalent to finding spanning trees with the maximum possible number of leaves.

Example of MCDS



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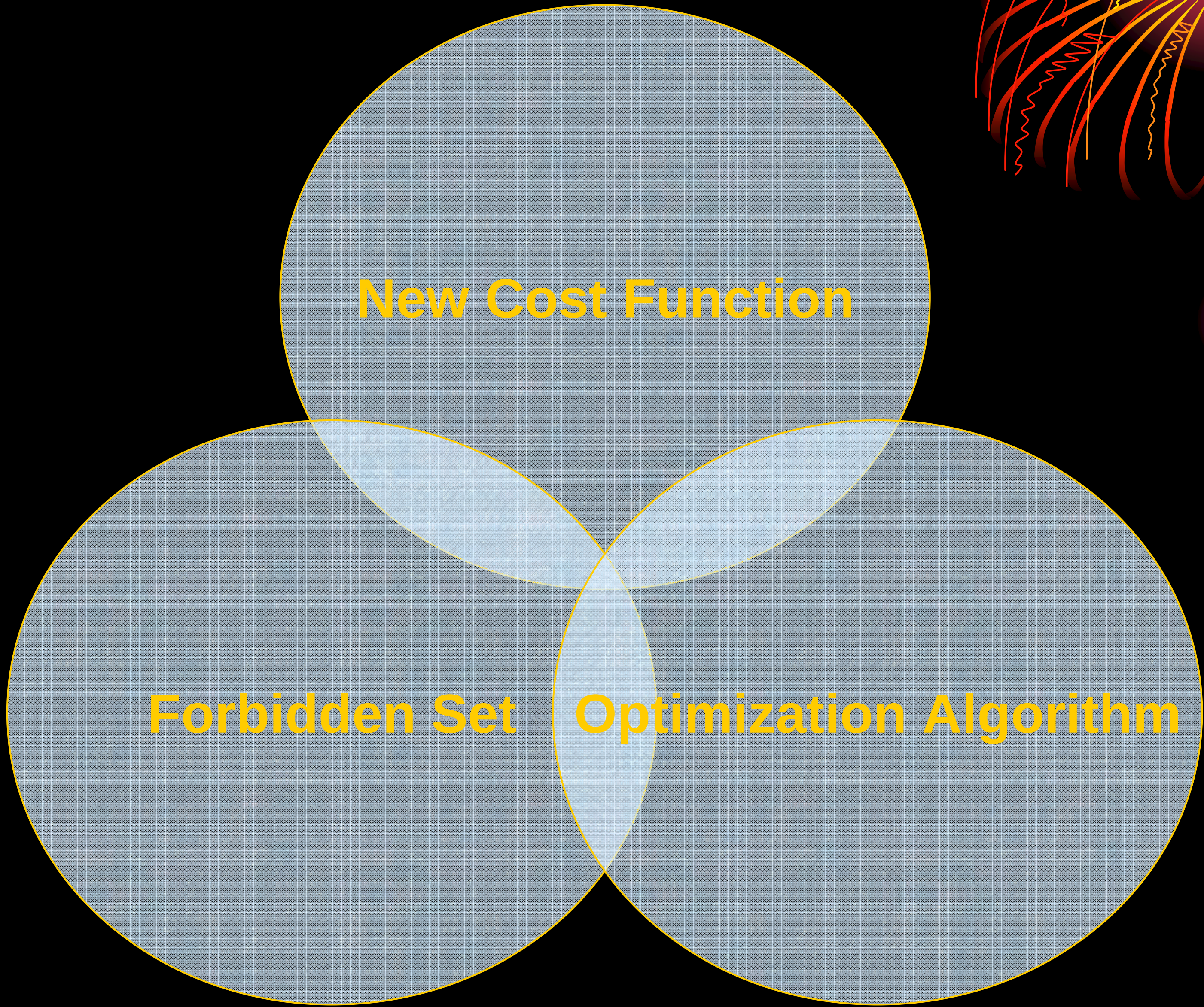
Main Idea

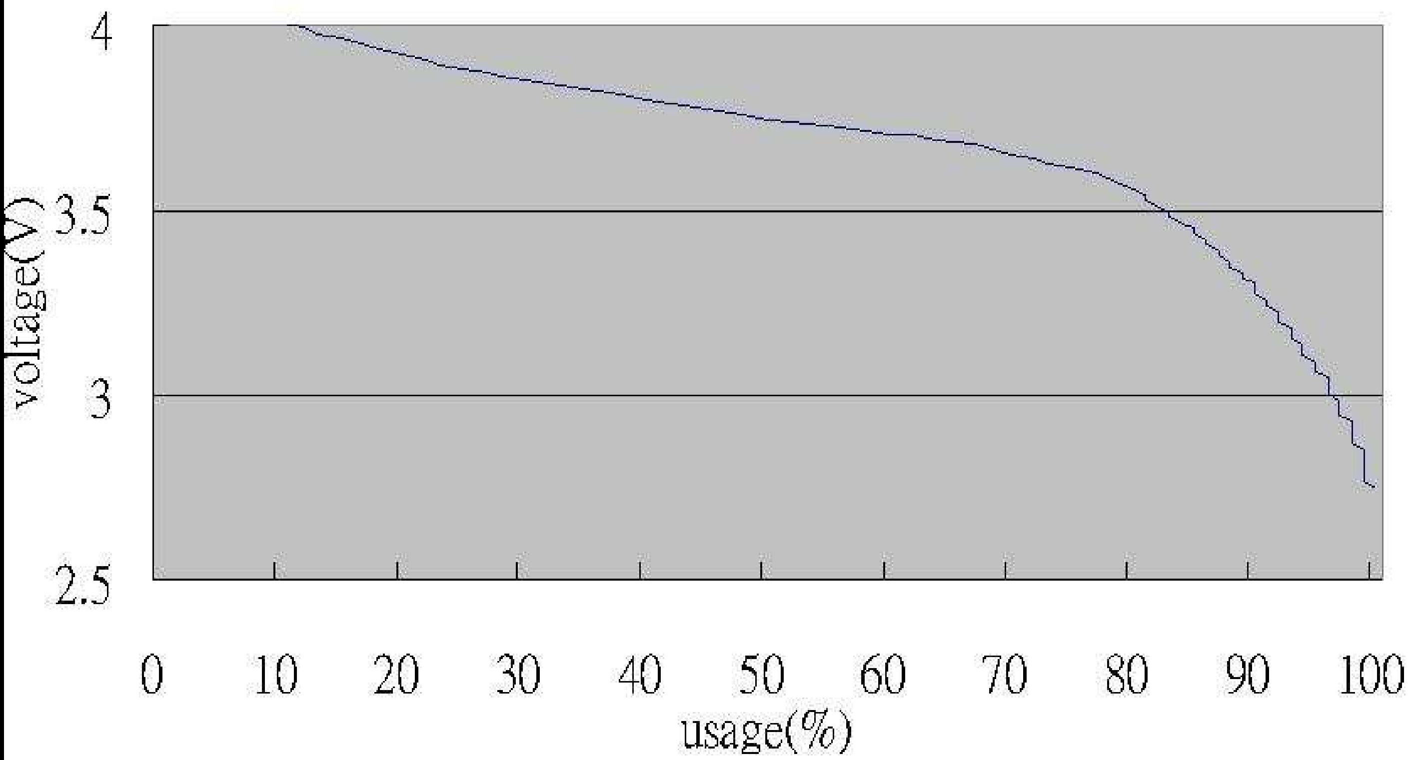


Influence of Remaining Battery Energy

- While battery works at low voltage level , the discharge speed is much faster than when it works at high voltage level

- Curve fitting of Li-ion battery discharge

$$u = 0.8275v^4 - 11.2582v^3 + 56.2396v^2 - 122.7769v + 100.1008$$



Link Cost

- **Energy cost model**

$$H_{jk} = \left(2.17 \times \left({}^{d_{jk}} \!\!\diagup_{43} \right)^4 + 7.5 \right) \mathrm{nJ}$$

- **Add the weighting function accounting for battery usage**

$$W_j(u) = \begin{cases} \dfrac{(0.1-u)\times 1 + 0.65\times 1.5 + 0.15\times 3 + 0.1\times 6}{1-u} & \mathrm{u} \le 0.1 \\ \dfrac{(0.75-u)\times 1.5 + 0.15\times 3 + 0.1\times 6}{1-u} & 0.1 < \mathrm{u} \le 0.75 \\ \dfrac{(0.9-u)\times 3 + 0.1\times 6}{1-u} & 0.75 < \mathrm{u} \le 0.9 \\ 6 & 0.9 < \mathrm{u} \le 1 \end{cases}$$

- **Link cost**

$$C_{jk} = W_j(u) \times H_{jk}$$

Forbidden Set

- **Definition of Forbidden Set F**

  $$F = \{v \in V \mid u(v) \geq \text{threshold}\}$$

- **For example, suppose the usage of node s is 30% and that of node t is 95%. When the threshold is set at 90%, node t will be included in forbidden set F, whereas node s will not.**

- **Forbidden set is introduced to avoid using nodes with low battery energy as relaying nodes in order to extend network lifetime.**

MCBR and MCBRF

- MCBR – Minimum cost routing algorithm based on the new cost model
- MCBRF – MCBR + forbidden set
- MCBRF-h: MCBRF with a threshold value of h

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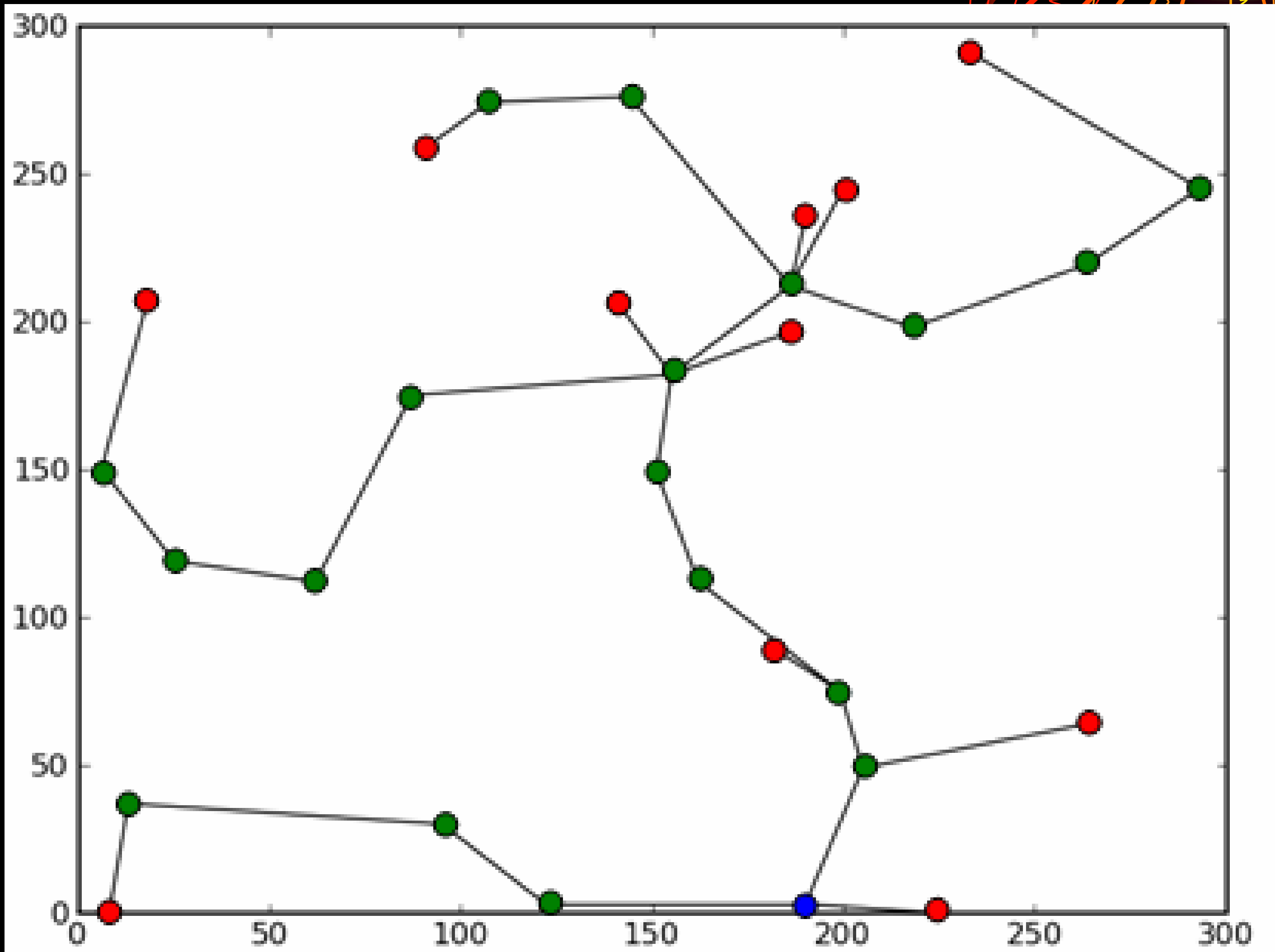
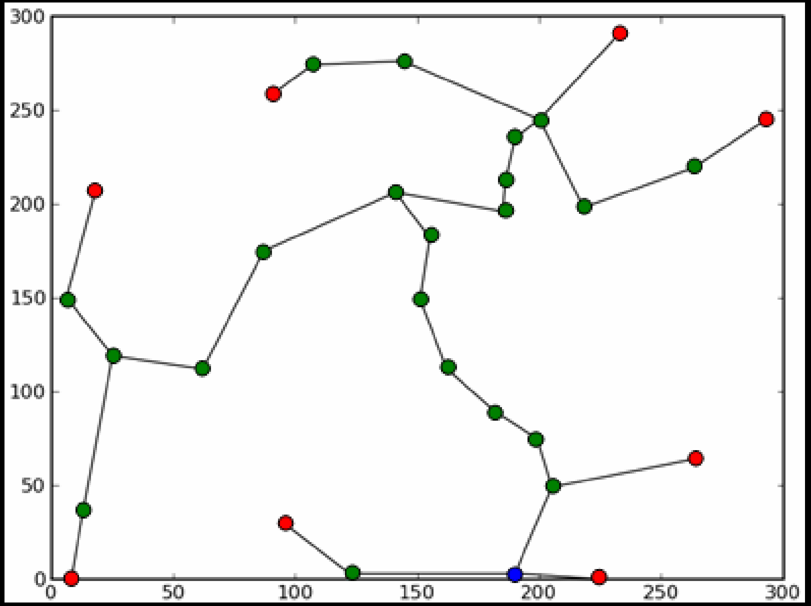
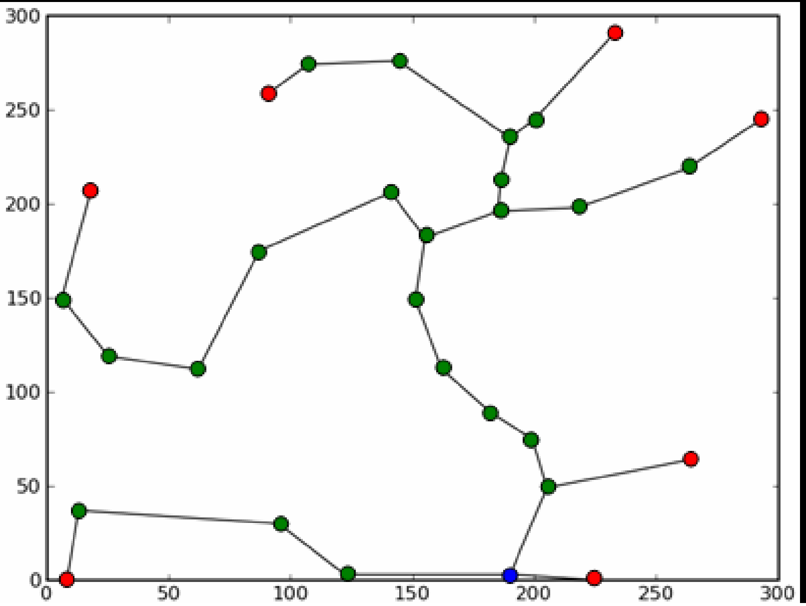
Scenario: 30,300 MCBR



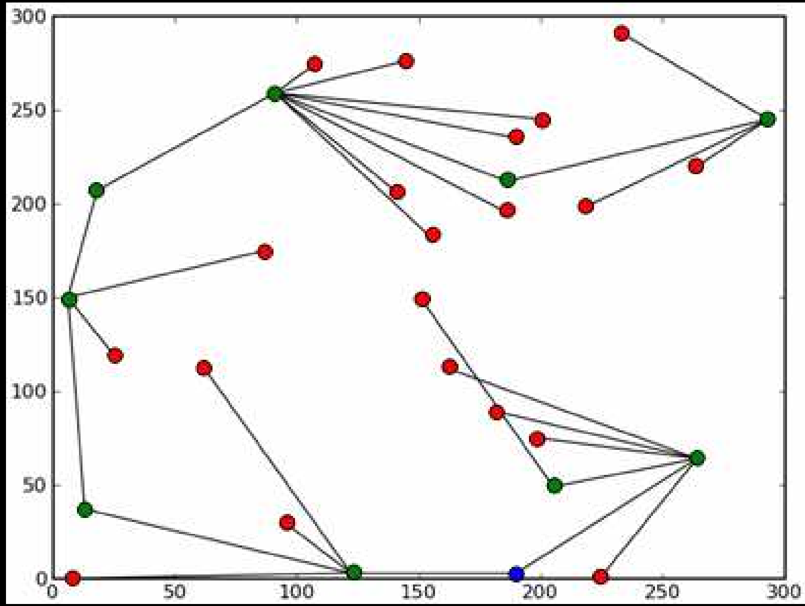
Scenario: 30,300 BIP



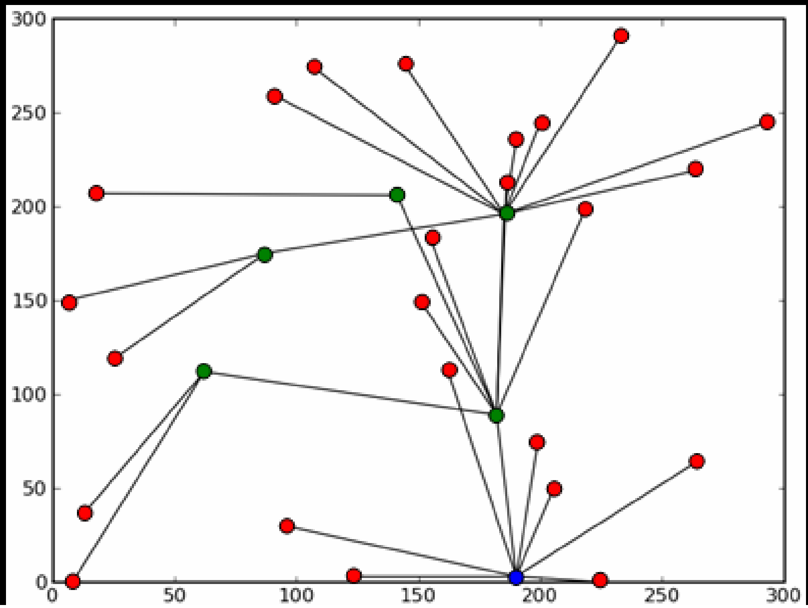
Scenario: 30,300 MLE



Scenario: 30,300 MWIS



Scenario: 30,300 MCDS



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Performance Metrics

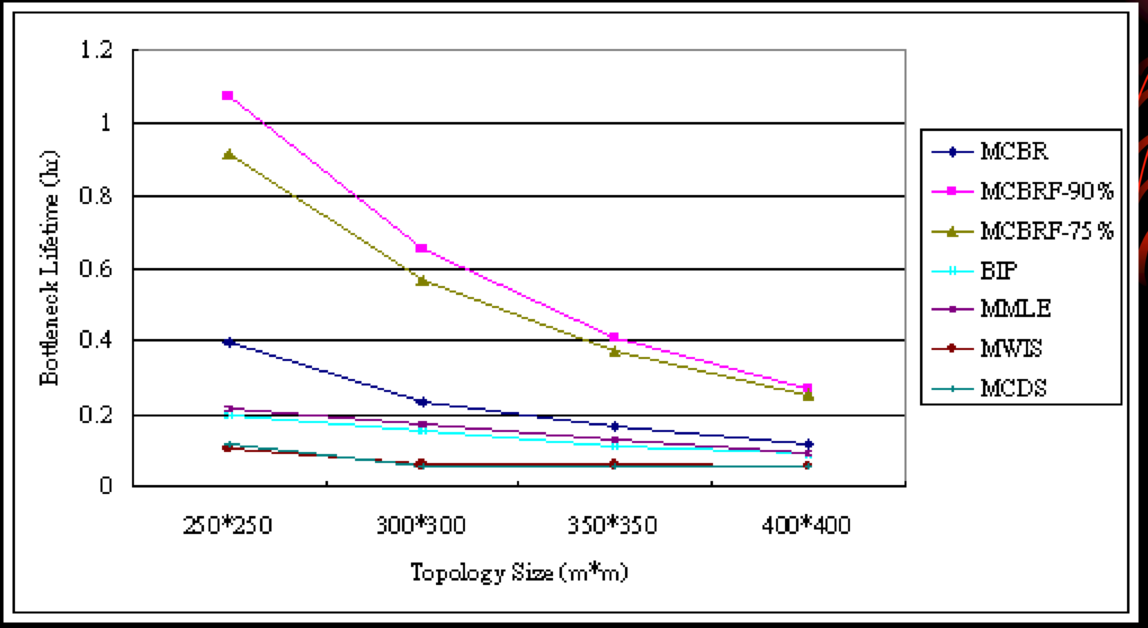
- Total power consumption of the broadcast route
- Network lifetime
- Broadcast time

Simulation methodology

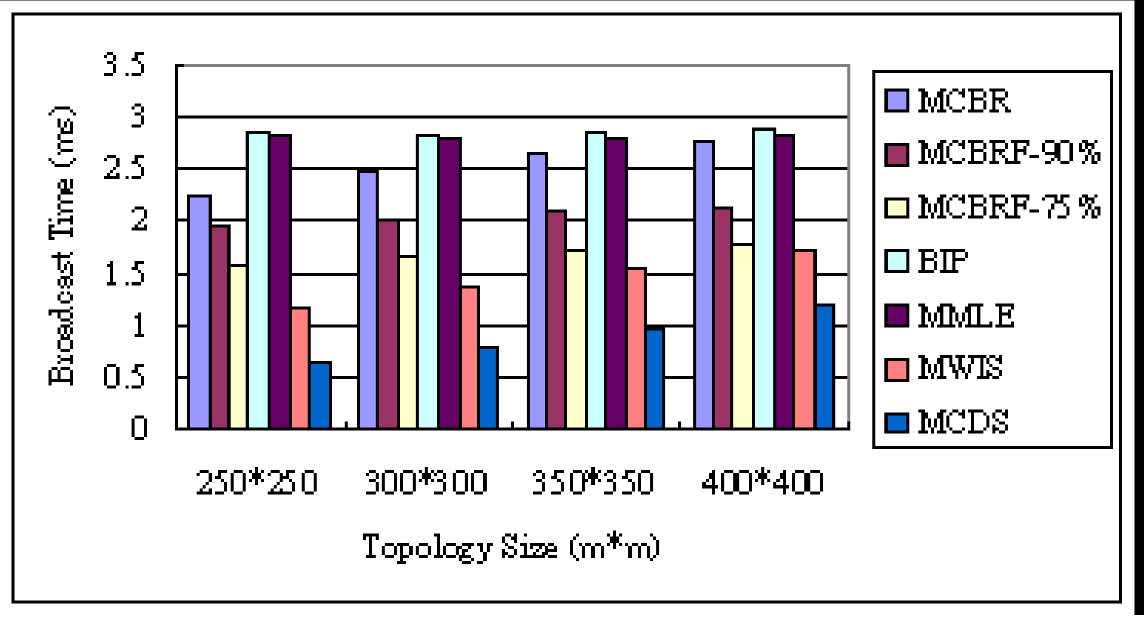
- For each combination of <nodes, area>, 100 different network topologies are generated at random.
- In each case, a node is randomly selected as the source node.
- Compare our methods with BIP, MLE, MWIS, and MCDS.

Number of nodes	30
Topology size	250*250, 300*300, 350*350, 400*400
Maximum transmission range	125 m
Battery voltage	Random between 3V ~ 4V
Packet size	512 bytes
Bit rate	2M bps

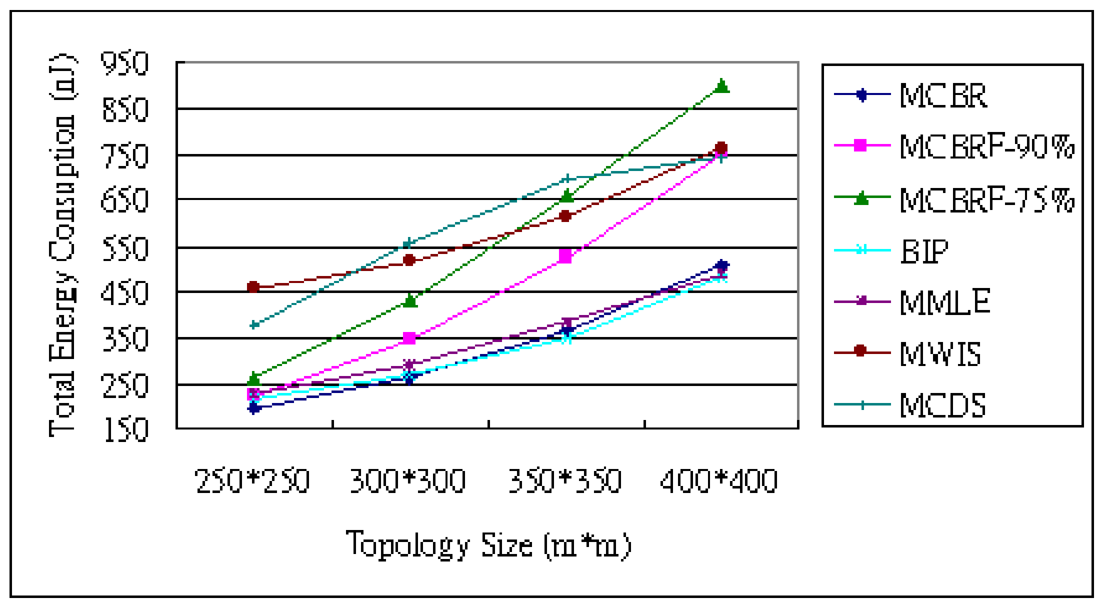
Node Lifetime



Broadcast Time



Total Power Consumption



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Conclusion

- **New cost model and forbidden set have been proposed**
- **Nodes with higher remaining battery capacity are more likely to be selected as relay nodes by our algorithms; those with low remaining energy are not allowed to be used as relay nodes → A more robust broadcast route is established with a longer lifetime**
- **Our algorithms strike good balance between network lifetime and broadcast latency**

Work in progress

- **Asymmetric cost model prompts a closer examination of the optimization algorithm**
- **Refined battery model for more realistic evaluation**

Thanks for listening