Using Mobile Relays to Prolong the Lifetime of Wireless Sensor Networks

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Overview

- The motivation of mobile relay
- The performance analysis for mobile relay in the ideal case
- Simulation and comparisons

The motivation of mobile relay

Homogeneous Network

- Simple and cheap sensors
- Achieve performance requirements through over-provisioning

Heterogeneous Network

- Use a small number of resource rich sensors to improve the performance
- Use controlled mobility to dynamically allot the resources

Adding one resource rich nodes may save many simple sensors

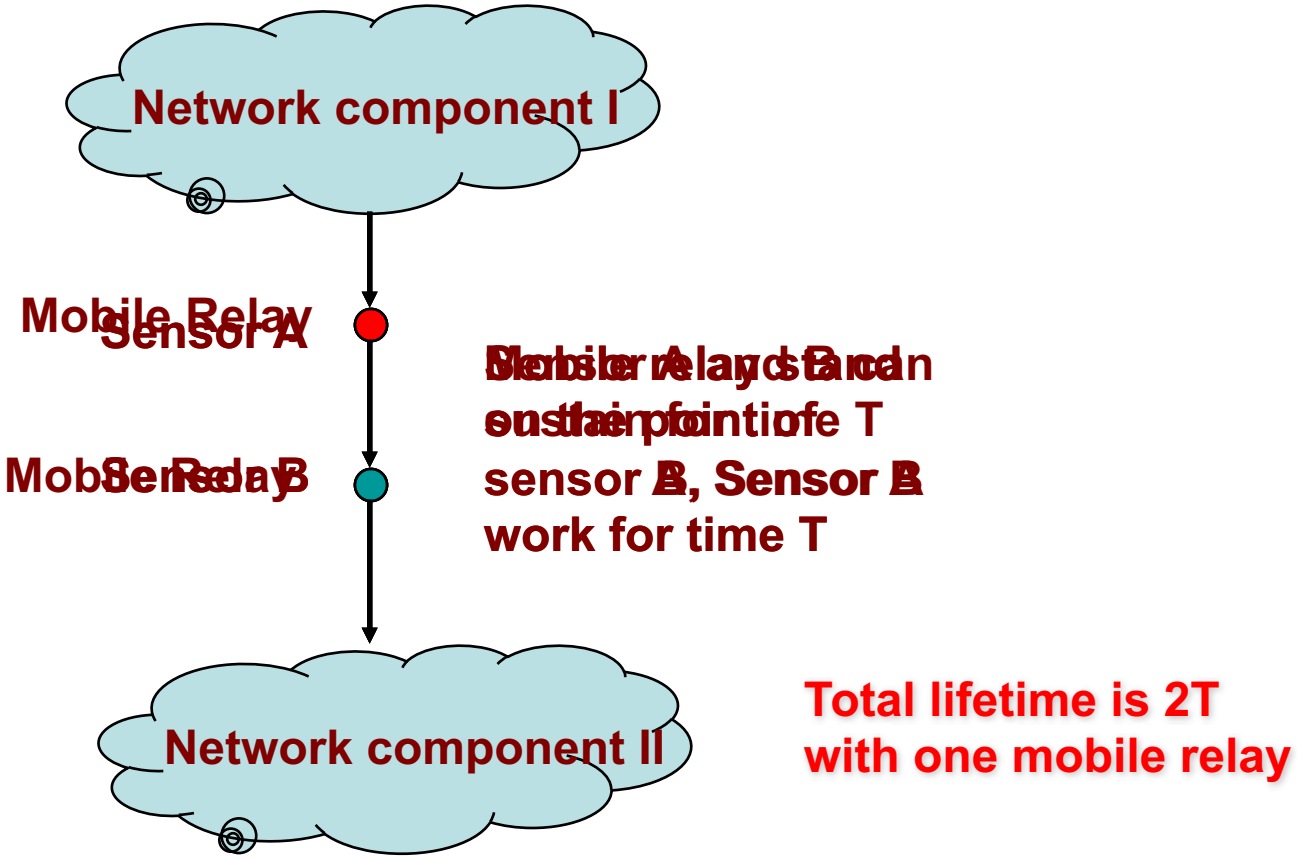
Our approach and main results

- Use rechargeable mobile sensors to “add” more energy to the network
- Theoretically one mobile relay can improve lifetime four times in large networks
- Simulation shows more than two times improvement

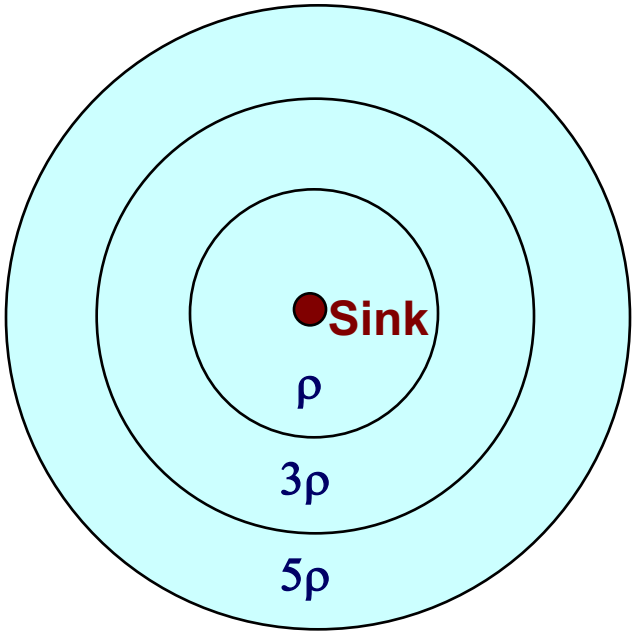
How to add more energy?

- Identify the energy bottlenecks – where nodes die quickly
- Use mobile relays to take over the task of those critical sensors
- Prevent the network from partitioning

A example of bottleneck points



General Bottleneck in Sensor Network



Sensors around the sink dies faster than others!

Lifetime bounds

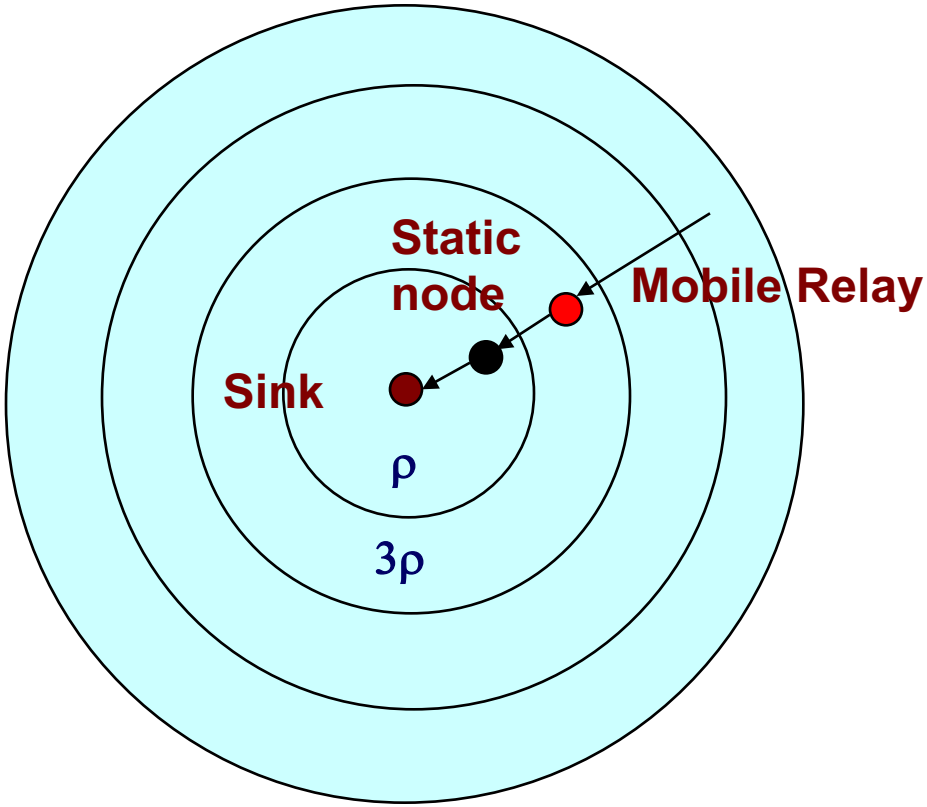
Network of static sensors

- Depends on the immediate neighbors of the sink
- The neighbors need to carry data for all the R^2 sensors in the network

$$T \quad \frac{E}{R^2 e}$$

Lifetime bounds

Network with one mobile relay



Lifetime bounds

Network with one mobile relay

- Depends on the sensors within two hops range of the sink
- Four times longer than the static network

$$T \quad \frac{4E}{R^2 e}$$

Can we achieve the bounds?

- Basic approach

  -- Use only one static node with the mobile relay to build a bridge to deliver the packet over the bottleneck area

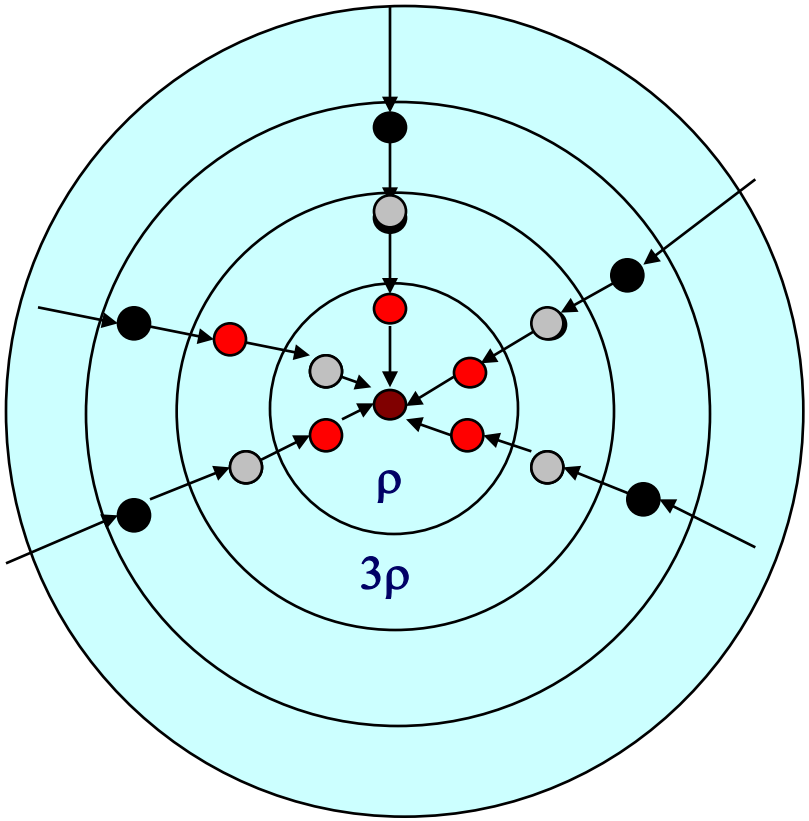
  -- Aggregate the traffic to that bridge so that all other critical nodes can rest

- Problem to solve

  -- How to move the mobile relays and build the bridge?

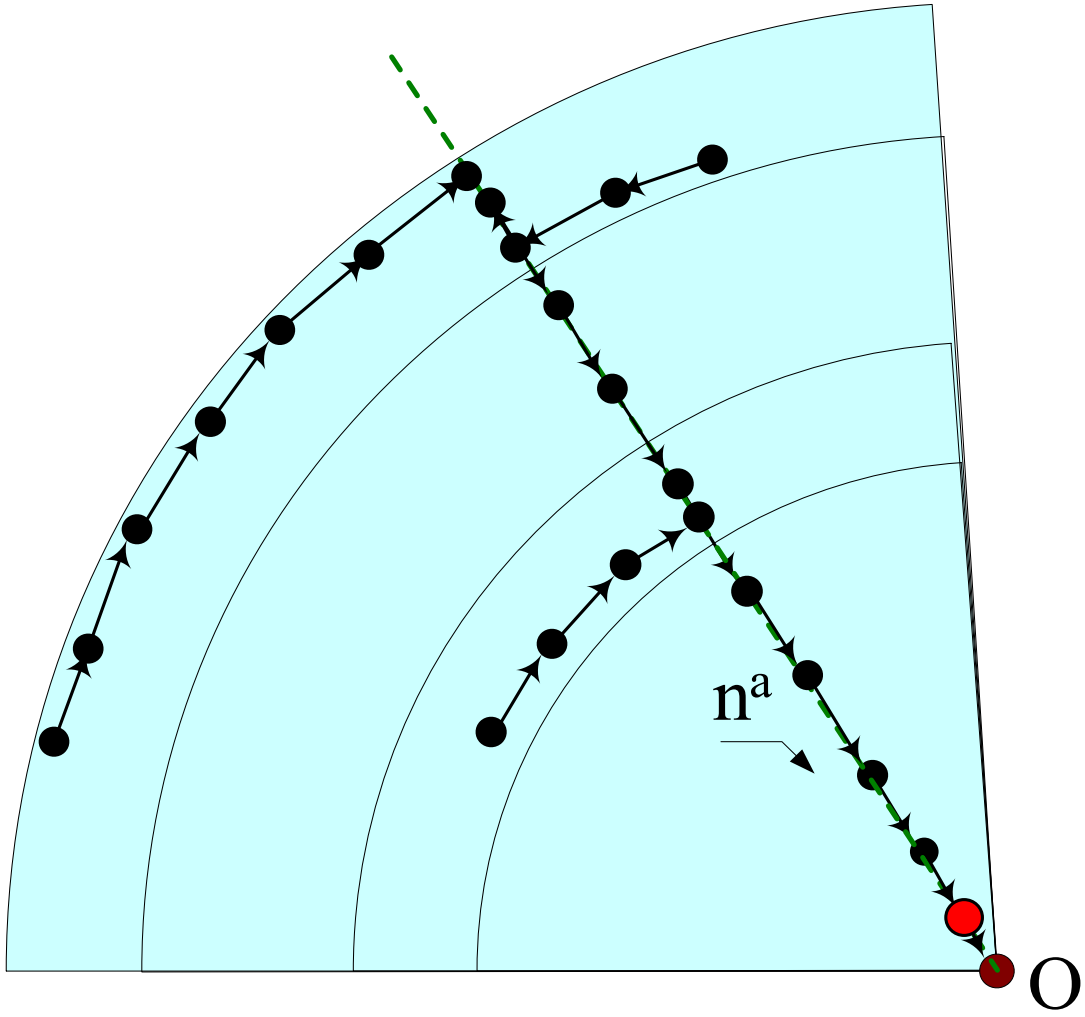
  -- Will other sensors die faster due to the longer route taken?

Building bridges to the sink



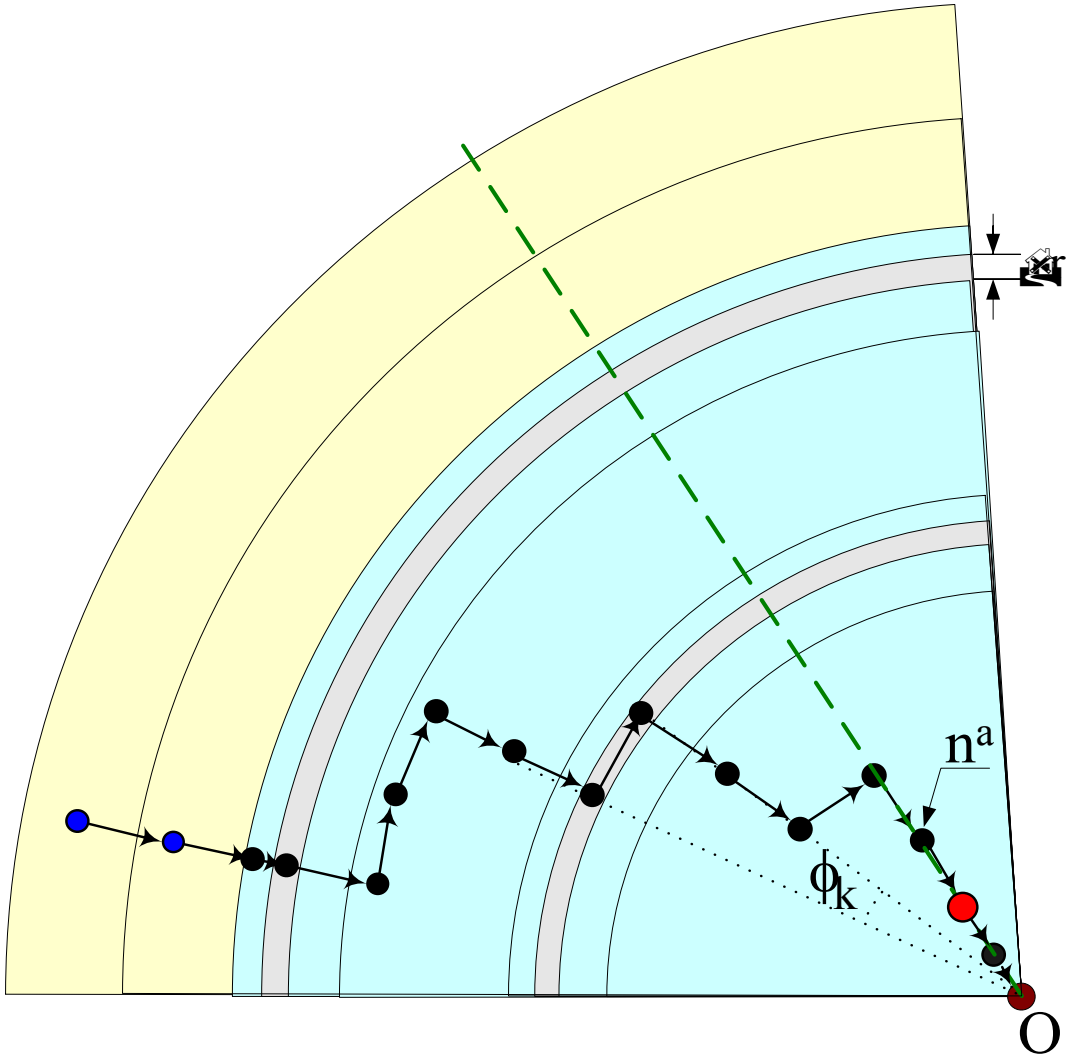
We can build 4ρ bridges in total

Aggregating the packets



Method 1 (ARA)
All static sensors help to deliver the packets to the bridge

Aggregating the packets



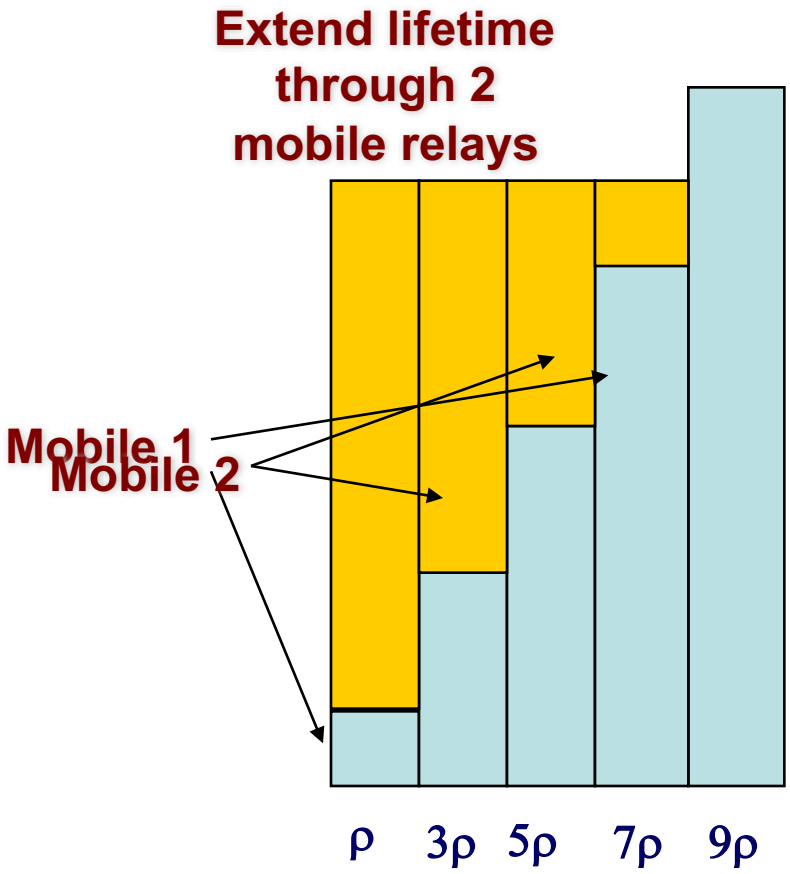
Method 2 (ARALN)
Only nodes near the sink need to know the position of the mobile relay

Achievable network lifetime with one mobile relay

$$T = \frac{4E}{R^2 e} \quad \frac{16E}{R^4 e}$$

- Asymptotically four times the static network lifetime when R is large

Network with more than one mobile relays



With *m* mobile relays the network lifetime can be extended by *4m* times

Simulations on finite networks

- Compare with energy conserving routing
- For mobile relay, solve an optimization problem

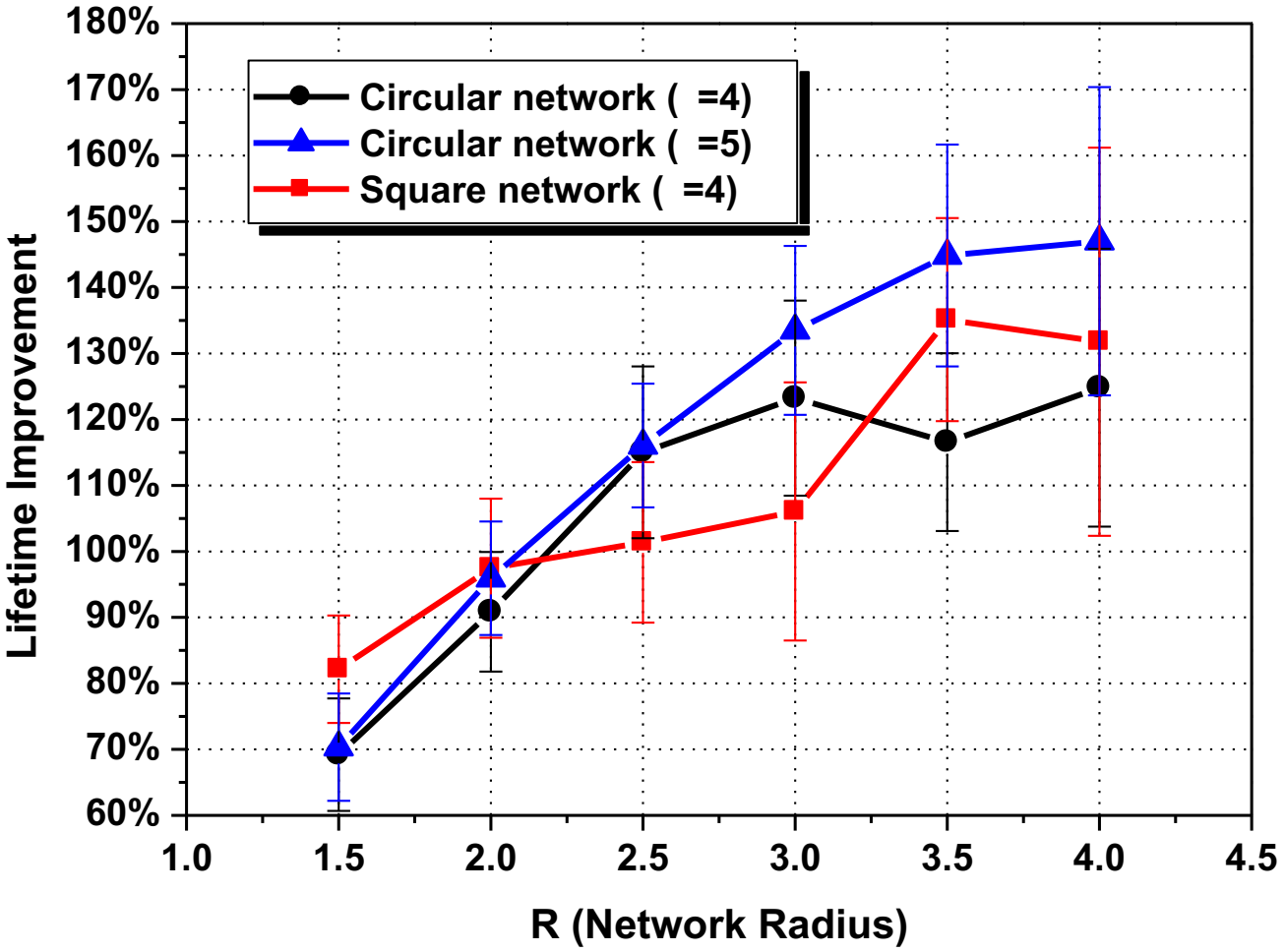
$$Maximize \quad t_k$$

$$s.t. \quad \sum_j x_{ij}^k - \sum_j x_{ji}^k = s_i \cdot t_k \qquad i,k$$

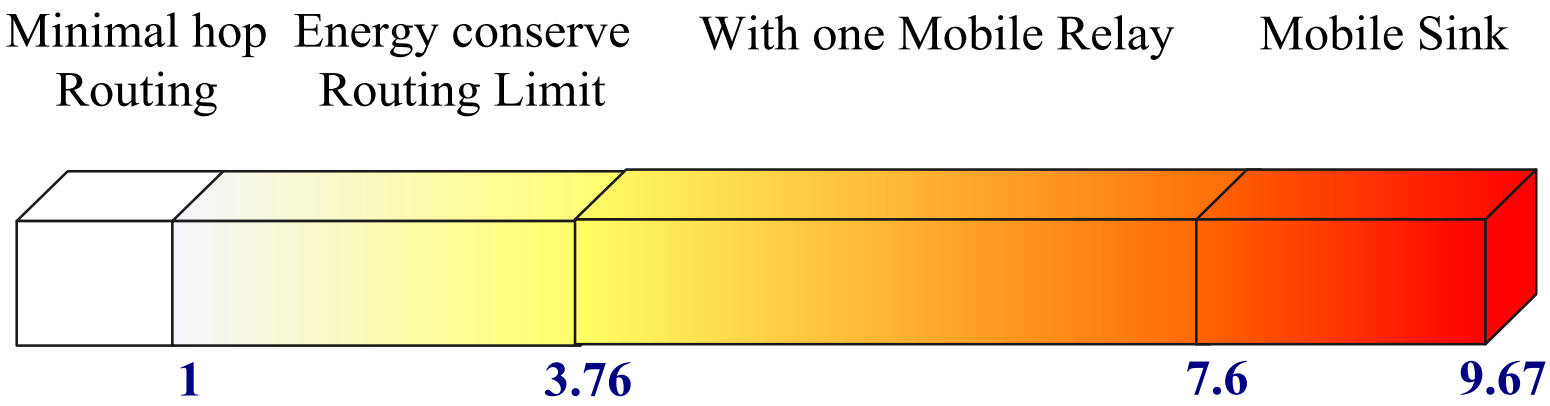
$$x_{ij}^k \quad 0 \qquad (i,j), \quad k$$

$$\sum_{k\ i\ j} x_{ij}^k \cdot e \quad E \qquad i \quad 0$$

Improvements under different networks



Comparing with other methods



Normalized Lifetime

Mobile relay or Mobile sink?

Mobile Sink

- Better improvement on lifetime

  improvement is O (R)

Mobile Relay

- Robust

  the network can operate without the mobile relay
- The ability to heal topology defects
- Small moving areas

  mobile relay only need to move in a small area
- Fewer impacted static nodes

Conclusion

- Resource rich nodes can significantly improve the network performance
- With one mobile relay, we can gain four times lifetime
- Controlled mobility is an important issue for dynamic assignment of resources

Future Works

- Distributed routing and mobility algorithms for mobile relay approach
- Mobile relays with longer transmission range
- Dynamically adjust to time varying traffic flows
- Collaboration of multiple mobile relays

Thank you!