Joint Mobility and Routing for Lifetime Elongation in Wireless Sensor Networks

INFOCOM 2005

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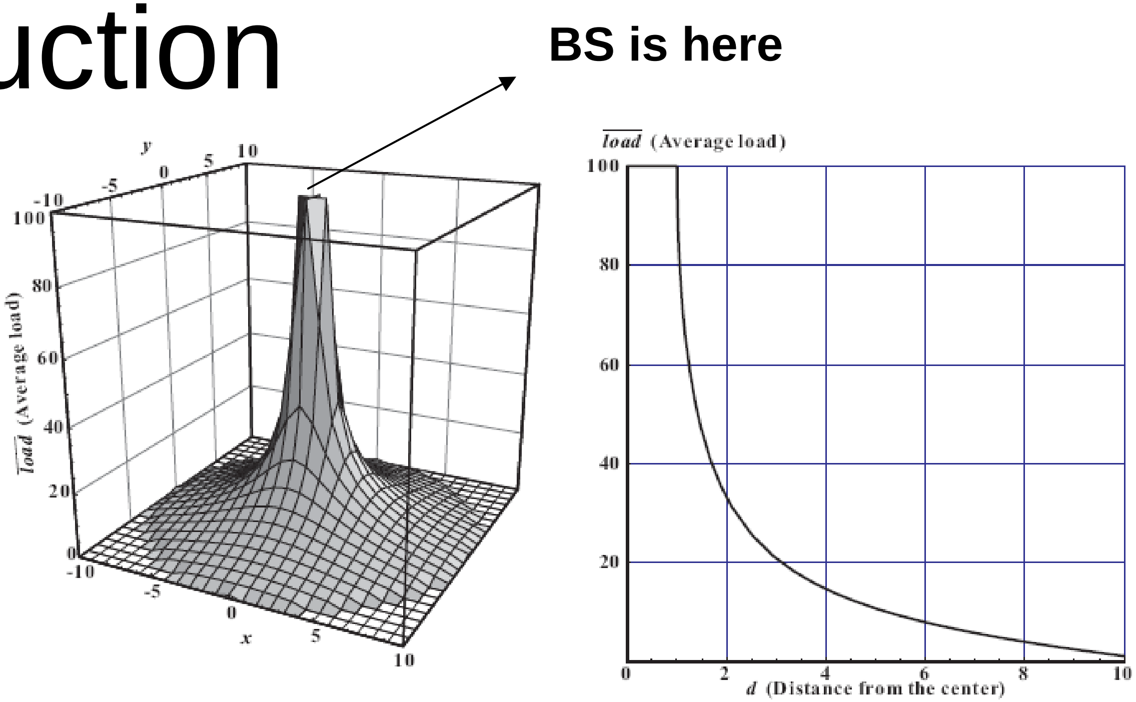
Outline

- Introduction
- Analysis results and Proposed Model
- Simulation results
- Discussions
- Conclusions

Introduction

- Many energy conservation protocols have been proposed:
  - Energy conserving routing
  - Topology control
  - Clustering
  - Data aggregation
- These protocols all focus on the sensor nodes

Introduction



- The sensor nodes around a BS (Sink) have to forward data for other nodes whose number can be very large.
- The load of sensor nodes are unbalanced

Introduction

- This paper shifts the focus to the behavior of BS (Sink)
- The load of sensor nodes can be more balanced if the BS changes its position from time to time
- Problem: load balance data collection in wireless sensor networks

Introduction

- Network Model
  - N sensor nodes
  - 1 BS (Sink)
  - A circle C_{OR}
  - Radius R
  - Density: ρ
  - Data sending rate: λ
  - Comm. range: r

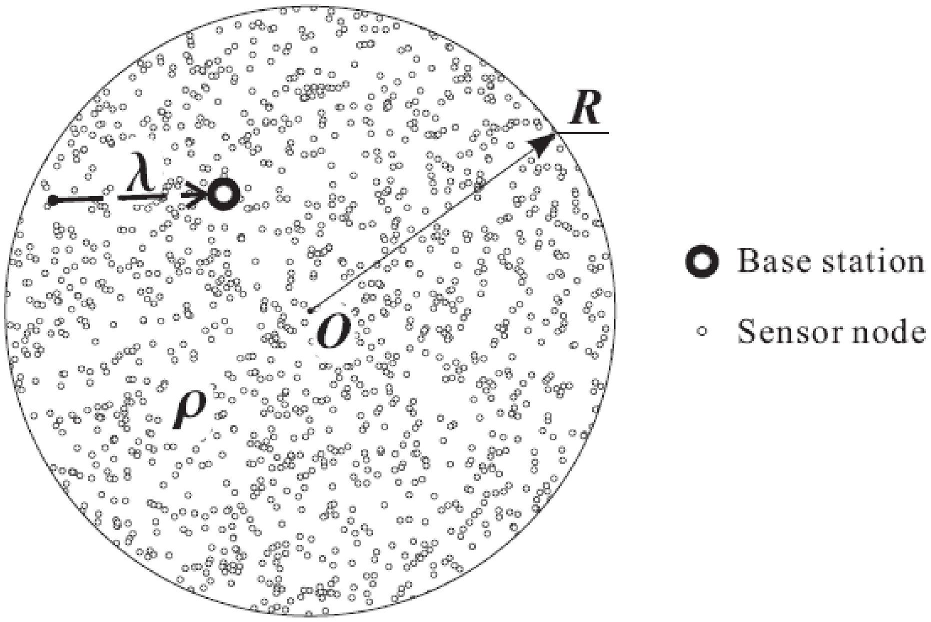


Fig. 1. Network model.

Introduction

- Network lifetime
  - The time span from the sensor deployment to the first loss of coverage
- $load_n$: the load of node n
- $\overline{load}_n$:average load of node n
- Energy efficiency protocol
  - If it minimizes the accumulative energy consumption for fulfilling its task

$$Minimize \quad load_N \equiv \max_{n \in N} \overline{load}_N(strategies)$$

Constraints: specific to given strategies

Analysis results

- For Static BS
  - The optimal position for a BS is in the center of the circle

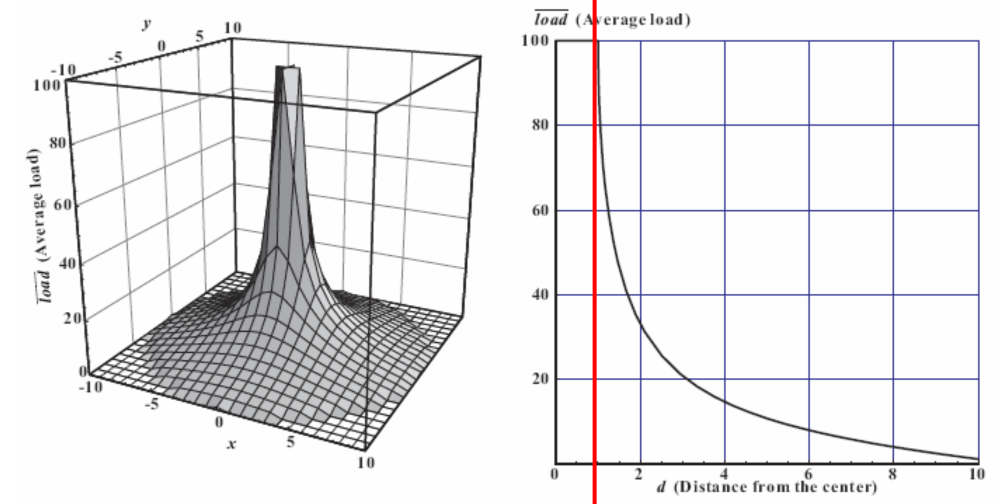


Fig. 4. Load distribution with a centered static base station. We assume $R = 10$, $r = 1$, $\rho = 8/\pi$, $\lambda = 1$, and $\varepsilon = 1$.

- For Mobile BS
  - Reduce 75% load

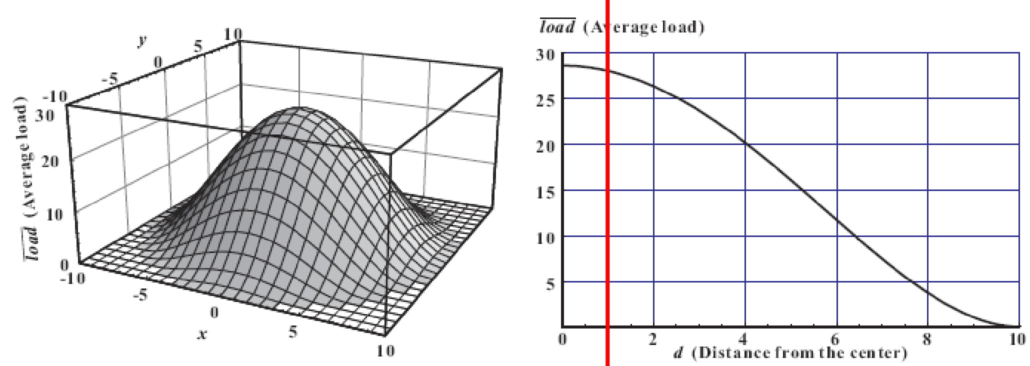


Fig. 6. Load distribution with a mobile base station. We assume $R = 10$, $r = 1$, $\bar{\theta} = 0.2$, $\rho = 8/\pi$, $\lambda = 1$ and $\varepsilon = 1$.

The proposed model

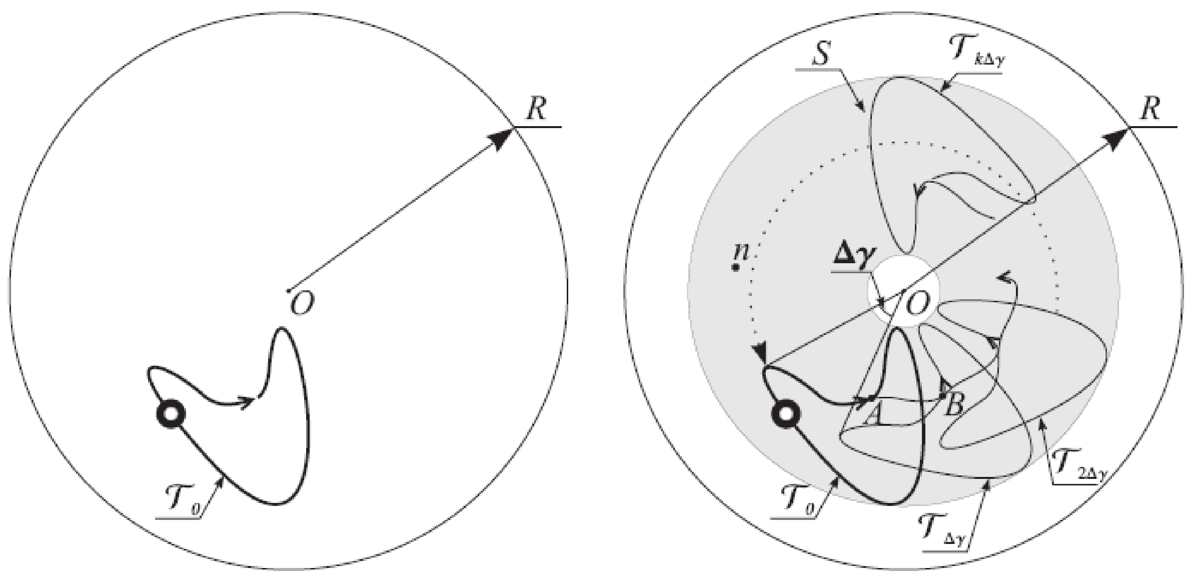
$$Minimize \quad load_N \equiv \max_{n \in N} \overline{load}_N(M, R)$$

Constraints: M: mobility constrains
R: routing constrains

- First we fix the routing strategy to short path routing and search for the optimum mobility strategy
- Then based on the optimum mobility strategy to find a routing strategy that performs better than short path routing

The proposed model

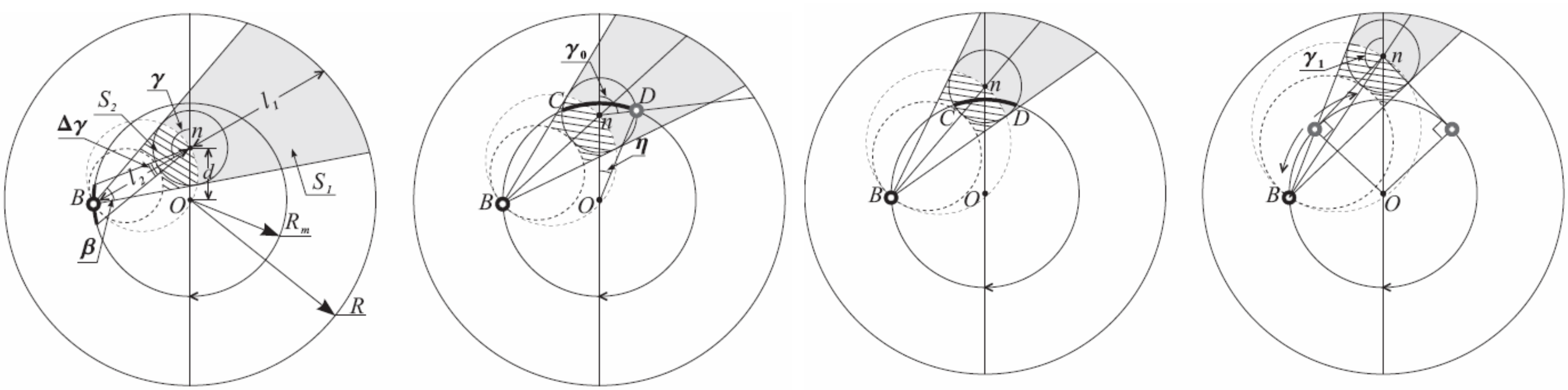
- Periodic mobility
  - Recurrent movements with a constant period
- Symmetric strategy and non-symmetric strategy



(a) Non-symmetric strategy (b) Symmetric strategy

The proposed model

- Two categories of mobility search
  - Movements on concentric circles
  - Identical frequency movements in annuli



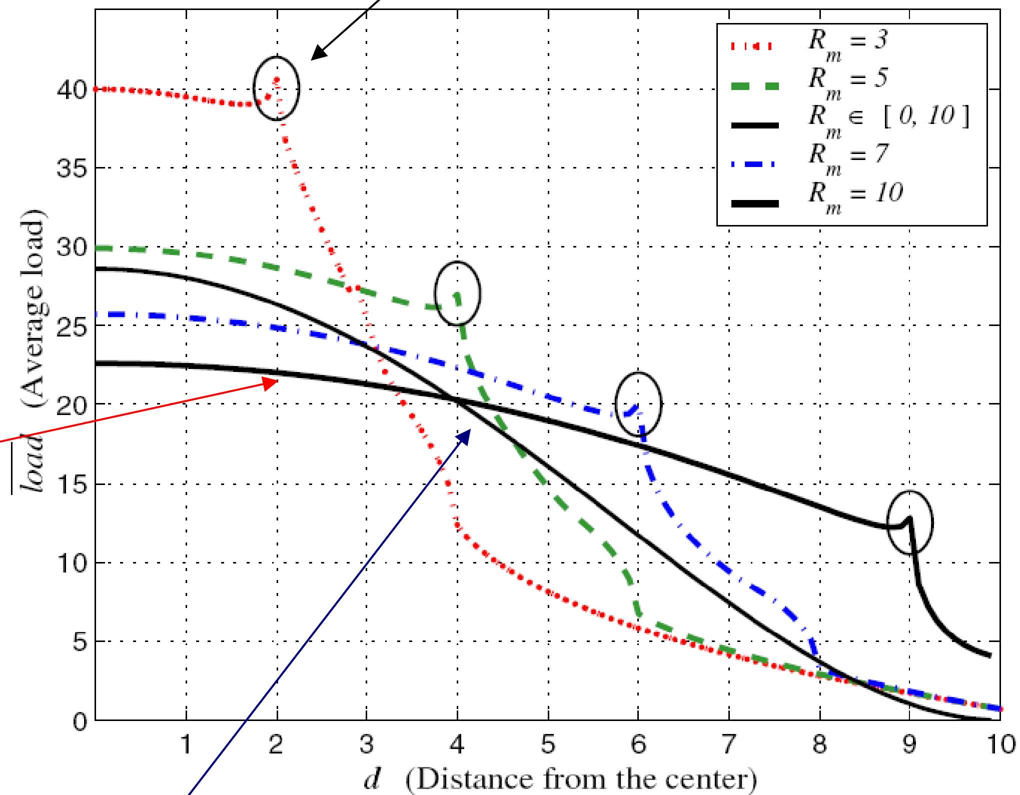
(a) $0 \le d < R_m - r$ (b) $R_m - r \le d < R_m$ (c) $R_m \le d < R_m + r$ (d) $R_m + r \le d < R$

R_m: the radius of concentric circles

The proposed model

- The optimum symmetric strategy is the one whose trajectory is circle C_{OR}
  - The periphery of the network
- The maximum average load is always achieved at the network center

Due to imperfections of approximation

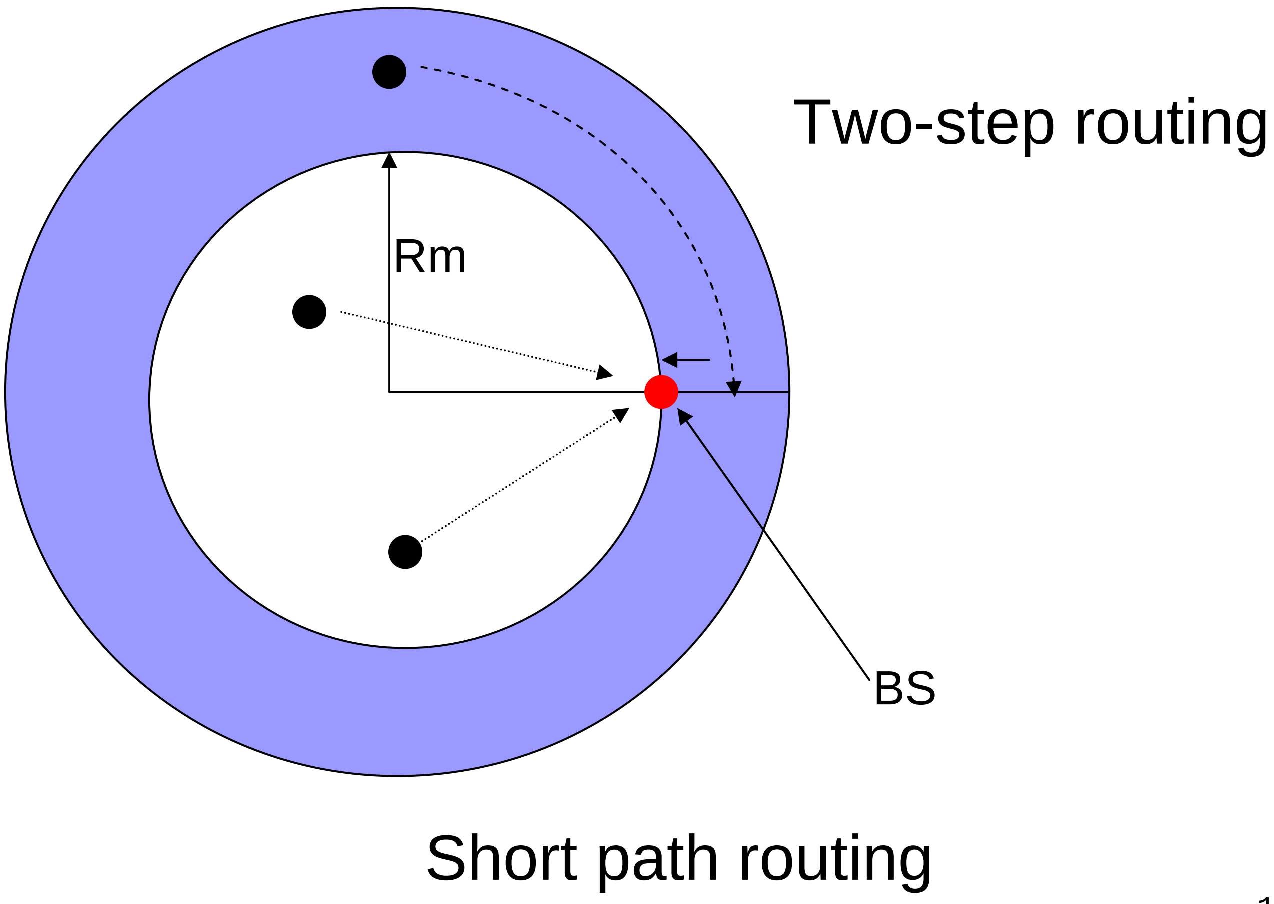


Rm = [0, 10] = 6

The proposed model

- Joint routing and mobility strategy
  - Find better routing strategy
- The BS only moves on the circle of radius R_m ($R_m < R$)
  - Inner circle: short path routing
  - Annulus: Two-step routing
    - Round routing
    - Short path routing

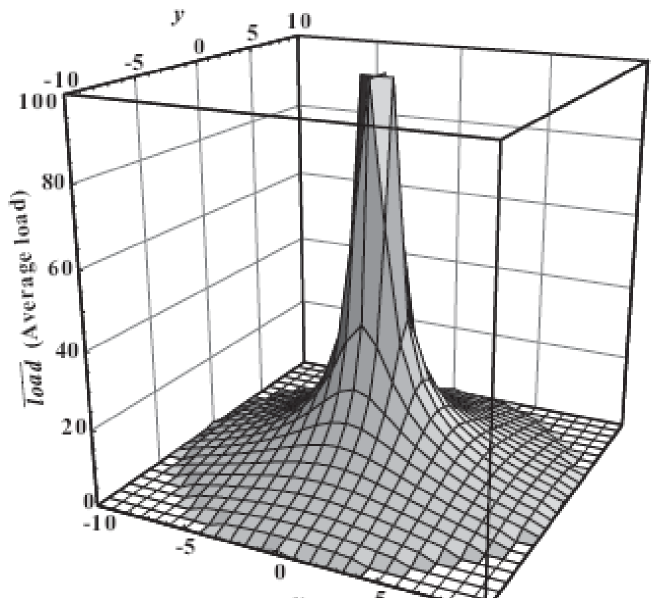
The proposed model



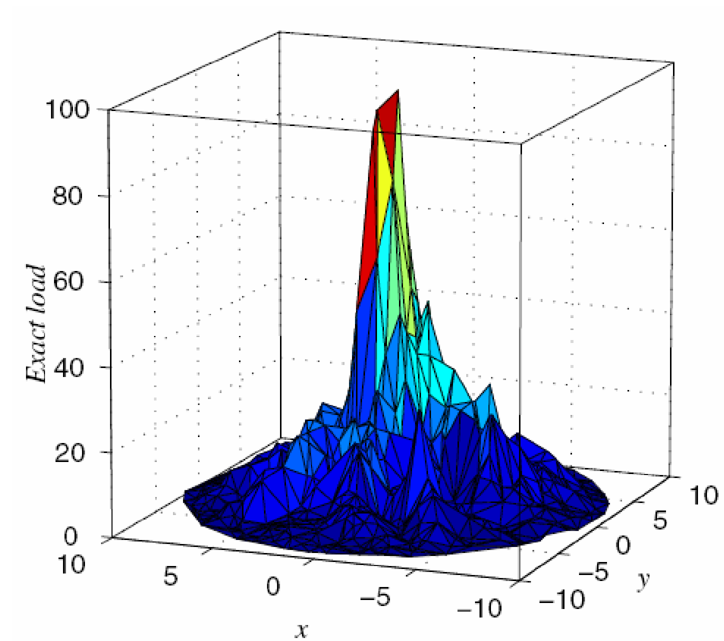
Simulation results

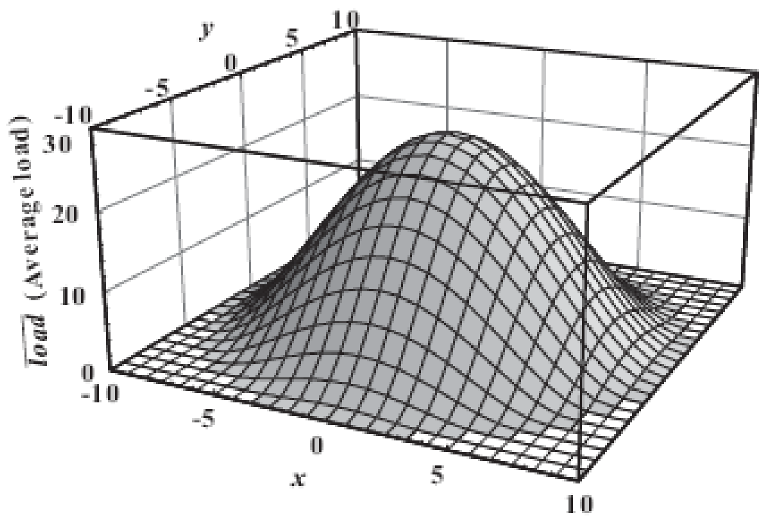
- Simulation parameters
  - 800 nodes
  - R = 10 units
  - Density: $\rho = 8/\pi$
  - Data sending rate: $\lambda = 1$
  - Comm. range: r =1
- Simulation tool: MATLAB

Simulation results

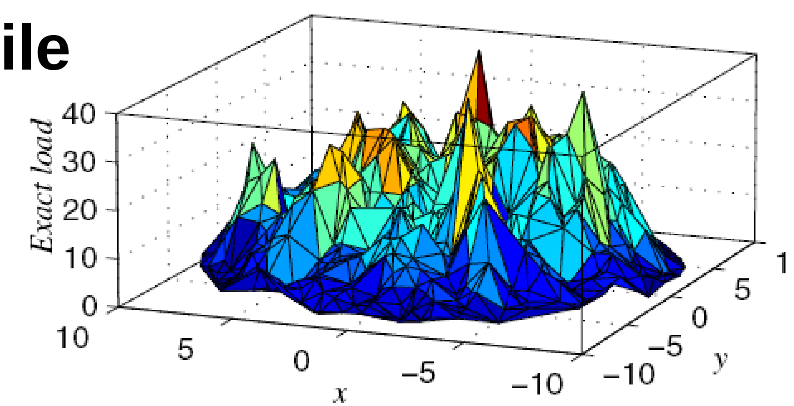


Static

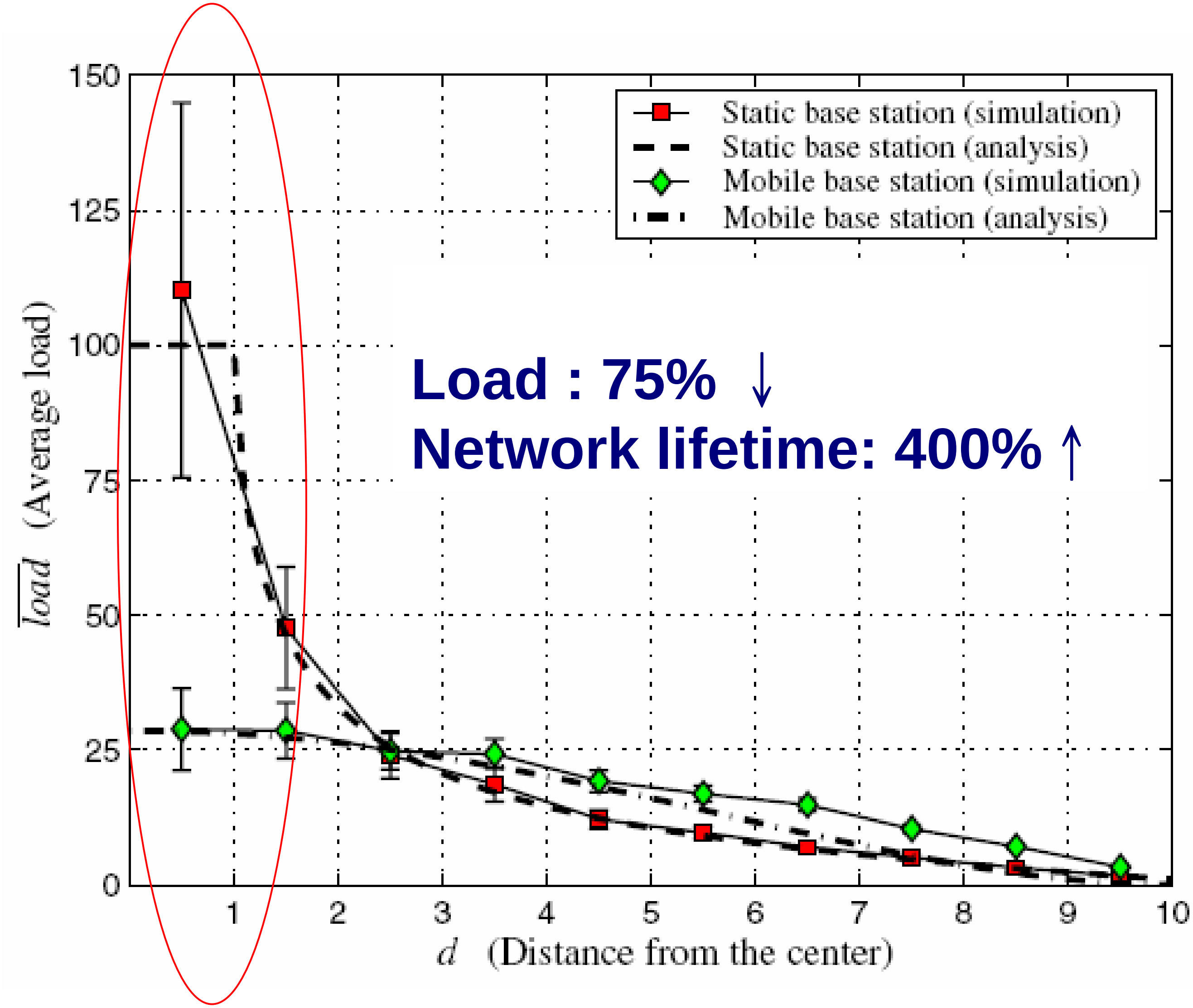




Mobile



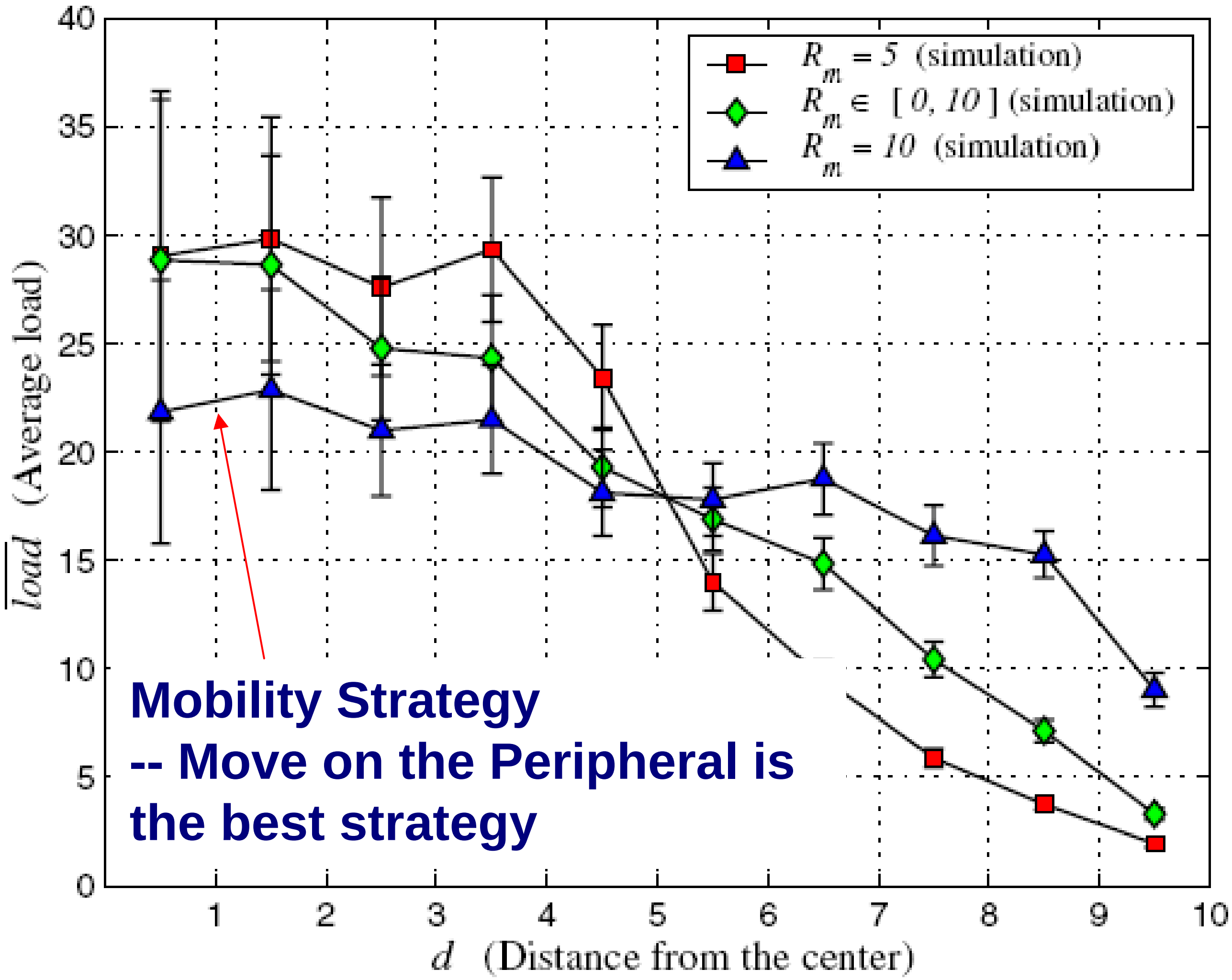
Simulation results



Load : 75% ↓

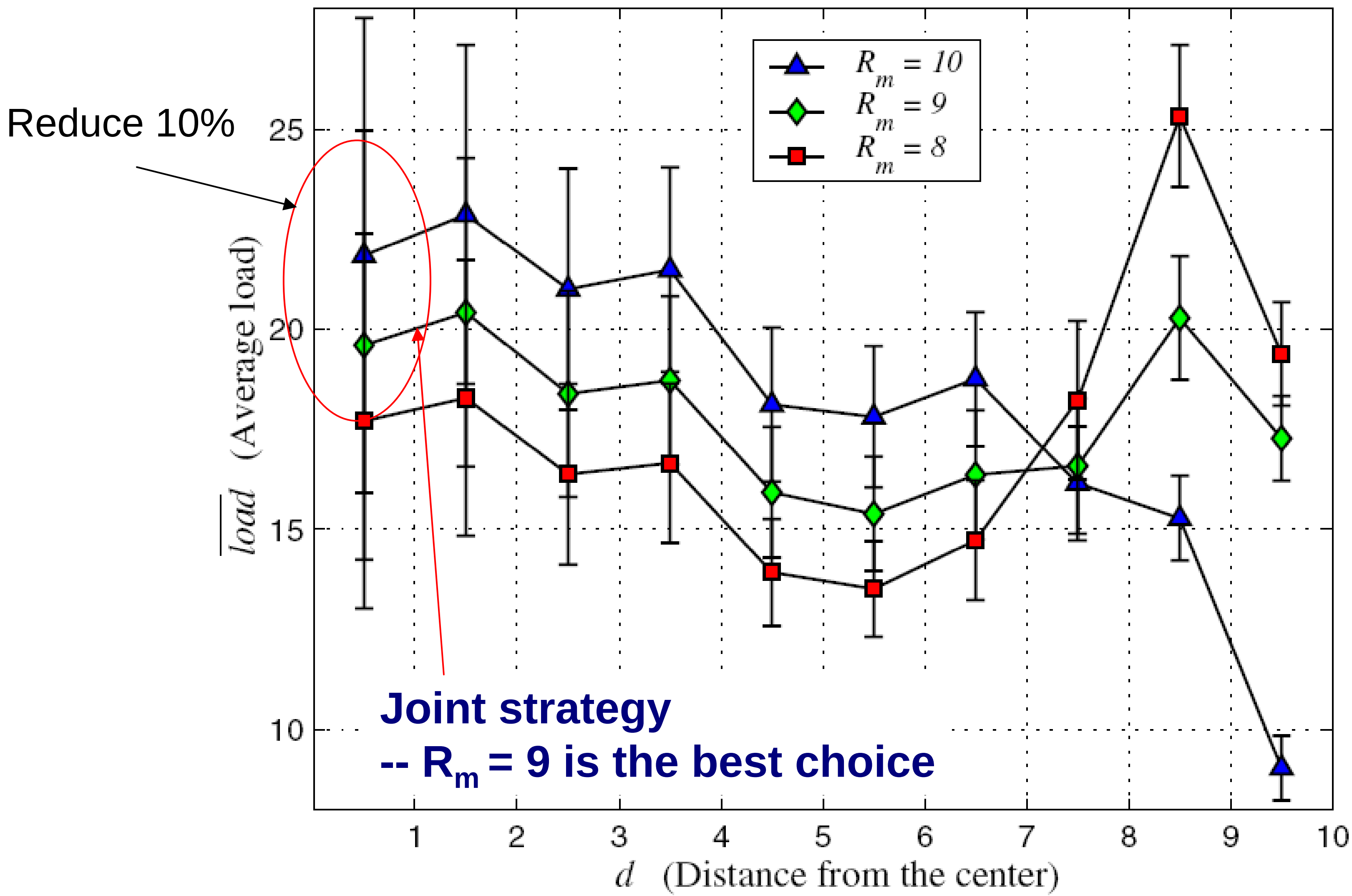
Network lifetime: 400% ↑

Simulation results



Mobility Strategy
-- Move on the Peripheral is the best strategy

Simulation results



Conclusions

- This paper shows that mobile BS can prolong the network lifetime
- Based on the round network model, the optimum mobility strategy is moving on the periphery of the network
- The authors also propose a joint mobility and routing strategy for lifetime elongation
- The joint strategy can achieve a 500% improvement of the network lifetime