Joint Mobility and Routing for Lifetime Elongation in Wireless Sensor Networks

INFOCOM 2005

2006.03.09
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: $\rho$
- Data sending rate: $\lambda$
- 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

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

Constraints: specific to given strategies
Analysis results

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

- For Mobile BS
  - Reduce 75% load

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

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

\[
\text{Minimize } \quad load_N = \max_{n \in N} \text{load}_N(M, R)
\]

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

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:

$$R_m = [0, 10] = 6$$
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

Two-step routing

Short path routing
Simulation results

- Simulation parameters
  - 800 nodes
  - $R = 10$ units
  - Density: $\rho = \frac{8}{\pi}$
  - 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

Joint strategy
-- $R_m = 9$ is the best choice

Reduce 10%
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.