# Energy Optimization under Informed Mobility

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Seminar: Ad Hoc Networks

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# Outline

- Background
- Approach
- Evaluation
- Conclusion
- Reference

# Background

- Motivation
- Energy models
- Optimal node position
- Informed mobility
- Related work

# Motivation

- Mobile Ad Hoc Networks
- Communication energy cost
- Limited battery power
- Energy optimization is important in wireless ad hoc networks

# Energy models

- The power is needed for successful wireless data transmission
  - determined by the distance between communication entities
  - the noise level of the communication channel

$$P_T(d) = a + bd^{\alpha}$$

$$E_T(d, l) = l \cdot P_T(d)$$

$$E_M(d) = kd$$

# Optimal Node Position

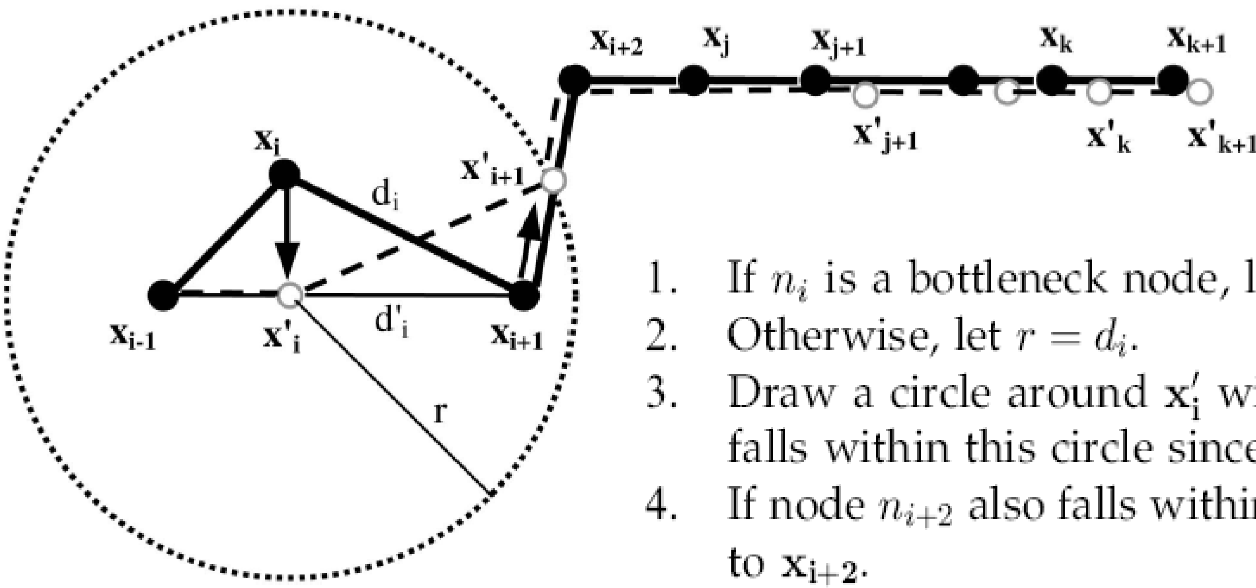
- The optimal positions of all N nodes in a one-to-one flow must lie entirely on the straight line between the source node $n_0$ and the destination node $n_{N-1}$

  – Minimize total transmission energy

  – Maximize system lifetime

# System lifetime maximization

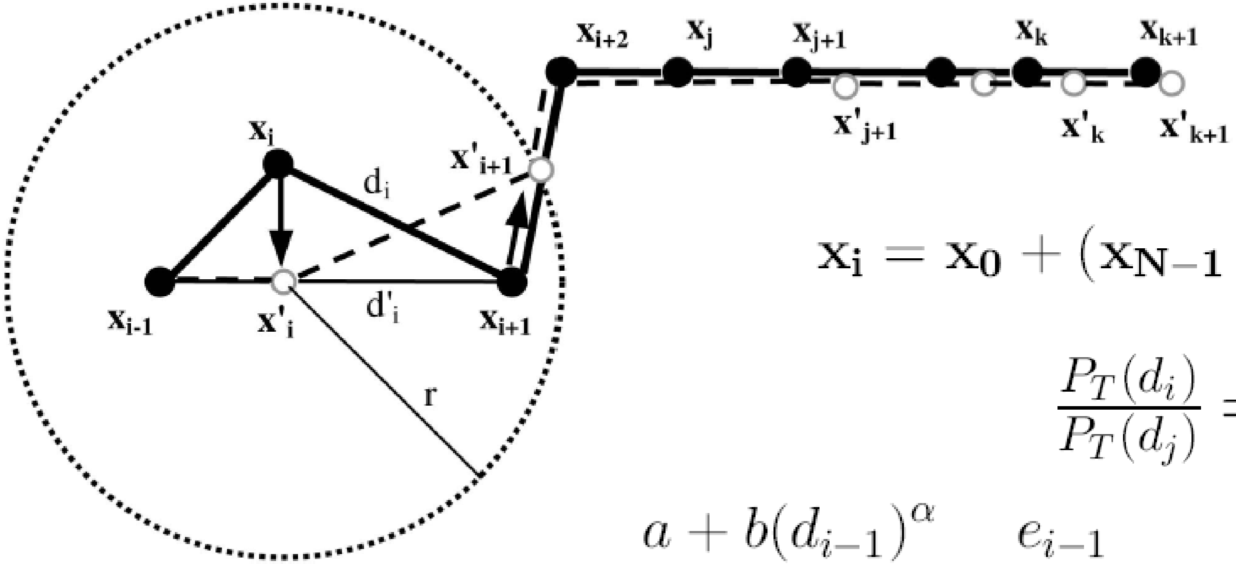
- All nodes in an optimal configuration should be located on the straight line between $n_0$ and $n_{N-1}$




1. If $n_i$ is a bottleneck node, let $r = d_i - \frac{d_i - d_i'}{M}$.
2. Otherwise, let $r = d_i$.
3. Draw a circle around $\mathbf{x}_i'$ with radius $r$; node $n_{i+1}$ falls within this circle since $r \geq d_i'$.
4. If node $n_{i+2}$ also falls within this circle, move $n_{i+1}$ to $\mathbf{x}_{i+2}$.
5. Otherwise, let $\mathbf{x}_{i+1}'$ be the point where the line $\mathbf{x}_{i+1}\mathbf{x}_{i+2}$ intersects the circle; move $n_{i+1}$ to $\mathbf{x}_{i+1}'$.

# System lifetime maximization

- Calculate the optimal position of $n_i$ for system lifetime maximization




$$\mathbf{x_i} = \mathbf{x_0} + (\mathbf{x_{N-1}} - \mathbf{x_0}) \cdot \frac{i}{N-1}$$

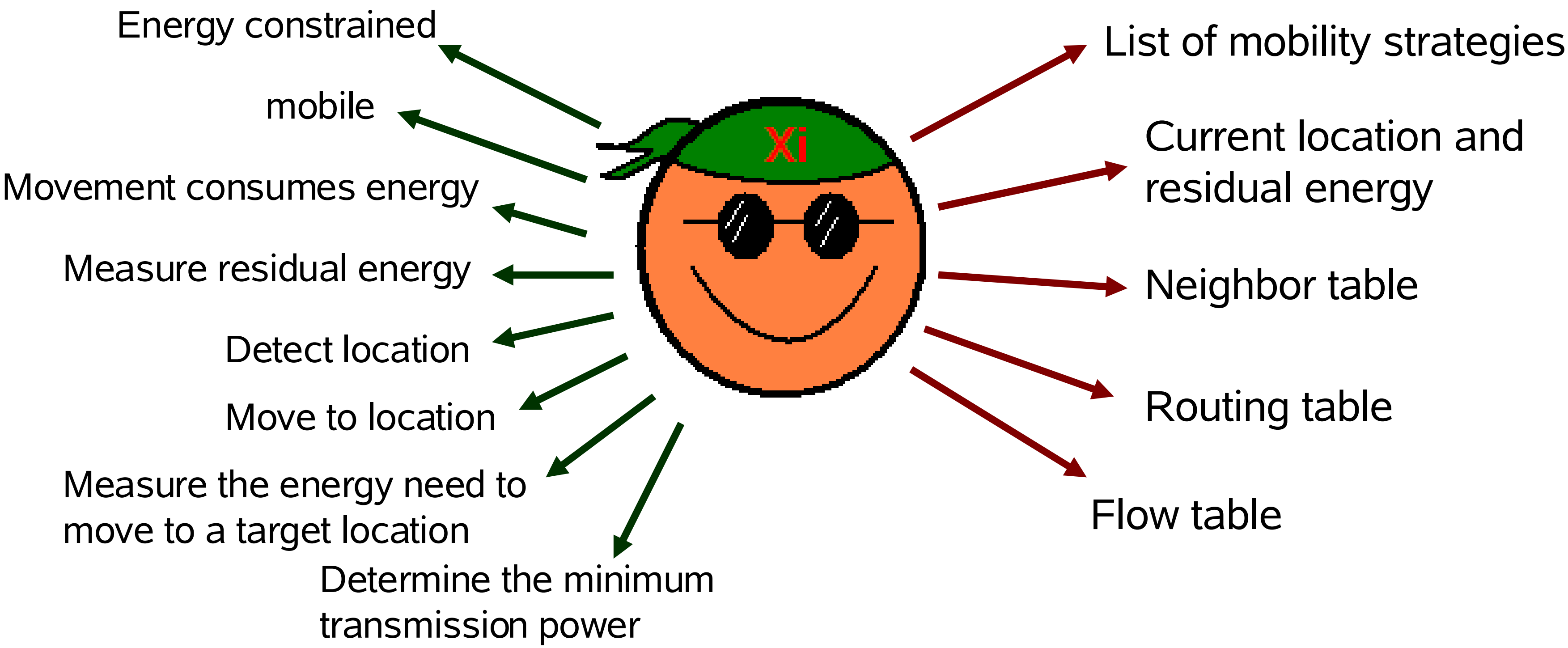
$$\frac{P_T(d_i)}{P_T(d_j)} = \frac{e_i}{e_j}$$

$$\frac{a + b(d_{i-1})^\alpha}{a + b(d_i)^\alpha} = \frac{e_{i-1}}{e_i} \qquad \frac{(d_{i-1})^\alpha}{(d_i)^\alpha} = \frac{e_{i-1}}{e_i}$$

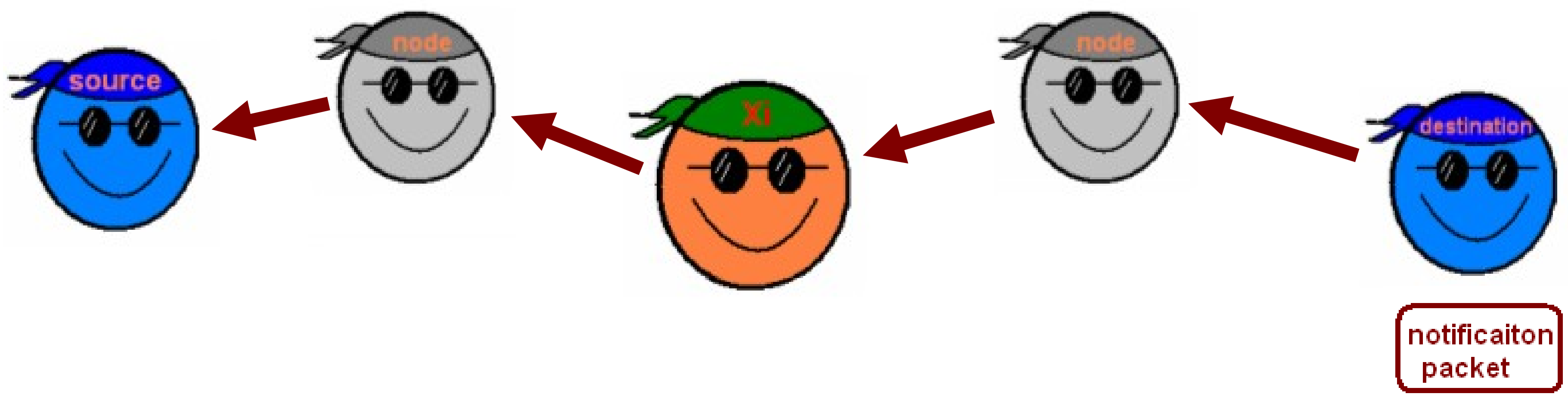
$$\mathbf{x_i} = \mathbf{x_0} + (\mathbf{x_{N-1}} - \mathbf{x_0}) \cdot \frac{\sum_{j=0}^{i-1} (e_j)^{\frac{1}{\alpha}}}{\sum_{j=0}^{N-2} (e_j)^{\frac{1}{\alpha}}} \quad \text{for } 0 < i < N-1$$

# IMobif

- A flow-based informed mobility framework that collects network information to facilitate decision-making with respect to mobility



# IMobif



# Related work

Towards Mobility as a Network Control Primitive

**Do not consider the mobility cost**

**Informed Mobility Framework**

# Approach

- The informed mobility optimization problem
  - Find the optimal node positions
  - Minimize total energy consumption
  - Maximize the energy utilization
- Use global information to make mobility decisions
- Localized algorithm

# Problem definition

Energy utilization function for minimize total energy consumption

$$G_1(\mathbf{E}, \mathbf{X}) = \sum_{<n_i, e_i> \in \mathbf{E}} (e_i - E_T^i(\mathbf{X}))$$

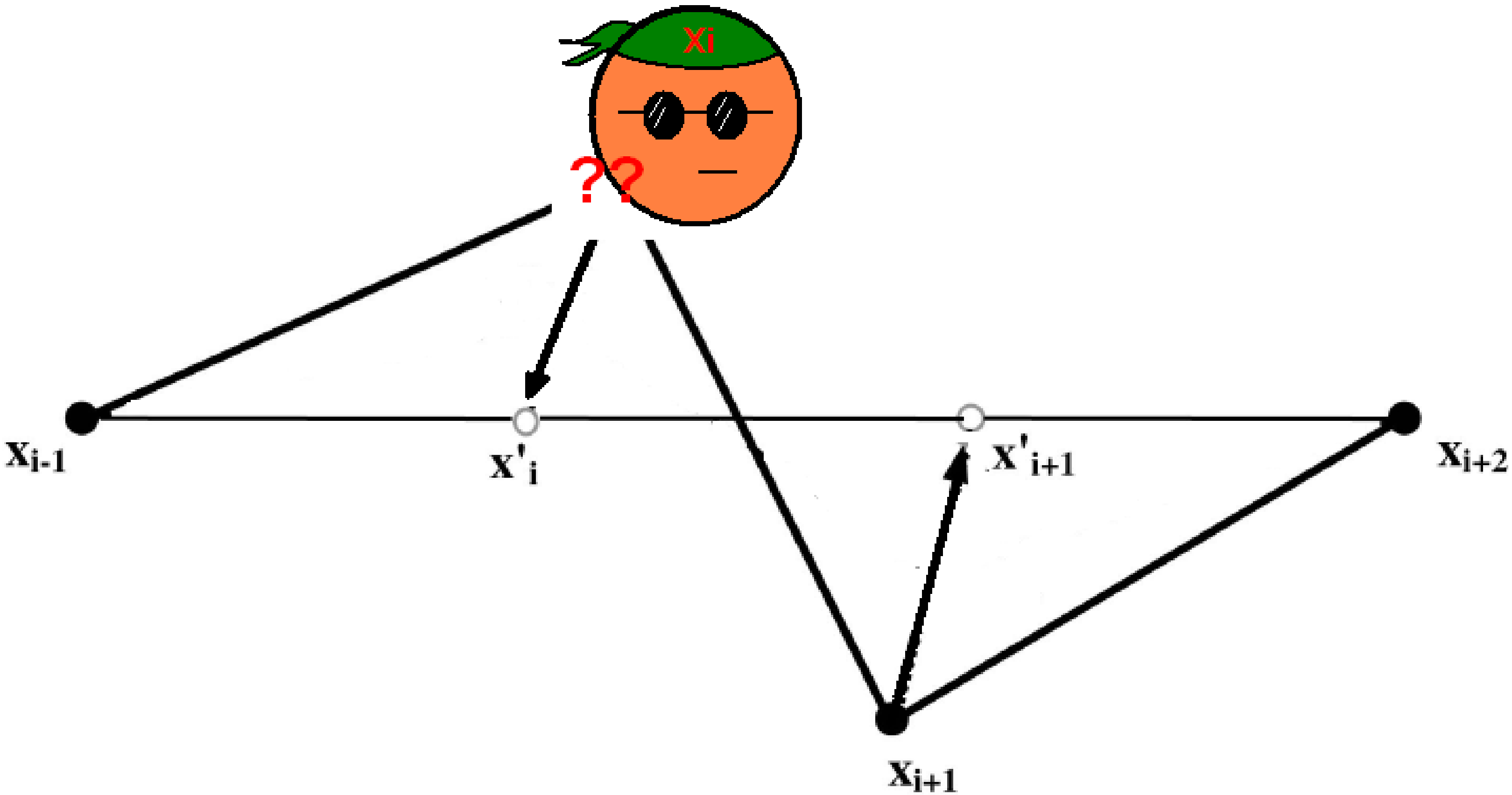
First sub-problem

Energy utilization function for maximize system lifetime

$$G_2(\mathbf{E}, \mathbf{X}) = \min_{<n_i, e_i> \in \mathbf{E}} \frac{e_i}{E_t^i(\mathbf{X})}$$

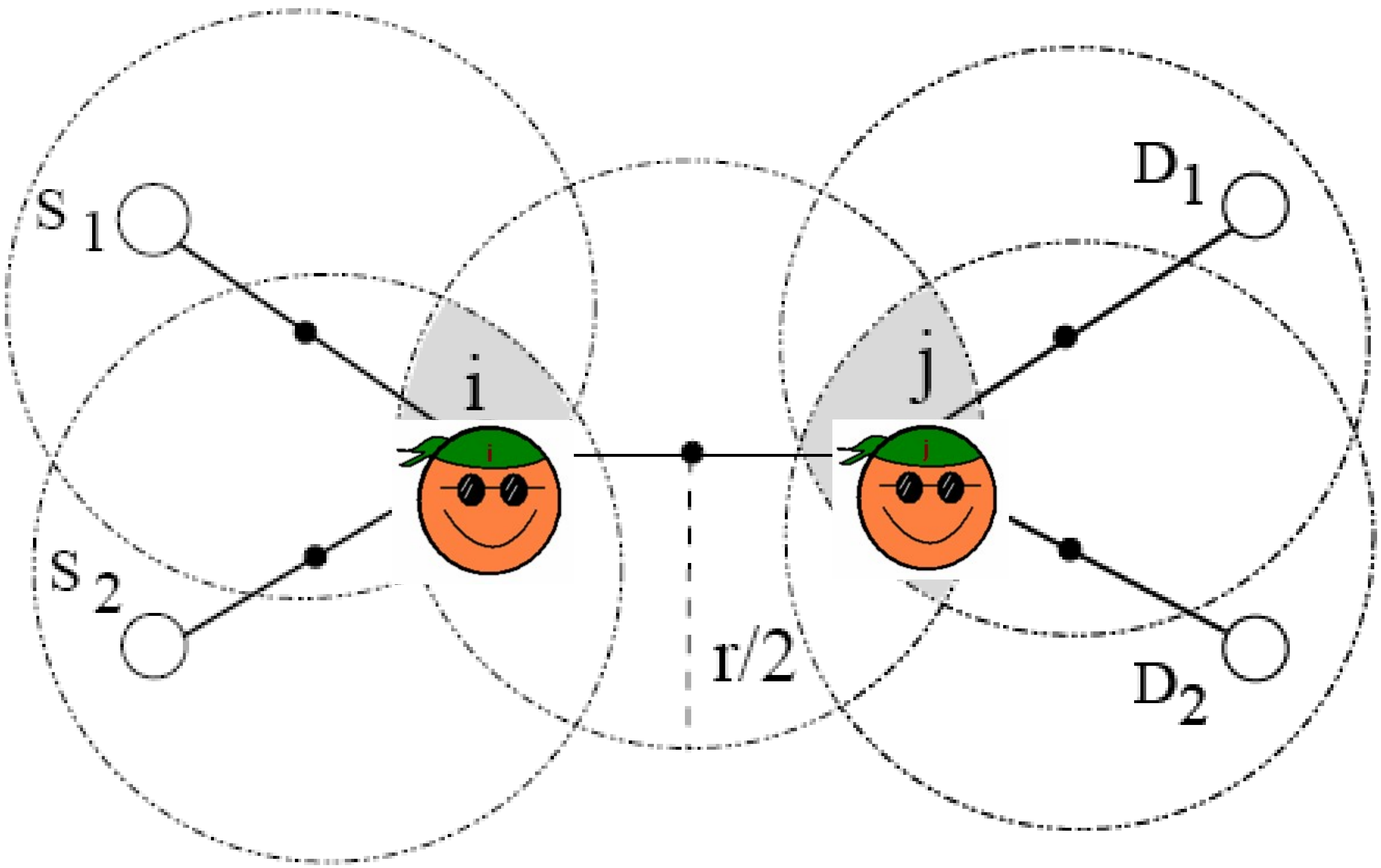
Second sub-problem

# Solutions for flows with fixed composition



# Solution for flows with dynamic composition

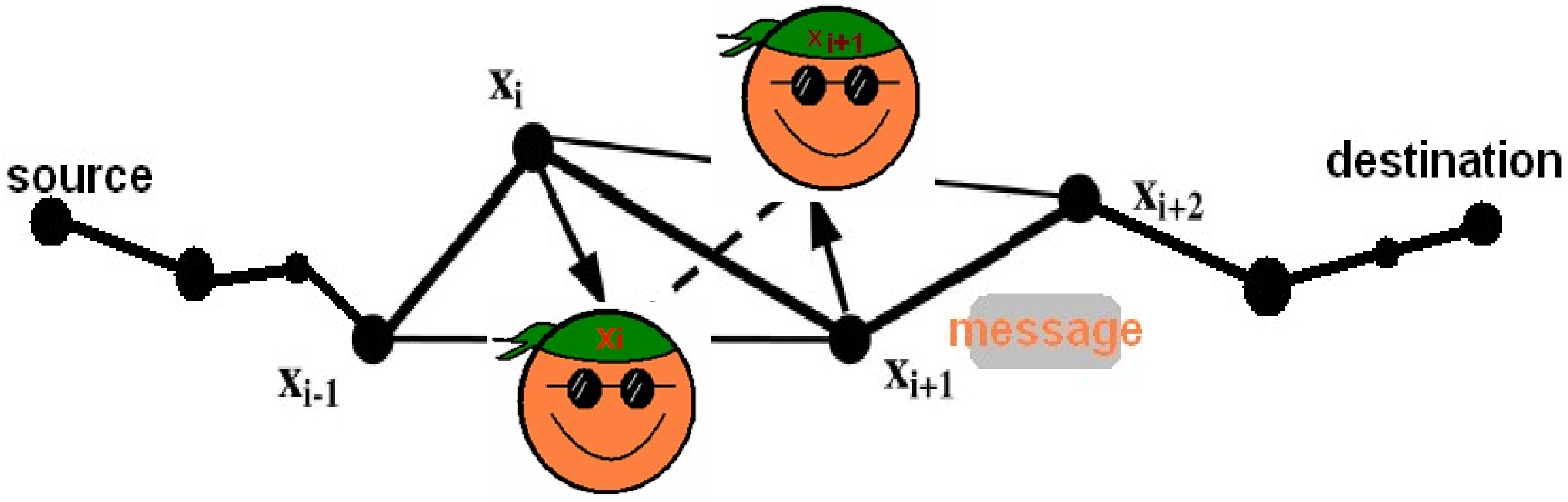
# Multiple flow considerations



# Localized Algorithms

- Global information
  - Position of the source node
  - Position of the destination node
- Propose localized algorithms to replace the position and residual energy of all flow nodes with the position and residual energy of the current node and its neighboring nodes in the flow

# Solutions for flows with fixed composition



# Minimizing total energy consumption

**function** GetNextPosition (Flow $f$) : Position
**begin**
    **return** $(f.prev.x + f.next.x)/2$
**end**

**procedure** GetMobilityPerformance (Flow $f$, **inout** Message $m$, Position $x$, Position $x'$)
**begin**
    $m.\text{benefit} = E_T(|x - f.next.x|, \lambda_f) - E_T(|x' - f.next.x|, \lambda_f)$
    $m.\text{cost} = E_M(|x - x'|)$
**end**

**procedure** AggregateMobilityPerformance (**inout** Message $m$)
**begin**
    $m.\text{aggregate\_benefit} += m.\text{benefit}$
    $m.\text{aggregate\_cost} += m.\text{cost}$
**end**

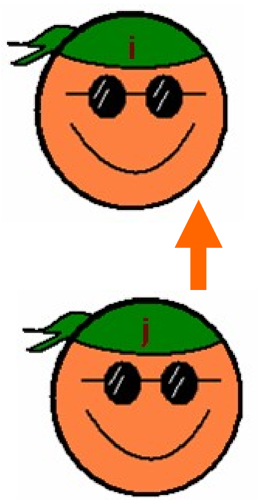
# Maximizing system lifetime

**function** GetNextPosition (Flow $f$) : Position
**begin**
    **return** $f.prev.x + (f.next.x - f.prev.x) \cdot \frac{(f.prev.e)^{\frac{1}{\alpha}}}{(f.prev.e)^{\frac{1}{\alpha}} + (e)^{\frac{1}{\alpha}}}$
**end**

**procedure** GetMobilityPerformance (Flow $f$, **inout** Message $m$, Position $x$, Position $x'$)
**begin**
    $m.\text{benefit} = \frac{e - E_M(|x - x'|)}{E_T(|x' - f.next.x|, 1)}$
    $m.\text{cost} = \frac{e}{E_T(|x - f.next.x|, 1)}$
**end**

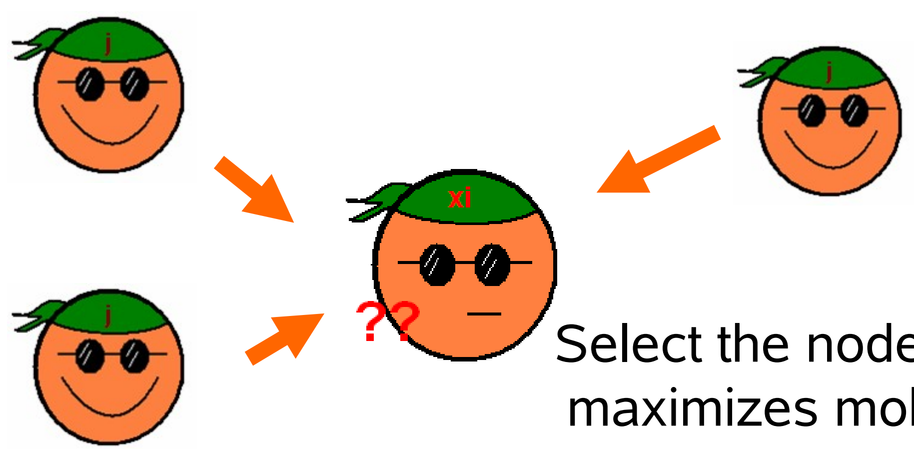
**procedure** AggregateMobilityPerformance (**inout** Message $m$)
**begin**
    $m.\text{aggregate\_benefit} = \min(m.\text{aggregate\_benefit}, m.\text{benefit})$
    $m.\text{aggregate\_cost} = \min(m.\text{aggregate\_cost}, m.\text{cost})$
**end**

# Solution for flows with dynamic composition




Periodically broadcasts the position and residual energy information of itself as well as its neighbors in the flow

Overhearing this message calculates the mobility benefit and the cost of joining this flow




Select the node that maximizes mobility gain

# Evaluation

- Simulation setup
- The Effect of controlled mobility on a wireless network
- Performance comparison of the approaches for energy consumption reduction without topology constraint
- Performance comparison of the approaches for energy consumption reduction with topology constraint
- Performance comparison of the approaches for system lifetime increasing

# Simulation setup

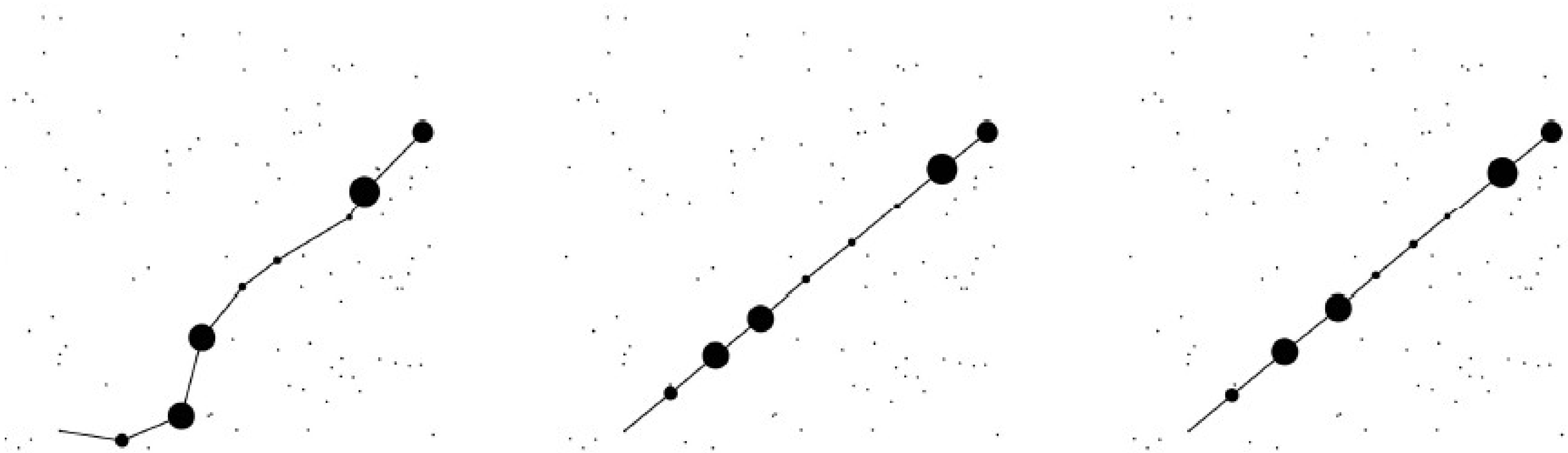
- 100 nodes in a 100m*100m area
- Communication range of each node is set to 20m
- The resultant average number of neighbors per node is approximately 12
- Randomly select two nodes as the source and destination of the flow
- Greedy routing

$$P_T(d) = a + bd^\alpha \qquad a = 10^{-7}\mathrm{J/bit},\ b = 10^{-10}\mathrm{Jm^{-\alpha}/bit}$$

$$E_M(d, l) = kd$$

- Flow rate is set to 1KBps

# The Effect of controlled mobility on a wireless network

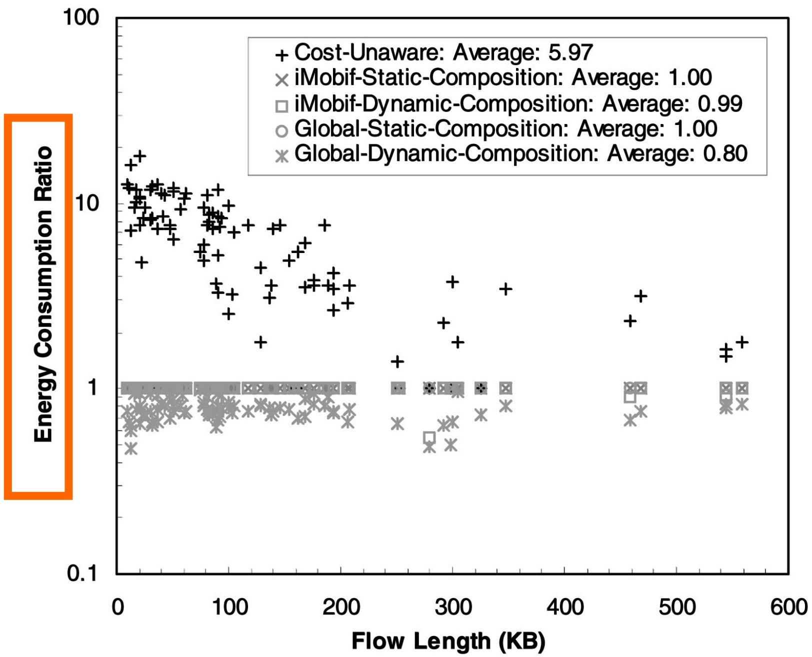


**IMobif is capable of reaching the optimal configuration using the localized approach**

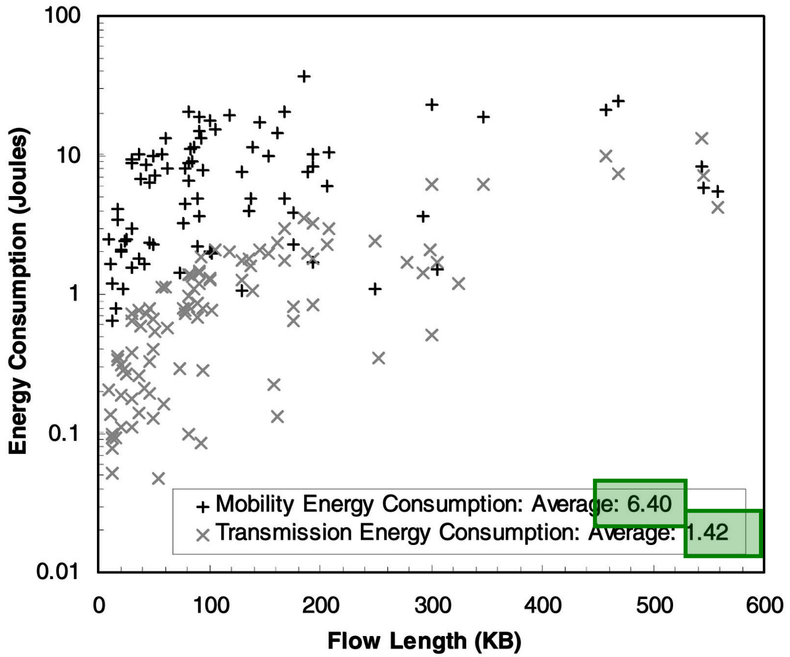
**Node location is independent of its residual energy**

**The distance between a node and the next node in the path is dependent on the node residual energy**

# Performance comparison of the approaches for energy consumption reduction without topology constraint



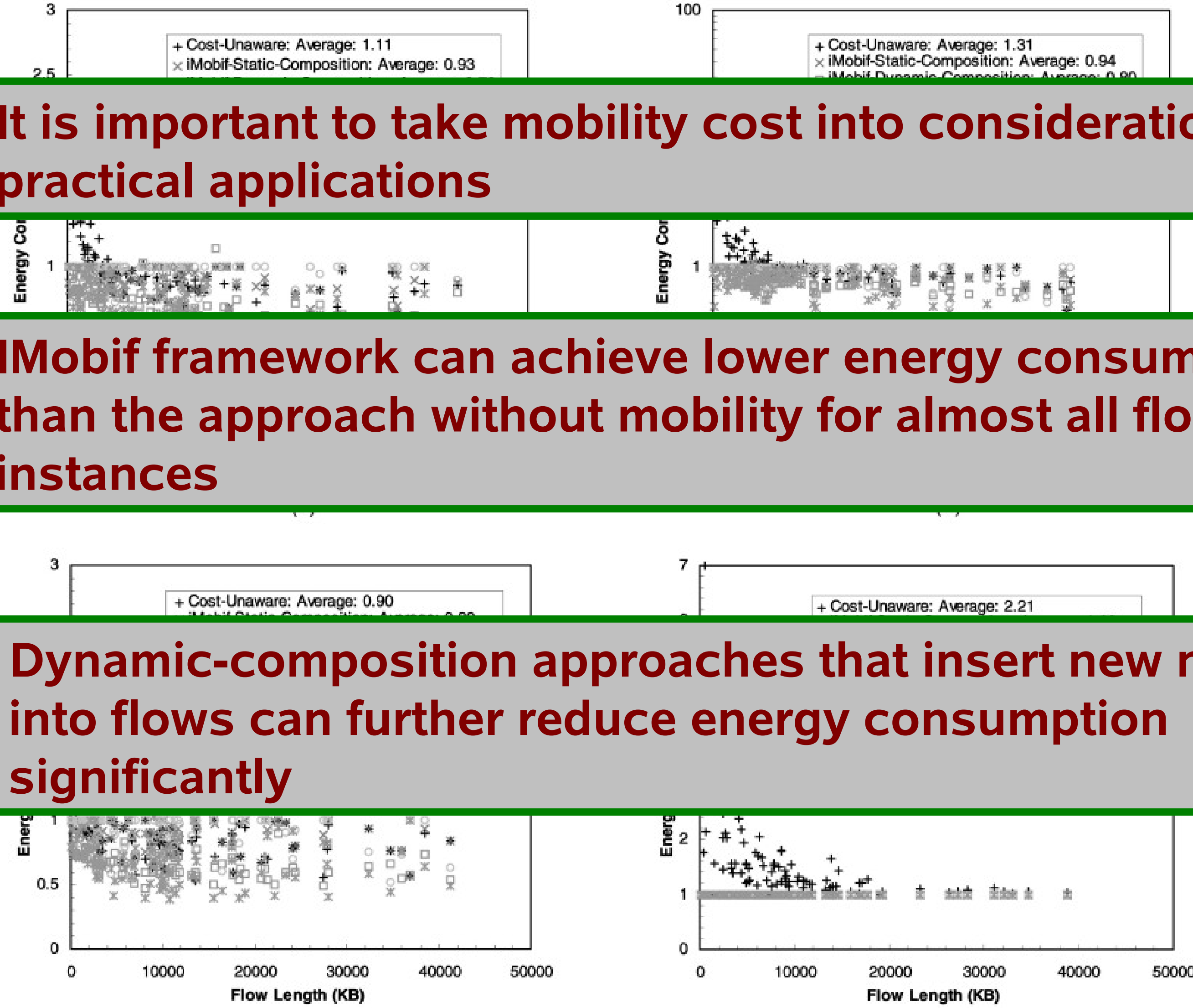

(a)




(b)

Energy consumption ratio for the five controlled mobility approaches as the ratio of the total energy consumed to the energy consumed in the baseline approach

# Performance comparison of the approaches for energy consumption reduction without topology constraint




(e)

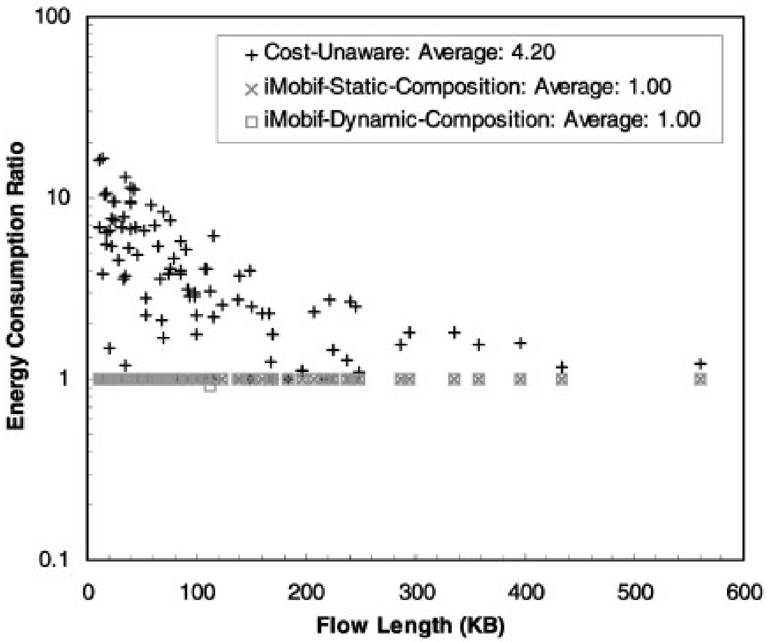
(f)

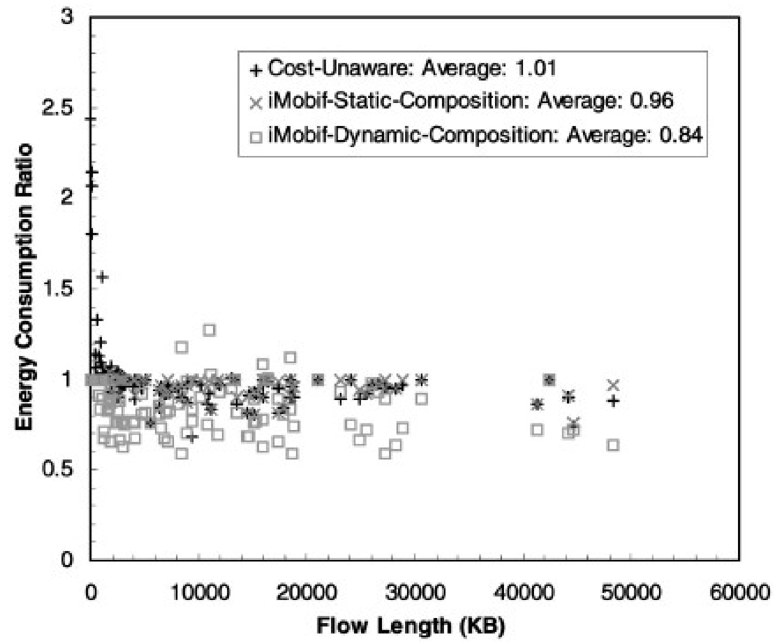
**It is important to take mobility cost into consideration for practical applications**

**IMobif framework can achieve lower energy consumption than the approach without mobility for almost all flow instances**

**Dynamic-composition approaches that insert new nodes into flows can further reduce energy consumption significantly**

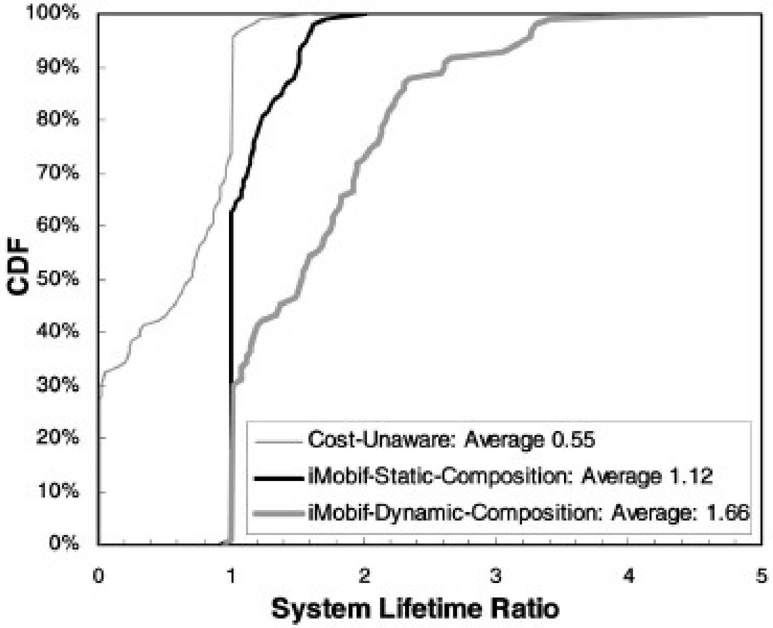
# Performance comparison of the approaches for energy consumption reduction with topology constraint

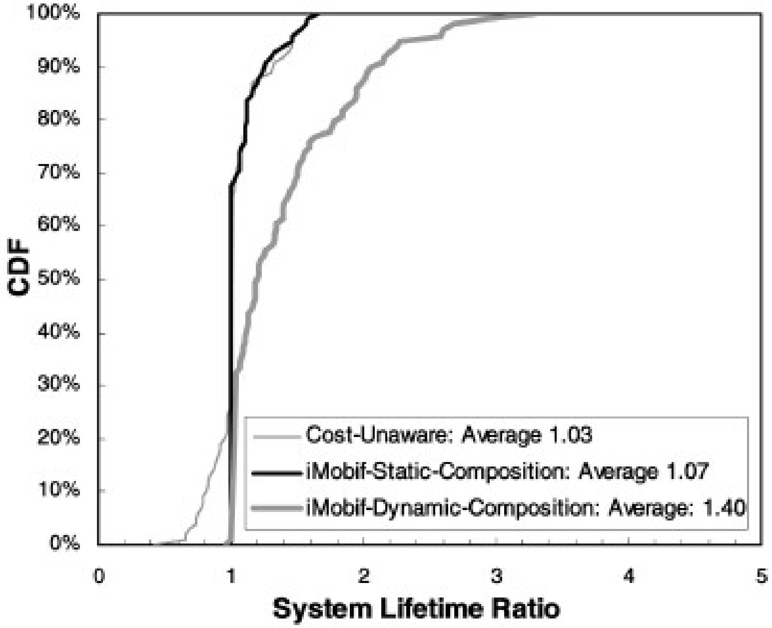



**Under mobility constraint, the controlled mobility approaches are slightly less effective for energy consumption reduction than in the case of no mobility constraint**

# Performance comparison of the approaches for system lifetime increasing




**The bottleneck nodes spend too much energy in moving to new locations**

**IMobif framework can achieve longer system lifetime than the approach without mobility for most flow instances**

# Conlustion

**IMobif**

- dynamically calculates the cost and benefit of a mobility strategy
- reducing total energy consumption
- increasing system lifetime
- most effective in environment where node mobility consumes little power while communication is heavyweight in terms of energy consumption
- extended to treat aggregated and concatenated flows as a single long flow and estimate its length based on historical data

# Future work

- Show the simulation about the multiple flow
- Study how to extend iMobif to satisfy the requirements of specific applications

# Reference


- Chiping Tang, Philip K. Mckinley, “Energy Optimization under Informed Mobility”
- D. Goldenberg, J. lin, A.S. Morse, B. Rosen, Y.R. Yang, “Towards Mobility as a Network Control Primitive”
- Chiping Tang, Philip K.McKinley, “iMobif: An Informed Mobility Framework for Energy Optimization in Wireless Ad Hoc Networks”

# THE END


THANKS~