Searching Strategy for Multi-Target Discovery in Wireless Networks

Zhao Cheng and Wendi B. Heinzelman
University of Rochester

Outline

- Problem statement
- Assumptions
- Solutions
- Results
- Conclusions and discussions

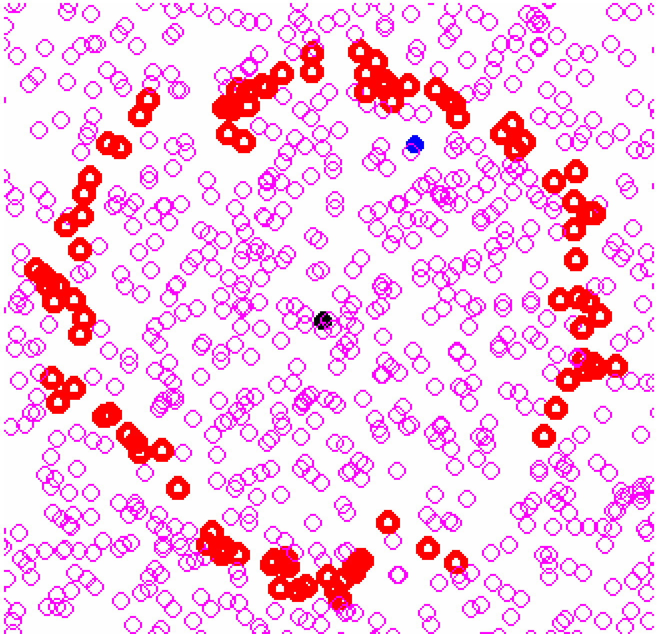
Motivation

- Why is multi-target discovery needed?
  - Route discovery with caches
  - Location estimation in sensor networks
  - Data aggregation in sensor networks
  - Network Time Protocol (NTP)

Problem Statement

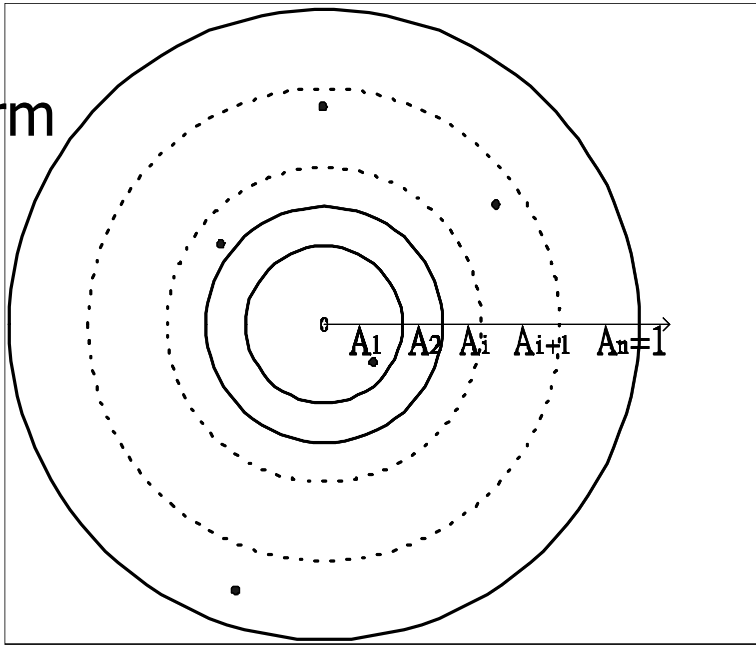
- How to efficiently discover k targets from a total of m targets in a homogeneous wireless network by flooding?
- Existing schemes
  - Simple flooding
  - DSR
  - Expansion ring (EXP)

$n=2, R_1=1, R_2=8$



Modeling the Problem

- Given: a total of m targets and the required number of targets k
- Perform: An n-ring searching scheme
  - Each searching ring area A_i
  - If the i th search fails, perform (i+1) th search
- Goal: Find optimal n and $\{A_1, A_2, \ldots, A_n\}$ to minimize the overall cost, i.e, the total expected searching area



Assumptions

- Static scenario during a specific query process
- Cost defined as the total searching area
- Nodes and targets are of uniform distribution
- The values of m and k are known a-priori

A Simple Case: Two Ring Search for 1 out of m Targets

- For the first search

$$P_1 = 1 - (1 - A_1)^m \qquad C_1 = A_1$$

- For the second search

$$P_2 = (1 - A_1)^m \qquad C_2 = A_1 + A_2 = A_1 + 1$$

- The expected cost

$$C^2 = P_1 C_1 + P_2 C_2 = A_1 + (1 - A_1)^m$$

Cost of Generic n-ring Scheme

The expected cost to find k out of m targets using n-ring searching

$$C^{n} = \sum_{i=0}^{n} P_i C_i = \sum_{i=0}^{n} ((I(A_i) - I(A_{i-1})) \sum_{j=1}^{i} A_j)$$

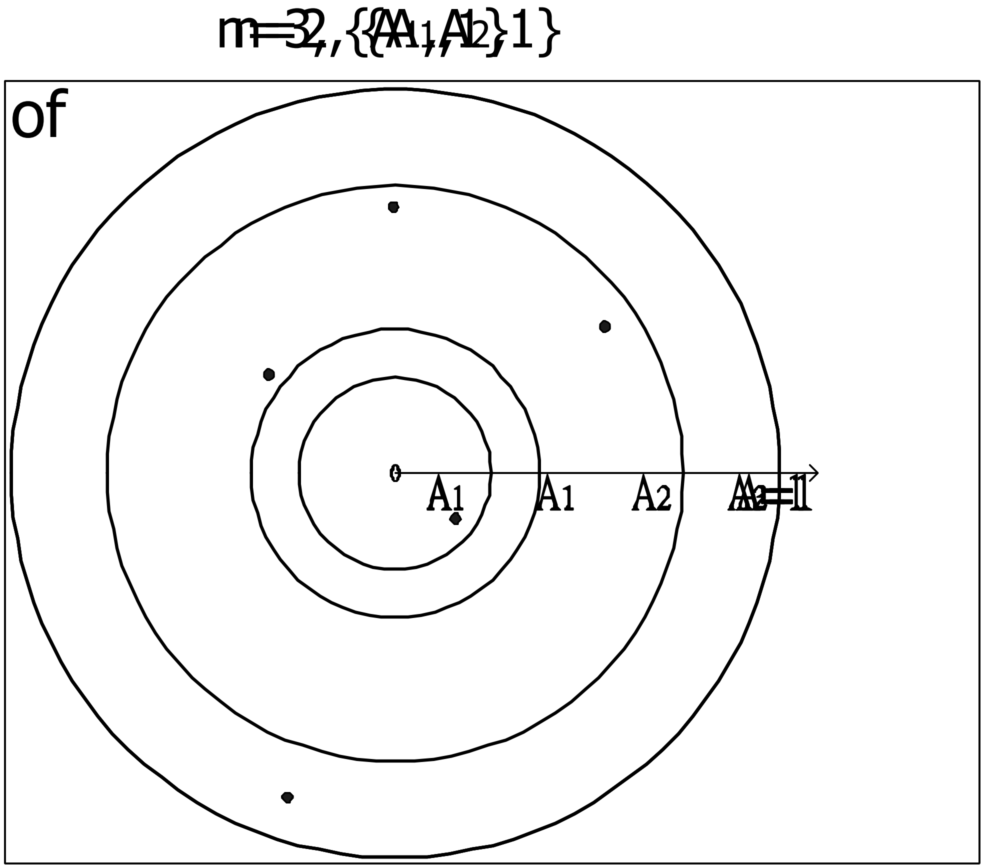
$$= \sum_{i=0}^{n-1} A_{i+1}(1 - I(A_i))$$

Where

$$I(p; m, k) = \sum_{i=k}^{m} \binom{m}{i} p^{i} (1 - p)^{m-i}$$

Finding the Minimum Cost: Brute Force

- Start with n=2. Try every possible A_1 in [0,1]
- Try n=3, try every possible combination of $\{A_1, A_2, A_3\}$
- Try n=4 …



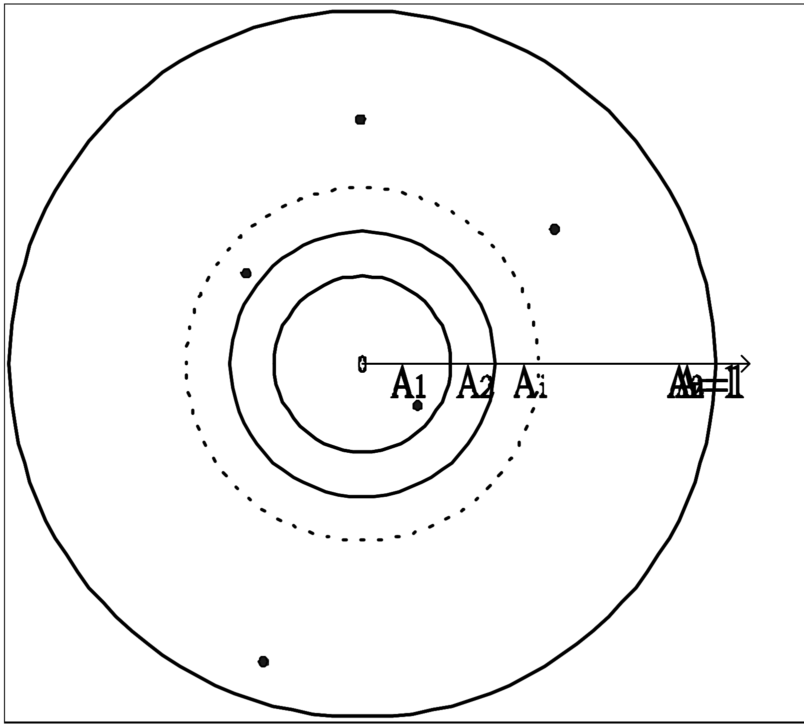
Finding the Minimum Cost: Online Ring Splitting

- Start with n=2, find the optimal A_1

$$C^2 = 1 + A_1 - I(A_1)$$

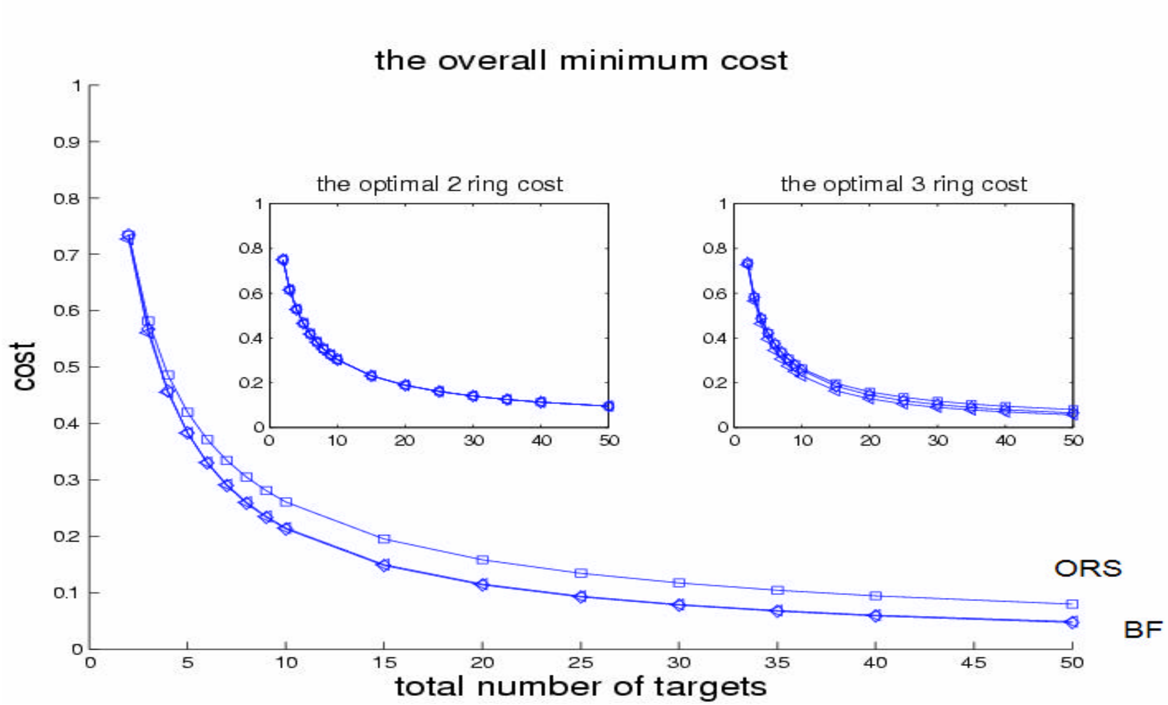
$$\frac{\partial C^2}{\partial A_1} = 0$$

- Adjust the new searching goal and split the remaining ring using a 2-ring search scheme
- Use A=1 if no valid A_1



Analytical Results (1 out of m)

- Multiple ring searching saves
- ORS is much simpler; BF is more efficient
- Two searches are good enough



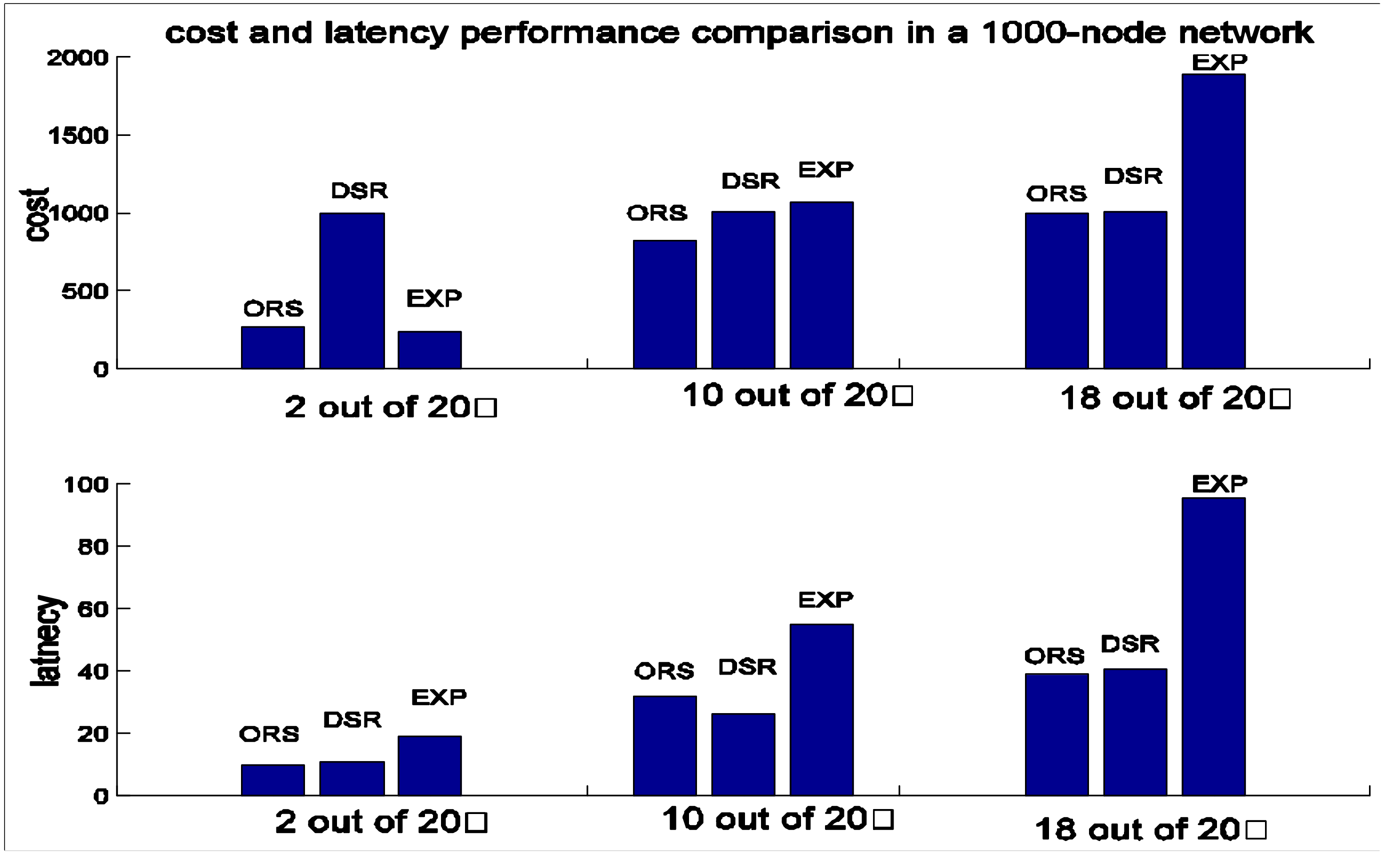
How to Use A Practically

- Mapping A into a hop value
  - Based on the scale of the network, estimate the network diameter
  - Map the searching area A into the hop value based on

$$A \propto R^2$$

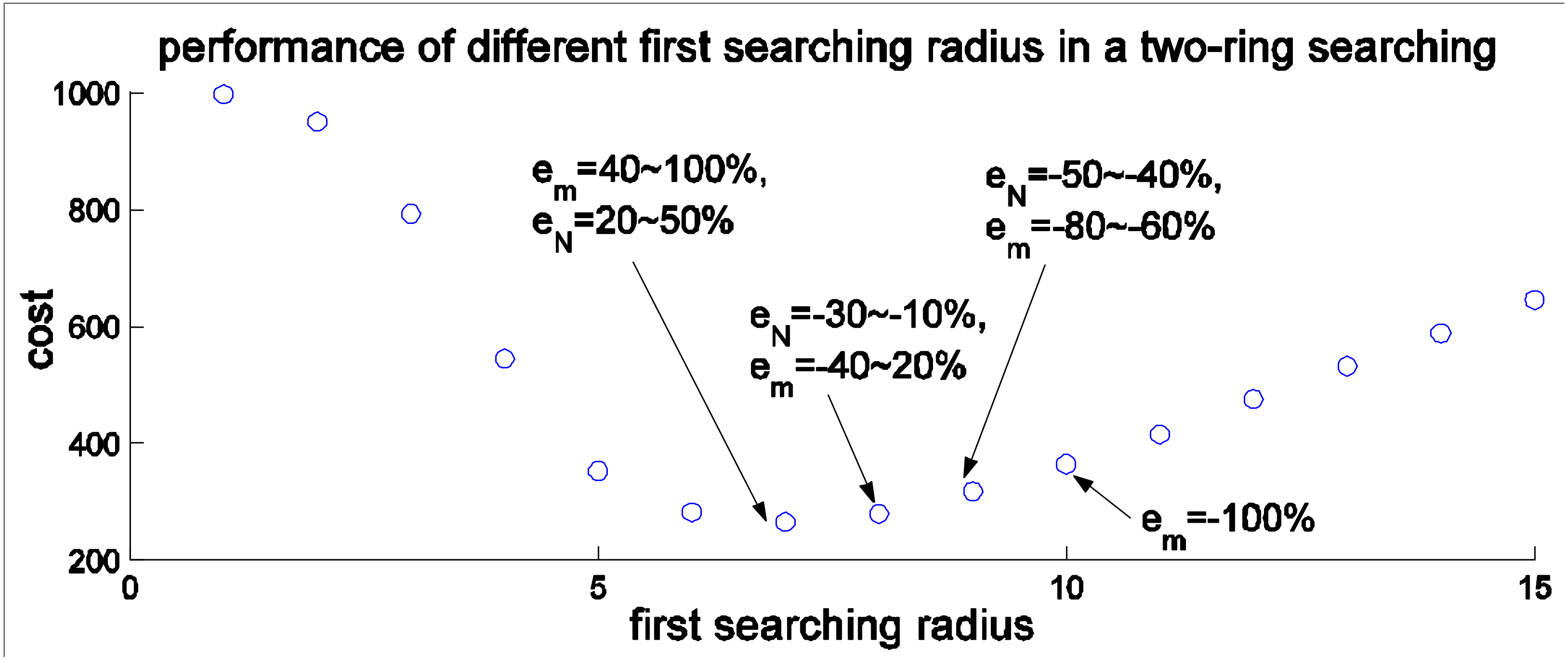
Simulation Results

- Comparing ORS with DSR and EXP



Simulation Results

- Robustness: find 2 out of 20 in a 1000-node network



Conclusions and Discussions

- Conclusions
  - Choosing good searching areas reduces cost
  - Using two searches is good enough
  - When the number of total targets is not precisely known, there are still cost savings
- Discussions
  - Non-uniform target distributions
  - Non-homogenous target

Thank you!