Title
Coalescence for Mobile Sensor Networks

Authors
Poduri, Sameera
Sukhatme, Gaurav S

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Coalescence for Mobile Sensor Networks

Sameera Poduri and Gaurav S. Sukhatme
Robotic Embedded Systems Lab, USC
http://robotics.usc.edu/~embedded

Introduction: network connectivity is both a necessity and a challenge

Motivation

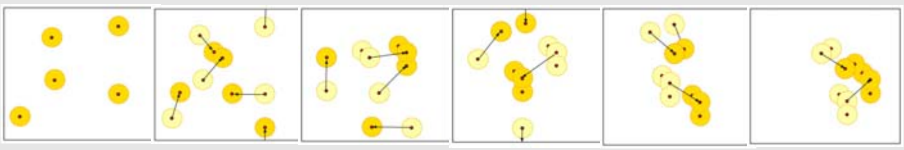
- what if connectivity is lost?
  example scenarios: robots start in a disconnected state, unintentionally lose connectivity, or intentionally disconnect for task completion
- tradeoff: cost of network formation vs. cost of maintaining connectivity

Coalescence

Definition: **isolated robots finding peers and forming a single connected component**

Problem Description: how much time for coalescence?

Given N isolated mobile robots placed at unknown locations within a bounded domain, how long will it take for them to coalesce into a single connected component?

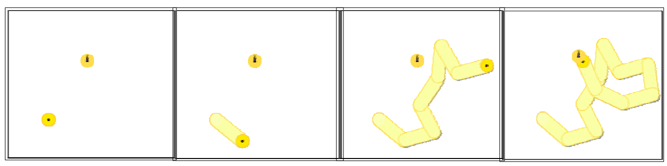


Assumptions:
- binary disc communication model
- robots are distributed uniformly at random
- domain is a torus

Proposed Solution: worst case analysis based on memoryless random walks

Random Mobility Model

- robots perform independent random walks
- after each fixed time step, each robot
  - chooses a random direction and moves with fixed speed
- robots within communication coalesce and move together



Coalescence time analysis

MT_k^N : k^{th} meeting time with N robots

$$CT^N = MT_{N-1}^N$$

Challenge:
- size and shape of clusters difficult to model

1. Hitting Time

$$E[HT] = \frac{1}{2R_c L}$$

2. Meeting Time

$$E[MT] = \frac{E[HT]}{1.27}$$

Upper bound: single cluster

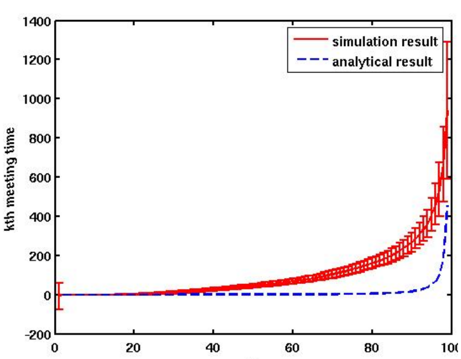
$$E[\Delta MT_k^N] \approx \frac{1}{N-k}\left(\frac{1}{2R_c L\sqrt{1+(k-1)\beta}}\right)$$

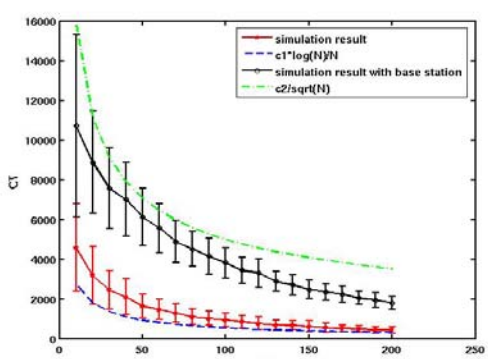
$$E[CT^N] = O\left(\frac{1}{\sqrt{N}}\right)$$

Lower bound: uniform clusters

$$E[\Delta MT_{N-2^k}^N] = \frac{1}{\binom{2^k}{2}} \cdot \frac{1}{2^{p-k}} \cdot E[MT]$$

$$E[CT^N] = \Omega\left(\frac{\log(N)}{N}\right)$$





Comparison of simulation results to analytical models:
(left) kth hitting time vs. k and (right) coalescence time vs. #robots averaged over 200 runs

Simulation Results

simulations in MATLAB validate assumptions and verify bounds

lower bound seems tight

Conclusions

- coalescence time is

$$O\left(\frac{1}{\sqrt{N}}\right) \text{ and } \Omega\left(\frac{\log(N)}{N}\right)$$

- area growth of connected component is the key factor