On hierarchical Routing in Wireless Sensor Networks
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Outline

Introduction
Routing algorithm
Implementation
Experimental results
Conclusions
Introduction

Point-to-point routing in WSNs

- State
- Stretch

Scalability
Route length: shortest path

Graph:
- State: O(1), O(logN), O(\sqrt{N}), O(N)
- Scalability: High, Compact, Hierarchical, Geographic

Shortest path

Maximum stretch

1 3 High
Introduction

Point-to-point routing in WSNs

- **State**
- **Stretch**

**Scalability**

**Route length:** shortest path

![Diagram showing scalability and state trade-offs](image)
Introduction

Point-to-point routing in WSNs

- State
- Stretch

Scalability
Route length: shortest path

- State: $O(1)$, $O(\log N)$, $O(\sqrt{N})$, $O(N)$

- Stretch:
  - (only theoretical)

Diagrams:
- Compact
- Hierarchical
- Geographic (needs localization)

Maximum stretch:
1, 3, High
Introduction

Point-to-point routing in WSNs

- State
- Stretch

Scalability
Route length: shortest path

- State: $O(N)$
- $O(\sqrt{N})$
- $O(\log N)$
- $O(1)$

Scalability
High

Hierarchical
(only theoretical)

Compact

Geographic
(needs localization)
Introduction

Hierarchical routing

- Many proposed algorithms and protocols
- No implementation based evaluation
  - Only high level simulations
  - No comparisons between the HR techniques

Objectives

- Flexible framework for landmark routing algorithm
- Evaluate HR routing protocols
Landmark routing

Multi-level cluster hierarchy

Cluster radius $r_i = 2^{i-1}$ hops

#clusters at level $i \sim \frac{N}{x^i}, x > 1$
Landmark routing

Multi-level cluster hierarchy

Cluster radius $r_i = 2^{i-1}$ hops

#clusters at level $i \sim \frac{N}{x_i^x}$, $x > 1$

$i = 0$

〇 = level 0 cluster
Landmark routing

Multi-level cluster hierarchy

Cluster radius $r_i = 2^{i-1}$ hops

#clusters at level $i \sim \frac{N}{x_i^i}, x > 1$

$i = 1$

〇 = level 0 cluster

〇 = level 1 cluster
Landmark routing

Multi-level cluster hierarchy

Cluster radius $r_i = 2^{i-1}$ hops

#clusters level $i$ ~

$i = 2$

○ = level 0 cluster
● = level 1 cluster
🔴 = level 2 cluster
Landmark routing

Advertisement radius $R_i$

$R_i \geq r_{i+1}$, e.g. $R_i = 2^i$

Level 0: $2^0 = 1$ hop
Landmark routing

Advertisement radius $R_i$

$R_i \geq r_{i+1}$, e.g. $R_i = 2^i$

Level 1: $2^1 = 2$ hops
Landmark routing

Advertisement radius $R_i$

$R_i \geq r_{i+1}$, e.g. $R_i = 2^i$

Routing table entry

- Cluster Level
- Cluster ID
- Path length
- Next-hop ID

Level 1: $2^1 = 2$ hops
Landmark routing

Address ID[0].ID[1].ID[2]
Landmark routing

Address ID[0].ID[1].ID[2]
Routing example: C.A.L → P.O.L
Landmark routing

Address ID[0].ID[1].ID[2]
Routing example:
C.A.L → P.O.L
→ L
Landmark routing

Address ID[0].ID[1].ID[2]

Routing example:
C.A.L → P.O.L
→ L
→ O
Landmark routing

Address ID[0].ID[1].ID[2]

Routing example:
C.A.L → P.O.L
→ L
→ O
Landmark routing

Address ID[0].ID[1].ID[2]

Routing example:
C.A.L → P.O.L
→ L
→ O
→ P
Implementation

Framework

- Captures common features of subset of HR protocols
- Allows for comparing techniques
- TinyOS
  - TOSSIM – low level simulation
- Testbed
Framework

Propagation of advertisements

- Periodic hierarchical beaconing (BHP)
  - Flooding up to $R_i$ hops
  - Optimize for unstable case, higher speed
- Hierarchical distance vector (HDV)
  - Local exchanges of routing tables and labels
  - Optimize for stable case, lower traffic
- Hybrid of PHB and HDV
  - Use HDV in stable case
  - Use PHB in unstable case
Simulation

Realistic radio model

Unit-disk model

Node distributions

- Grid
- Uniform
- Random

Metrics

- Stretch
- State
- Bootstrap and repair time
- Message volume and size
Simulation results

- Logarithmic growth with $N$
- Also holds for average state
Simulation results

- "Gracefull" increase in hop stretch
- Maximum hop stretch of 2
- PHB[e] has exponentially increasing beacon issuing time with level
Simulation results

- HDV sends fewer, but larger messages
Conclusions

Framework allows for experimentation
Simulation shows that Hybrid, HDV or PHB can be used depending on application requirements

Pros
- Simulation and testbed show feasibility of HR
- Low state
- Low average stretch

Cons
- Address changes
- No guarantee of low stretch
- Mobility?
Questions

- Ask away
Pairwise reachability between nodes: node A can reach node B iff there exists a valid route from A to B.