Virtual Localization for Mesh Network Routing

Monash University, Melbourne, Australia.
Center for Telecommunications and Information Engineering,

Nick Moore / Ahmet Sekercioglu / Gregory K. Egan
Sensor networks allow sensors to communicate back to a central point.
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Data must still be collected.
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Miniature sensors allow field measurements.
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Sensor Networks
• Battery power is limited, and processing power and network usage are therefore expensive.

• All nodes are equal.

All routing computation is distributed.

Mesh Sensor Networks
How can we route packets across the mesh?

Routing in a Mesh

- Location based routing
- Route hoarding
- Packet hoarding too inefficient
- Hierarchical partitioning too inflexible
Greedy Forwarding

Simplest algorithm for location-based routing: forward packet to whichever neighbor is nearest the destination.

Example:
- **JKL** is blocked by a `void`.
- **HEFMDG** is longer than **HEFC**.
- But **M** is closer to **G** than **C** is.
- **HEFMDG** is longer than **HEFC**.

Diagram:
- Arrows indicate the direction of forwarding.
Determining Location

- Radio distance-finding
- Anchor nodes (up to 20%)
- Naive solution: GPS
Virtual Location

- Generally only useful for routing purposes
- Internally consistent
- Geometries may not correspond either
- Axes do not correspond to real directions
- Location relative to other nodes

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Virtual Localization for Mesh Network Routing
Spring Models

Attraction

Repulsion

A

B

C
Forces and Potentials - Equations

Node attempts to minimize total potential energy

\[ \sum_{j \in N} U_{ij} = \Omega \]

Electrostatic-like repulsion from 2-neighbors

\[ q_1 \times 8 = \frac{d_{\text{rep}}}{1} \cdot \frac{q_1 + q_2 \cdot p}{1} = q_1 \Omega \]

Spring-like attraction from 1 to 1-neighbors

\[ q_1 \cdot q_2 \cdot p \cdot \frac{d_{\text{attr}}}{1} = q_1 \Omega \]

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Forces and Potentials - 1D

\[ U_C = U_{CA} + U_{CB} \]

\[ U_{CA} \text{ (repulsion)} \]
\[ U_{CB} \text{ (attraction)} \]
\[ U_C = U_{CA} + U_{CB} \]
Forces and Potentials - 2D
Each node is placed so that:

- At least one existing node is in range.
- No nodes are within Range/2.
- At least one existing node is in range.
- Each node is placed so that:

200 nodes

200-node Mesh

Similar to a rooftop network.
Comparison:

Actual Network Map

200-node Mesh

006000 : 200 / 200 / 200

006000 : 200 / 200 / 200
Virtual Localization for Mesh Network Routing

- Node range 100m
- Each node placed at random within a 1km x 1km grid
- 400 nodes

400-node Mesh

http://www.ctte.monash.edu.au/mesh/virt_loc/one.animated.gif

one.animated.gif
Questions

- Multiple root nodes / anchors
- Node mobility / energy conservation
- 3D, 4D virtual spaces (in submission to IEEE TPDS)
- More sophisticated routing algorithms

Further Work