GLIDER:
Gradient Landmark-Based Distributed Routing for Sensor Networks

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Topological Information

- Reflects connectivity
- Stable
- Compact
Geographic Routing in Sensornet

- Real geographic coordinates based
  - Only works in 2-D space
  - Sensitive to location inaccuracy and obstacles
  - Accurate coordinates are difficult and expensive to obtain

- Virtual coordinates based
  - Requires global embedding of the link connectivity graph in the plane
  - Forcing a 2-D layout on a 3-D deployment may ignore much of the actual connectivity present
GLIDER – the Basics

- A communication graph $G = (V, E)$ on sensor nodes $V$, with path length measured by shortest path hop counts
- Landmark Voronoi cell (LVC)
- Combinatorial Delaunay Triangulation (CDT) – estimate global topology
Theorem: If $G$ is connected, then the CDT graph $D(L)$ for any subset of landmarks $L$ is also connected.

Then:

- Every path in $G$ can be “lifted” to a path in $D(L)$
- Every path in $D(L)$ can be realized as a path in $G$

$D(L)$ is an appropriate simplification of $G$ for determining a global routing strategy
A Global Local Scheme

- Requires relatively stable global topology to afford proactive routing at an abstract combinatorial level

- Such high-level routes can then be realized as actual paths in the network by using reactive protocols

GLIDER

- G is decomposed into two parts
  - The common auxiliary atlas M (CDT) that encodes global connectivity information accessible to every node
  - The node names that encode node specific information and stored in each node
Naming/Addressing and Routing

• Encoding global information for proactive routing
  – IP
  – Geographical location
  – Distance to a selected subset of nodes landmarks
GLIDER -- Routing

- Global routing
- Local routing
  - Inter-tile routing
  - Intra-tile routing
Local Coordinates and Greedy Routing

$\sigma = \text{mean}(p_{L_1}^2, \ldots, p_{L_k}^2)$

$c(p) = (p_{L_1}^2 - \sigma, \ldots, p_{L_k}^2 - \sigma)$

d $(p, q) = |c(p) - c(q)|^2$

Greedy strategy: to reach $q$, gradient descent on the function $d(p, q)$
Examples
Local Landmark Coordinates – Local Minima

- **Theorem:** In the continuous Euclidean plane, gradient descent on the function $d(p, q)$ always converges to the destination $q$, provided that there are at least three non-collinear landmarks.

- in the discrete case, we observe that landmark gradient descending does not get stuck on networks with reasonable density.
Node Density vs. Success Rate of Greedy Routing

2000 nodes distributed on a perturbed grid.
Perturbation ~ Gaussian(0, 0.5r), where r is the radio range

<table>
<thead>
<tr>
<th>average number of neighbors</th>
<th>2.9</th>
<th>3.2</th>
<th>4.1</th>
<th>≥ 5.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>percentage of success</td>
<td>20</td>
<td>70</td>
<td>95</td>
<td>100</td>
</tr>
</tbody>
</table>
On-board Memory Requirement

- Geographical routing
  - Its coordinate and those of its neighbors
- GLIDER
  - Its coordinate and those of its neighbors
  - CDT
Simulations -- Load Balancing and Path Length
Simulations – Hot Spots Comparison
GLIDER – Summary

• We make no attempt to provide a global geometric embedding

• A topology-enabled naming and routing scheme that based purely on link connectivity information

• Works by separating the global topology and the local connectivity
  – Use topological information to build a routing infrastructure
  – Propose a new coordinate system for a node based on its hop distances to a subset of landmarks

• Advantages
  – location-free
  – infrastructure (CDT) is lightweight
  – routing is efficient and local
  – takes only connectivity graph as input
  – robust to network models (UDG, quasi-UDG, what else?)
Future Work

• Criteria and algorithms for landmark selection
• Potential multi-resolution LVC hierarchies
• Possible distributed methods for handling network dynamics