

GLIDER:

Gradient Landmark-Based Distributed Routing for Sensor Networks

Qing Fang

Jie Gao

Leonidas J. Guibas

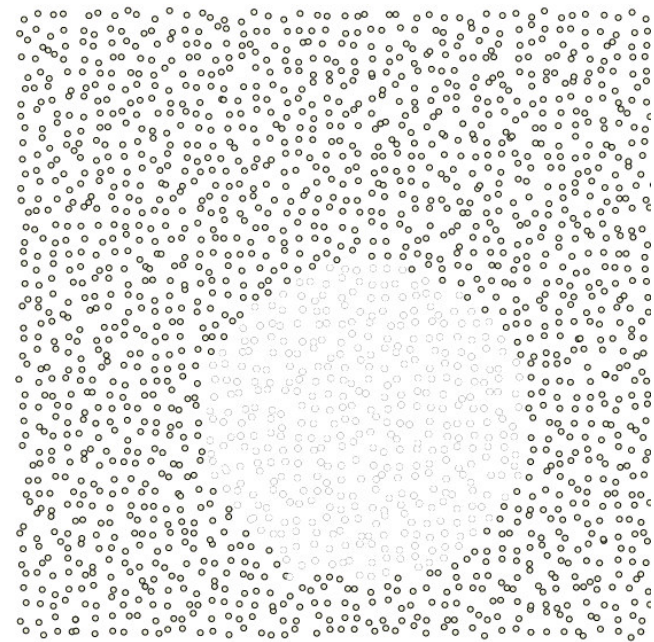
Vin de Silva

Li Zhang

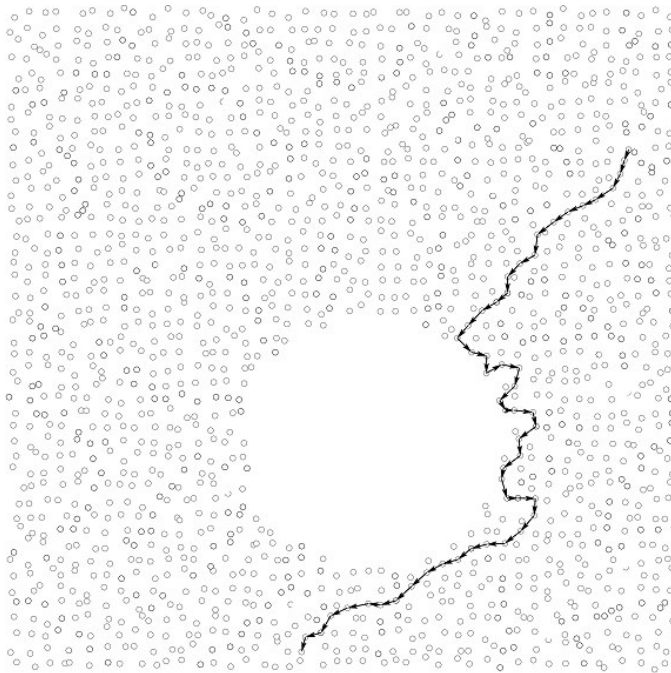
Stanford University

Topological Information

- Reflects connectivity
- Stable
- Compact



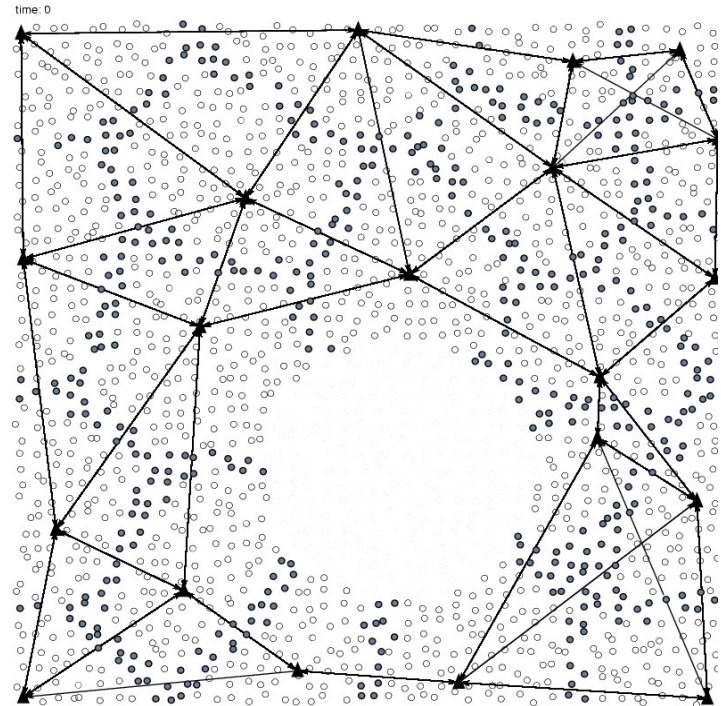
Geographic Routing in Sensornet



- 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

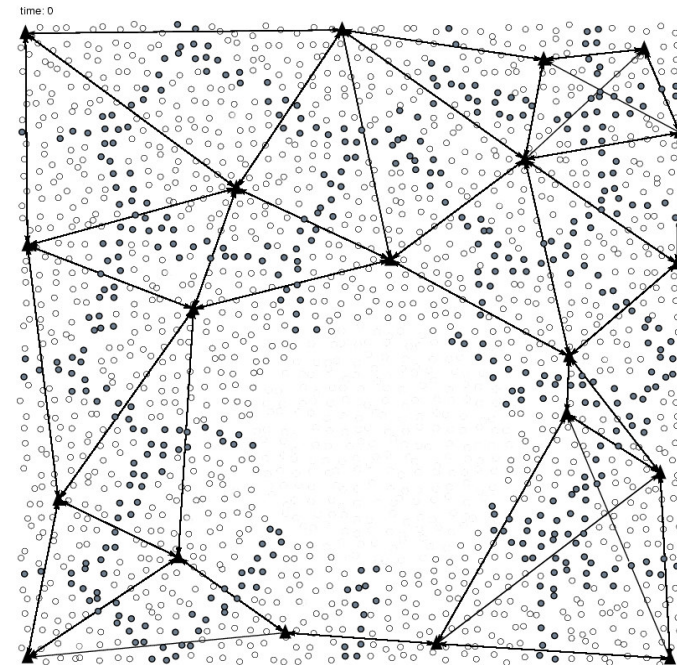


Theorem: If G is connected, then the CDT graph $D(L)$ for any subset of landmarks L is also connected.

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**

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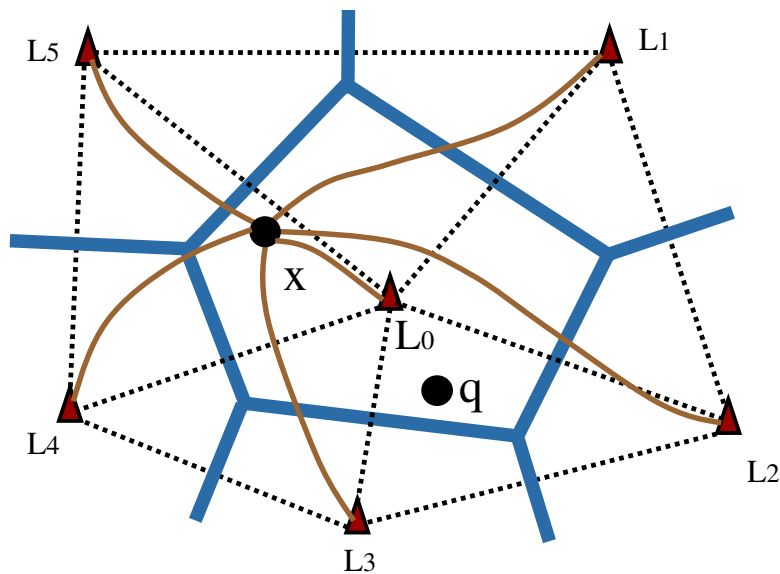
- G is decomposed into two parts
 - The common auxiliary atlas M (CDT) that encodes global connectivity information accessible to every node
 - The node names that encode node specific information and stored in each node

Naming/Addressing and Routing

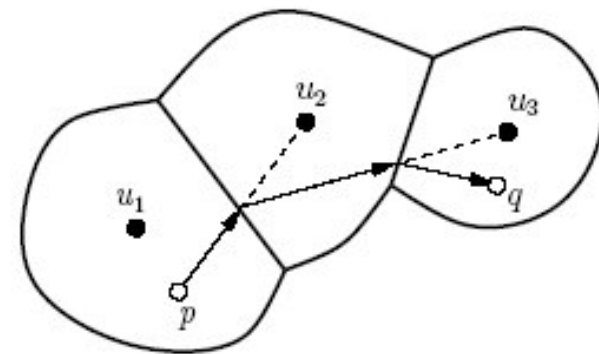
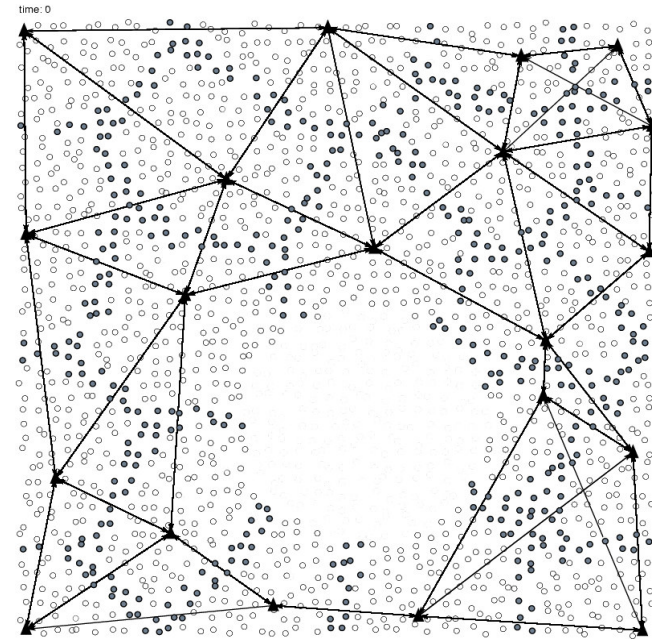
- Encoding global information for proactive routing
 - IP
 - Geographical location
 - Distance to a selected subset of nodes landmarks

GLIDER -- Routing

- Global routing
- Local routing
 - Inter-tile routing
 - Intra-tile routing

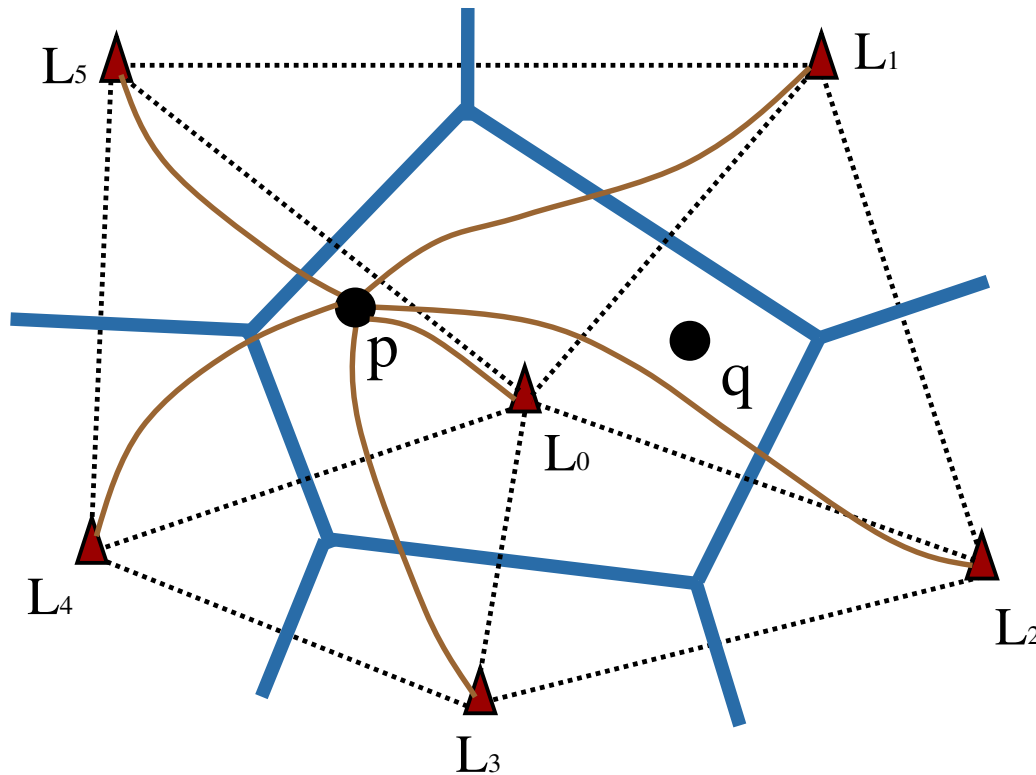


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Local Coordinates and Greedy Routing



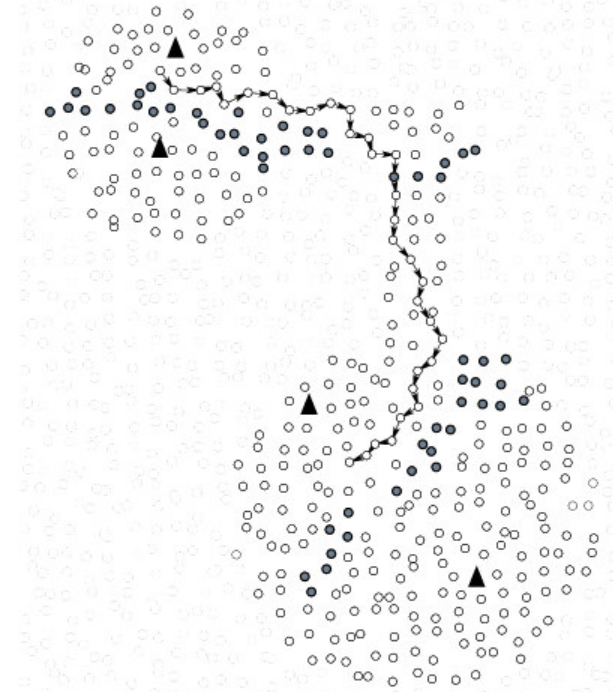
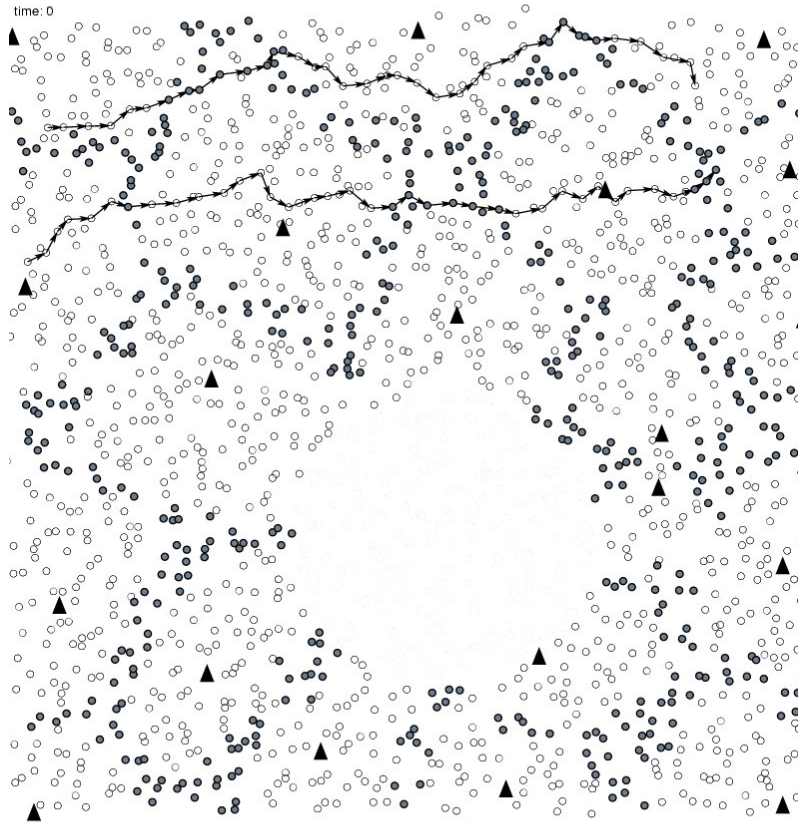
$$\sigma = \text{mean}(pL_1^2, \dots, pL_k^2)$$

$$c(p) = (pL_1^2 - \sigma, \dots, pL_k^2 - \sigma)$$

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

Greedy strategy: to reach q , gradient descent on the function $d(p, q)$

Examples

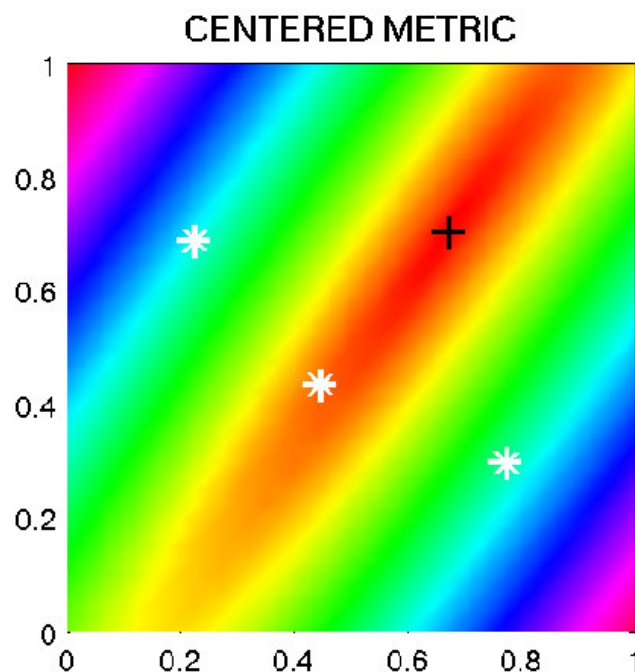


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Local Landmark Coordinates – Local Minima

- **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 \sim Gaussian(0, 0.5r), where r is the radio range

average number of neighbors	2.9	3.2	4.1	≥ 5.3
percentage of success	20	70	95	100

On-board Memory Requirement

- Geographical routing

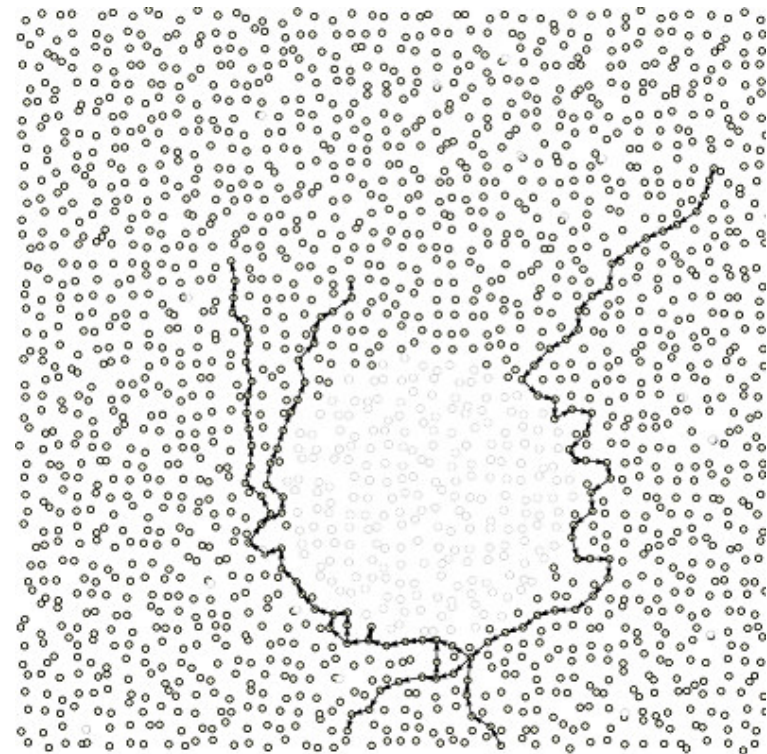
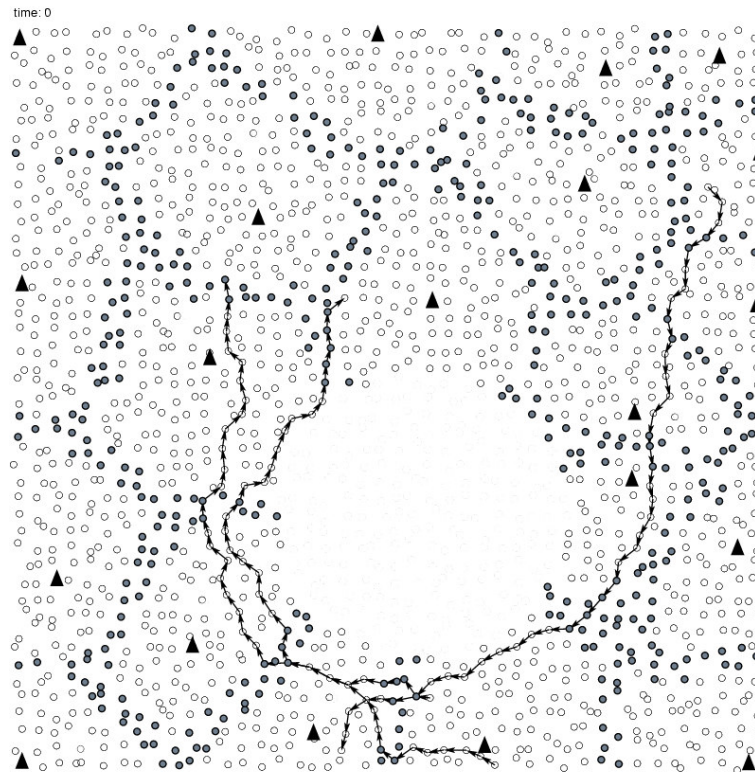
Its coordinate and those of its neighbors

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Its coordinate and those of its neighbors

CDT

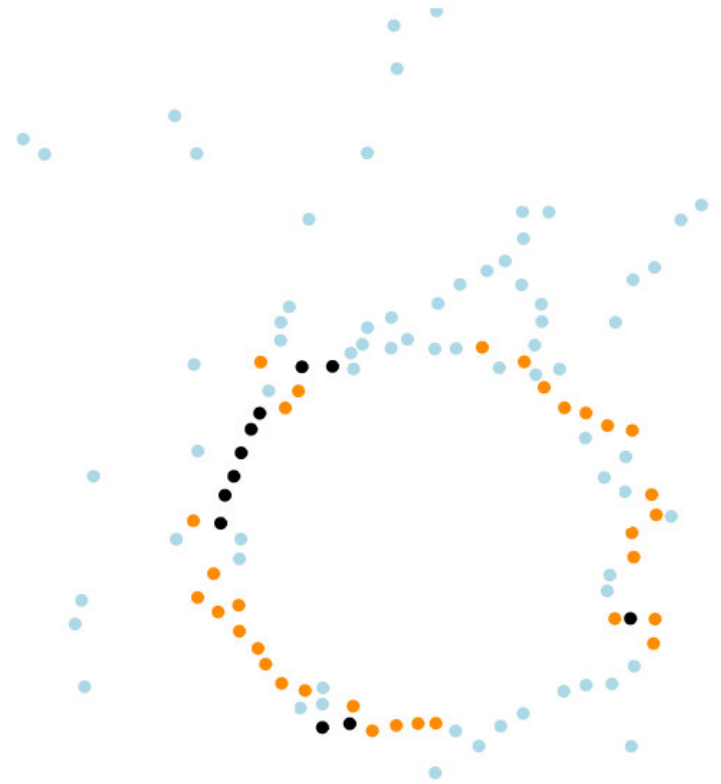
Simulations -- Load Balancing and Path Length



Simulations – Hot Spots Comparison



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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