Virtual Geographic Routing

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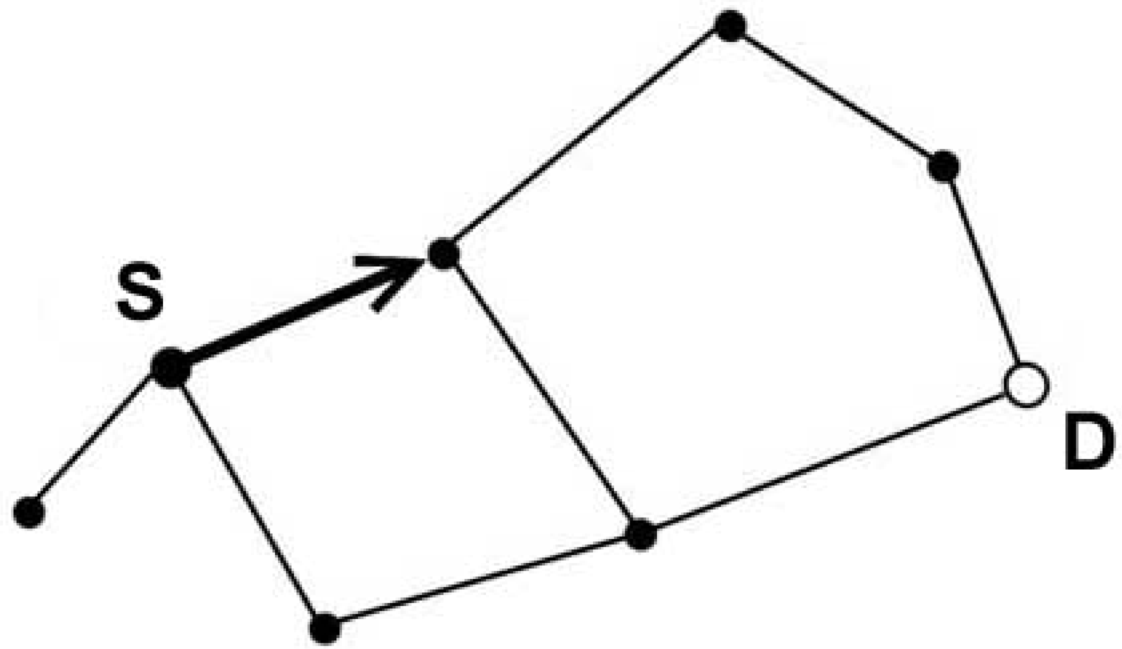
Virtual Geographic Routing

- Virtual Geographic Routing (VGR) is an ad hoc routing protocol that is scalable to massive numbers of nodes.

- VGR does geographic routing using virtual coordinates in K-dimensional space.

Geographic Routing

- At every hop, the message is forwarded to a neighboring node that is closer to the destination



Geographic Routing

- Advantage: Geographic routine (GR) requires only a small fixed amount of routing information at each node, so is massively scalable

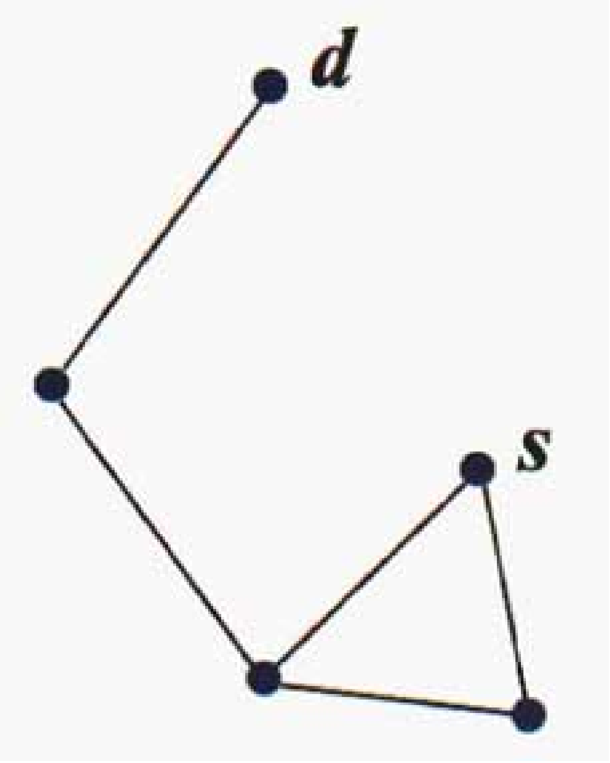
- Disadvantage: Nodes must know their locations in space
  - Typically requires GPS units, which increase the size, weight, cost and power consumption of the nodes and do not function in all environments

VGR

- VGR replaces x,y spatial coordinates with K virtual coordinate developed using only connectivity information
- The virtual coordinates are the number of the hops from K anchor nodes
  - Anchors may be self-selected or set *a priori*
- Virtual coordinates developed using algorithm similar to distributed Bellman-Ford
- The geographic routing algorithm works with virtual coordinates
  - Various distance metrics may be used: Euclidean works well

Failures of Geographic Routing

- Geographic routing fails when it encounters a local minimum of the distance function (also called a *void, hole* or *lake*).

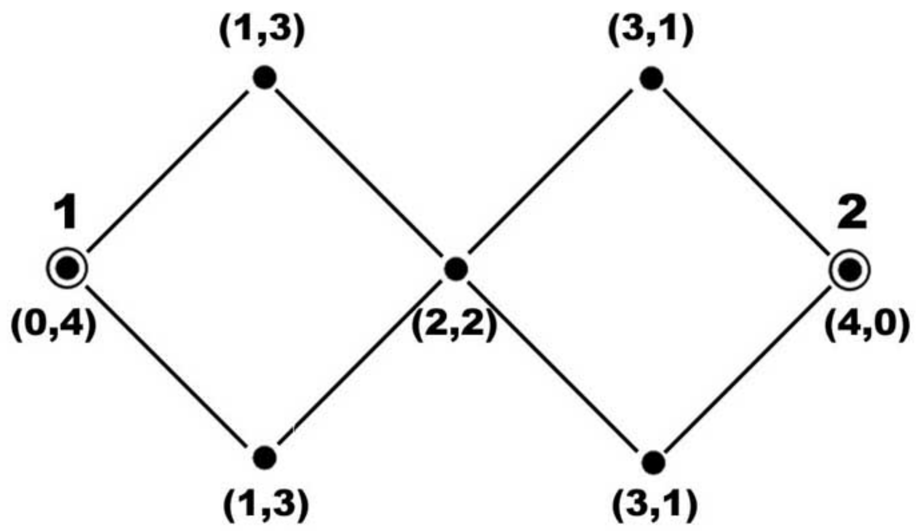


Dealing with Voids

- Perimeter routing
  - Derive planar subgraph and use the right-hand rule
  - Only works for unit graphs and in two dimensions
    - Real networks don't tend to be unit graphs
    - We require more than two dimensions for good routing in VGR
- Expanding ring search
  - Search for node closer to the destination than the current node and use it as an intermediate destination
  - Cache the result to cut down network overhead

Aliasing

- Different VGR nodes can have the same virtual coordinates



- We also use an expanding ring search to learn the path from an aliased node to the destination and cache the result

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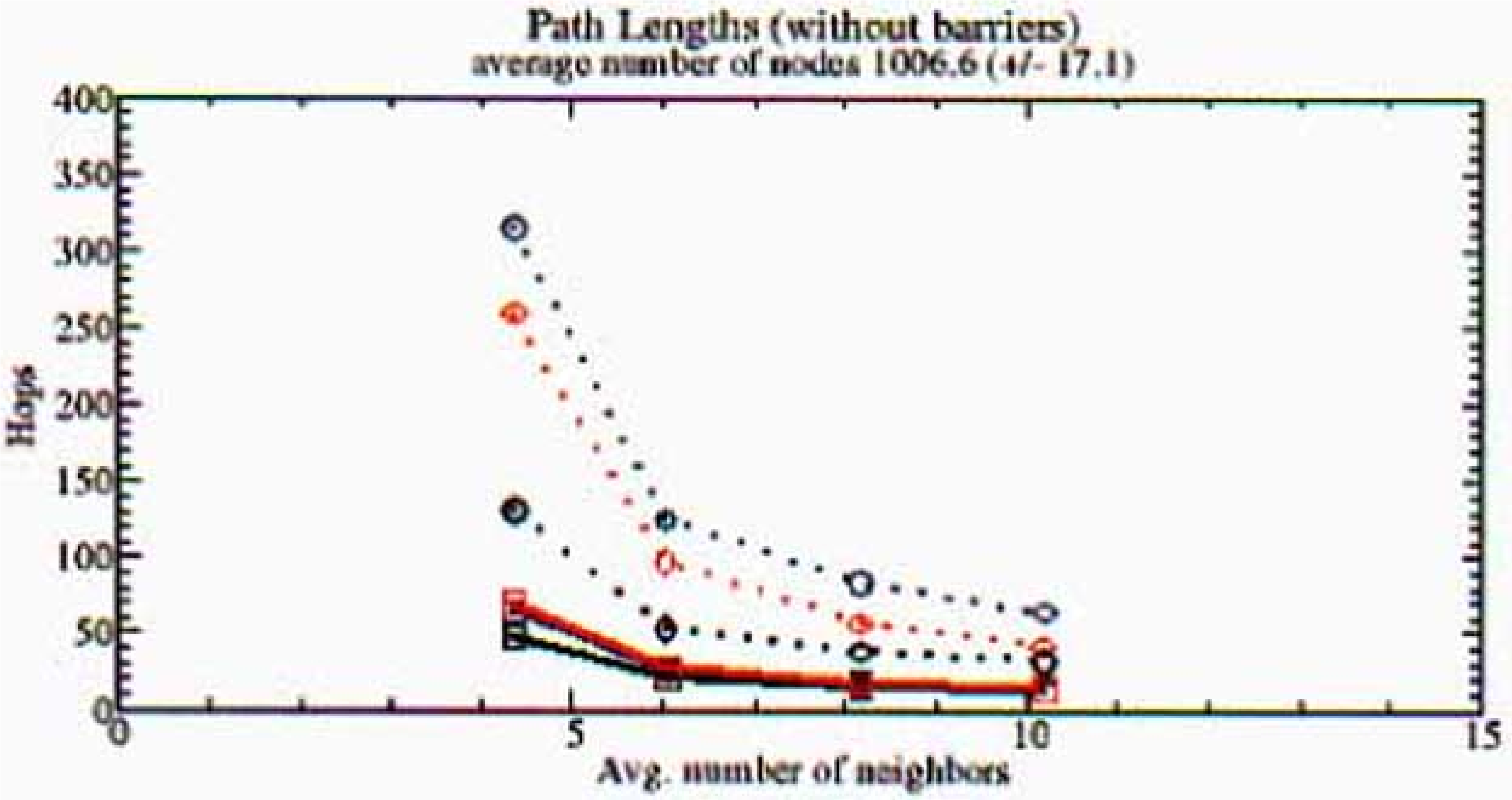
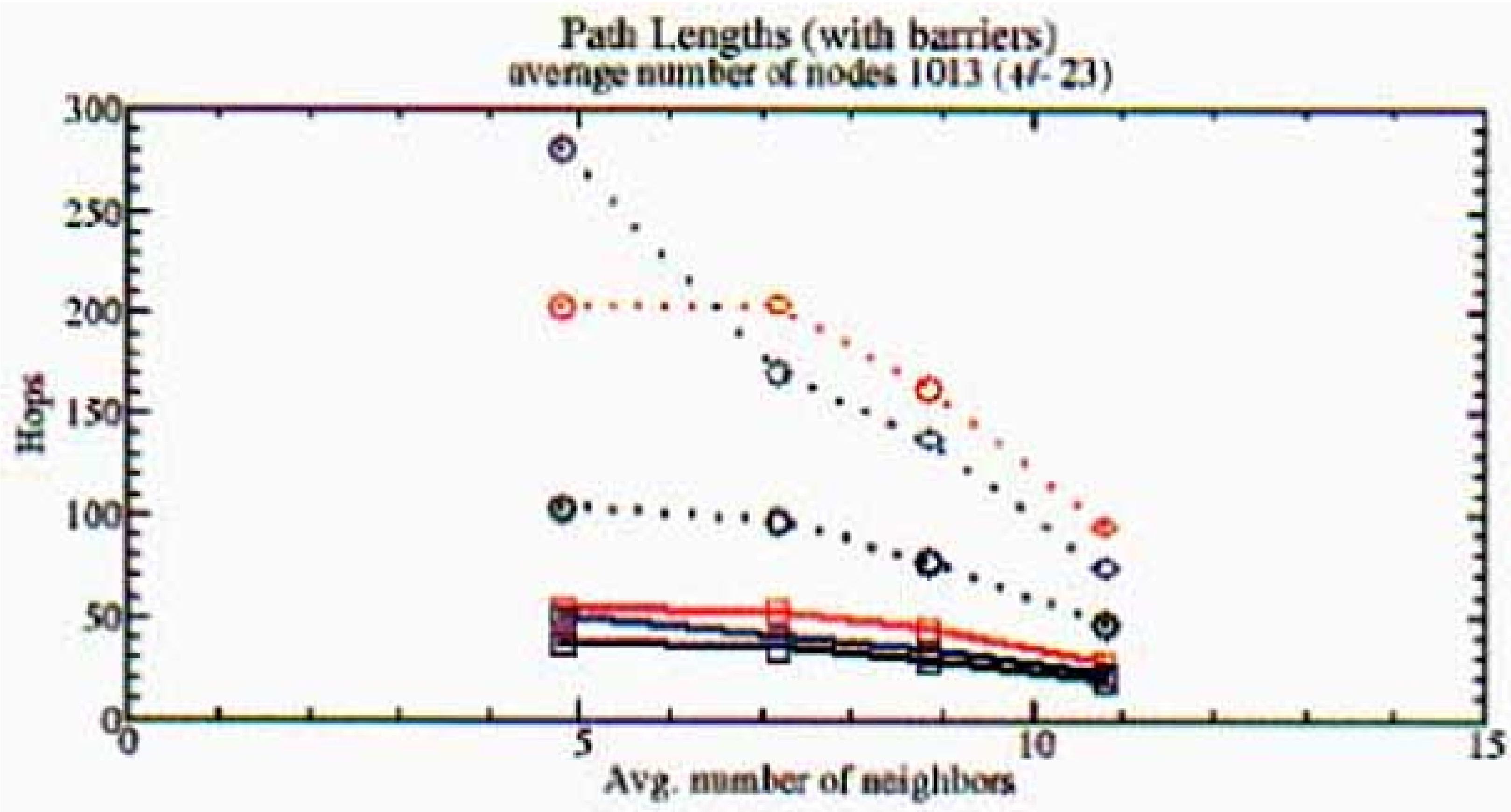
Performance

- Performance data were gathered using simulation on random node layouts in two dimensions
  - Simulated up to 10000 nodes
- The performance of VGR is comparable to that of “real” GR and has much lower overhead in the presence of obstacles
- Neither RGR nor VGR develops shortest paths, but the average path length approaches the shortest path length as the average node degree increases

Performance (2)



Performance (3)



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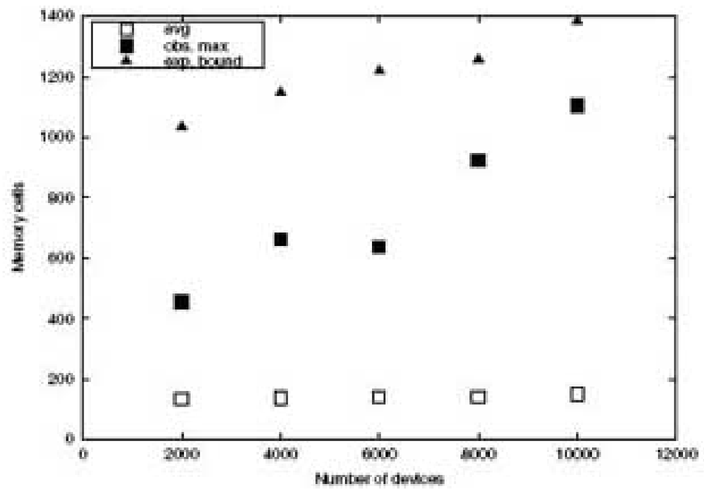
Performance (4)

- The important scalability metric is the amount of local storage used for routing information at each node
- As the average node degree rises above about 8, the average local storage requirement levels off, and the expected maximum local storage requirement is bounded logarithmically in the network size.



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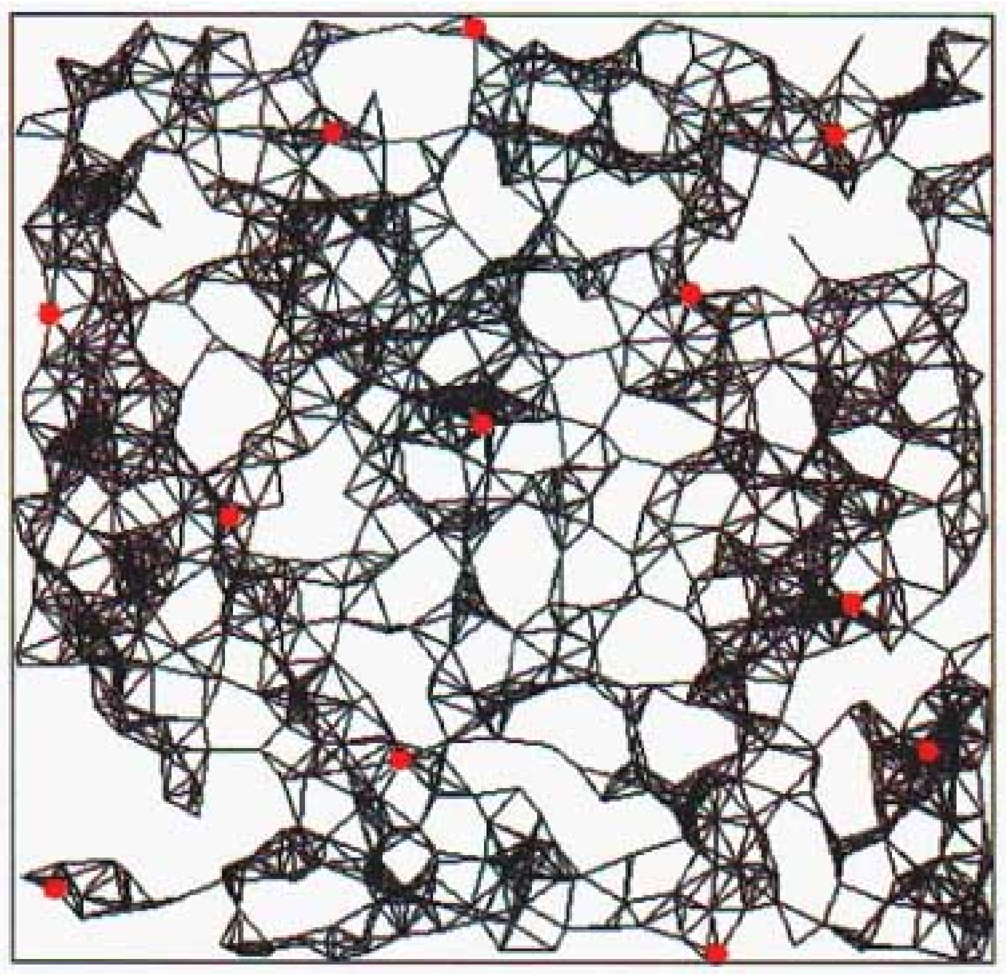
Performance (5)

- In the presence of obstacles, RGR is much more susceptible to voids than VGR
  - RGR expends a much greater proportion of its hops on routing around voids than VGR when obstacles are present

	No Barriers			With Barriers		
	GR	VGR	GR/VGR	GR	VGR	GR/VGR
fraction geo. hops	0.95	0.93	1.02	0.66	0.90	0.73
ratio search hops / total hops	0.0034	0.0030	1.13	0.778	0.046	17
max/average flood radius	8.4/2.66	8.5/2.28	0.99/1.16	40.5/4.7	14.3/2.76	2.83/1.70
max/average hops to alias	—	2.3/0.99	—	—	16.6/3.56	—

1016-Node Graph
12 Anchors, Average Node Degree 9.3



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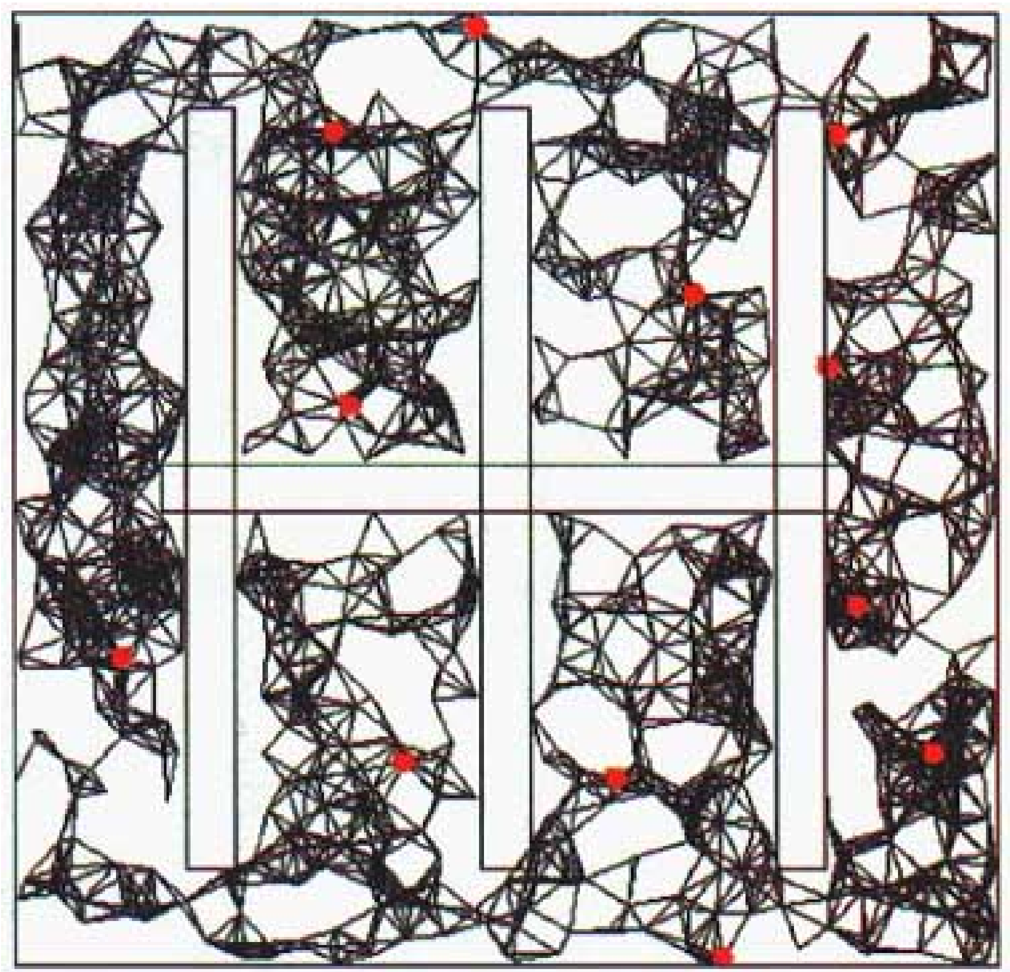
1024-Node Graph With Barriers
12 Anchors, Average Node Degree 9.9



Other Work

- "Geographic routing without location information," Rao, Ratnasamy, Papadimitriou, Shenker and Stoica, *MobiCom*, 2003.
  - Develops 2- or 3-dimensional spatial coordinates using only connectivity information.
  - Their approach is more complicated than ours, using 2 or 3 fixed beacons and requiring all nodes to learn the internode distance between each pair of perimeter nodes.

Other Work (2)

- "Localization from mere connectivity," Shang, Rumi, Zhang and Fromherz, *MobiCom*, 2003.
  - Develops 2- or 3-dimensional spatial coordinates using a centralized algorithm
  - The coordinates are not used for routing
- "Geographic routing in hyperbolic space," Kleinberg, *slides available on Web,* 2006.

References

- “Simulation Analysis of Virtual Geographic Routing,” Nicol, Goldsby and Johnson, *WinterSim*, 2004.
- *Robust Message Routing for Mobile Ad Hoc (Wireless) Networks*, Goldsby, Tsang, Johnson, Chen, Bierbaum and Ammerlahn, SAND2003-8762.