Networking for Sensor Nets II

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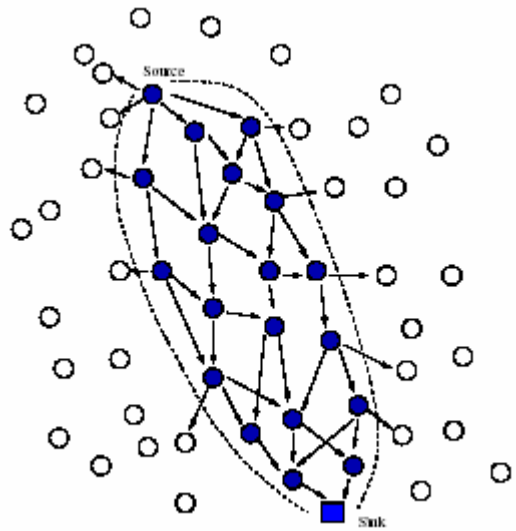


Geographic Routing, Large-Scale Analysis

- Geographic routing
  - Simplest type of attribute-based routing
  - Can be done with little or no preprocessing; topology state kept at each node is minimal
  - Can be made energy-aware
- Analysis of optimal radio range for nodes
  - to balance delay vs. bandwidth
  - to insure adequate network connectivity

Geographic Routing

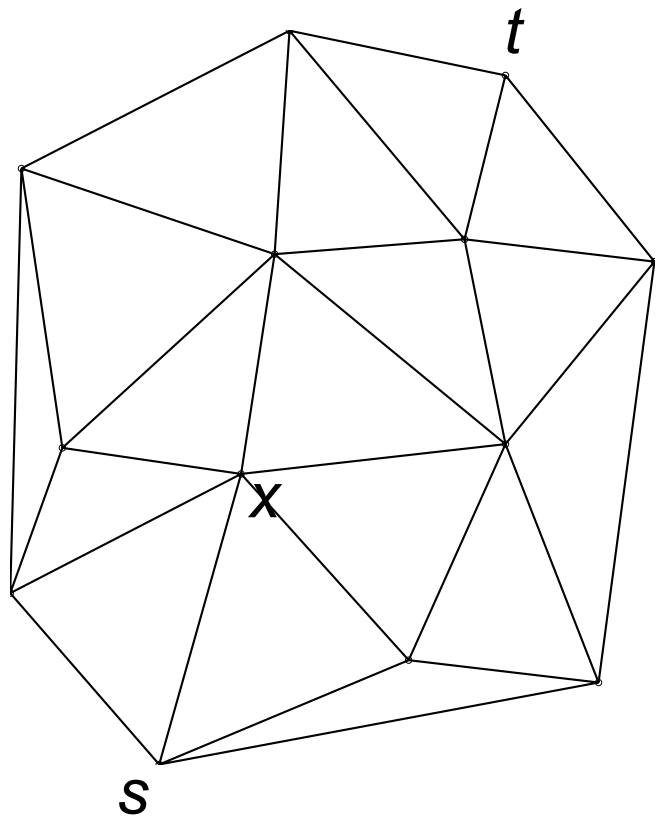
Key assumptions:

- nodes know their geographic location
- each node knows its immediate 1-hop neighbors
- the routing destination is specified either as a node with a given location, or as a geographic region
- each packet can hold a bounded amount of information to help with the routing algorithm

Greedy Unicast Geographic Routing

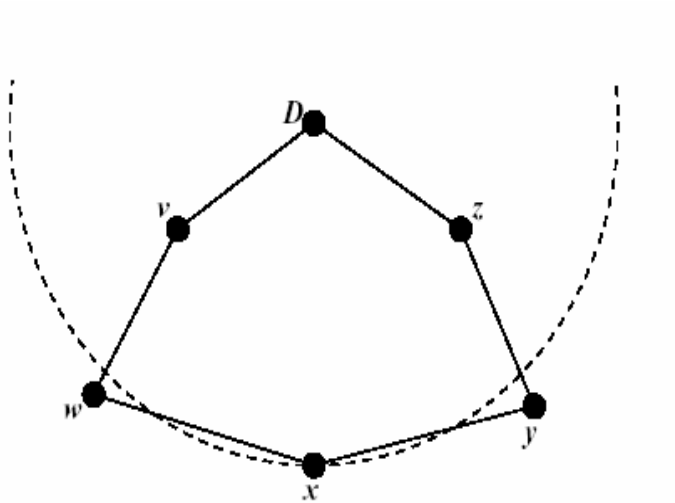
To go from source *s* to destination *t*, at each intermediate node *x* advance to the neighbor that makes progress towards *t*.

- greedy distance routing (GPSR)
- compass routing



Greedy Protocols Can Get Stuck

- The intermediate node *x* can be a local optimum towards the destination
- To prove that such situations cannot happen we need to assume special properties about the connectivity graph *G*
- In general, local optima can arise if the graph contains “holes”



Measures of Path Quality

- First and foremost, a protocol should guarantee packed delivery, when such delivery is possible
- Second, the quality of the path produced should be good when compared to the optimal path available. Different path costs can be used:

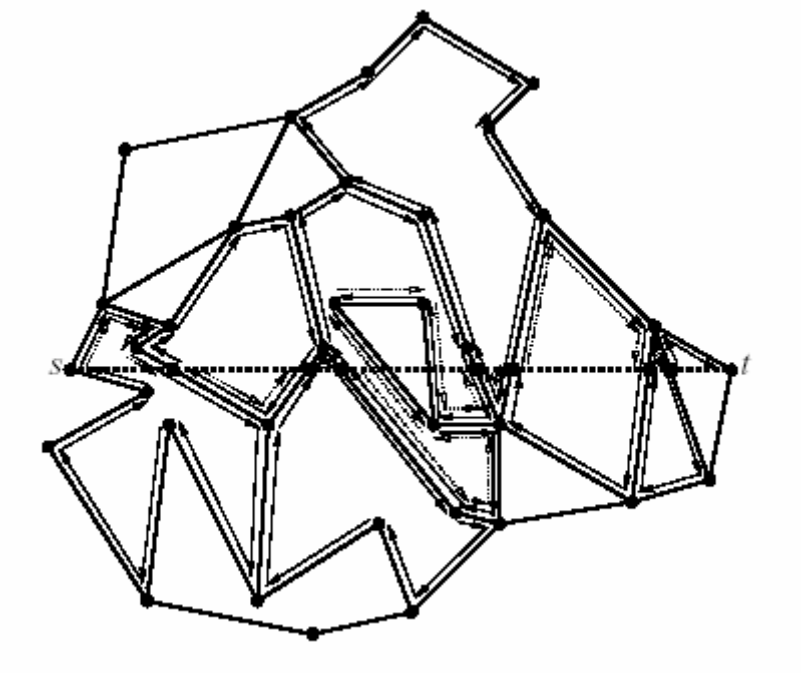
$$c(\pi) = \sum_{e \in \pi} l^d(e),$$

$$d = 0,1,2,3,4,...$$

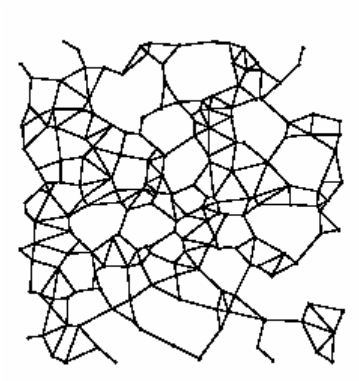
- These can be made roughly equivalent by assuming a constant node density or a minimum node spacing

Planarizations of the Routing Graph

- To guarantee packet delivery, it may be advantageous to disable some connections, so as to make the routing graph planar
- On a planar graph, perimeter routing guarantees delivery
- The quality of paths can be bad, however

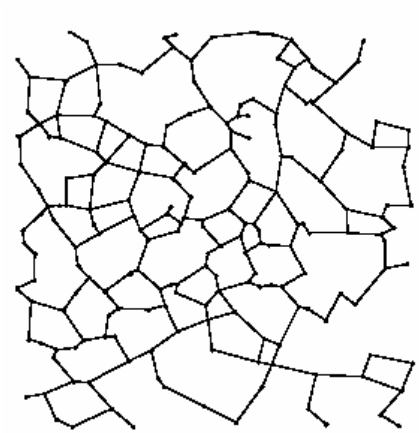


Geometric Graphs

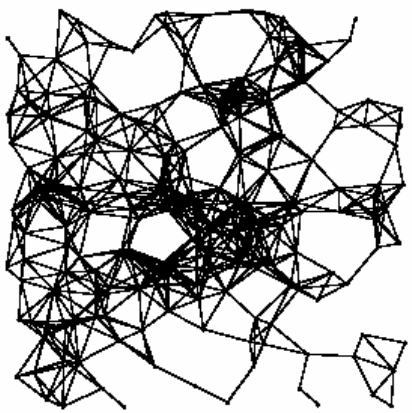


- path quality?
- distributed construction?

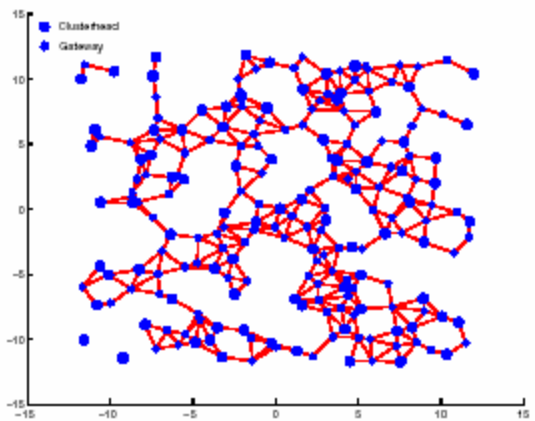
Gabriel Graph



Restricted Delaunay Graph (RDG)



Relative Neighborhood Graph (RNG)



Greedy Perimeter Stateless Routing (GPSR)

Planarize the connectivity graph *G*

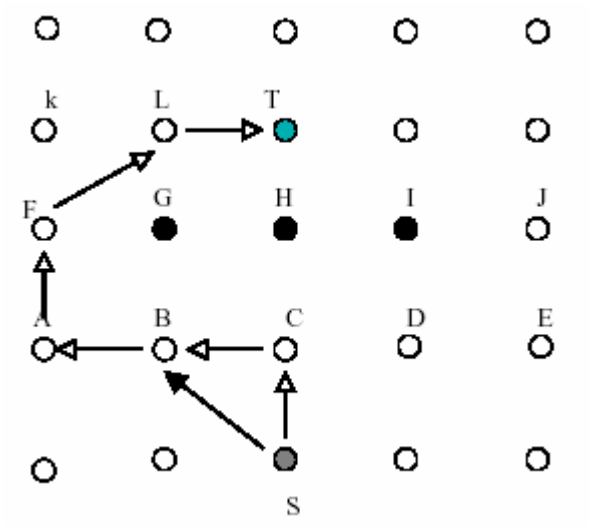
- Use greedy distance protocol on the full *G*
- If stuck, switch to perimeter protocol on the planarization of *G*,until a node closer to the destination than the stuck node is encountered

Energy-Aware Routing

- Nodes providing circumnavigation around holes may carry a lot of traffic in GPSR and become depleted
- GEAR (Geographically and Energy Aware Routing) provides both geographic routing to a region (multicast) as well as load-balancing for power preservation

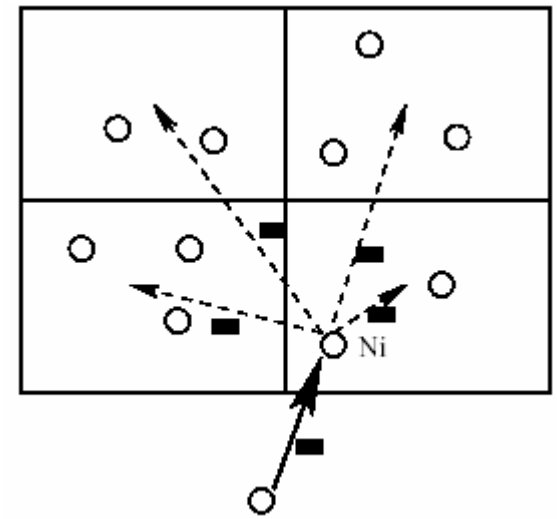
Learning Routes Around Holes

- Maintain “learned cost to destination region” at each node
- Initially cost is based on geometric distance
- Over time, it can be adapted to include energy information and thus to produce routes that avoid failed nodes or those whose power is low



Recursive Geographic Forwarding

Once inside region, use
divide-and-conquer to
avoid expensive
broadcast/region flooding



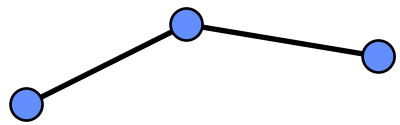
Large-Scale Network Analysis

- Goal: broadly understand the trade-offs involved in varying the field size, number of nodes, and broadcast radius on the connectivity of the network and its performance characteristics (delay, bandwidth)
- Usually assume
  - each node has a communication range that is a disk of radius *R* centered at the node
  - random node placement

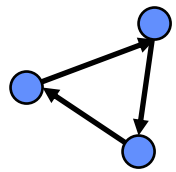
Types of Network Connectivity

A graph G may be

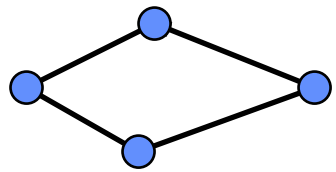
- connected



- strongly connected

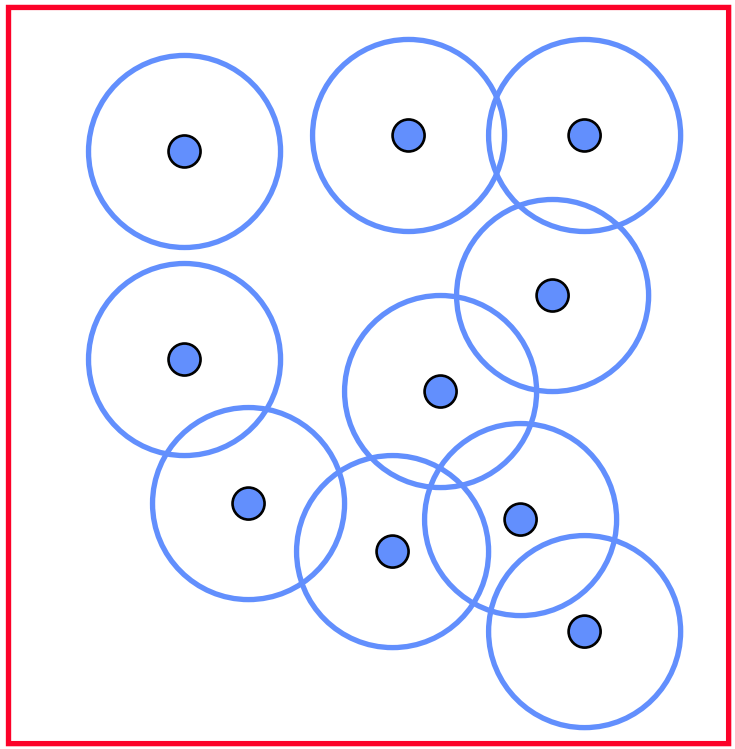


- bi-connected



Random Disk Overlap Model

- Represent nodes by disks of radius *R*/2 centered at the nodes
- Throw *n* such at random inside a square of side L
- What is the probability that their overlap graph is connected (bi-connected)?



Impact of Node Communication Range (*R*)

- Increasing R increases connectivity
  - more robust network
  - smaller delay (fewer hops to destination)
- But also
  - uses more power
  - cause more interference among nodes, thus diminishing the effective bandwidth per node

Key Issues

- Geographic routing:
  - termination
  - path quality
  - amount of state kept in packet or network
  - load balancing
- Large-scale analysis:
  - understand trade-offs in setting node communication range, number of nodes to be deployed, etc