Virtual Localization for Mesh Network Routing

Nick Moore / Ahmet Şekercioğlu / Gregory K Egan

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

Sensor Networks

- Miniature sensors allow field measurements
- Data must still be collected
- Sensor networks allow sensors to communicate back to a central point

Mesh Sensor Networks

- All nodes are equal.
- All routing computation is distributed.
- Battery power is limited, and processing power and network usage are therefore expensive.

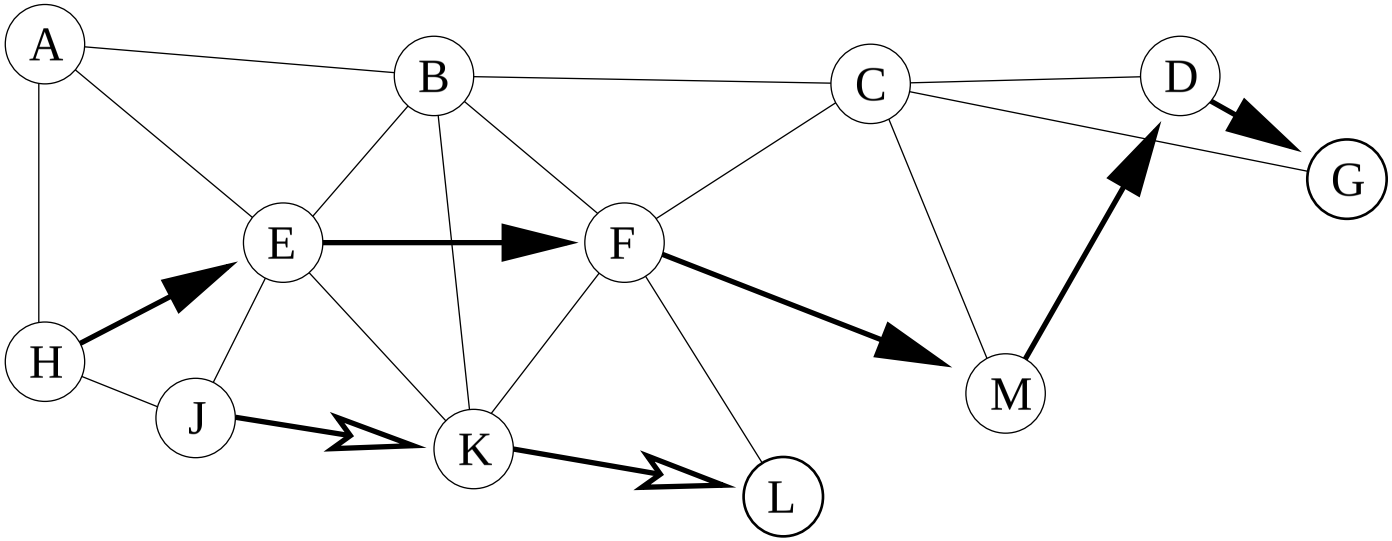
Routing in a Mesh

How can we route packets across the mesh?

- hierarchical partitioning too inflexible
- packet flooding too inefficient
- route flooding
- location based routing

Greedy Forwarding

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



- $\overrightarrow{HEFMDG}$ is longer than $\overrightarrow{HEFCG}$,
  but F forwards to M as M is closer to G than C is.
- $\overrightarrow{JKL}$ is blocked by a 'void'.

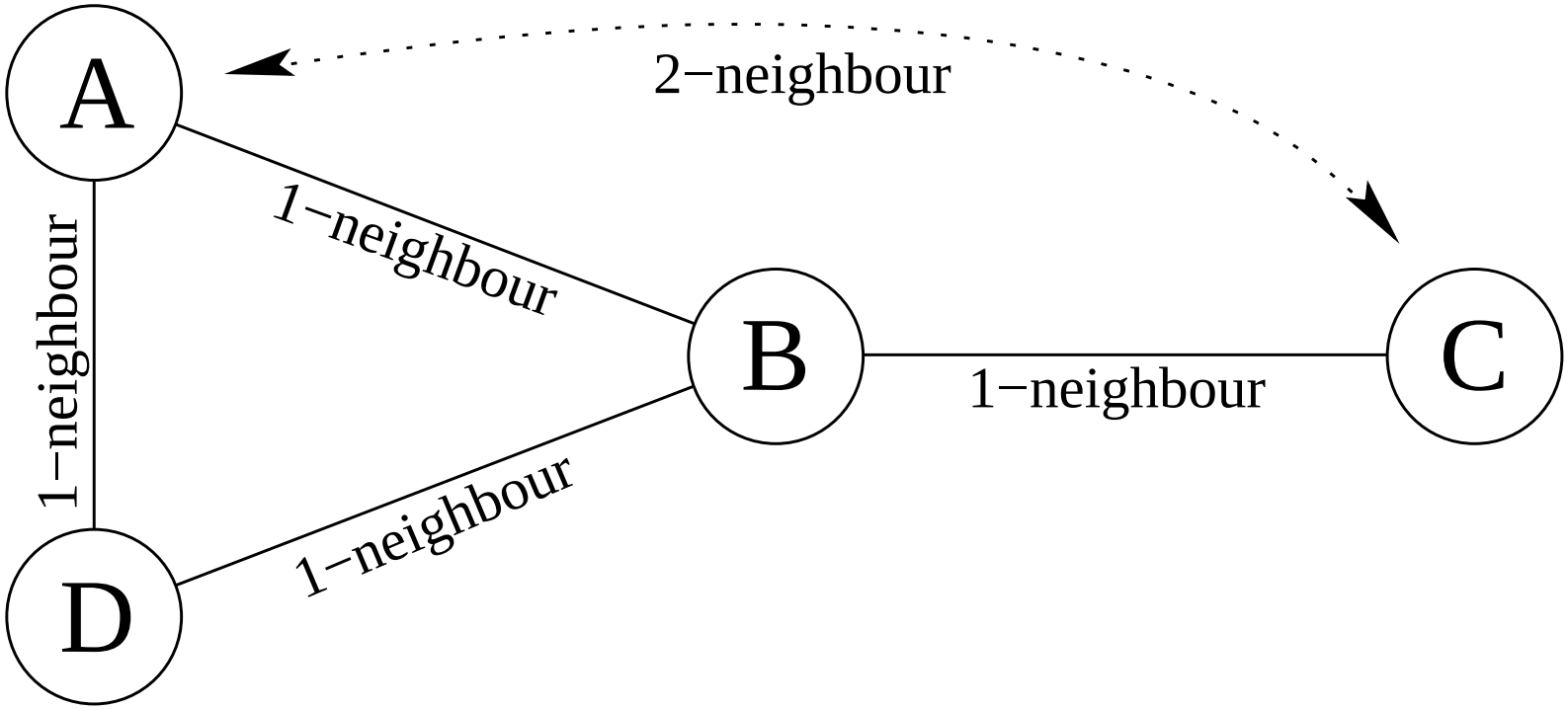
Determining Location

- Naïve solution: GPS
- 'Anchor' nodes (up to 20%)
- Radio distance-finding

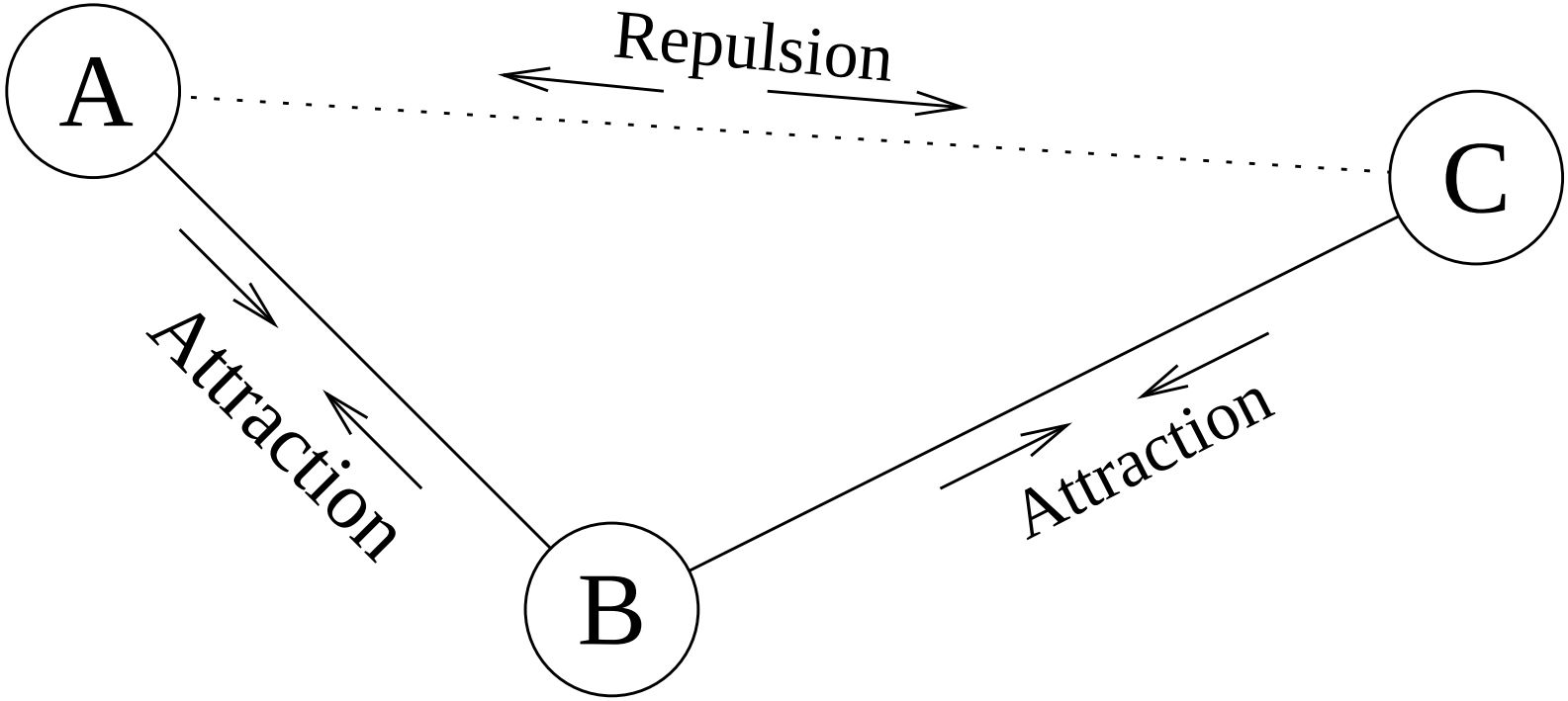
Virtual Location

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

n-neighbours



Spring Models



Forces and Potentials - Equations

- Springlike attraction $F \propto d$ to 1-neighbours

$$U_{ij} = k_{att} \cdot d_{ij}^2 \quad ; \quad k_{att} = 1$$

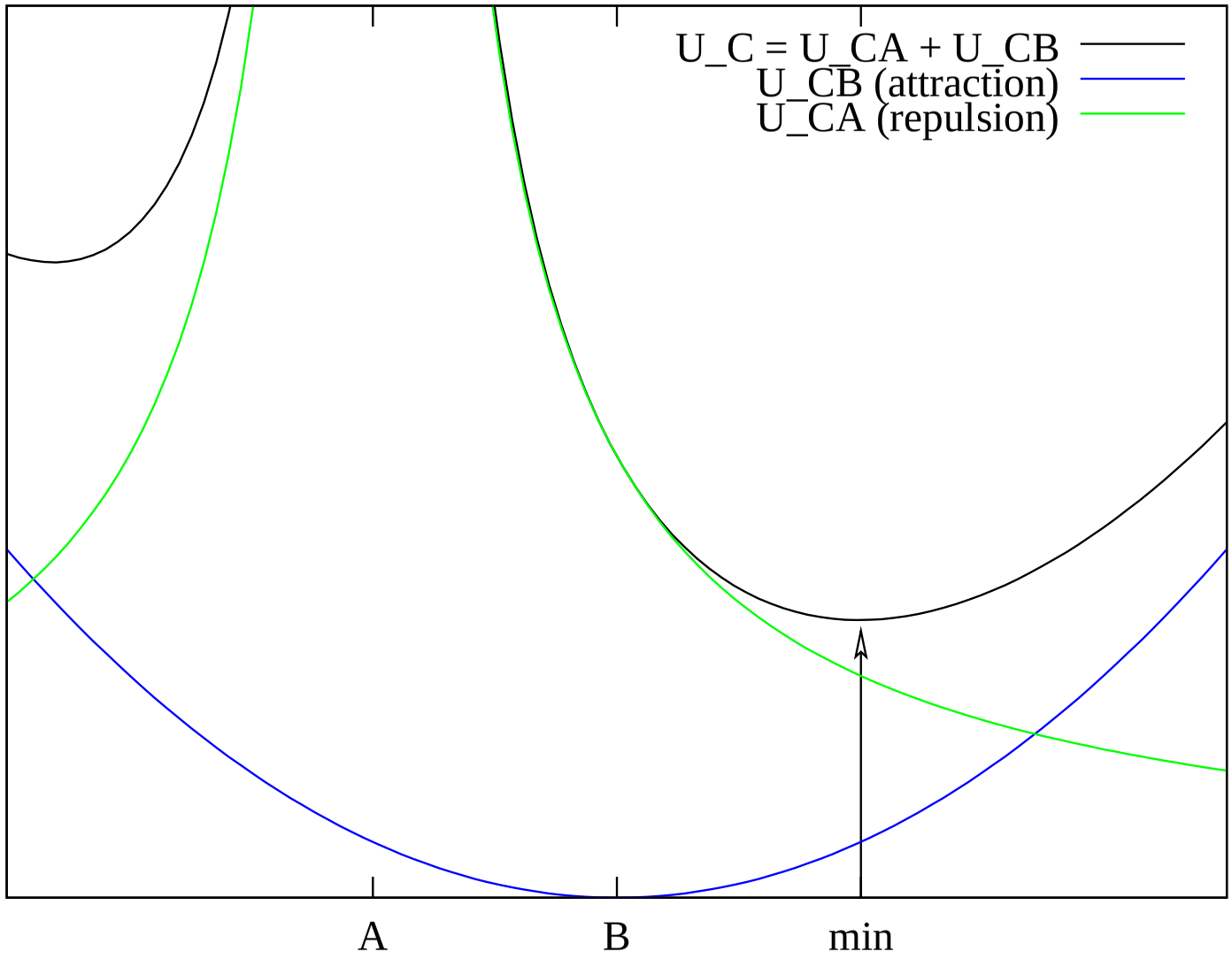
- Electrostatic-like repulsion $F \propto 1/d^2$ from 2-neighbours

$$U_{ik} = k_{rep} \cdot \frac{1}{d_{ik} + 1} \quad ; \quad k_{rep} = 8 \times 10^6$$

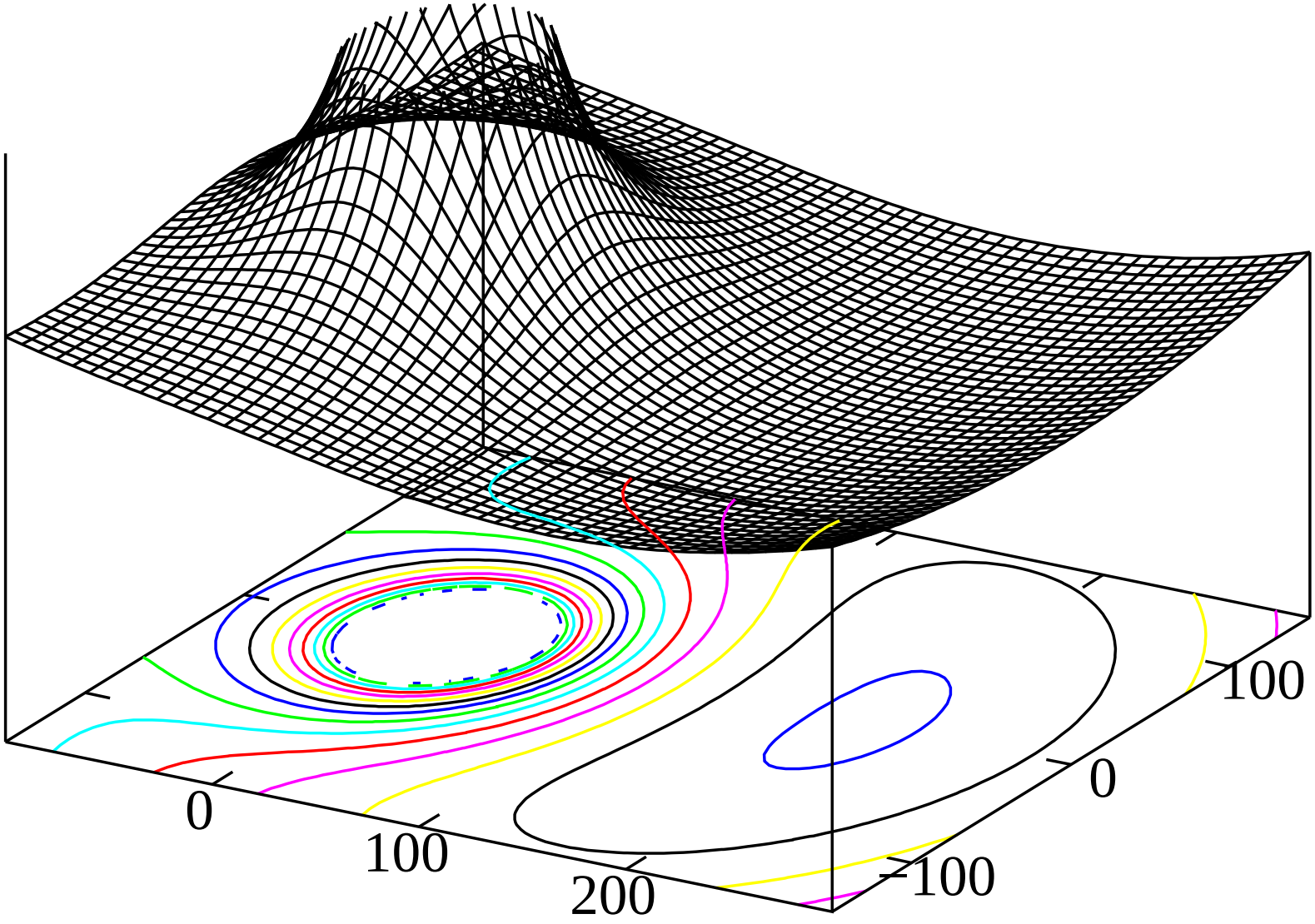
- Node attempts to minimize total potential energy

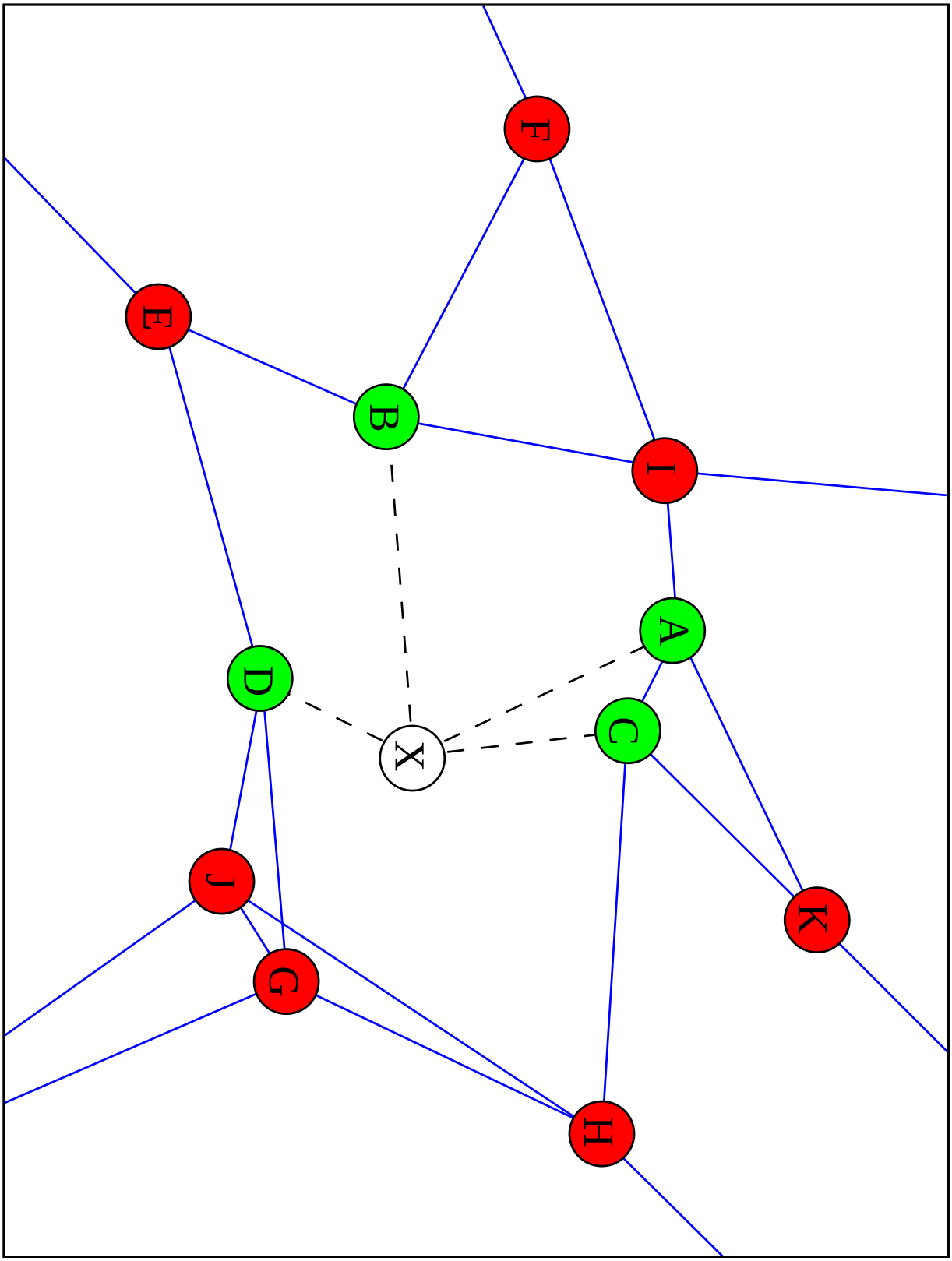
$$U_i = \sum_{j \in N} U_{ij}$$

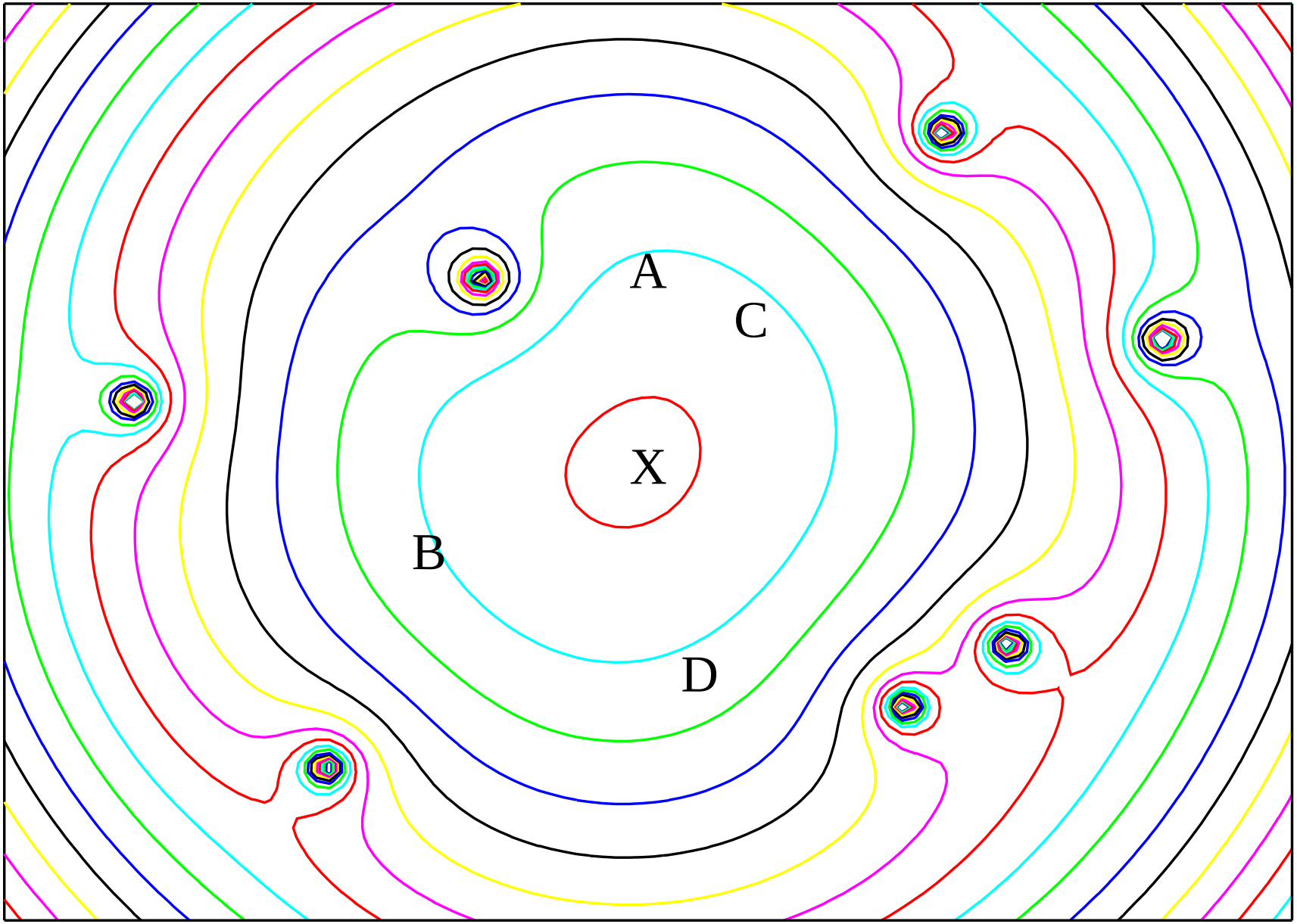
Forces and Potentials - 1D



Forces and Potentials - 2D




F
E
B
I
A
D
C
X
J
K
G
H


A
C
X
B
D

200-node Mesh

- 200 nodes
- Each node is placed so that:
  - ◇ at least one existing node is in range
  - ◇ no nodes are within range/2
- similar to a rooftop network

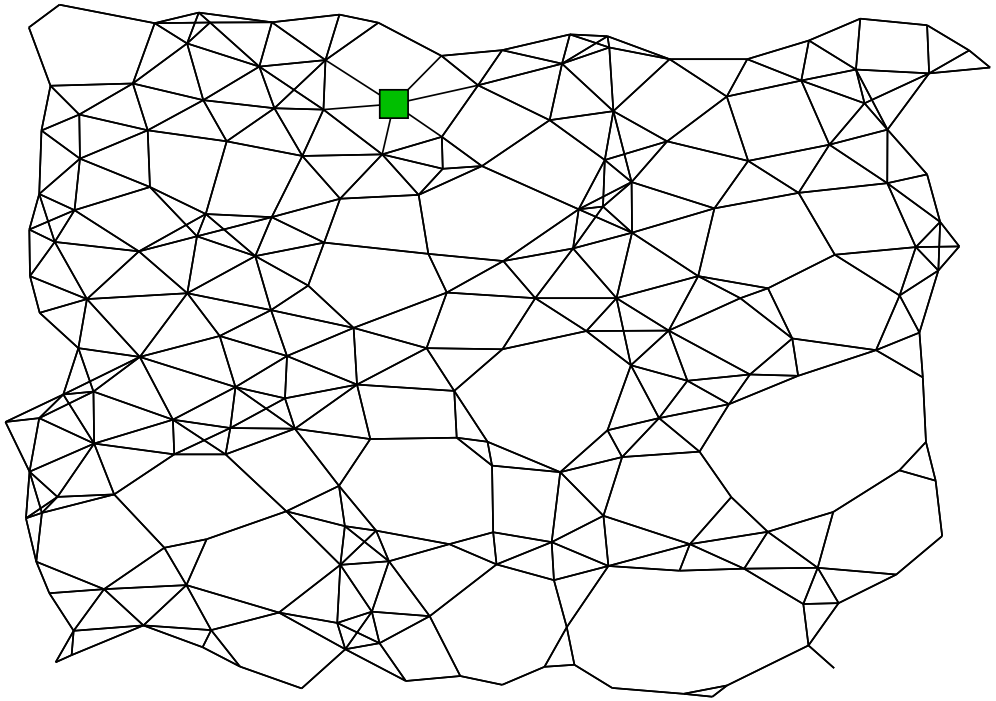
`http://www.ctie.monash.edu.au/mesh/virt_loc/two.gif`

`./two.animated.gif`

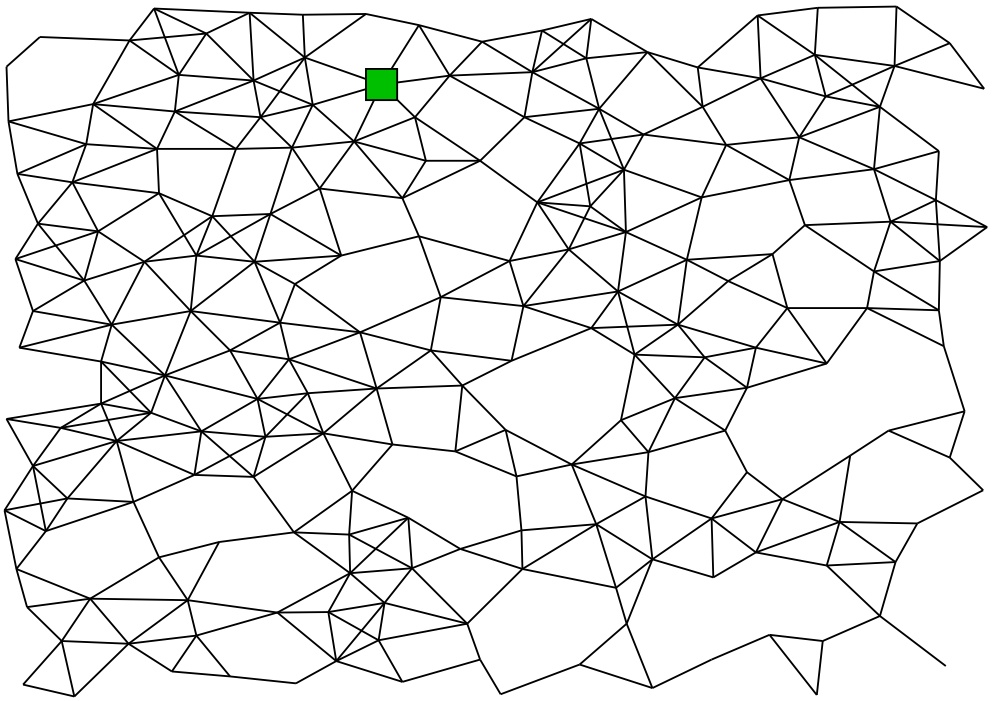
200-node Mesh

Comparison:

006000 : 200 / 200 / 200



Actual Network Map



400-node Mesh

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

`http://www.ctie.monash.edu.au/mesh/virt_loc/one.gif`

`./one.animated.gif`

Further Work

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

Questions?