

# Virtual Localization for Mesh Network Routing

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## 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.

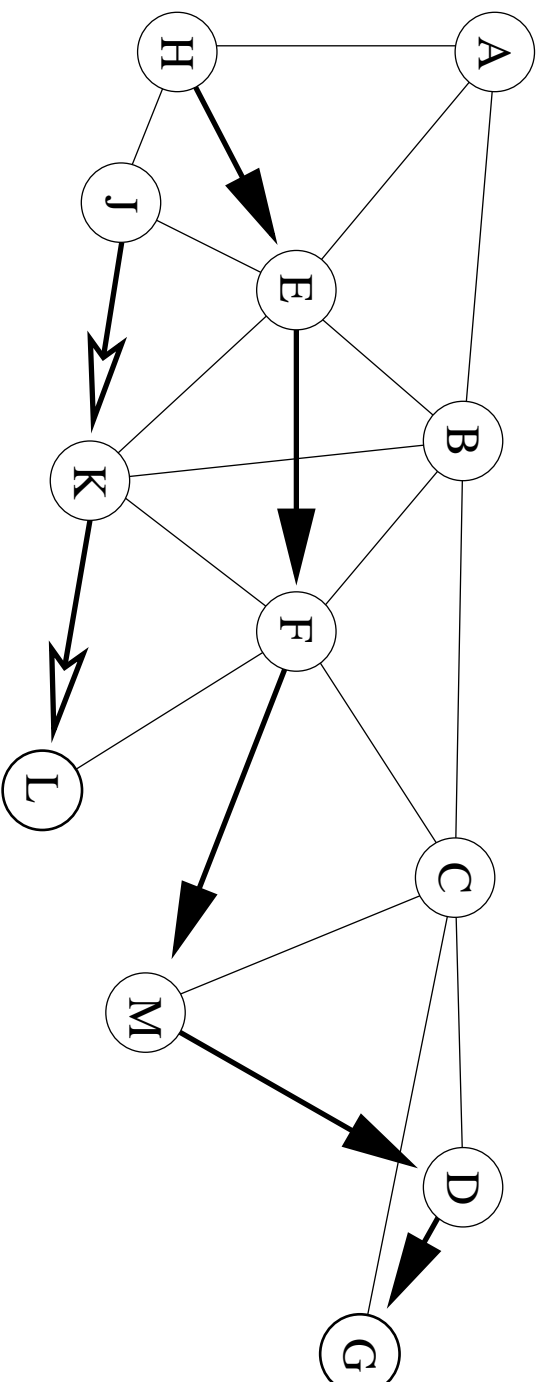
## Routing in a Mesh

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’.

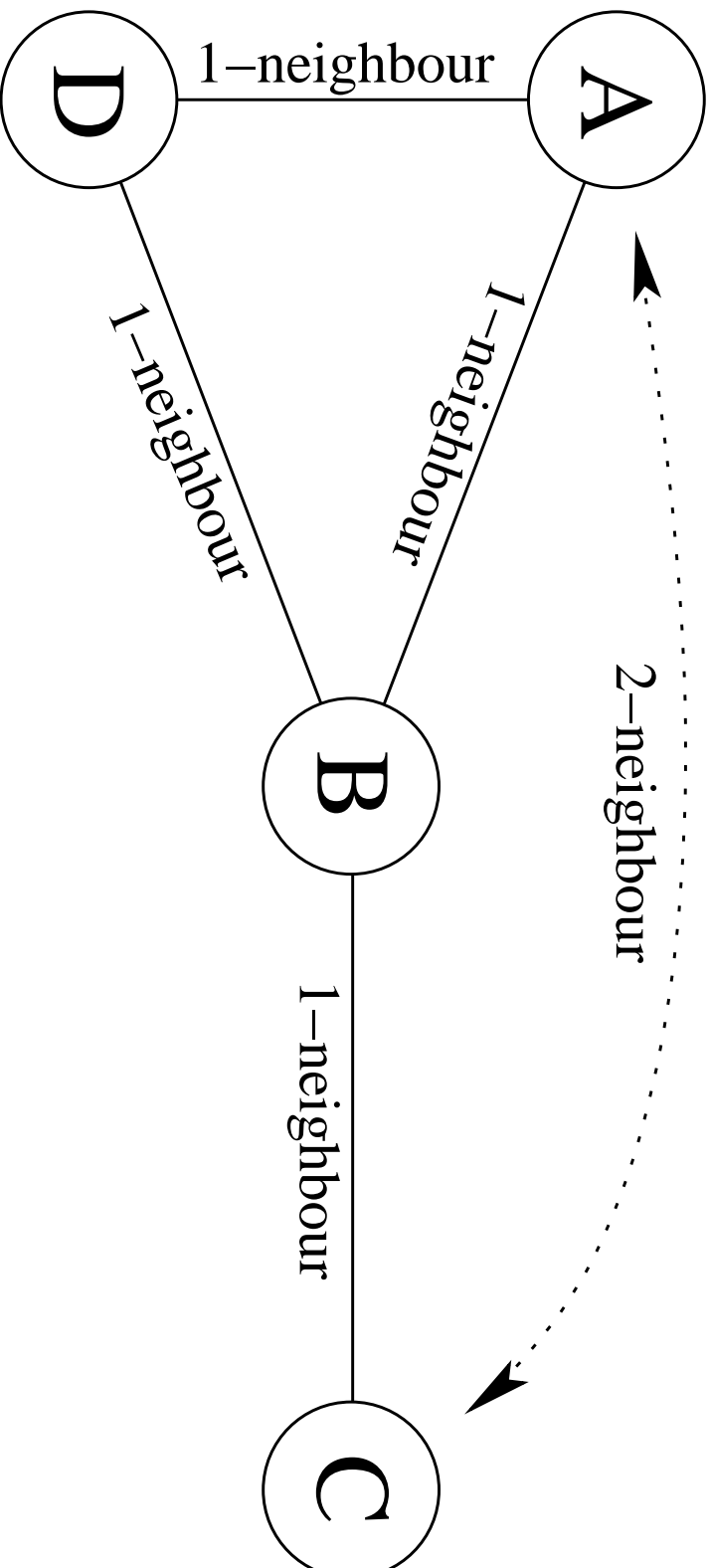
## Determining Location

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

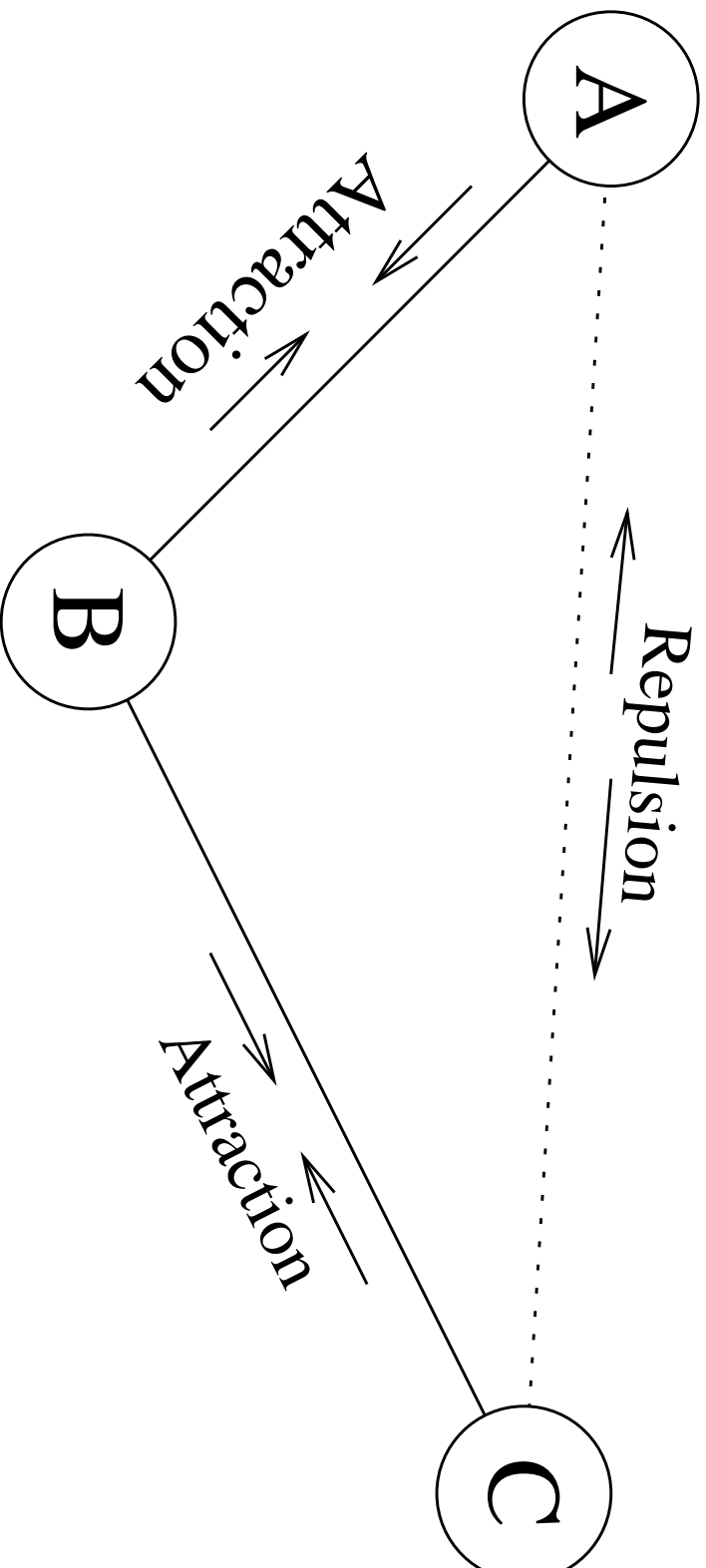
## Virtual Location

- 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

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

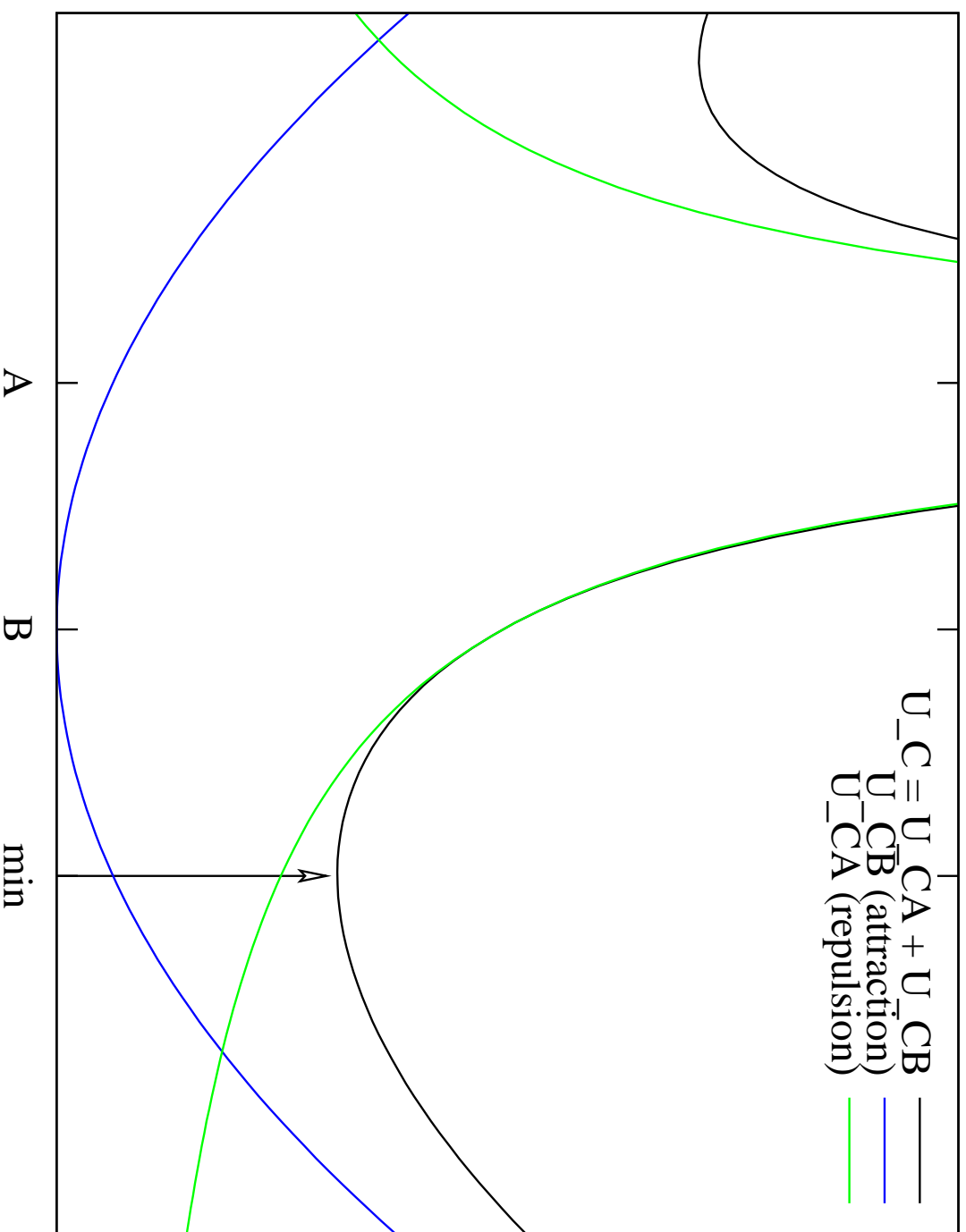
- Electrostatic-like repulsion  $F \propto 1/d^2$  from 2-neighbours

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

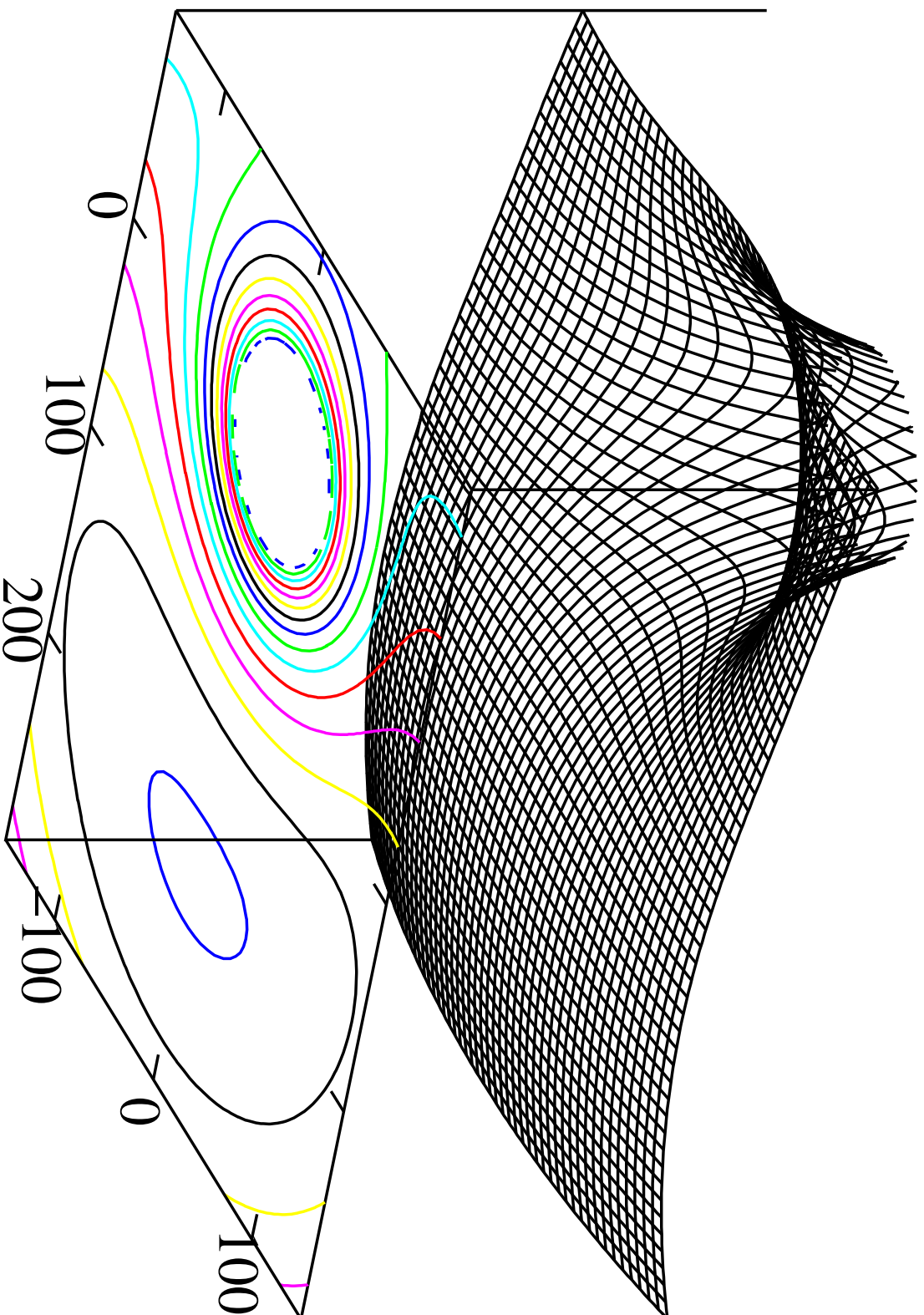
- Node attempts to minimize total potential energy

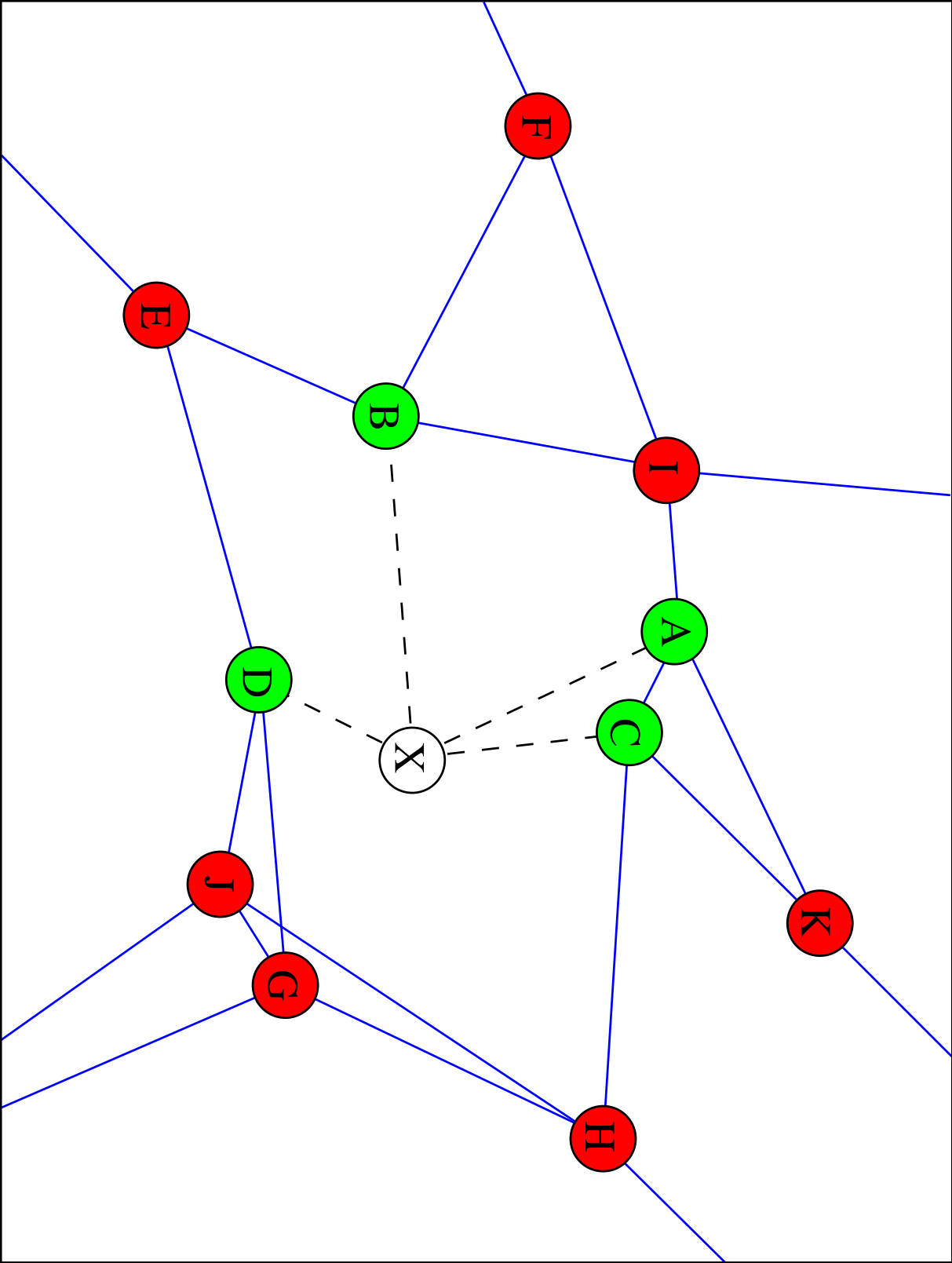
$$U_i = \sum_{j \in N} U_{ij}$$

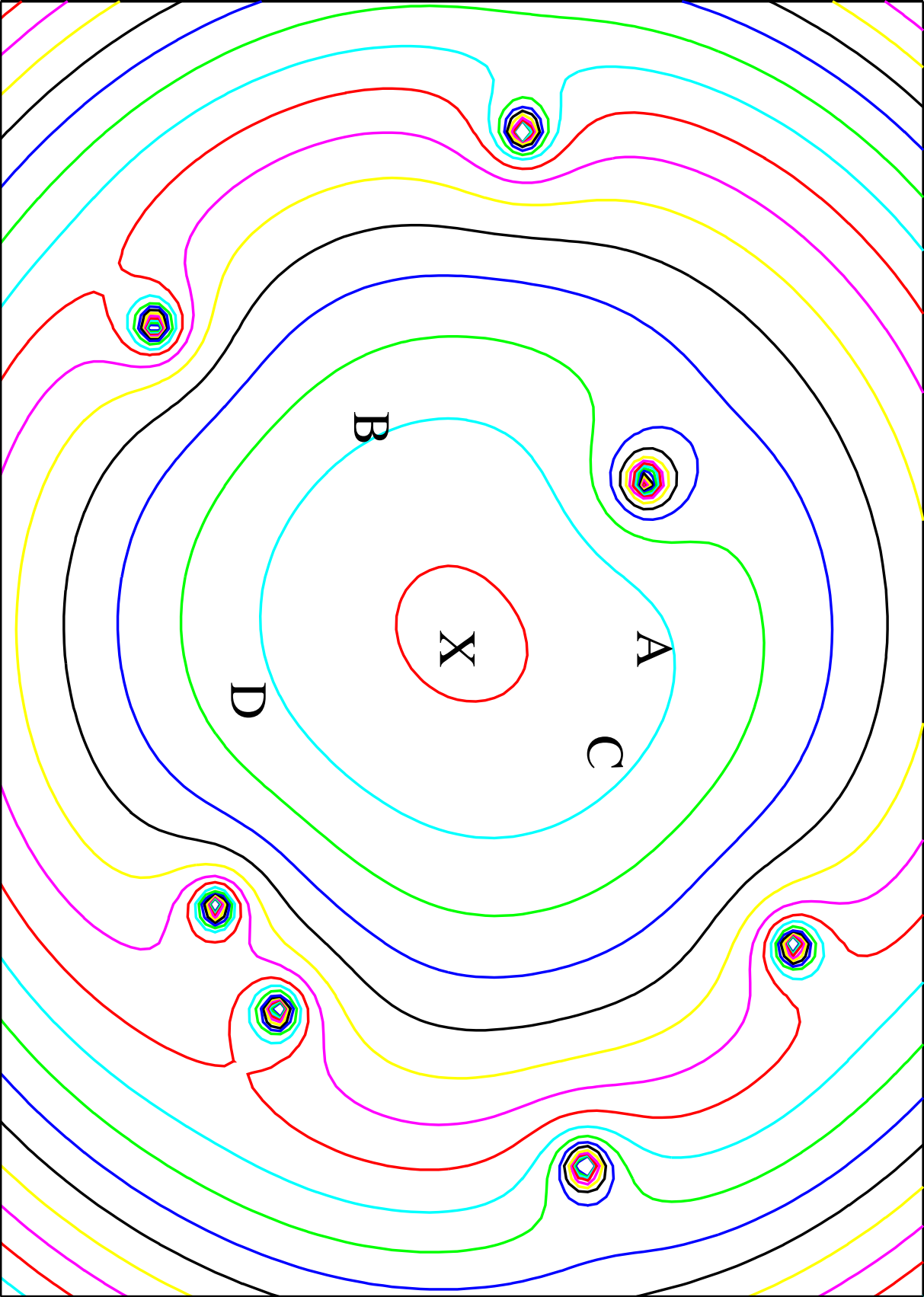
## Forces and Potentials - 1D



# Forces and Potentials - 2D







## 200-node Mesh

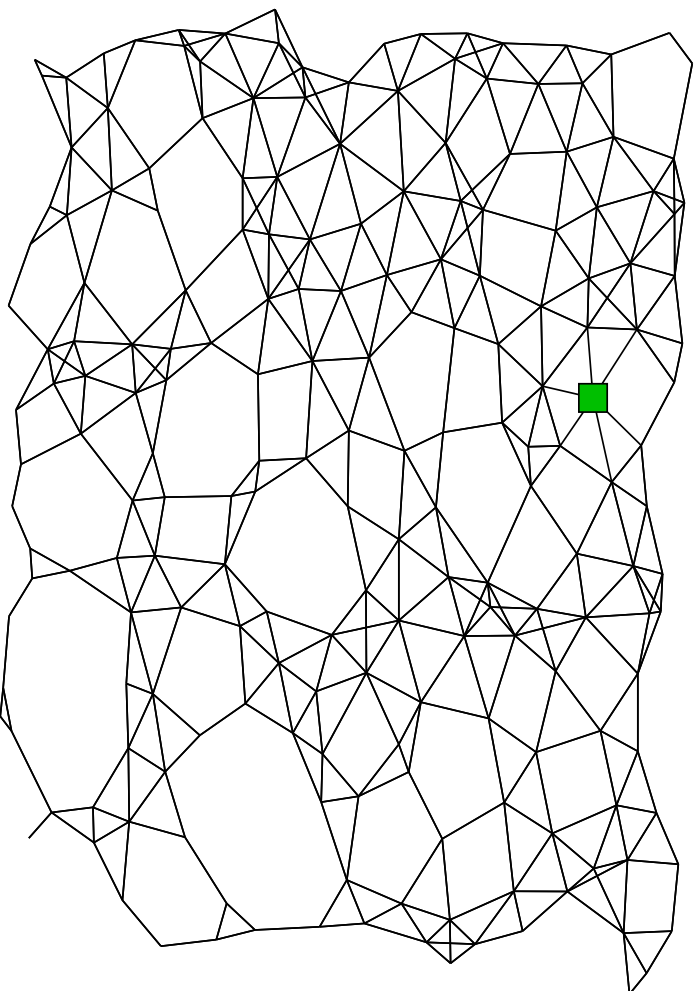
- 200 nodes
- Each node is placed so that:
  - ◇ at least one existing node is in range
  - ◇ no nodes are within range/2
- similar to a rooftop network

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http://www.ctie.monash.edu.au/mesh/virt_loc/two.gif  
./two animated.gif
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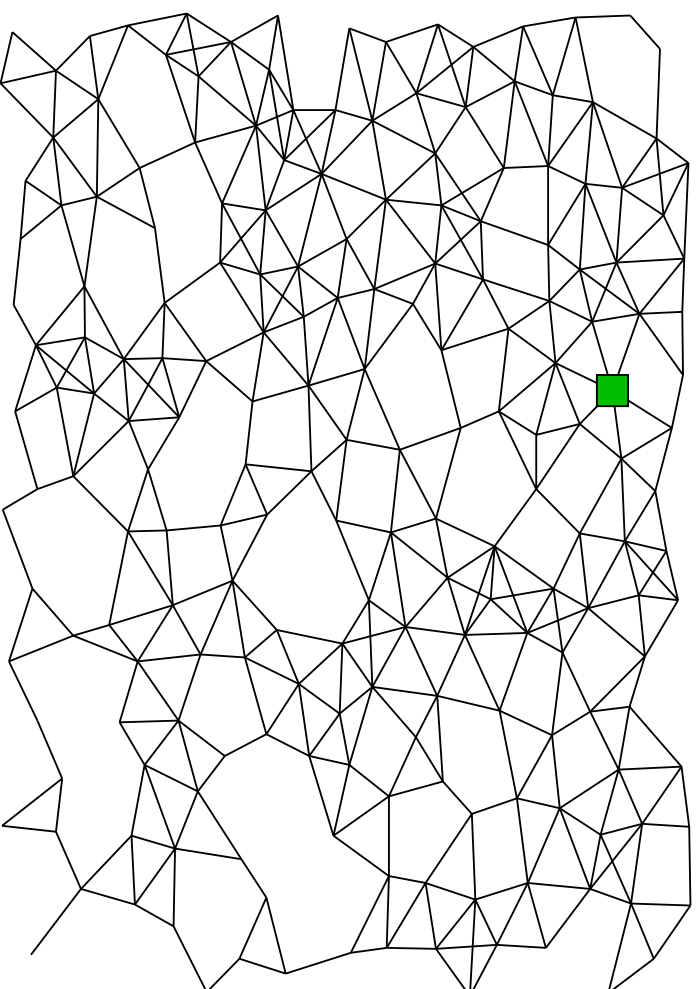
# 200-node Mesh

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

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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?