Sensor Networks

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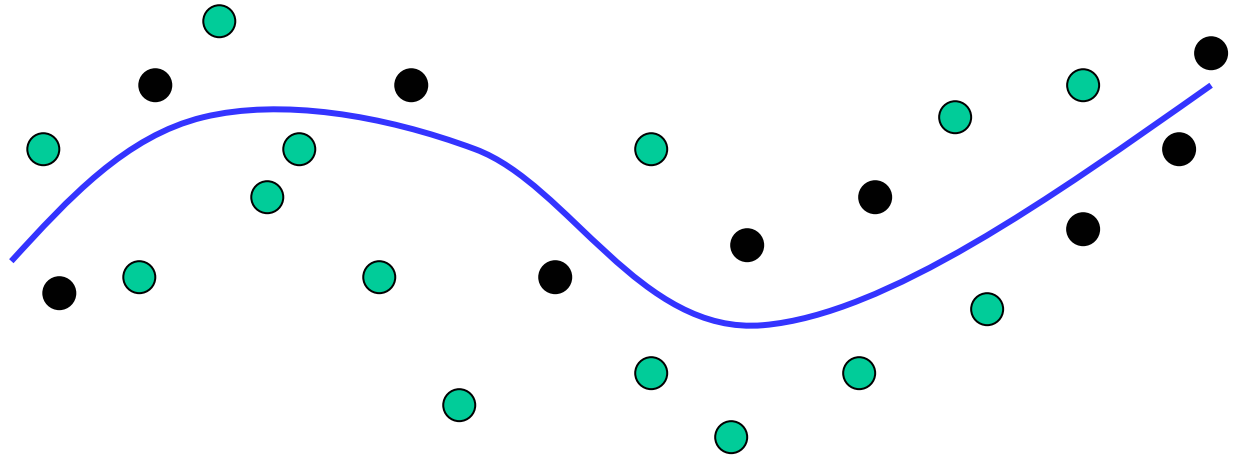
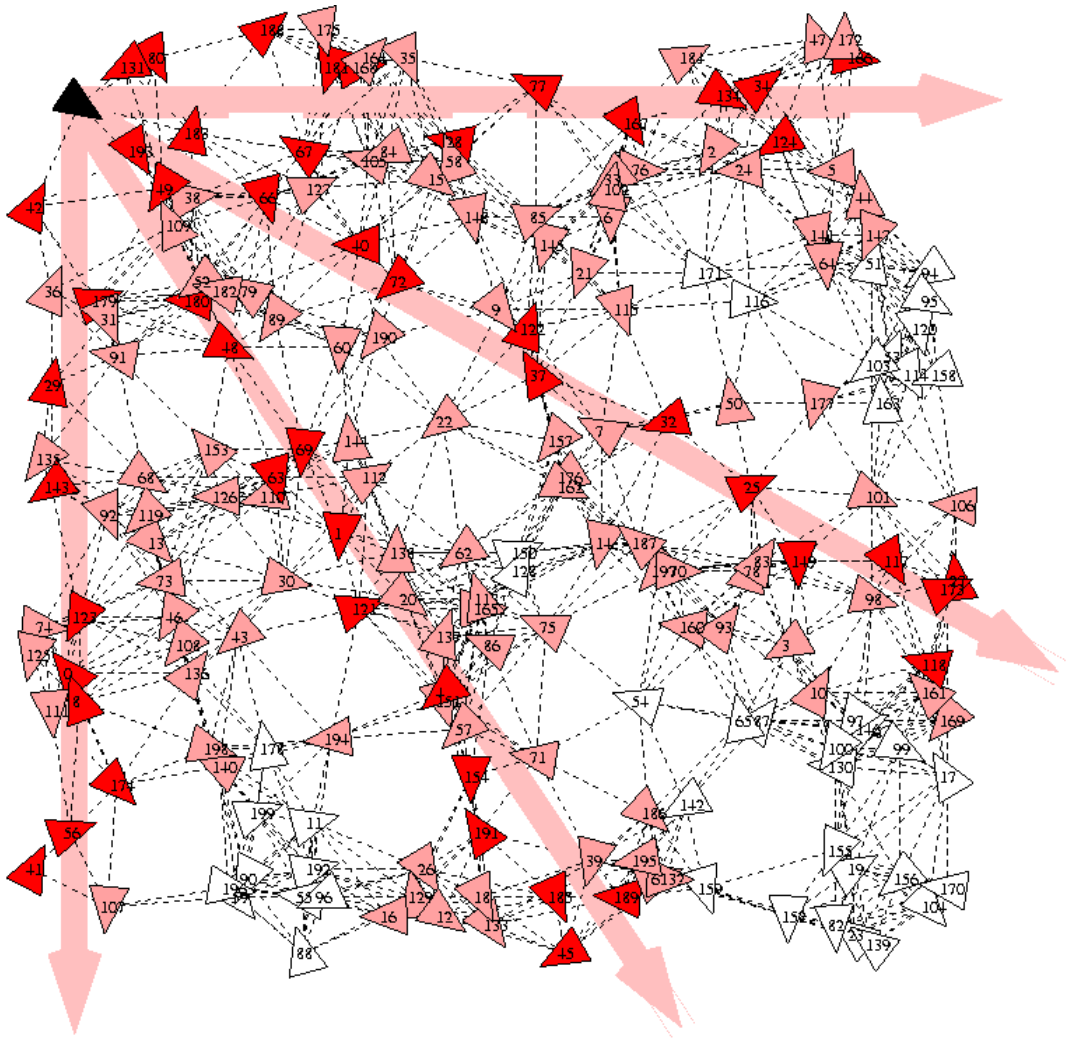
Joint work with Dragos Niculescu

Routing in sensor networks

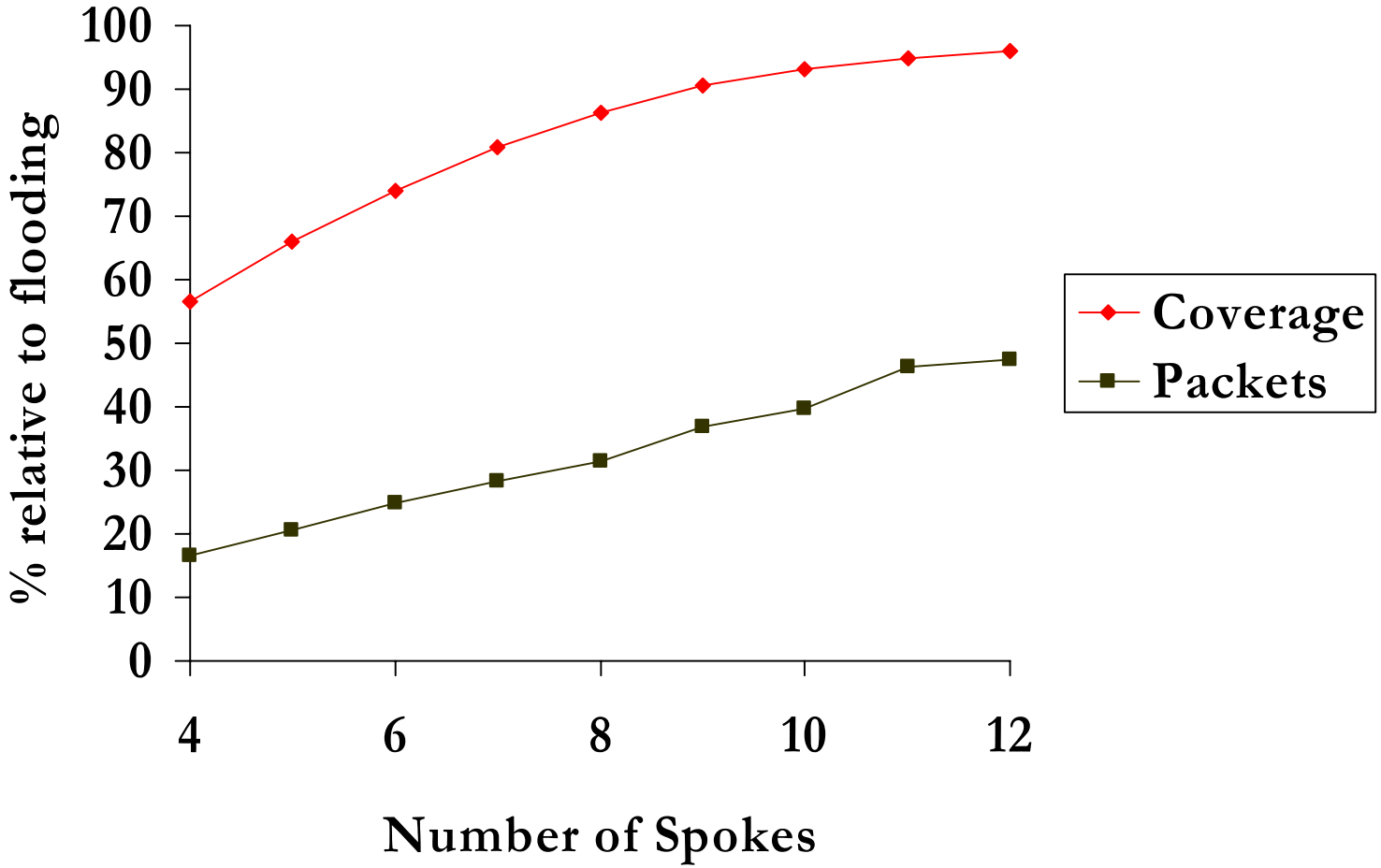
- **Fundamental Idea**
- **Trajectory based forwarding**
  - Route packets along a specified trajectory
    - Generalization of Source Based Routing and Cartesian routing
    - Trajectory specified in the packet



Spoke flooding



Flooding along spokes



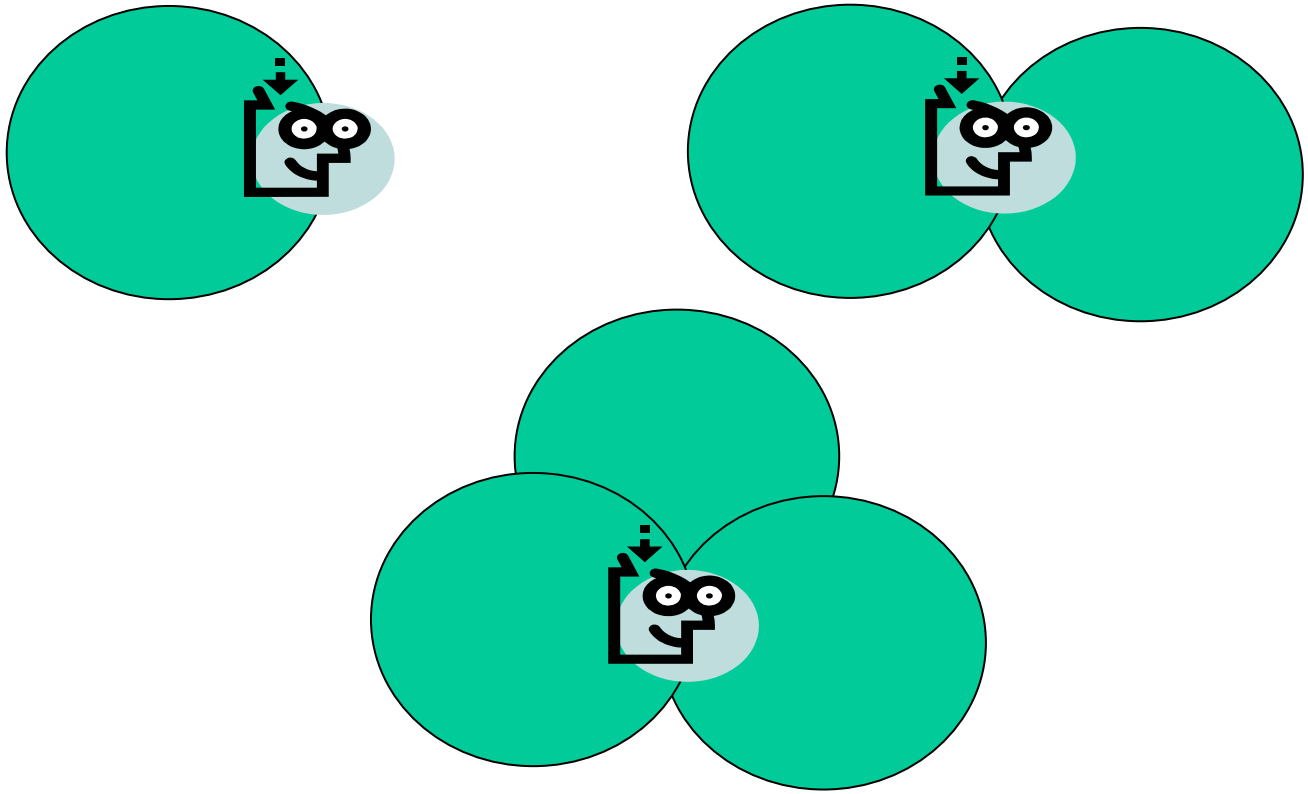
Deriving position info for routing

- **Need position information for forwarding**
- **Rely on GPS or local positioning system**
- **APS or ad-hoc positioning**
- **Some able to sense with higher precision than others**
  - Due to Multimodality, proximity to action, expensive sensor etc
- **How can we add to information assurance**
- **One approach:**
- **If you don't know, ask!**
  - i.e., derive a value by using someone else's value
    - Location, range, orientation
  - Derive a value by knowing other attributes
    - Velocity, acceleration, time

APS: ad-hoc positioning system by Dragos Niculescu and Badri Nath in Globecom 2001
APS using AoA by Dragos Niculescu and Badri Nath Rutgers Tech Rept.

APS (ad-hoc positioning system)

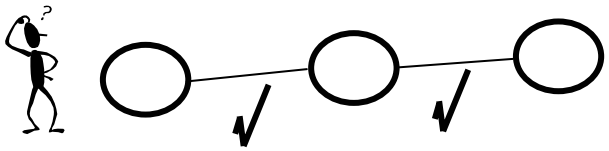
- **If you know ranges from landmarks, it is possible to derive your location (GPS)**



GPS accounts for error in measurements by making additional measurements

APS outline

- **Few nodes are authorities or landmarks**
- **Other nodes derive their locations by contacting these landmarks**
- **The contact need not be direct (like GPS)**
- **To estimate distances to neighbors**
  - Use hop count, signal strength or euclidean distance
  - Use routing algorithm such as distance vector to get hop count, neighbor distances
- **Once distances to landmarks are known use triangulation to determine location**

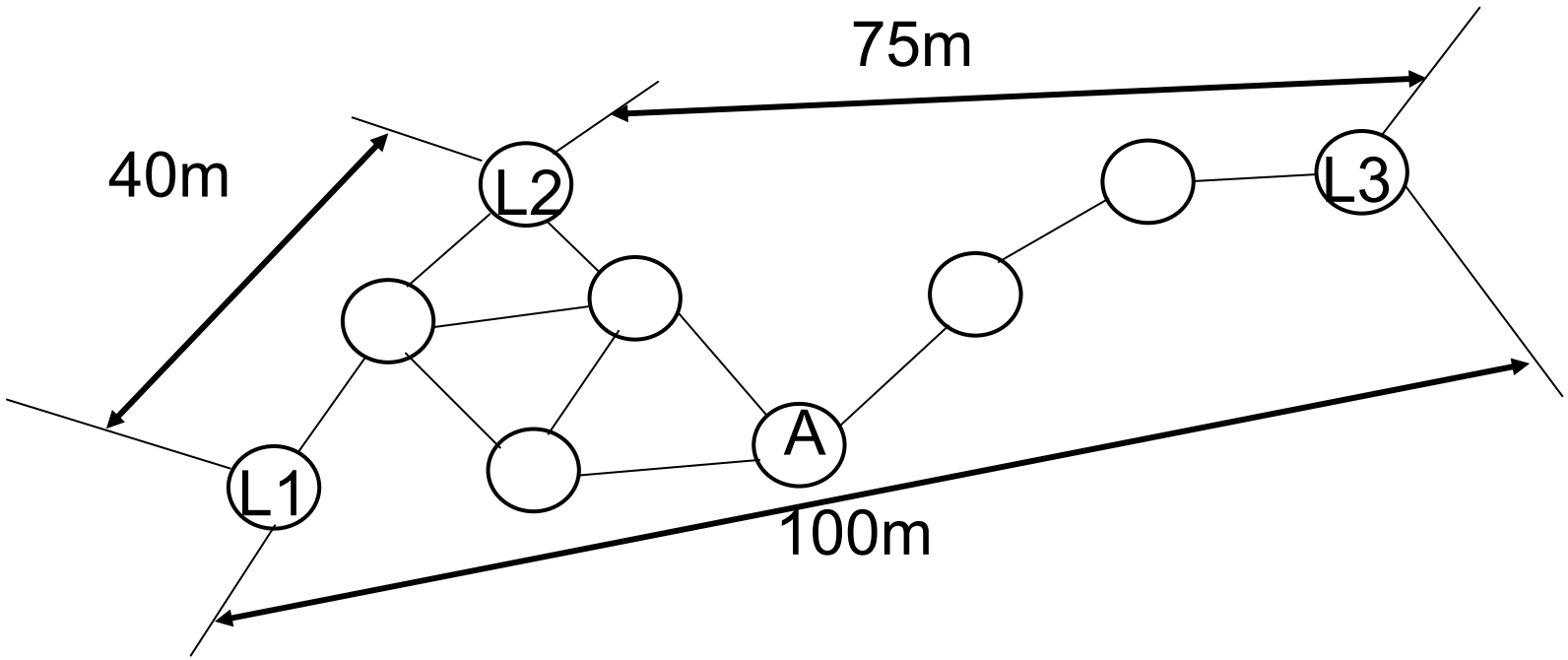


Know hops but do I know how far I am?

APS- distance propagation

- Like in DV, neighbors exchange estimate distances to landmarks
- Propagation methods
- DV-hop- distance to landmark, in hops
- DV-distance – travel distance, say in meters (use Signal strength)
- DV-euclidean – euclidean distance to landmark

DV-hop propagation example



L1 → 100 + 40/(6+2) = 17.5
L2 → 40 + 75/(2+5) = 16.42
L3 → 75 + 100/(6+5) = 15.90

Dv-hop propagation

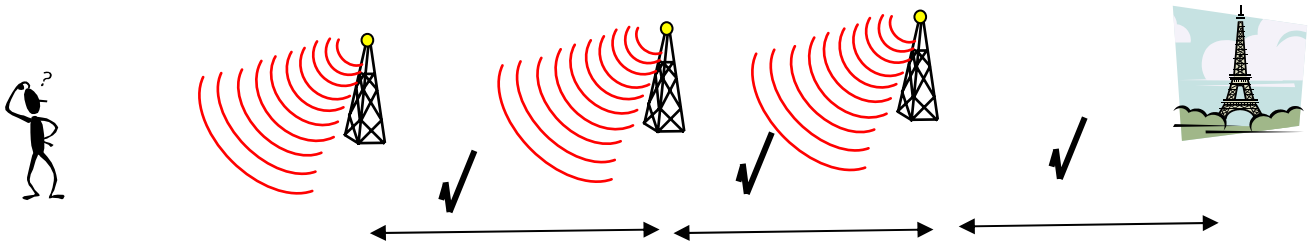
- **Landmarks compute average hop distance and propagate the correction**
- **Non-landmarks get the correction from a landmark and estimates its distances to other landmarks**
- **A gets a correction of 16.42 from L2**
- **It can estimate the distance to L1, L2, and L3 by multiplying this correction and the hop count**
- **A can then perform triangulation with the above ranges**

Every part, or whole of nature is an approximation of the truth

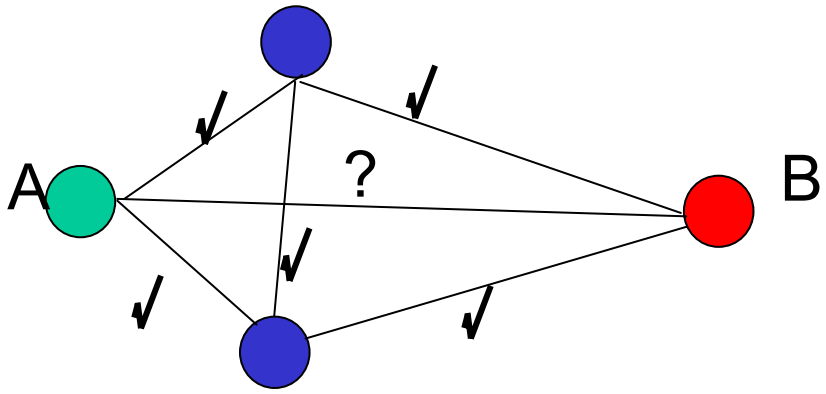
--Feynman series

Dv-distance

- Each node can propagate the distance to its neighbor to other nodes
- Distance to neighbor can be determined using signal strength
- Propagate distance, say in meters, instead of hops
- Apply the same algorithm as in DV-hop

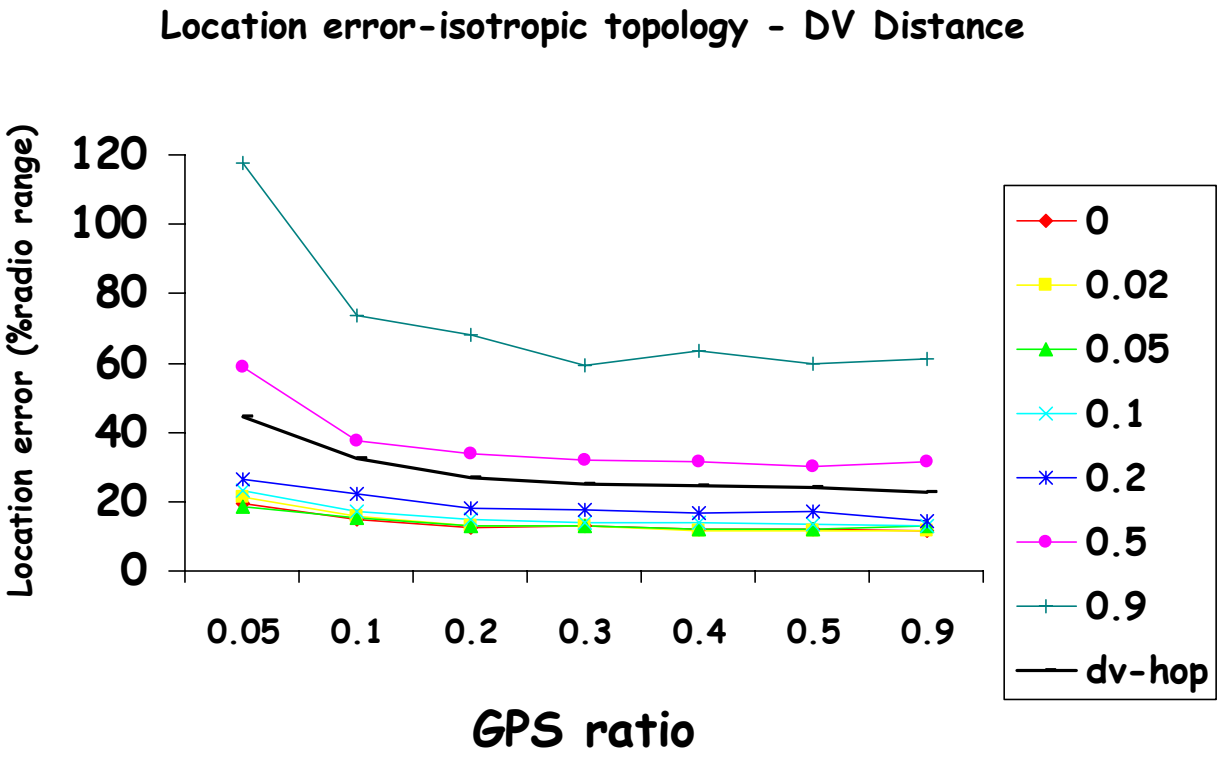


Euclidean distance

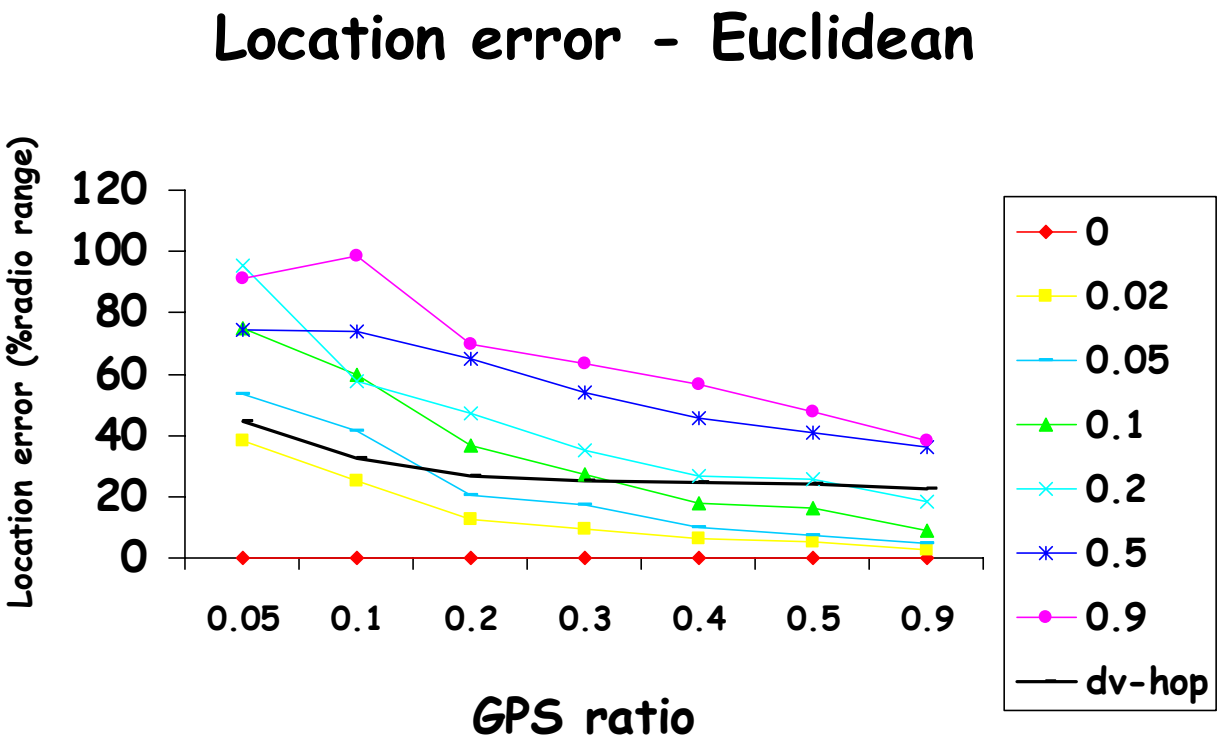


- Contact two other neighbors who are neighbors of each other
- If they know their distance to a landmark and their locations
- One can determine the range to the landmark
- Distances ➔ Angels. From Angles determine AB
- Three such ranges gives a localization
- D1, D2, D3 ➔ x,y

Performance – location error

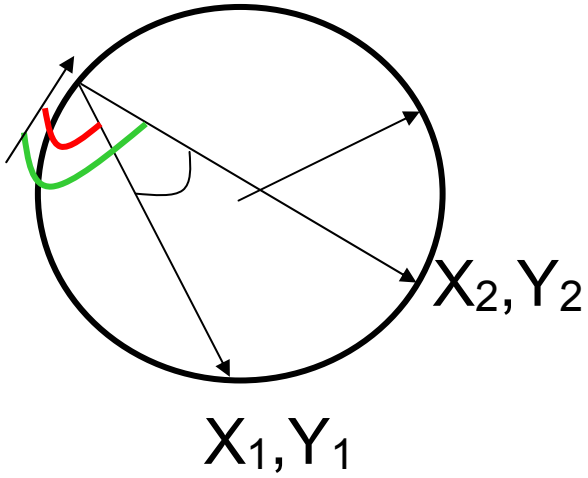


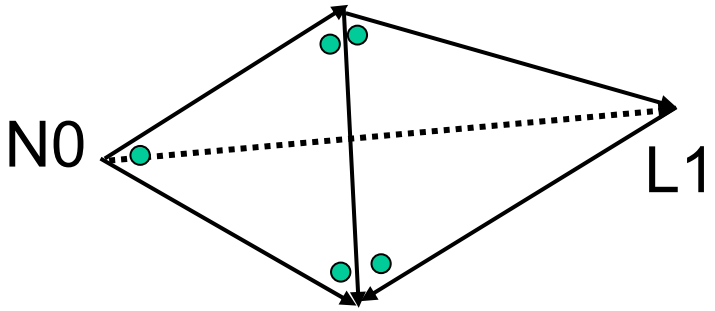
Performance – location error for euclidean



Angle of arrival

- One can determine an orientation w.r.t a reference direction
- Angle of Arrival (AoA) from two different points and their distances
- You can locate a point on a circle. Similar AoA from another point gives you three circles . Then triangulate to get a position





AoA capable nodes

- **Cricket Compass (MIT Mobicom 2000)**
  - Uses 5 ultra sound receivers
  - 0.8 cm each
  - A few centimeters across
  - Uses tdoa (time difference of arrival)
  - +/- 10% accuracy
- **Medusa sensor node (UCLA node)**
  - Mani Srivatsava et.al
- **Antenna Arrays**

Summary

- **All methods provide ways to enhance location determination**
- **Can provide location capability indoors**
- **Low landmarks ratio**
- **Suited well for isotropic networks**
- **General topologies**
- **Other metrics for forwarding?**
- **Orientation, centroid, max forward progress, ….**

Related Work:
Positioning using a grid – UCLA
Using radio and ultrasound beacons – MIT cricket
Pre-mapping using radio propagation – Microsoft (RADAR)
Centralized solution -- Berkeley