Approximate-Point-In-Triangulation Test

Presentation for
Distributed Systems Seminar

Presented by
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Content for this presentation mainly from:
Tian He, Chengdu Huang, Brian M. Blum, John A. Stankovic, and Tarek Abdelzaher. Range-free Localization Schemes for Large Scale Sensor Networks. Proceedings of the 9th Annual International Conference on Mobile Computing and Networking (MobiCom 2003), San Diego (CA), USA, September 2003. (Citation: [He 2003])

What we want

- Localization of the motes
- Cheap hardware
- Accuracy

Range-Based VS Range-Free

Range-Based:

Use absolute point-to-point estimation

(distance estimation (range) or angle estimation)

→Expensive hardware

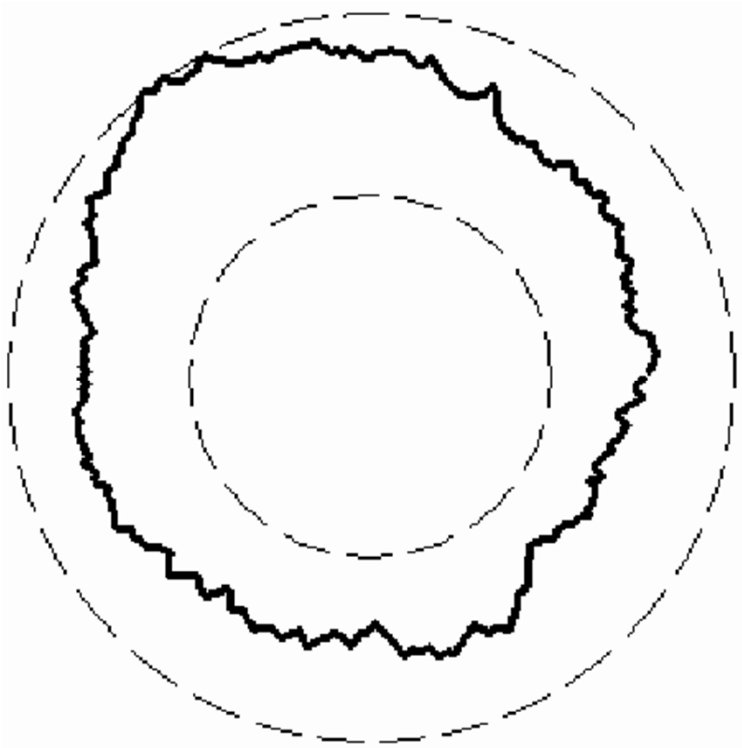
Range-Free:

No assumption about availability and validity of information

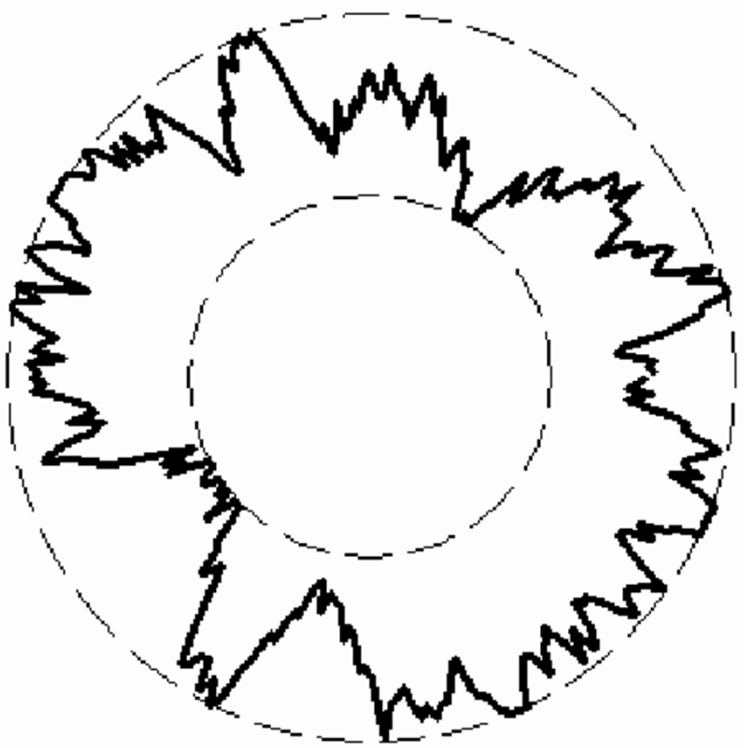
(No assumption about correlation between absolute distance and signal strength)

→ Cost-effective

Radio-Pattern is NOT a circle!



DOI=0.05



DOI=0.2

DOI = Degree of Irregularity

Image Source: [He 2003]

Signal strength decreasing monotonically

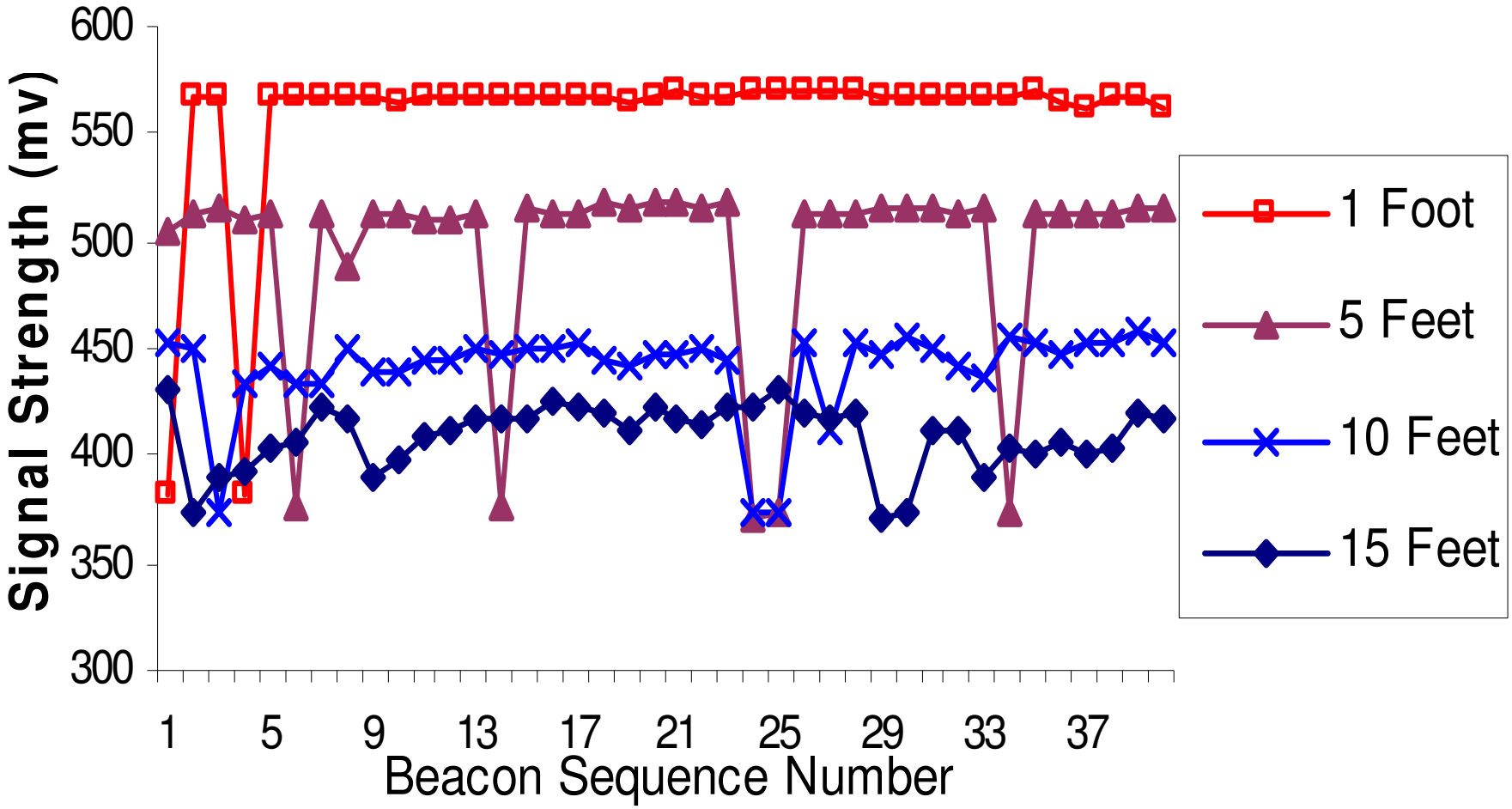


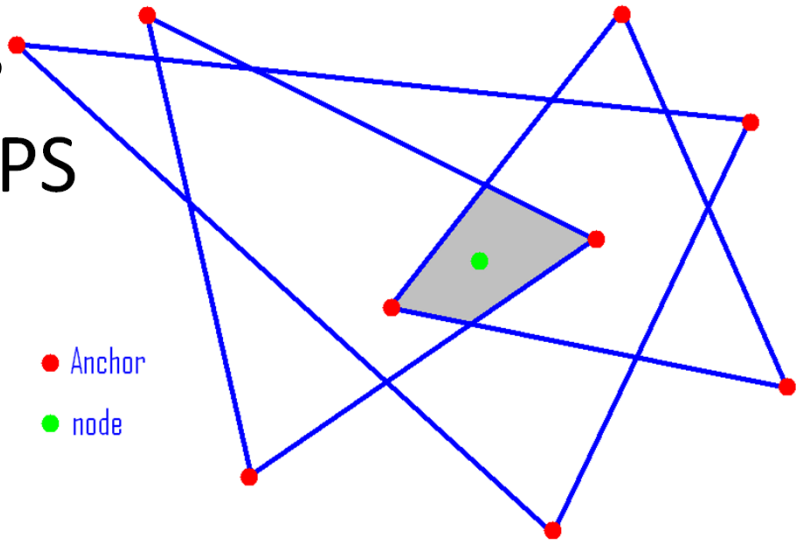
Image Source: [He 2003]

APIT Settings

Small percentage of nodes equipped with

- high-powered transmitters
- Location information via GPS

→ Anchors



Rest

- Cheap devices (nodes) using information of anchors

Main Algorithm

1. Beacon exchange
2. Point-In-Triangulation Testing
3. Approximate-PIT aggregation
4. Calculation of Center-Of-Gravity

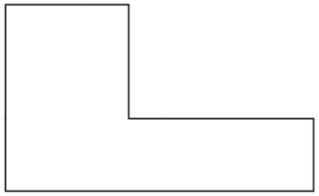


Fig 1

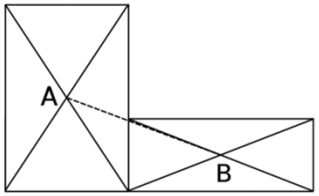


Fig 2

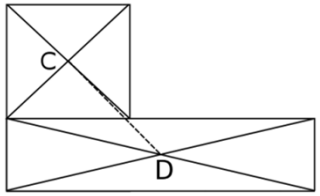


Fig 3

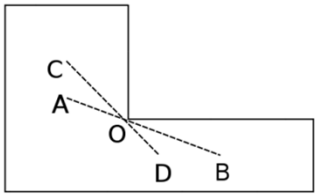


Fig 4

Beacon contains:

Anchor ID, Location, Signal Strength

Image Source: Wikipedia: http://en.wikipedia.org/wiki/Center_of_mass

Perfect PIT Test

Proposition I: Node M in triangle if:

M shifted in any direction
→New position is nearer / further from at least one anchor

Proposition II: Node M outside if:

M can be shifted in a direction
→New position is nearer / further to all three anchors

Perfect PIT Test

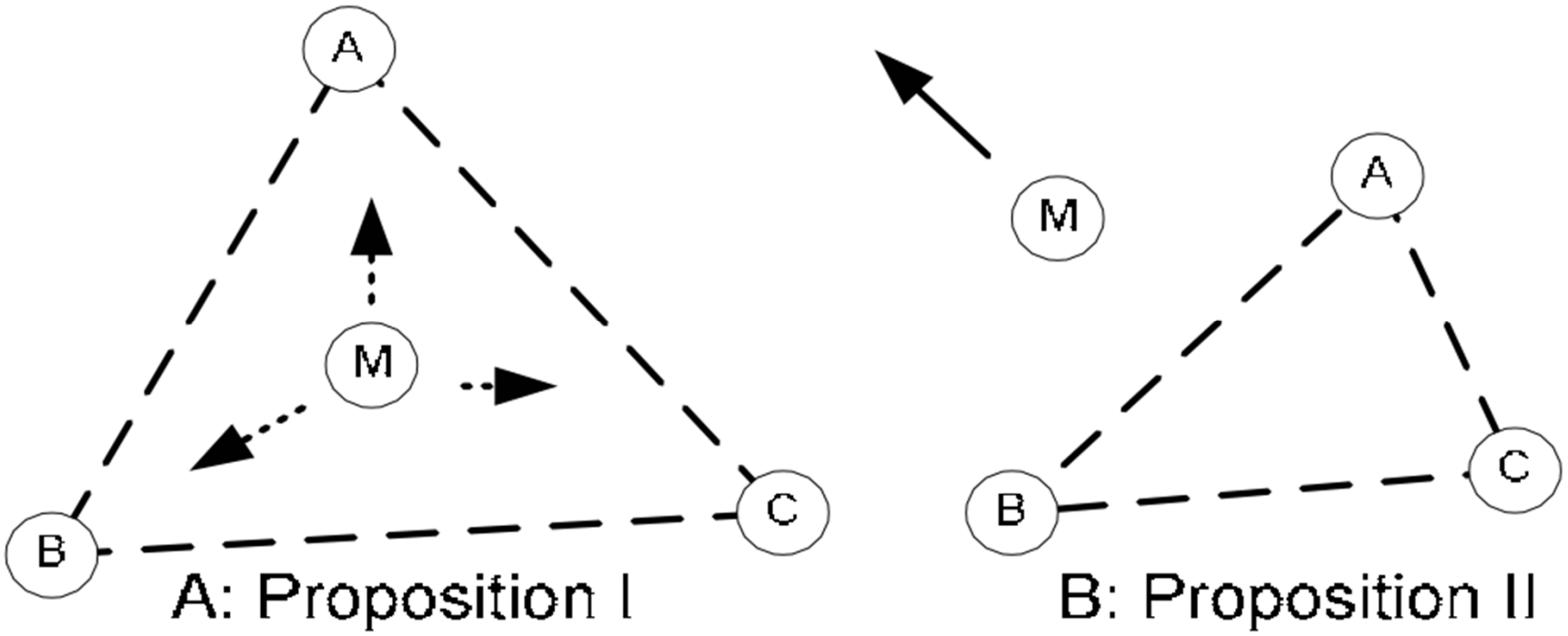


Image Source: [He 2003]

Problem

- PIT Test without moving?

Approximate PIT Test

Node M ask its neighbours for their received signal strength

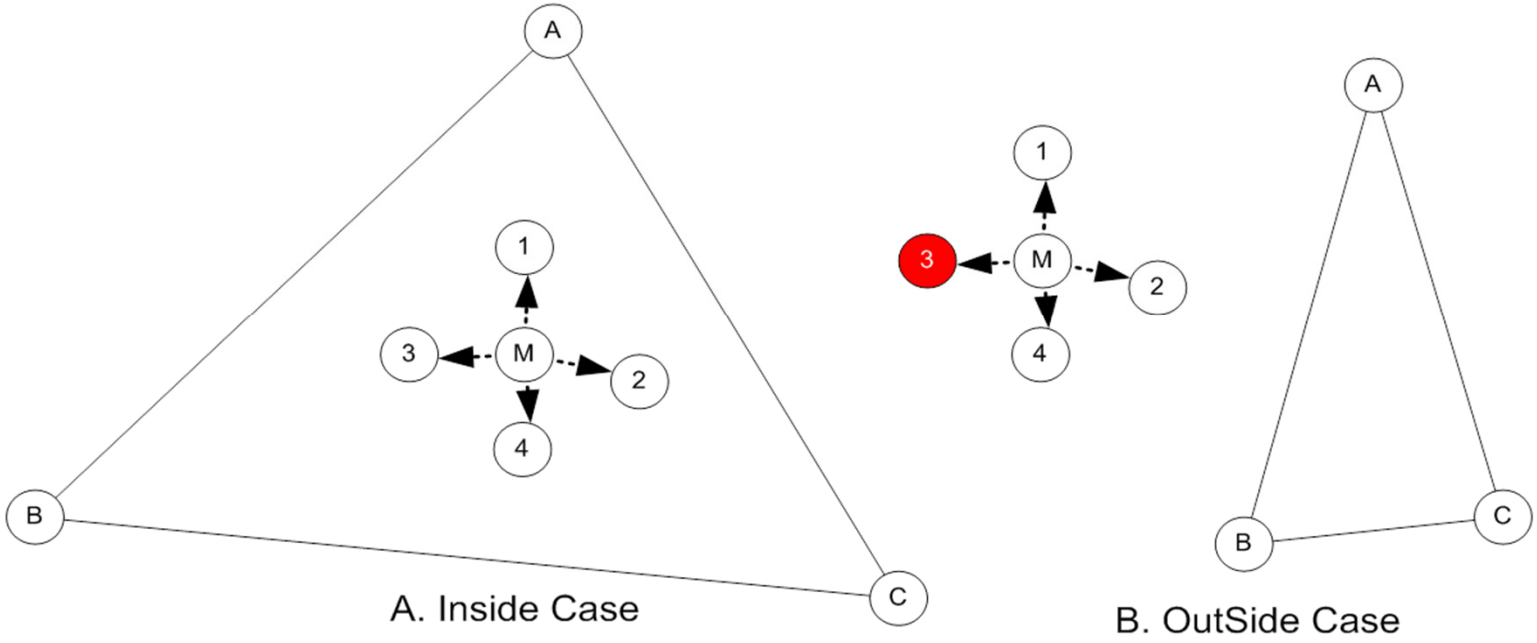
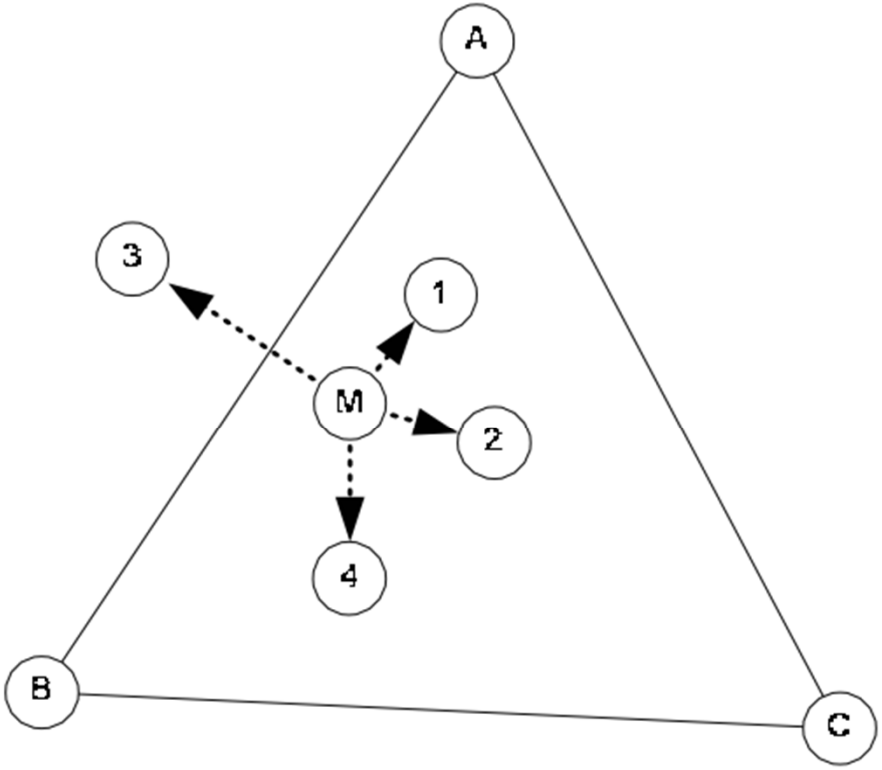
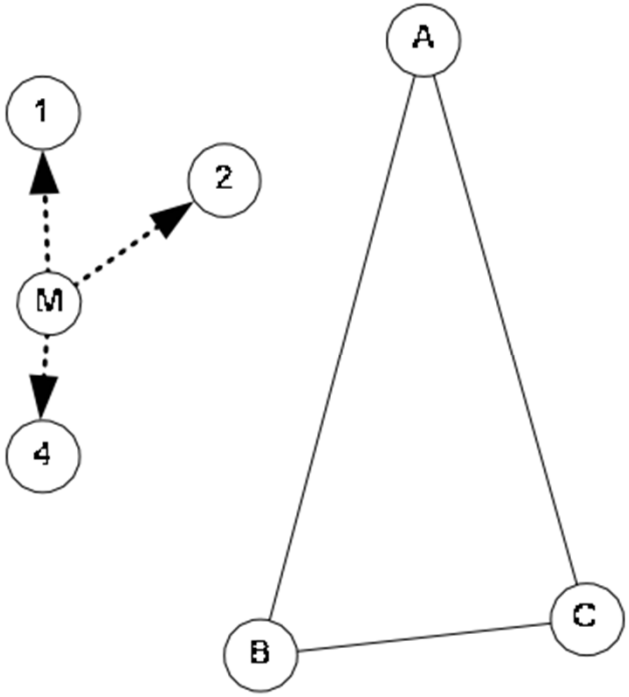


Image Source: [He 2003]

Known errors



A. InToOut Error



B. OutToIn Error

Image Source: [He 2003]

OutToInError VS InToOutError FARBE

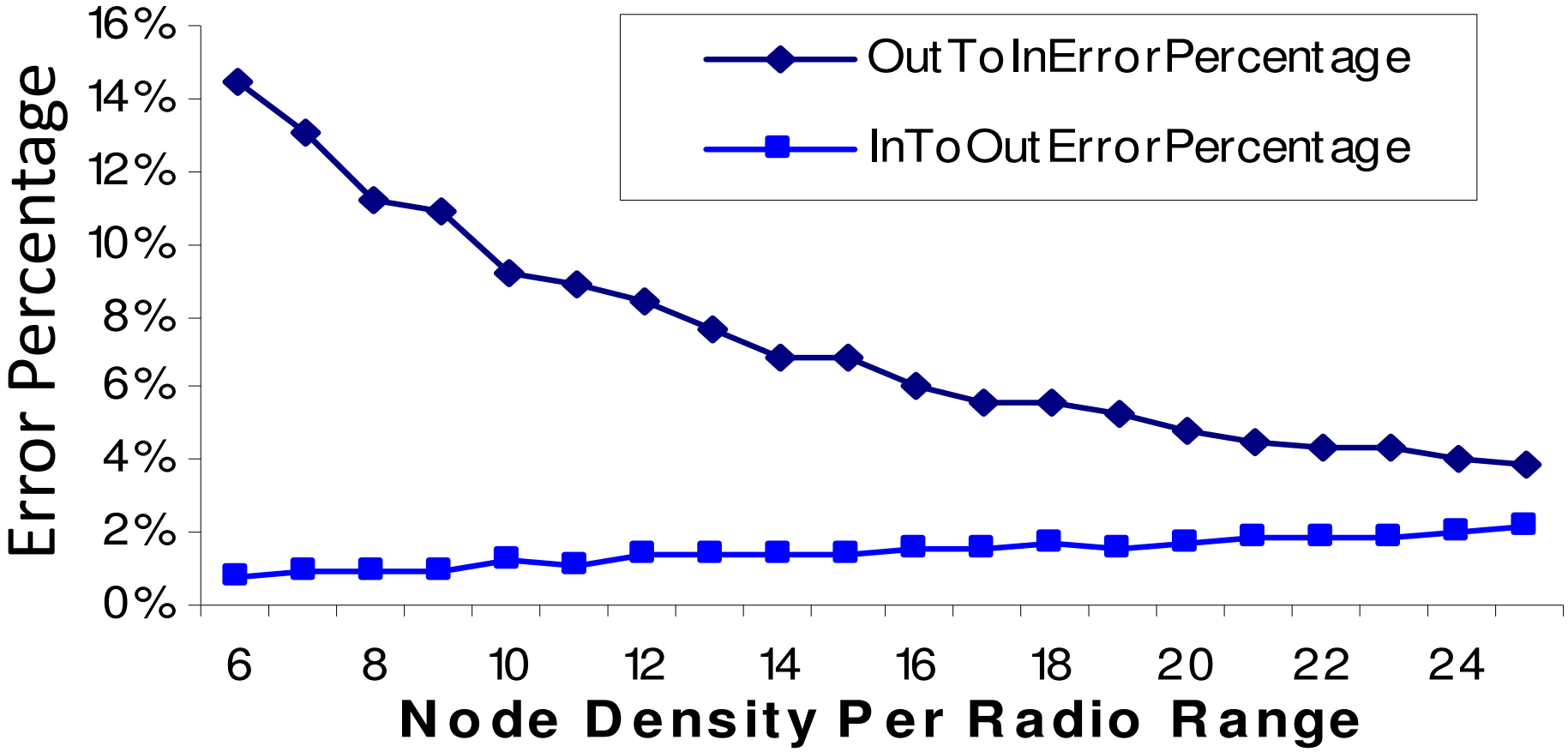


Image Source: [He 2003]

APIT Aggregation

Robust approach to mask errors of individual APIT tests:

Inside decision
→ +1

Outside decision
→ -1

→ Area with highest value must be location

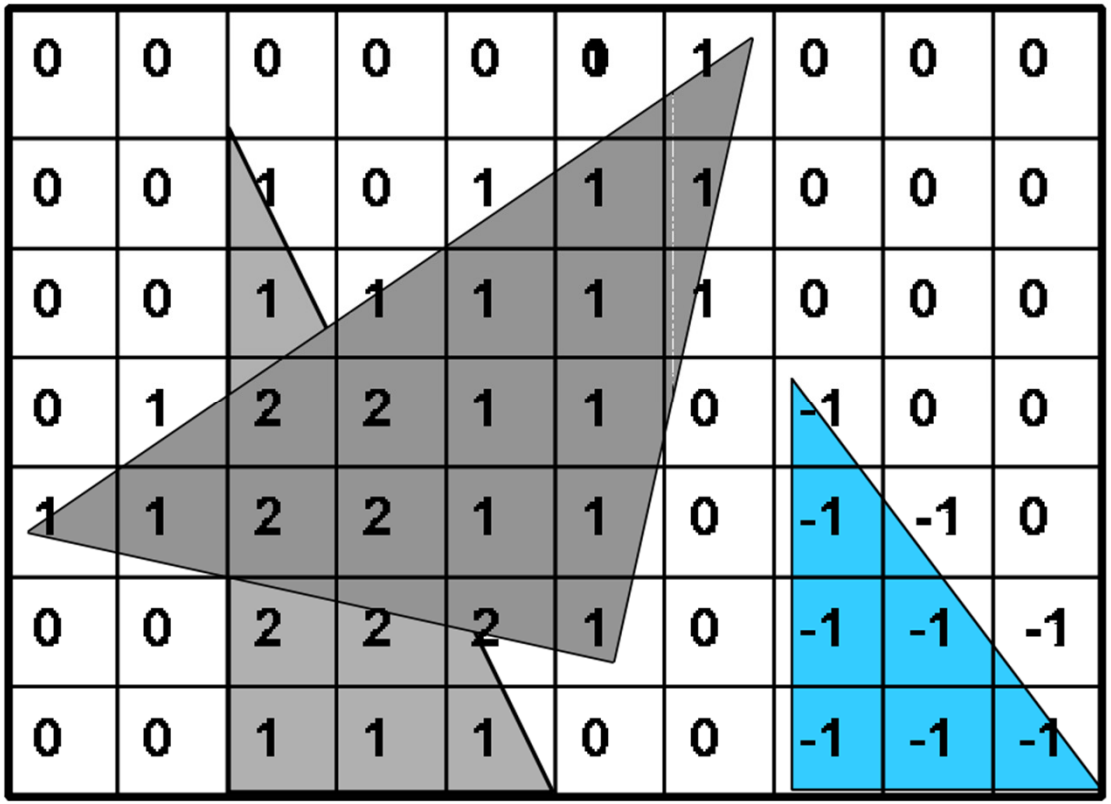


Image Source: [He 2003]

Walk through

	(X,Y)		SS
A	20	20	1mv
B	45	31	2mv
C	23	56	3mv

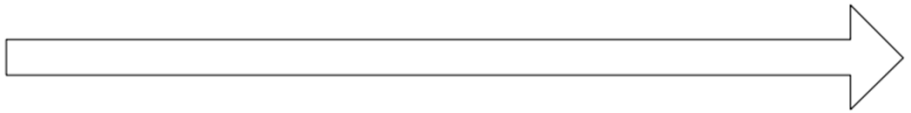
Node M

	(X,Y)		SS
A	20	20	2mv
B	45	31	3mv
C	23	56	1mv

Node 1

Source: [He 2003]

Walk through



	(X,Y)		MySS	SS1	.....	SSn
A	20	20	1mv	2mv		6mv
B	45	31	2mv	3mv		7mv
C	23	56	3mv	1mv		7mv

Node M

Source: [He 2003]

Walk through (Algorithm revisited)

1. Receiving beacons from anchors and maintaining a table
2. Exchange tables with neighbours
3. Run APIT on every column
4. Repeat for each combination of three anchors
5. Find area with maximum averlap
6. Calculate Center-Of-Gravity

Comparison

To

- Centroid Localization
- DV-Hop Localization
- Amorphous Localization

Centroid Localization

Askes anchor beacons for location information

Calculate average:

$$(X_{est}, Y_{est}) = \left(\frac{X_1 + \cdots + X_N}{N}, \frac{Y_1 + \cdots + Y_N}{N} \right)$$

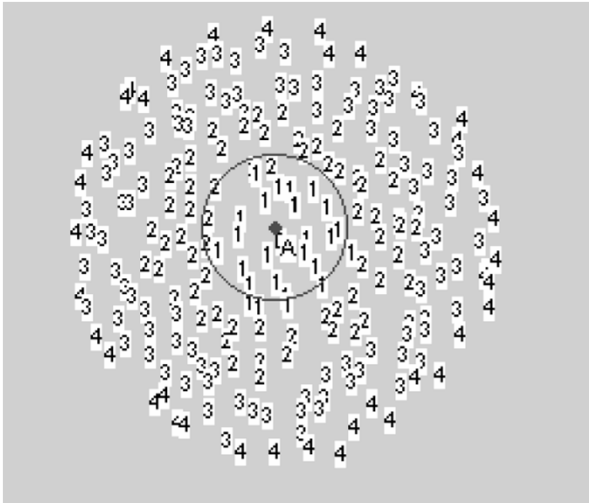
→ Simple solution

Source: [He 2003]

DV-Hop Localization

Count number of hops

→Shortest distance in hops to every anchor



Convert hop count into physical distance:

$$HopSize_i = \frac{\sum \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum h_j}$$

Source: [He 2003]

DV-Hop Localization

Node has calculated distance to more than 3 anchors

→ Use triangulation

Amorphous Localization

Similar to DV-Hop

- Get hop distance (as number)
- Distance estimation (physical distance)

Uses a more complicated formula to calculate the HopSize (Kleinrock and Silvester formula)

$$HopSize = r(1 + e^{-n_{local}} - \int_{-1}^{1} e^{-\frac{n_{local}}{\pi}\left(\arccos t - t\sqrt{1-t^2}\right)} dt)$$

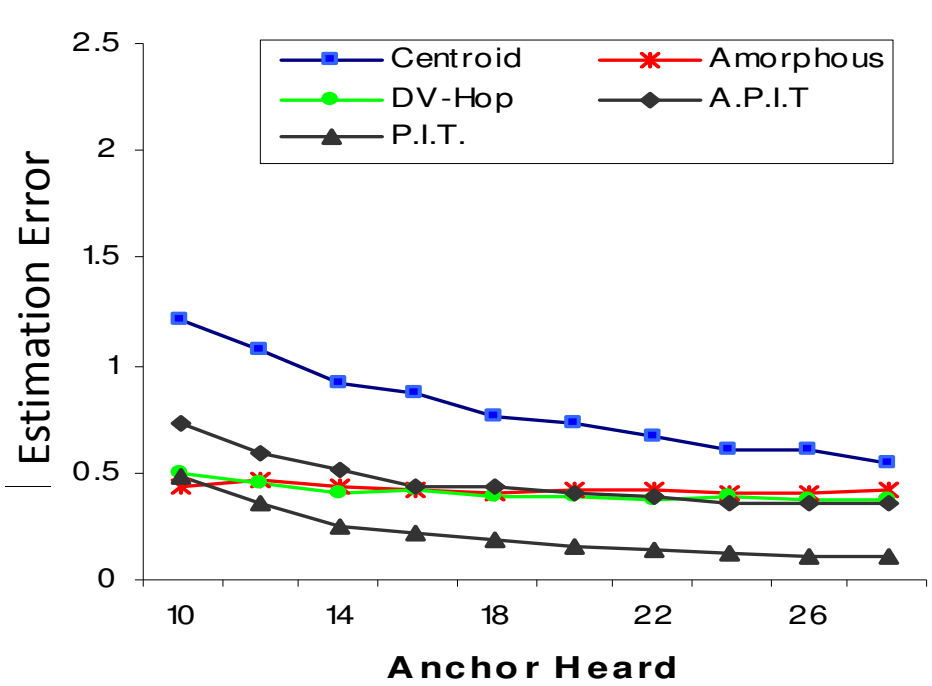
Source: [He 2003]

Amorphous Localization

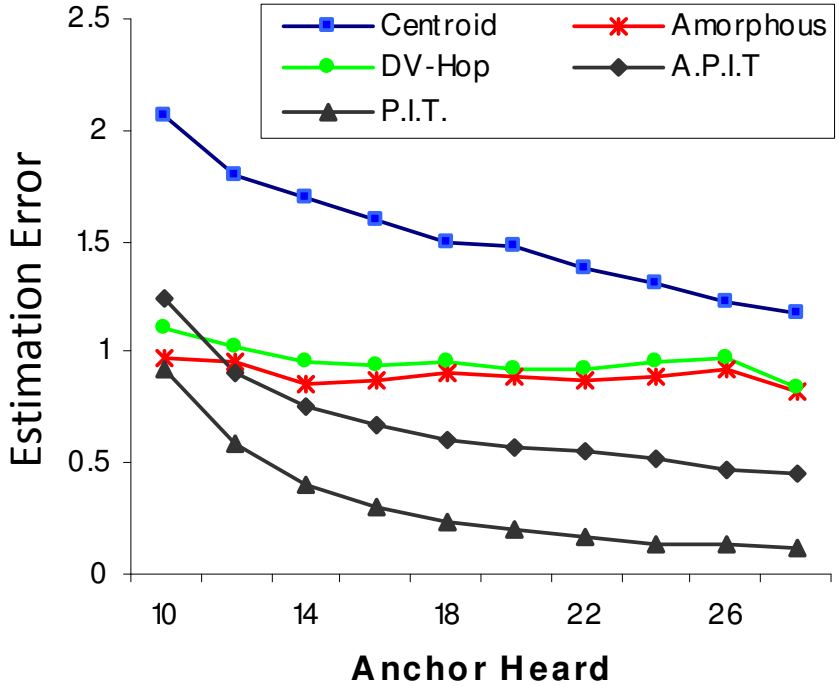
Node has calculated distance to more than 3 anchors

→ Use triangulation

Random VS Uniform node placing



uniform



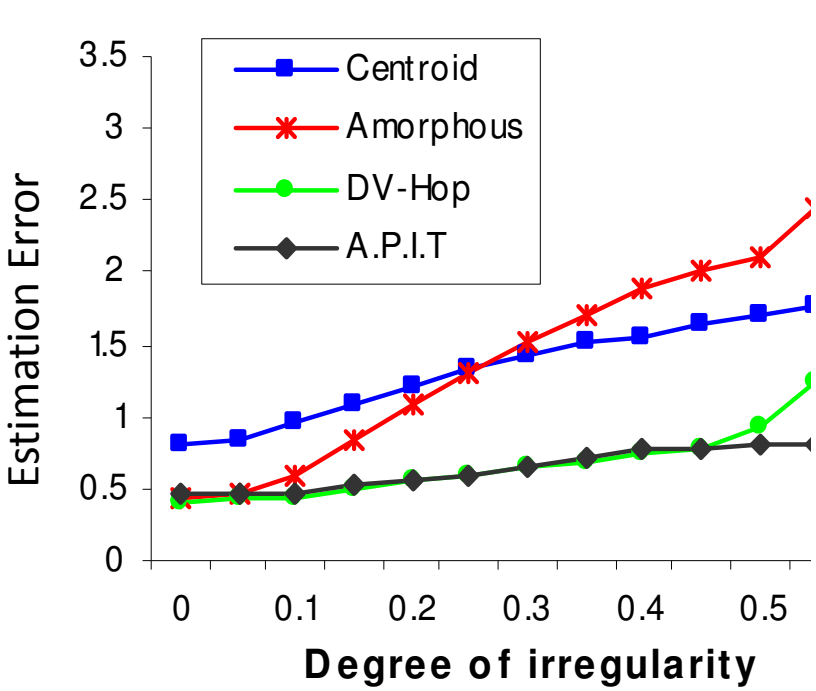
random

AH=10~28, ND=8, ANR=10, DOI=0

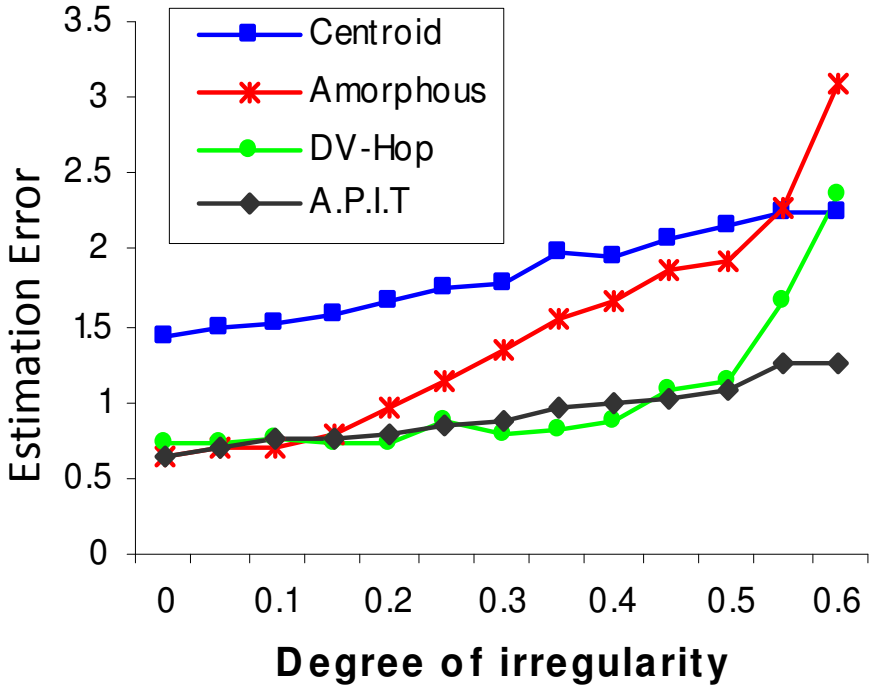
AH=Anchors Heard; ND=Node Density; ANR=Anchor to Node Range Ratio; DOI=Degree of Irregularity

Image Source: [He 2003]

Effect of DOI (irregular signal)



Uniform



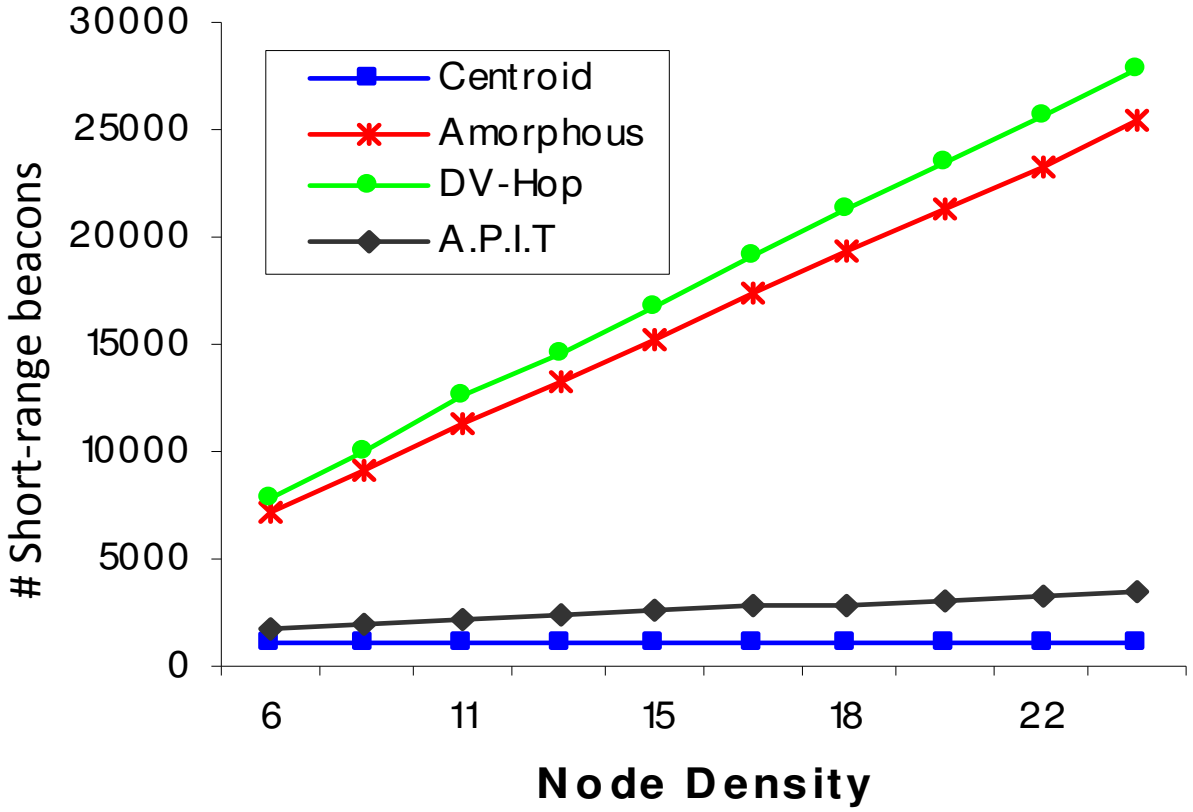
Random

AH=16, ND = 8, ANR=10

AH=Anchors Heard; ND=Node Density; ANR=Anchor to Node Range Ratio

Image Source: [He 2003]

Communication overhead for varied Node Density



It looks the same for varied anchors heard!

Image Source: [He 2003]

Summary

APIT

- Range-free → cost-effective

Performs best when:

- Irregular radio pattern
- Random node placement
- Low communication overhead desired

Questions