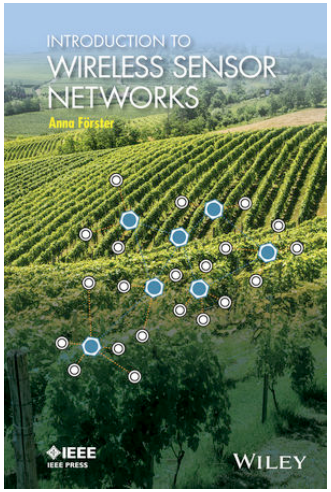


INTRODUCTION TO WIRELESS SENSOR NETWORKS

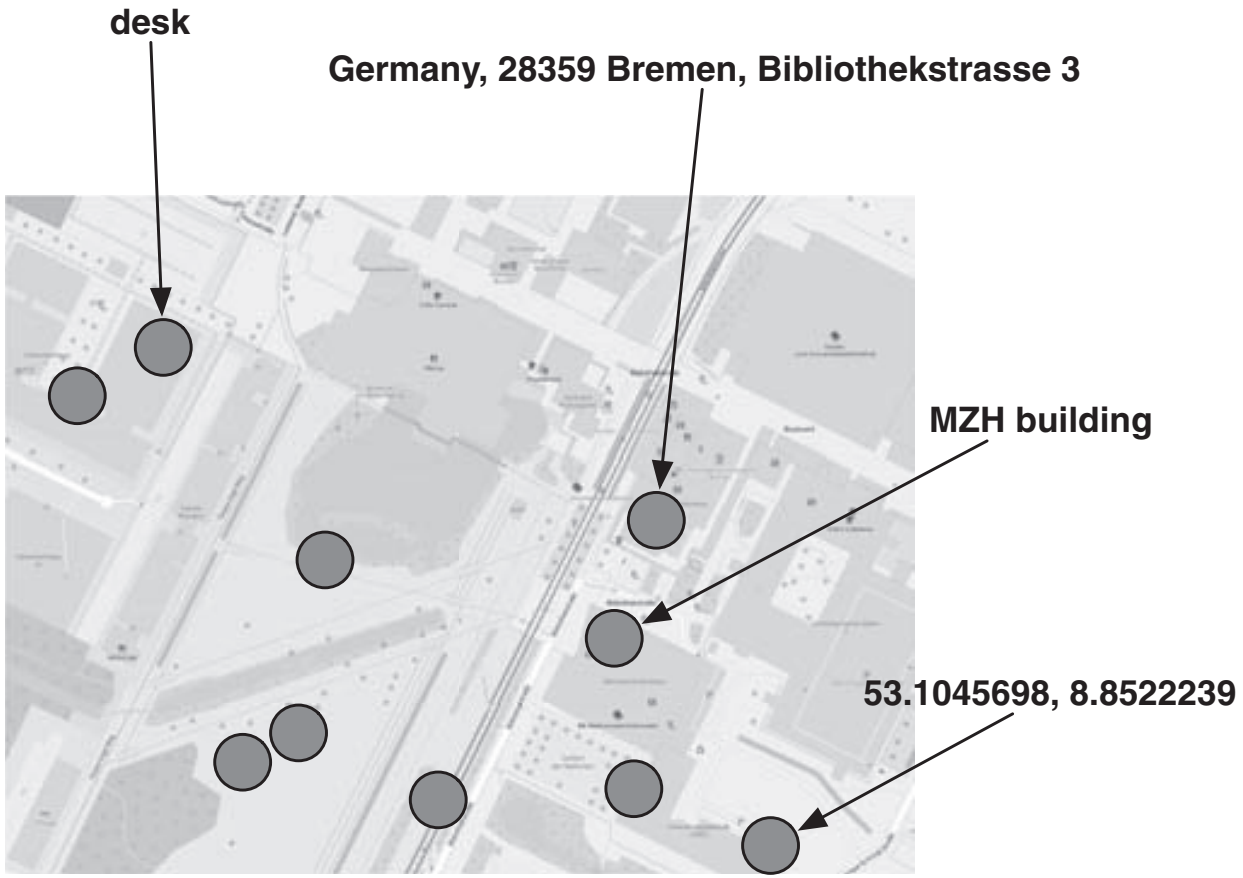
CHAPTER 8: LOCALIZATION TECHNIQUES

Anna Förster

OVERVIEW

1. Localization Challenges and Properties
    1. Location Information
    2. Precision and Accuracy
    3. Localization Costs
2. Pre-Deployment Schemes
3. Proximity Schemes
4. Ranging Schemes
    1. Triangulation
    2. Trilateration
5. Range-Based Localization
6. Range-Free Localization

Types of Location Information



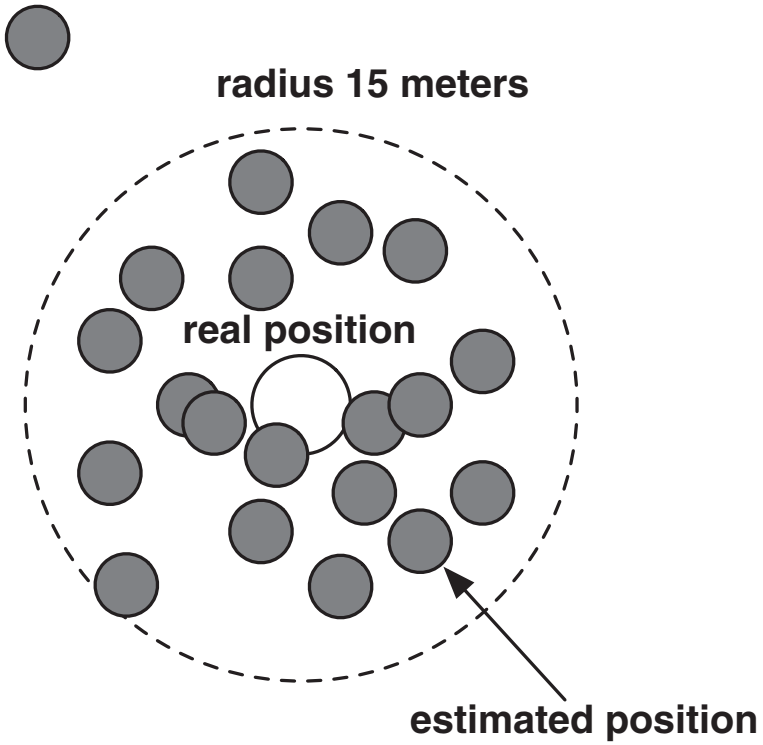
Symbolic against physical location

Precision and Accuracy

- ***Localization accuracy*** *is the largest distance between the estimated and the real position of the sensor node.*

- ***Localization precision*** *is how often a given accuracy is really achieved.*

Precision and Accuracy



- Example (left): Accuracy of 15 meters with 95% precision (19 out of 20 points are in a radius of 15 meters)
- Typical GPS accuracy and precision

Costs

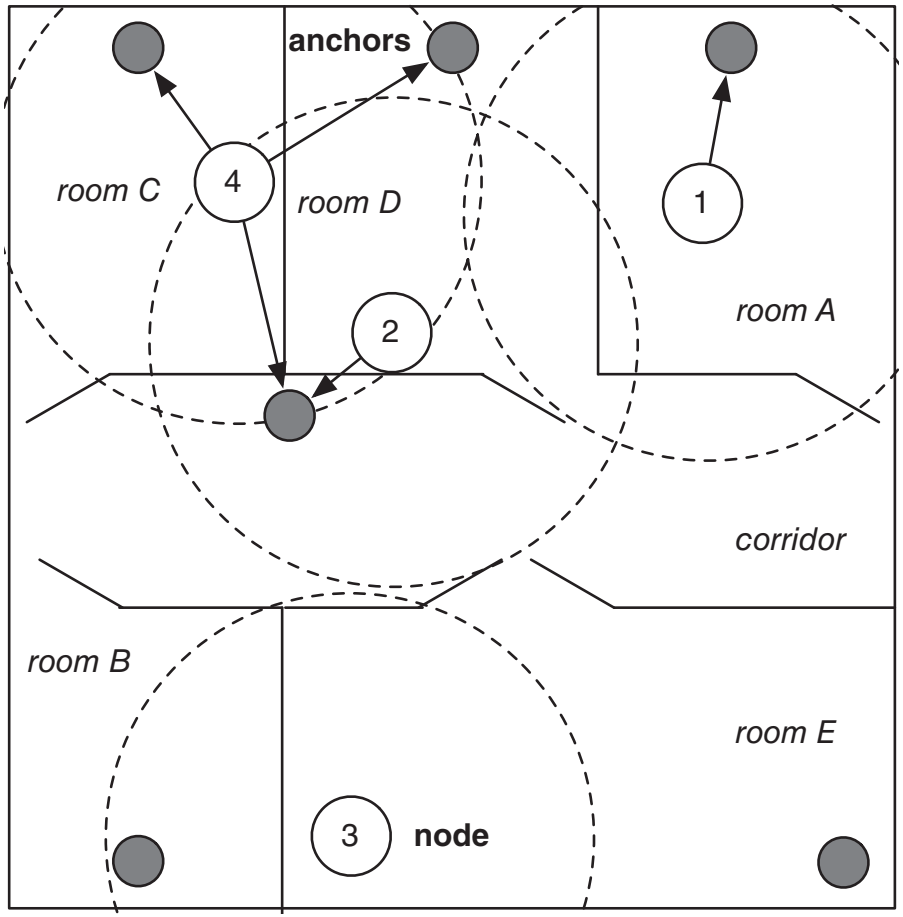
- **Financial** costs: $$$
- **Space** costs: how many space is required for a localization device on board
- **Communication** costs: how much communication is required for localization
- **Energy** costs: how much energy is required for localization
- **Infrastructural** costs: do we need a special infrastructure to enable localization

Pre-Deployment schemes

Install location information before deployment:

- Tell each item where it is (e.g. rooms, furniture, etc.)
- Install GPS sensors

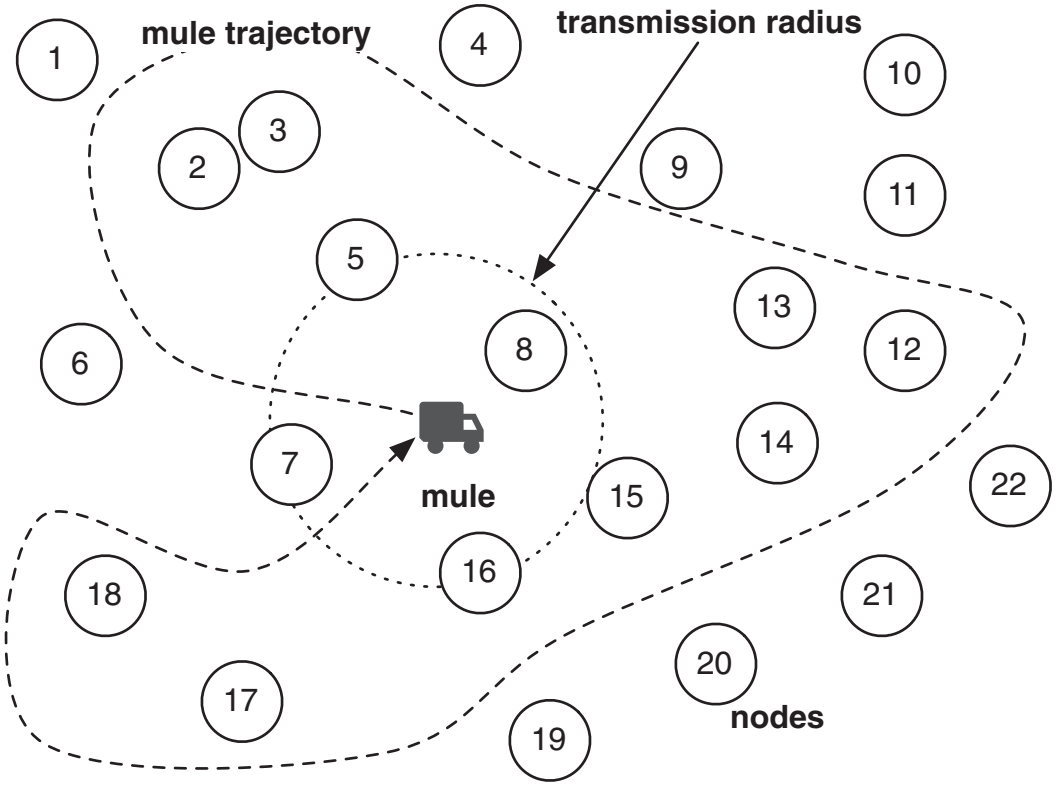
Proximity Schemes



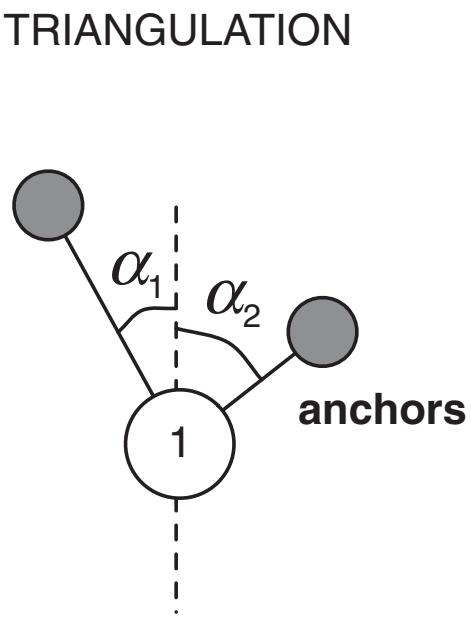
- Guess the approximate location of a node by seeing where are its neighbors
- Example: node 1 is in room A, because its only neighbor is there too
- Very error prone and imprecise
- **Fingerprinting** can improve the performance

Location Mules

Less tedious than fingerprinting, but more expensive in terms of hardware:

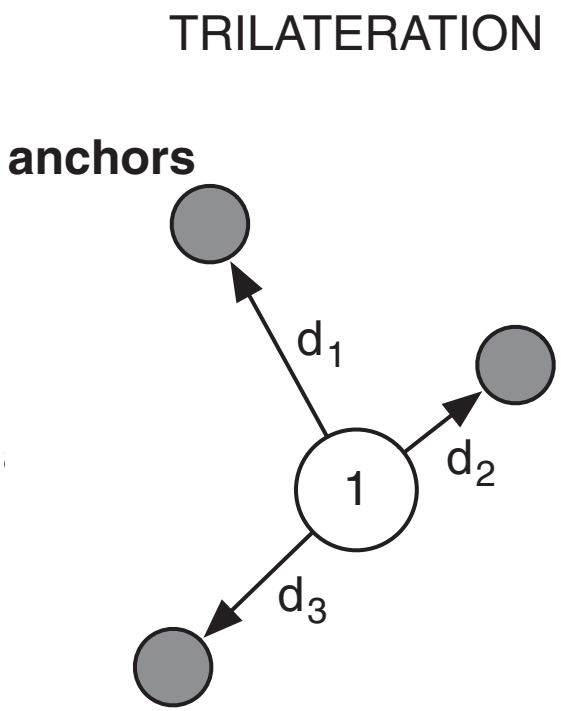


Ranging schemes: Triangulation



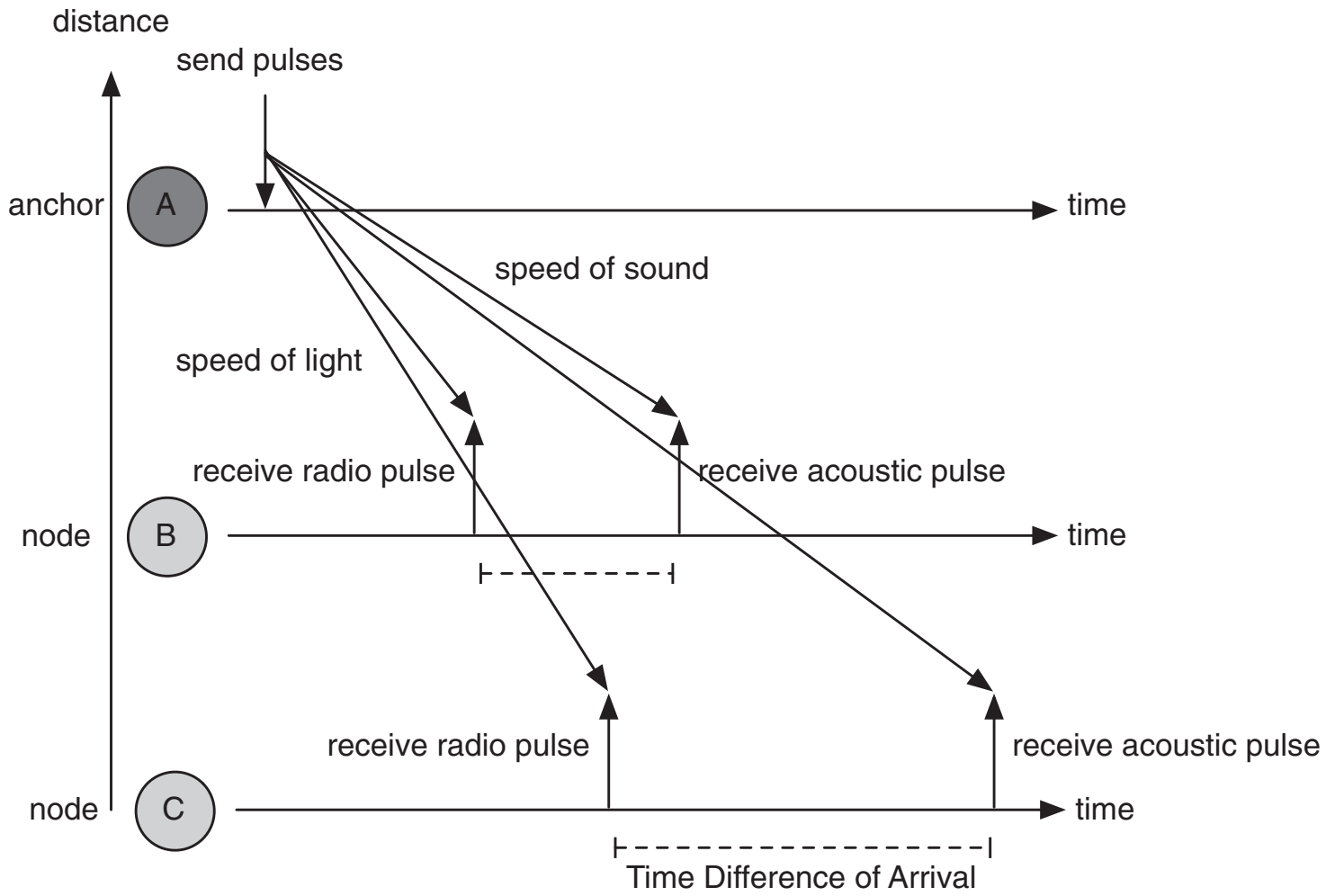
- Measure the angles between the node and the anchors
- How to measure angles?
  - **Need for unidirectional antennas**
- Minimum of two anchors, mathematically not very challenging
- Quite good precision

Ranging Schemes: Trilateration



- Measure the distances between the node and the anchors
- How to measure distance?
  - **Use signal strength (very imprecise)**
  - **Use time difference of arrival of two different communication interfaces (e.g. radio and sound)**
- Minimum of three anchors, mathematically more challenging than triangulation

Time Difference of Arrival



Localization Algorithms

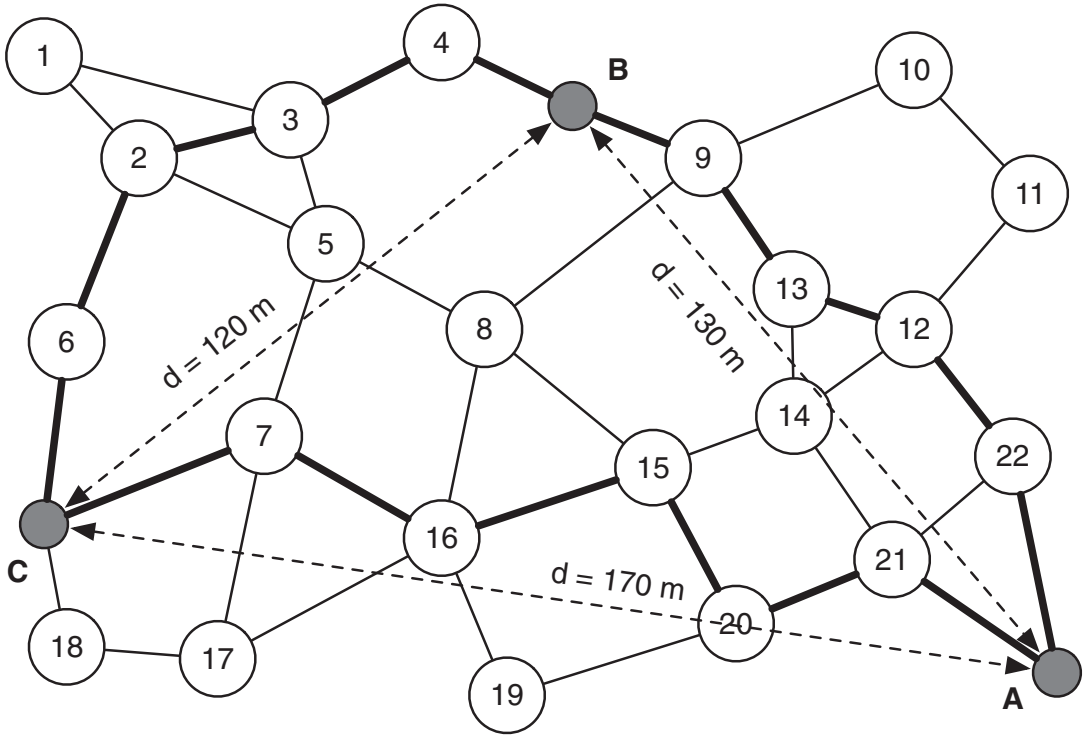
Range-Based Localization

- A protocol (algorithm), which uses range-based techniques for localizing
- Requires anchors (which know their locations precisely)
- The node looks for anchors and localizes itself
- The node can now also serve as anchor for others
  - Iterative Localization

Range-Free Localization

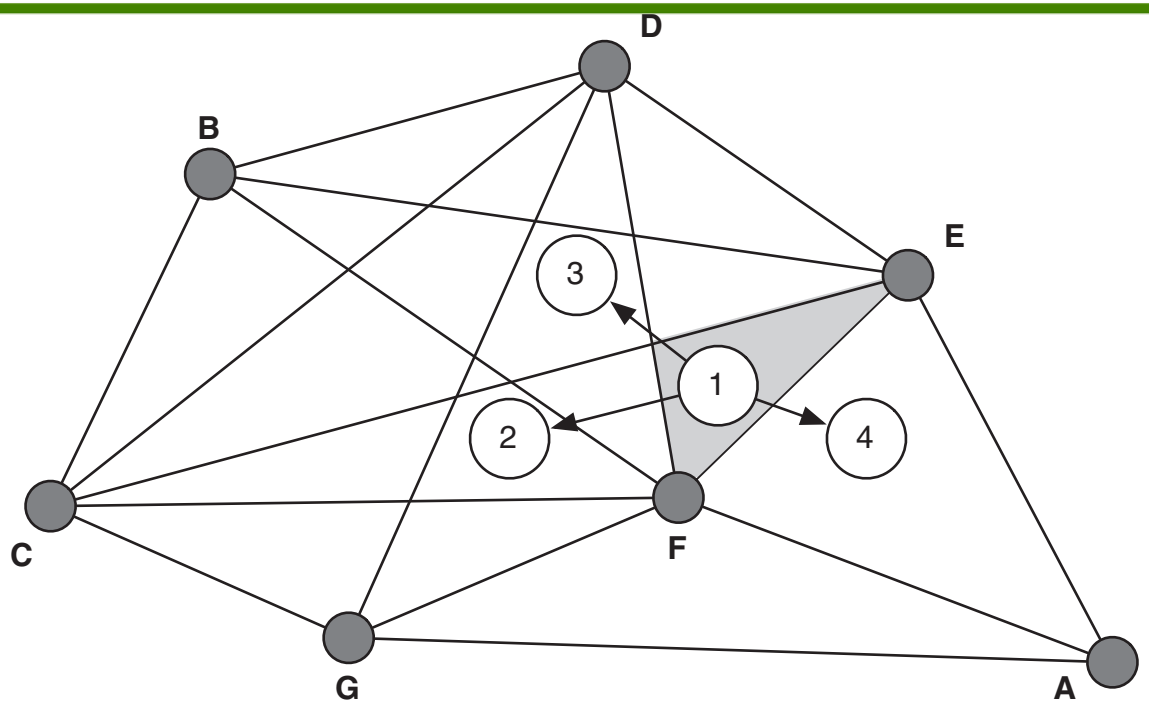
- A protocol, which combines ranging techniques with proximity schemes

Hop-Based Localization



- Make experiments first and compute mean length of hop, e.g. here 26 meters
- Use this metric to compute the distances between all nodes
- Use trilateration

Point in Triangle (PIT)



- Based on moving the node:
  - If you move it in any direction and the distance to all anchors increase/decrease, then it is outside
- Not very practical to move nodes around (unless robots)
- Instead, use your neighbors as a “moved” version of yourself

Localization: Summary

- Location information can be symbolic or physical
- **Pre-deployment methods** include manual or semi-manual procedures of “burning” the right position information onto the right sensor nodes. This is a financially cheap and quite accurate but a very error-prone and tedious process.
- **Proximity-based methods** look for communication neighbors with known positions (anchors) and simply take this information as their own. This is simple but not accurate.
- **Range-based algorithms fi**rst measure either the angles or the distances to known anchors and then use triangulation or trilateration to compute quite accurately their own locations. Performing the measurements is challenging and requires additional hardware (angles and distances) or are quite unreliable (distances like hops).