Freie Universität Berlin

Distance-Based Multi-hop Localization in Mobile Wireless Sensor Networks

8. GI/ITG KuVS Fachgespräch "Drahtlose Sensornetze"
13. - 14. August 2009

Heiko Will, Norman Dziengel, Jochen Schiller

Freie Universität Berlin

Agenda

I. Motivation – Infrastructureless Indoor localization

II. Major Problems

III. Idea: Approximate Anchors

IV. Five Phase Algorithm

V. Simulation Environment

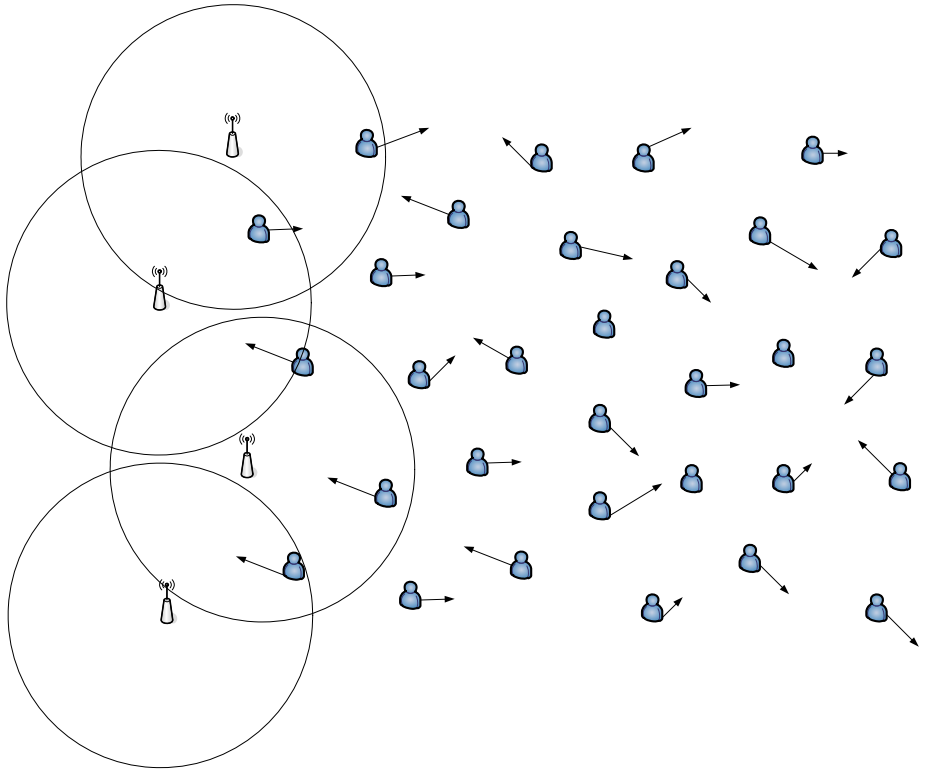
VI. Results & Evaluation

VII. Future Work

Freie Universität Berlin

I. Motivation

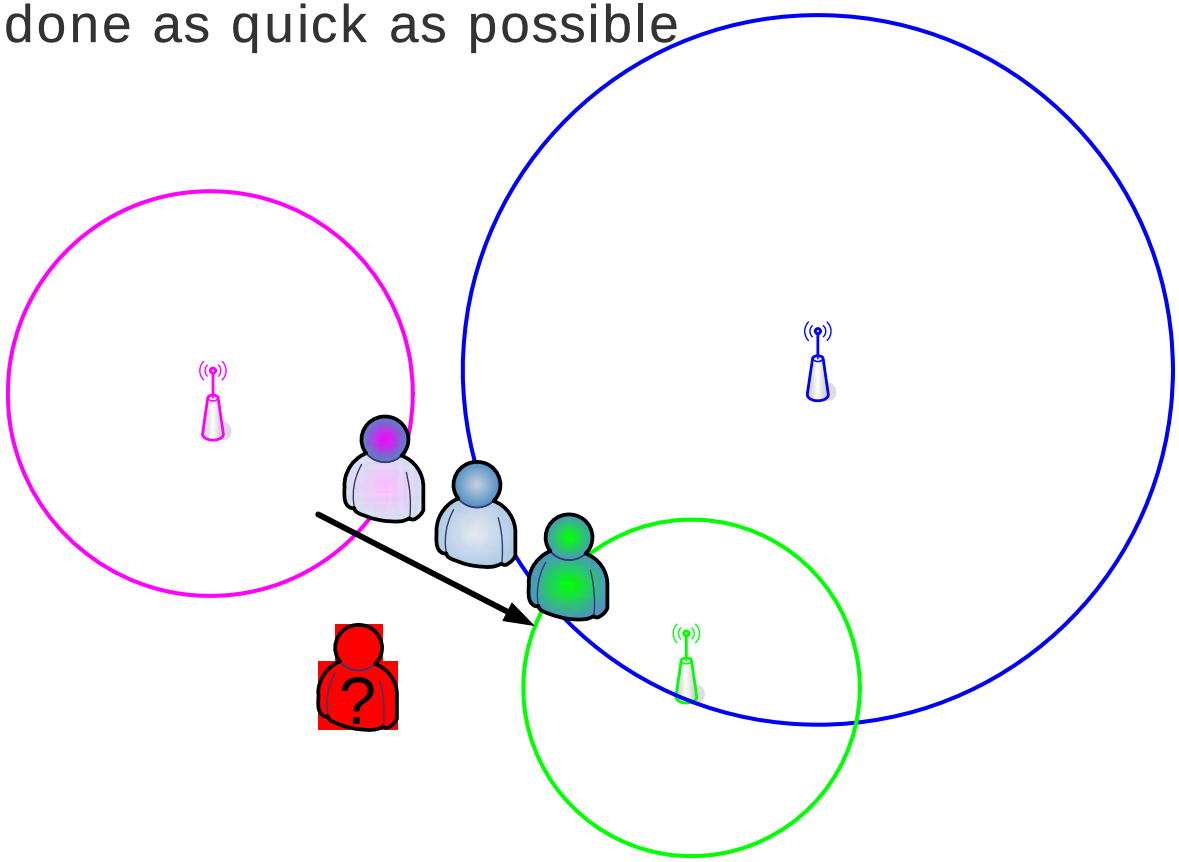
- A large number of nodes with a limited radio range
- Only a few fixed anchors
- Nodes are highly mobile
- Runtime-measurement for distance calculation
- No Infrastructure



Freie Universität Berlin

II. Problem: Mobile Nodes

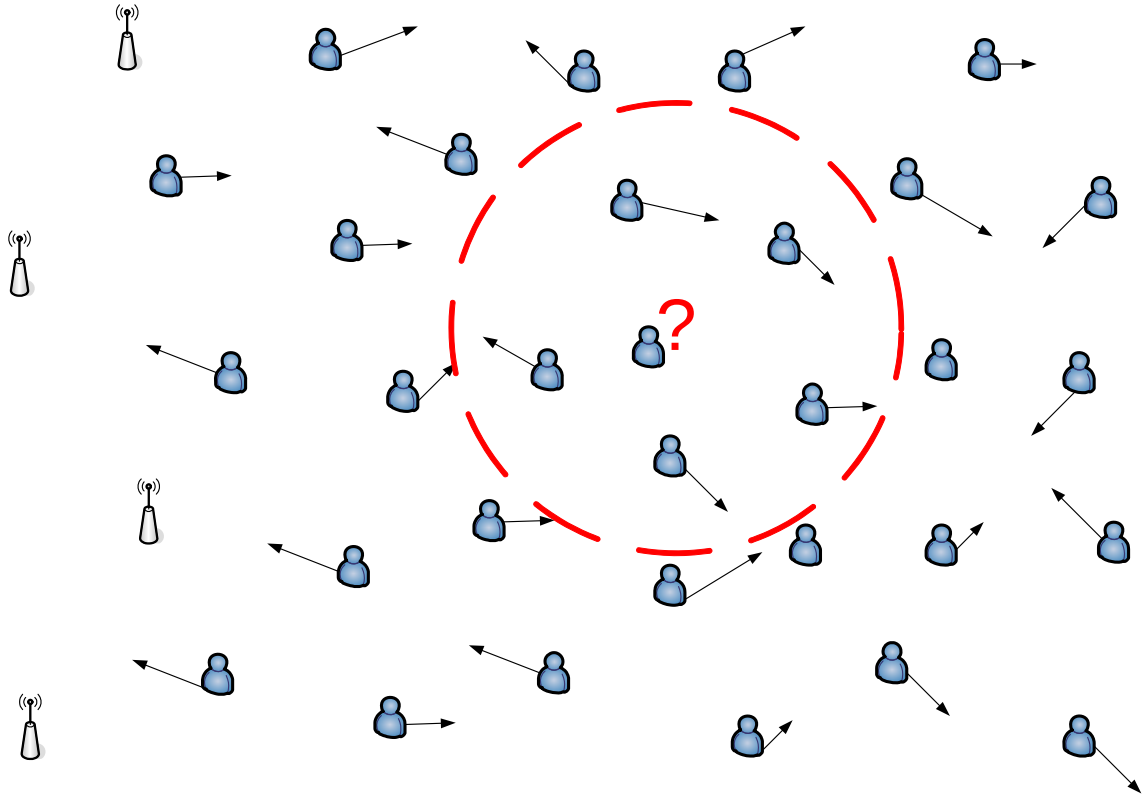
- Lateration needs D+1 rangings
- Moving between rangings decreases accuracy
- Maybe compensated with motion sensing
- A single ranging must be done as quick as possible



Freie Universität Berlin

II. Problem: Distributed Approach

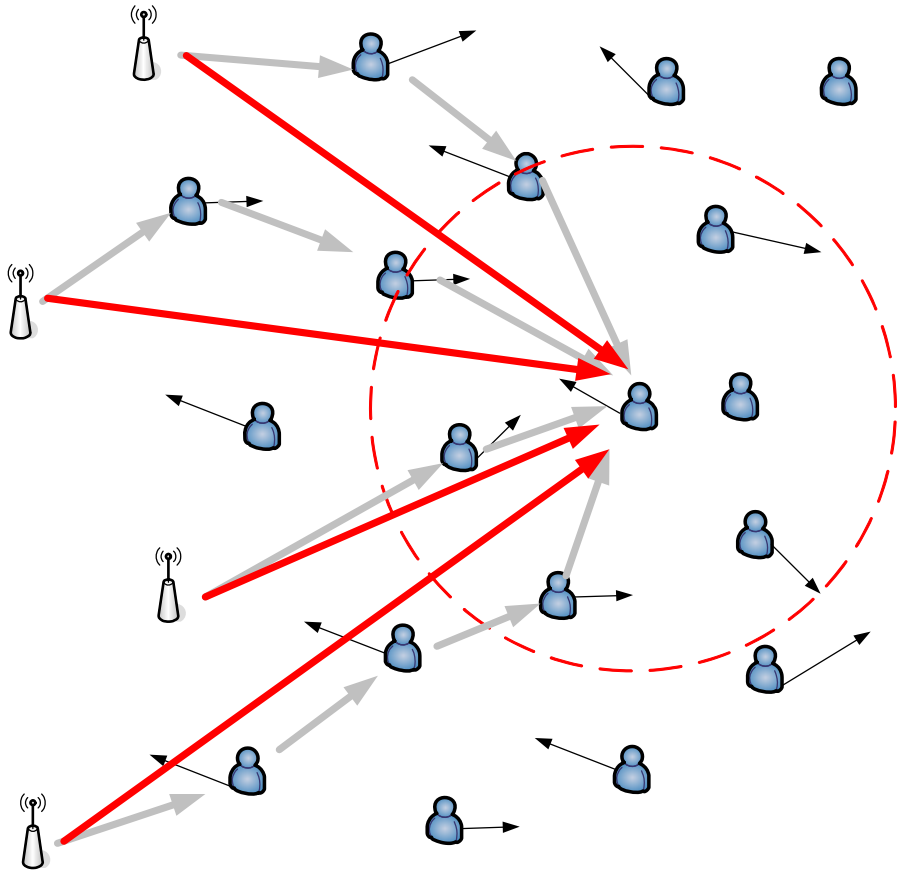
- No Anchors are in range
- Information must be gathered from neighbors
- This could be anchor distance or position
- More nodes than needed could be used for refining



Freie Universität Berlin

III. Idea: Aproximate Anchors

- Only anchor-distances, not neighbour positions are needed
- Error resulting of mobility is much smaller
- There is no „viral“ spread of local position errors
- But how to get precise distances



Freie Universität Berlin

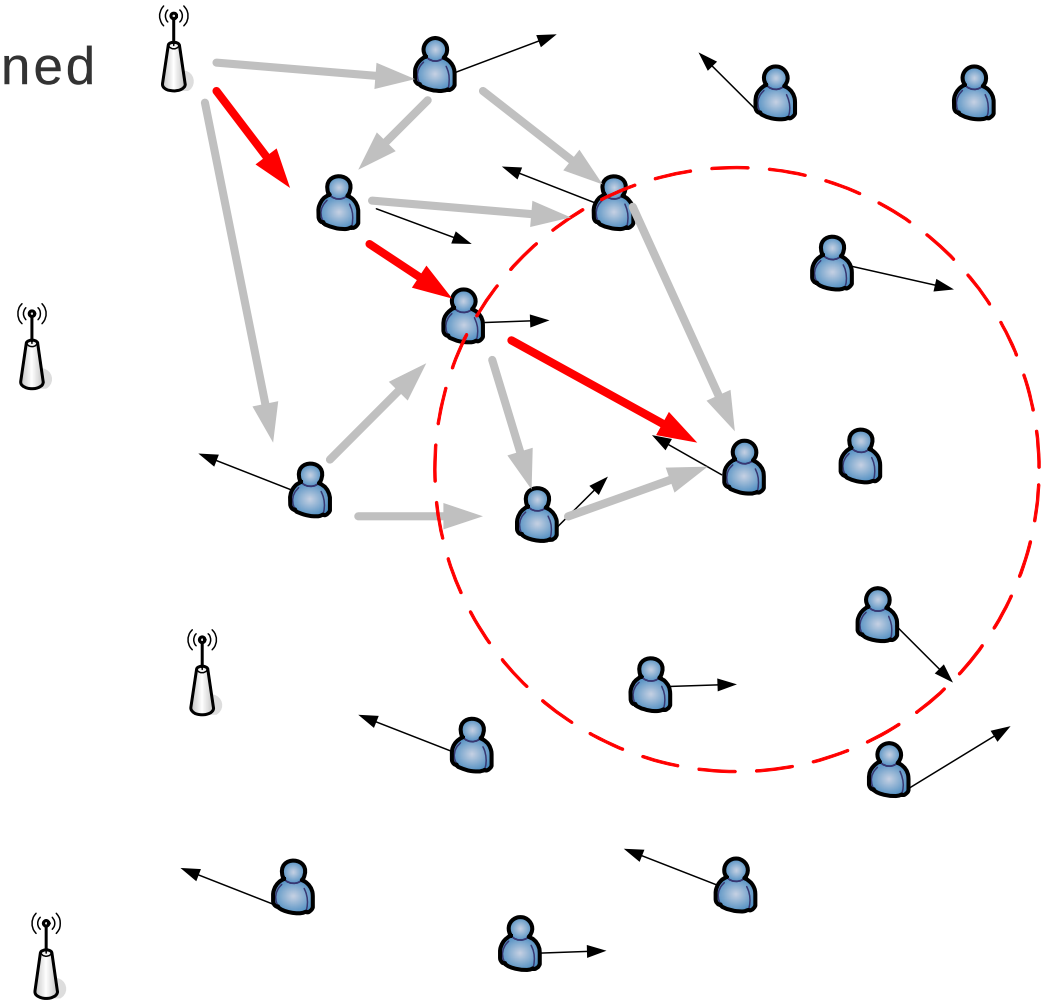
IV. Five Phase Algorithm

- Phase 1 Acquire Neighbor Distances
  - Estimate distances to all neighbors
  - Get distances from neighbors to all anchor nodes
- Phase 2 Calculate Anchor Distances
  - Calculate the total distances to all anchors
- Phase 3 Greedy Phase
  - Choose shortest path to each anchor and store it
  - Paths could not be too short, due to multipath effects
- Phase 4 Anchor Selection
  - Choose between different sets of anchor quadruplets (if #anchors>4)
  - Three anchor selection algorithms implemented
- Phase 5 Quad Lateration
  - Standard Quad Lateration

Freie Universität Berlin

IV. Details Phase 3: Greedy Dist. Accumulation-Alg.

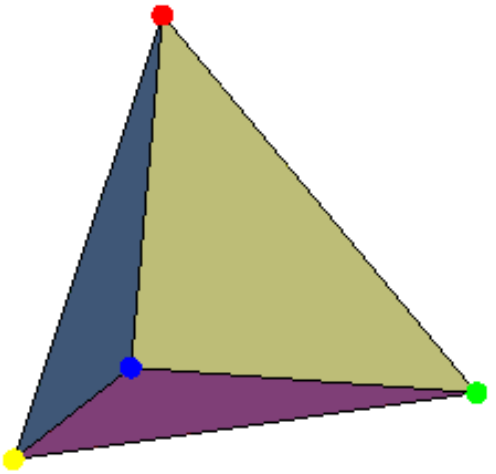
- A calculated distance is always longer than the real distance
- Every possible link is examined
- Immobile nodes are getting precise distances over time
- Mobility could lead to improper distances

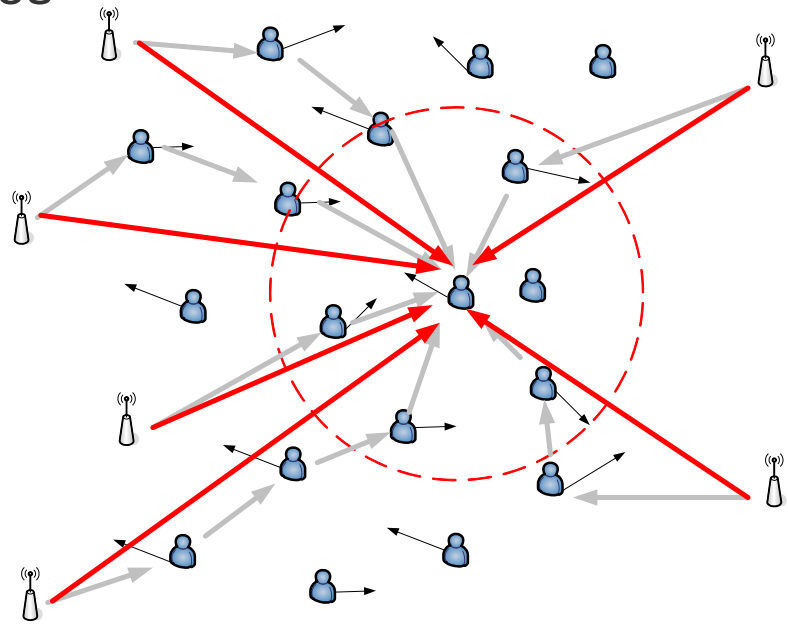


Freie Universität Berlin

IV. Details Phase 4: Which Anchor to choose?

- Volume - Algorithm
  Four anchors describe a tetrahedron
  Biggest tetrahedron will be chosen
- Nearest Neighbor – Algorithm
  simply the nearest anchor will be chosen
- Brute Force – Algorithm
  compares all solutions with real distances





Freie Universität Berlin

V. Simulation Environment

Simulator Features

- Real-time graphical simulation environment
- DirectX for 3D visualization
- Simulates more than 1000 nodes
- Nodes have different movement vectors (configurable by user or generated randomly)
- Different radio ranges
- Distance Request to neighbors within radio range

Simulated Environment

- Volatile, manlike node movement
- Erroneous radio ranges
- Communication between nodes is simplified

Freie Universität Berlin

V. Experiment Setup

Environment Settings

- 100m x 100m area
- Height of 15m to simulate a large building
- Ranging error is set to 3,33%
- While the radio range is set to 30m

Node Settings

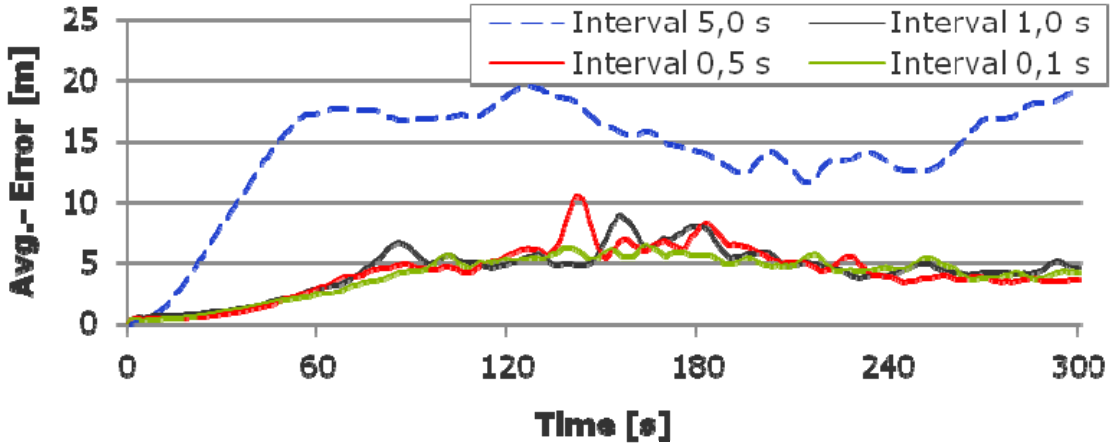
- Nodes move with randomly changing directions and movement speeds
- Speed is limited to 2m/s to simulate humans with normal walking speed
- Nodes start moving on the same spot
- Four fixed anchors placed outside the area

Freie Universität Berlin

VI. Results & Evaluation - Localization Interval

Comparing avg. localization error by changing localization intervals

- Nearest Neighbor Anchor Selection
- 4 anchors
- 300 nodes



Evaluation

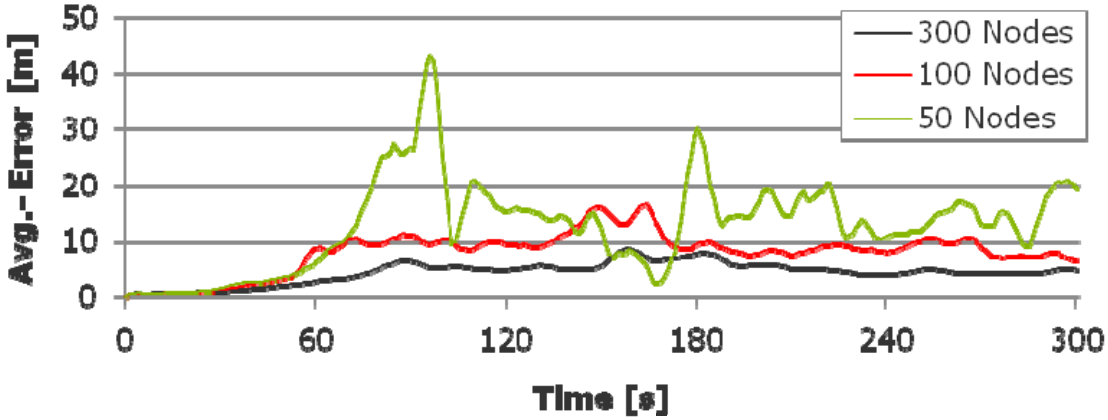
- For walking speed the interval has nearly no impact
- Intervals larger than one second increase the avg. error
- From this observation we conclude that, the interval should be compressed to compensate movement error.

Freie Universität Berlin

VI. Results & Evaluation – Node count

Comparing avg. localization error by changing the quantity of nodes

- Nearest Neighbor Anchor Selection
- 4 anchors
- localization interval: 1s



Evaluation

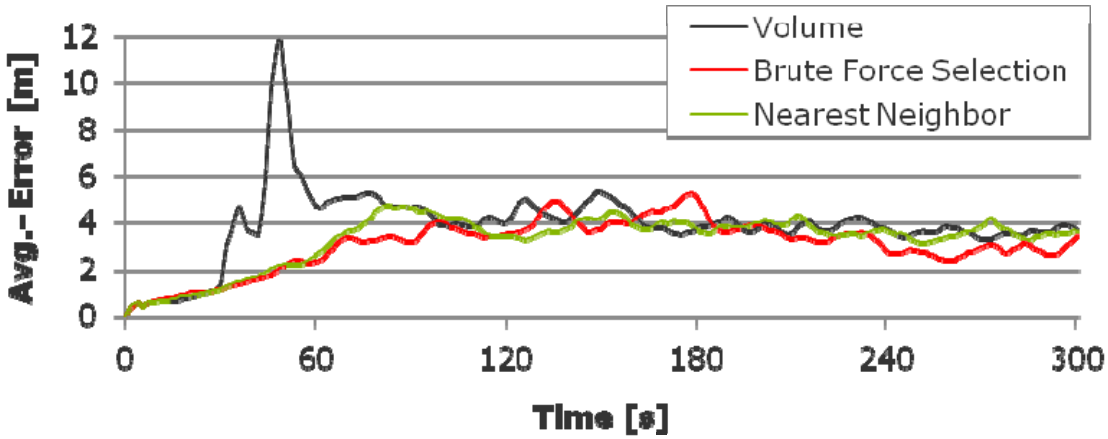
- Node count has bigger influence than localization interval
- Node count < 50 leads to nodes with insufficient number of anchors

Freie Universität Berlin

VI. Results & Evaluation – Anchor Selection Alg.

Comparing avg. loc. error by changing anchor selection algorithms

- 4 anchors
- 1 second localization interval
- 4 anchors
- 300 nodes



Evaluation

- Nearest Neighbor Algorithm is close to optimal algorithm
- Volume Algorithm performs nearly as good as NN Algorithm
- We propose NN Algorithm due to complexity of Volume Algorithm

Freie Universität Berlin

VII. Future Work

- Real World implementation and evaluation
- Research on efficient ranging processes
- Integration into routing and MAC layers
- Research on applicable QoS components
- Refining with sensor fusion

Thank you…

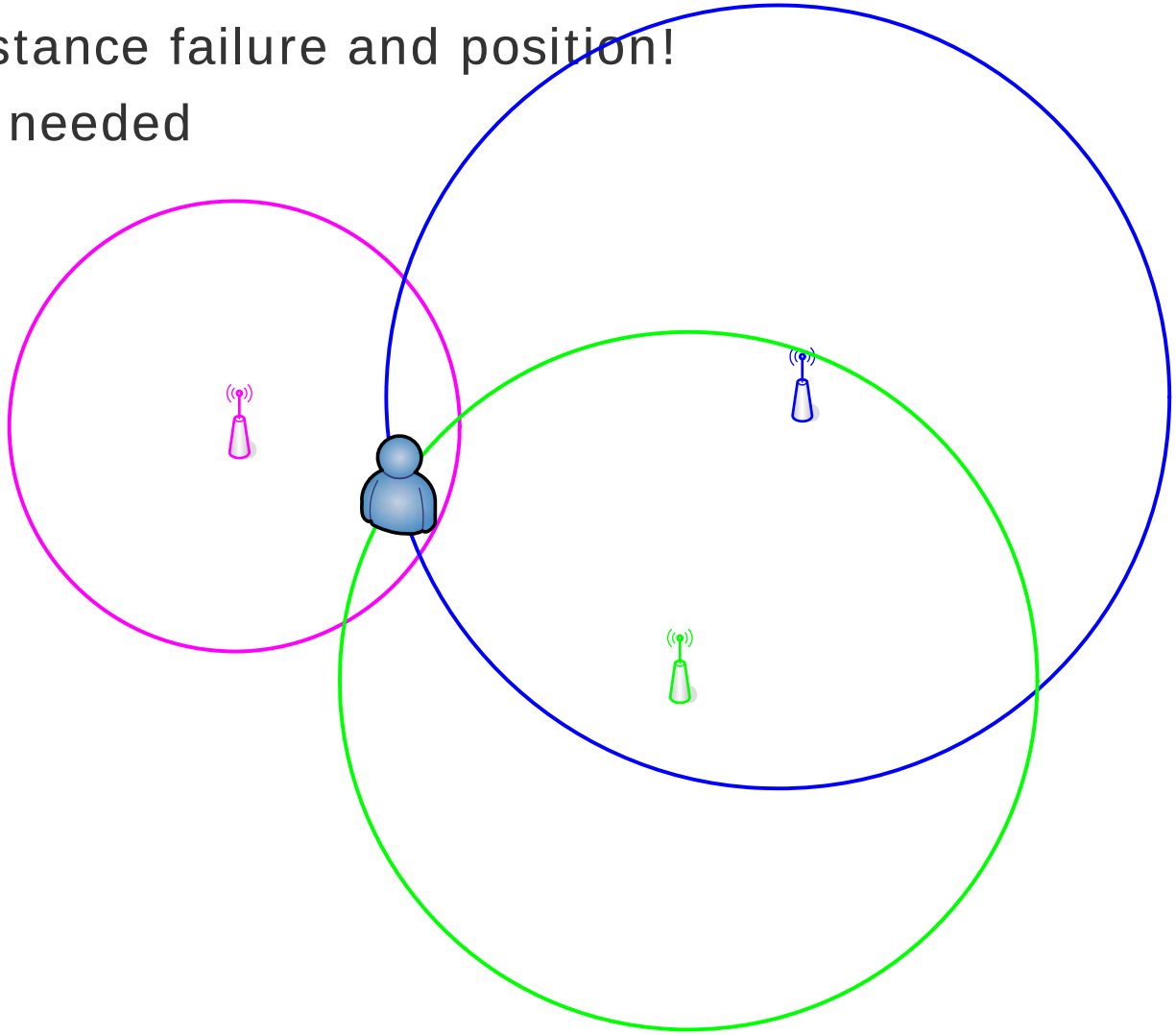
Freie Universität Berlin

Ersatzfolien

Freie Universität Berlin

Lateration as Localisation-Algorithm

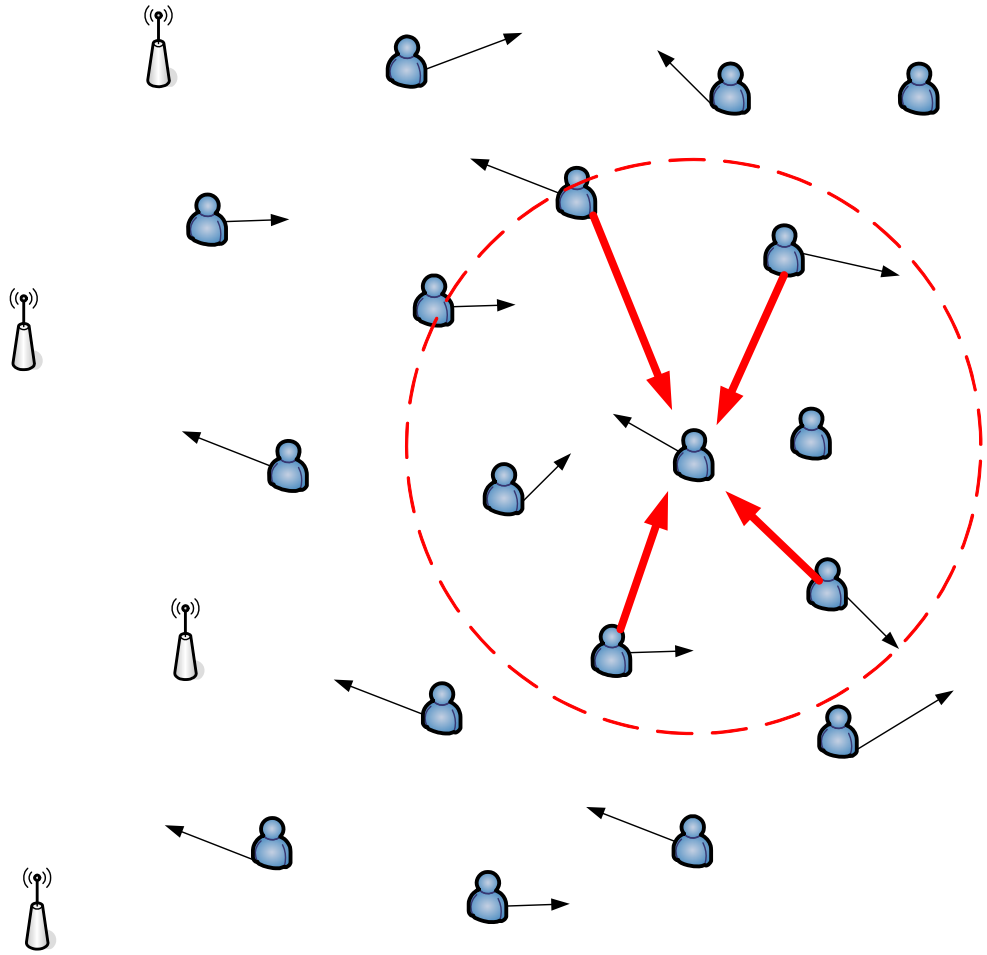
- Simple geometric algorithm
- Based on distances
- Accuracy depends on distance failure and position!
- For 3D four anchors are needed



Freie Universität Berlin

Localization Problems

- Only calculated, not real positions are useable because they are erroneous by themselves
- Motion error adds up every hop
- Which nodes to choose?



Freie Universität Berlin

Problem: When to range?

- Range as often as you can!
- Ranging the same neighbors in the same interval, fixes the movement-error
- It should be the best strategy to compress the interval as much as possible
- The optimum is achieved, if ranging is synced with the hop-count of each node
- A good approximation is to sync at a random point in the given (compressed) interval.

Freie Universität Berlin

Refining and verifying positions

- There is more data available than needed for the localization – it could be used for refining
- Especially sensor-fusion could be a big point
- From a calculated position, the distances to other neighbors could easily be calculated and used for further refining.
- Nodes could calculate and populate assumptions about their quality of known distances to anchors

Freie Universität Berlin

Outlook

- In a simulation we achieve an overall accuracy below 2 meters in very dense networks
- Ranging errors of the transceivers haven't been evaluated yet!
- Immobile nodes could become anchors
- A better anchor-choosing-algorithm can improve accuracy to below 60cm