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UNIVERSITÄT FREIBURG

Algorithms for Radio Networks

Localization

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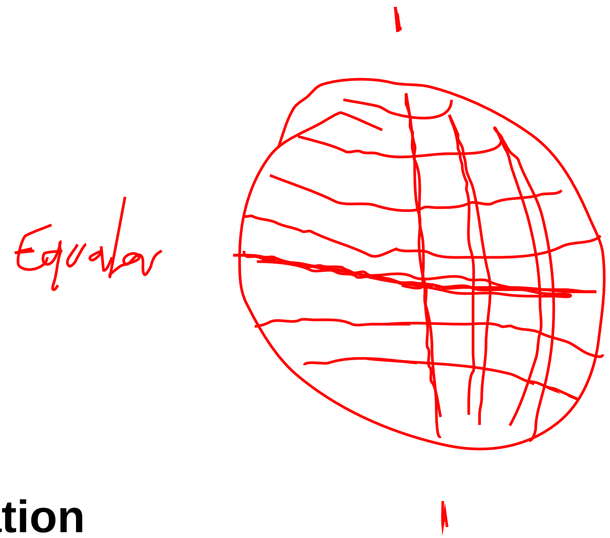
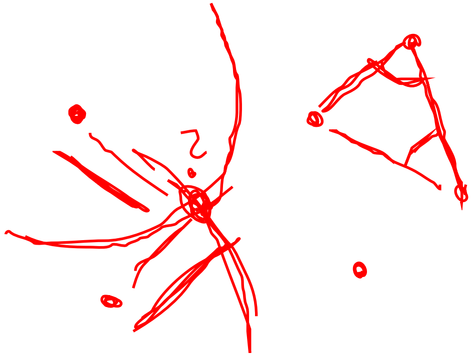
Localization

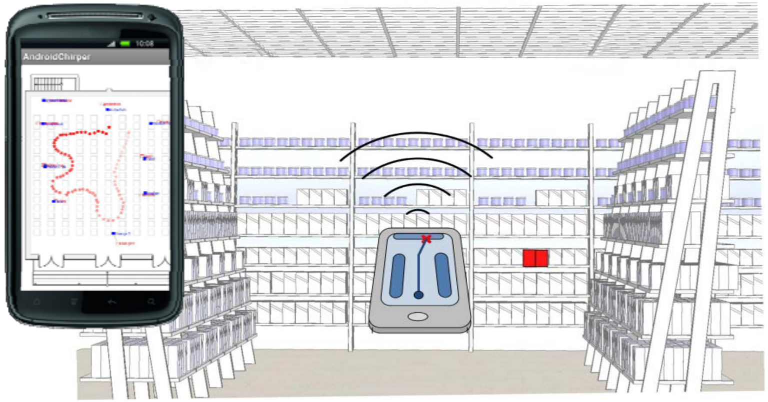


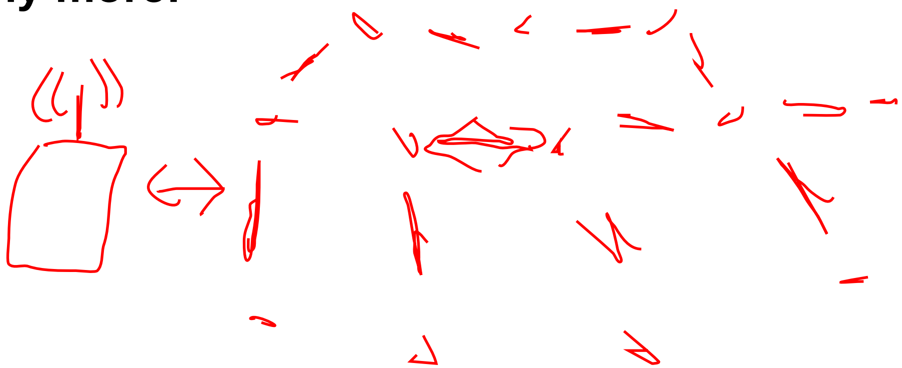
- **Localization in an empty environment?**
  - **Requires some “stuff” around**
  - **Determine the physical position or logical location**
- **Reference points (“landmarks”)**
  - **Natural: Trees, mountains, river bend, earth’s surface, sun, stars, ...**
  - **Artificial: Road signs, Surveyor’s mark, Retro-reflector, buoys, lighthouse, radio beacon, ...**
- **Coordinate systems**
  - **Global coordinate frame, Earth coordinates**
  - **Local reference frame: Cartesian grid, floor tiles**
  - **Absolute or relative coordinates**



Localization

- Applications
  - Surveying, geodesy
  - Naval navigation, aviation, space flight
  - Navigation of people inside buildings in urban areas
  - Cars on roads, logistics
  - Navigation of robots: Autonomous mobile units
  - Industrial machines, tools: Drills, rivet hammers
  - Networks: Routing algorithms, sensor networks
  - ...and many more!





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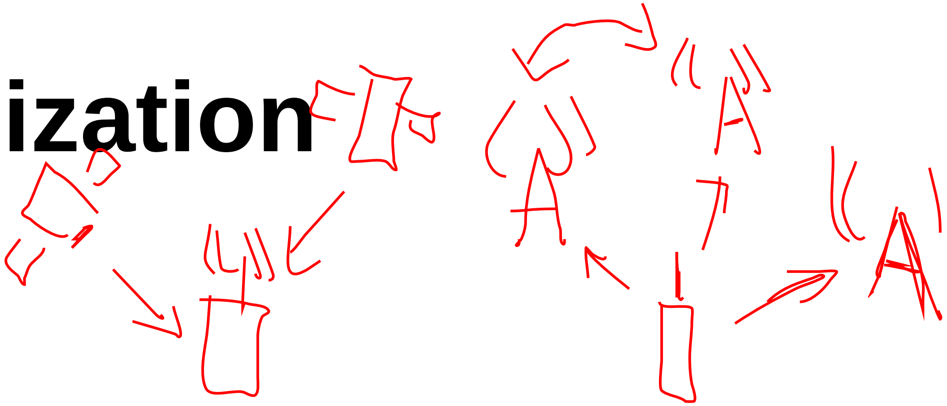
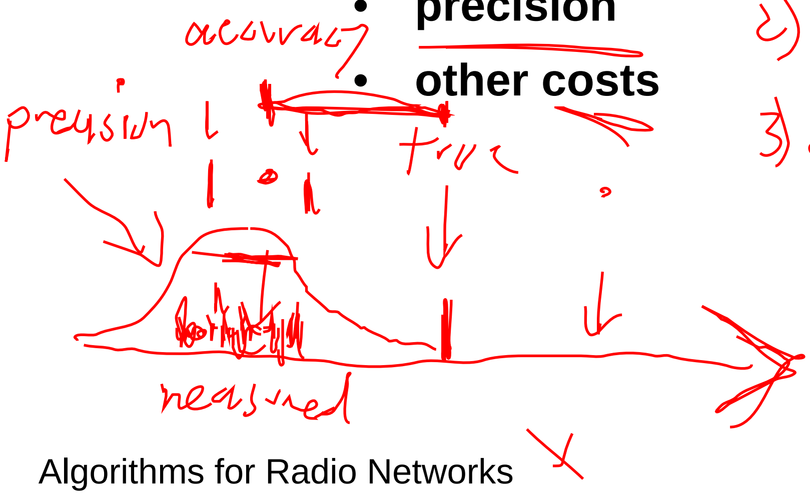
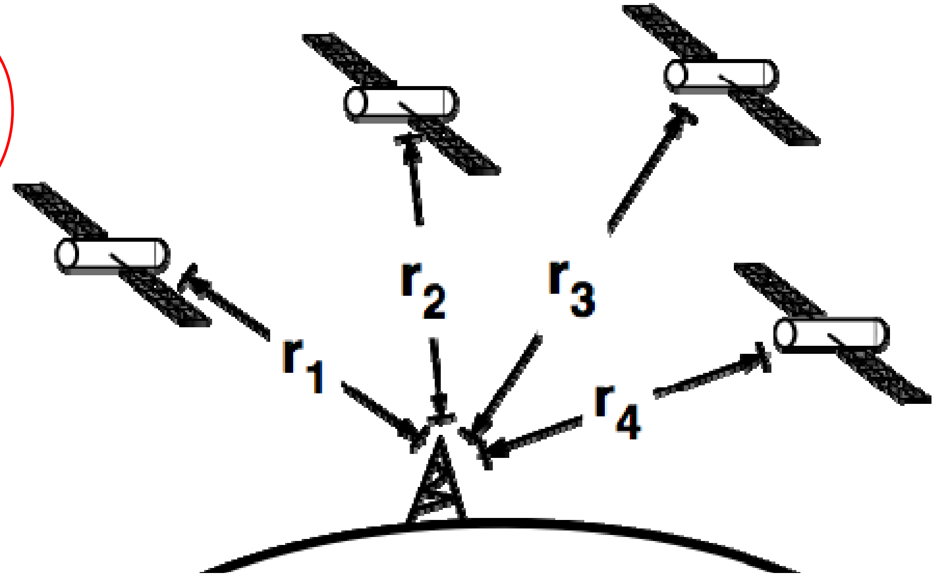


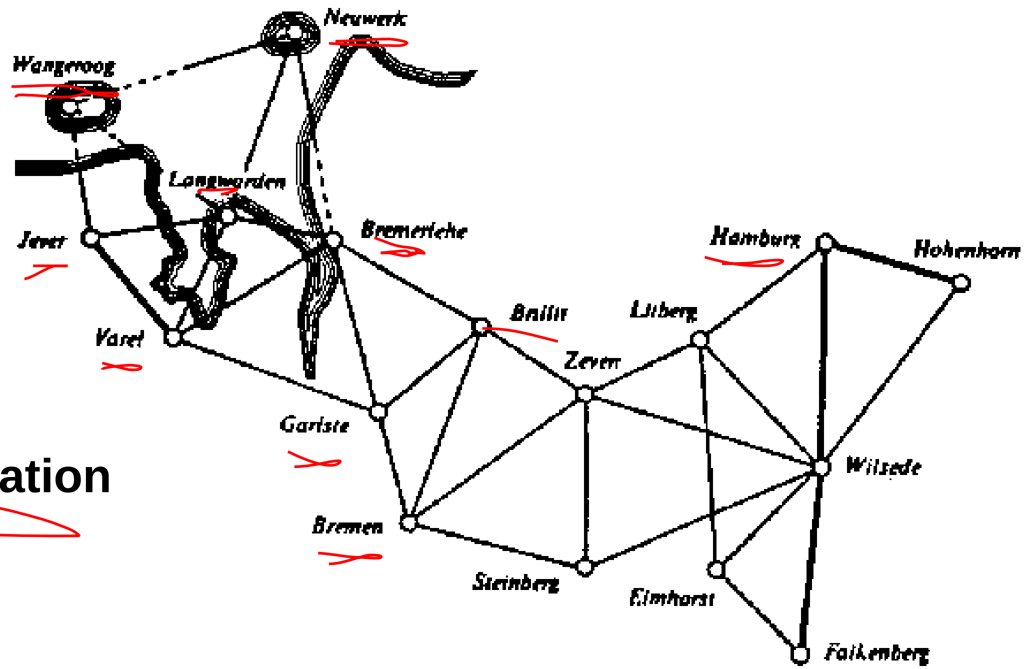
- Parameter
  - Centralized or distributed computing
  - Availability of position information: Active vs. passive localization
  - Application
    - Indoors, outdoors, global
  - Sources of information: Sound, light, radio signal, magnetic field, ...
- Metrics
  - accuracy
  - precision
  - other costs

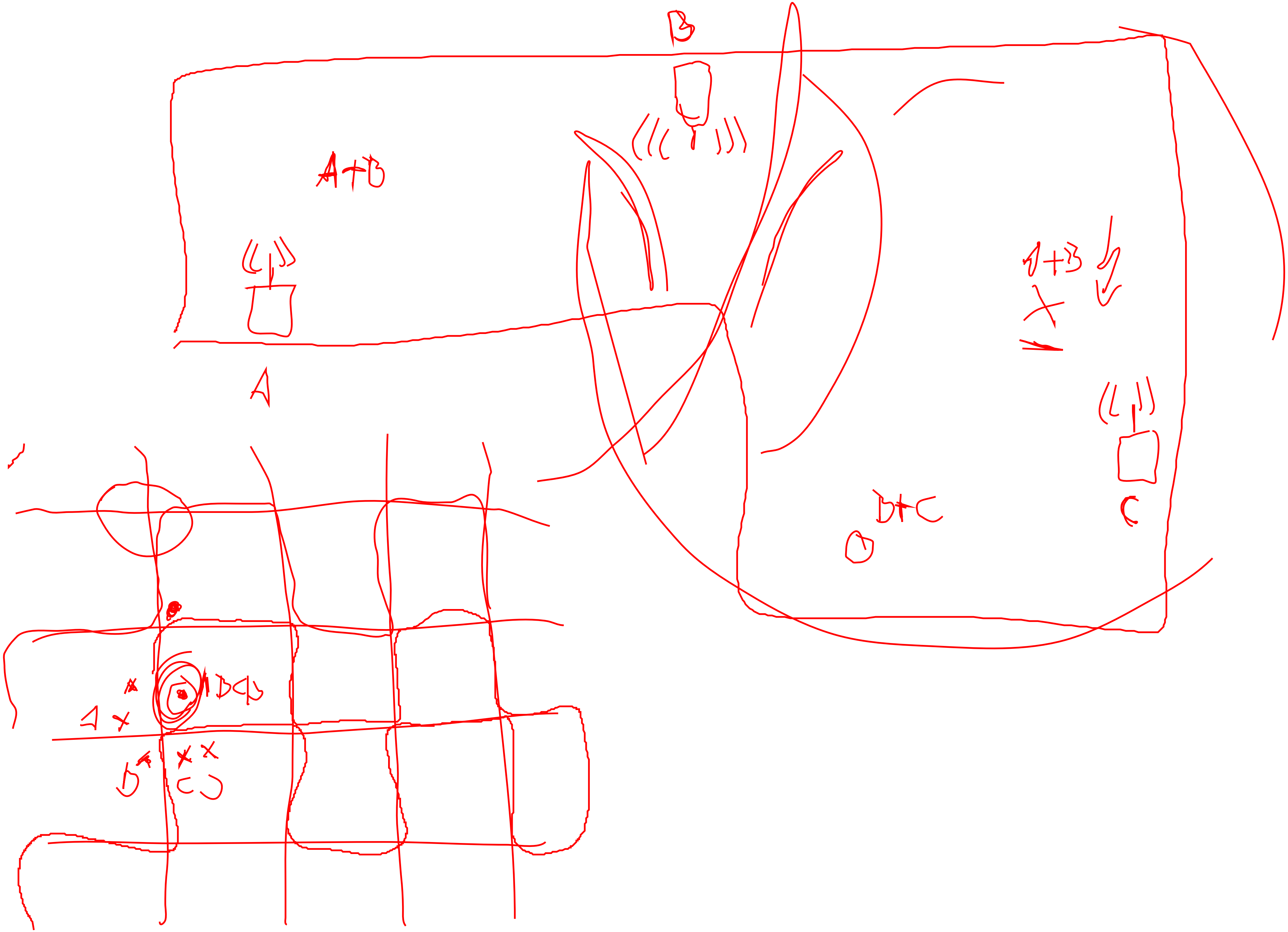


Sources of Information



- **Neighborhood information**
  - **Range provides coarse location information**
    - **e.g. GSM / UMTS cell, wireless IDs**
- **Triangulation and trilateration**
  - **Angle differences**
  - **distance measurement**
- **Analysis of the environment**
  - **Characteristic "signature" by radio conditions in the environment**
- **Inertial navigation systems**
  - **Measurement of acceleration and rotation**





B
A+B
A
A+B
B+C
C

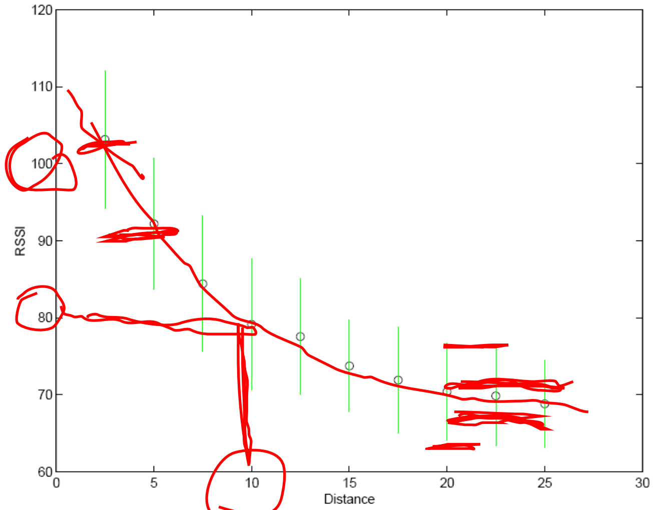
RSSI

- Received Signal Strength Indicator
  - Using the path loss at a known transmission power
  - Measurement of the received signal

$$P_{\text{recv}} = c \frac{P_{\text{tx}}}{d^{\alpha}} \Leftrightarrow d = \sqrt[\alpha]{\frac{c P_{\text{tx}}}{P_{\text{recv}}}}$$

α < 2 : tunnels
α > 2 : obstacles

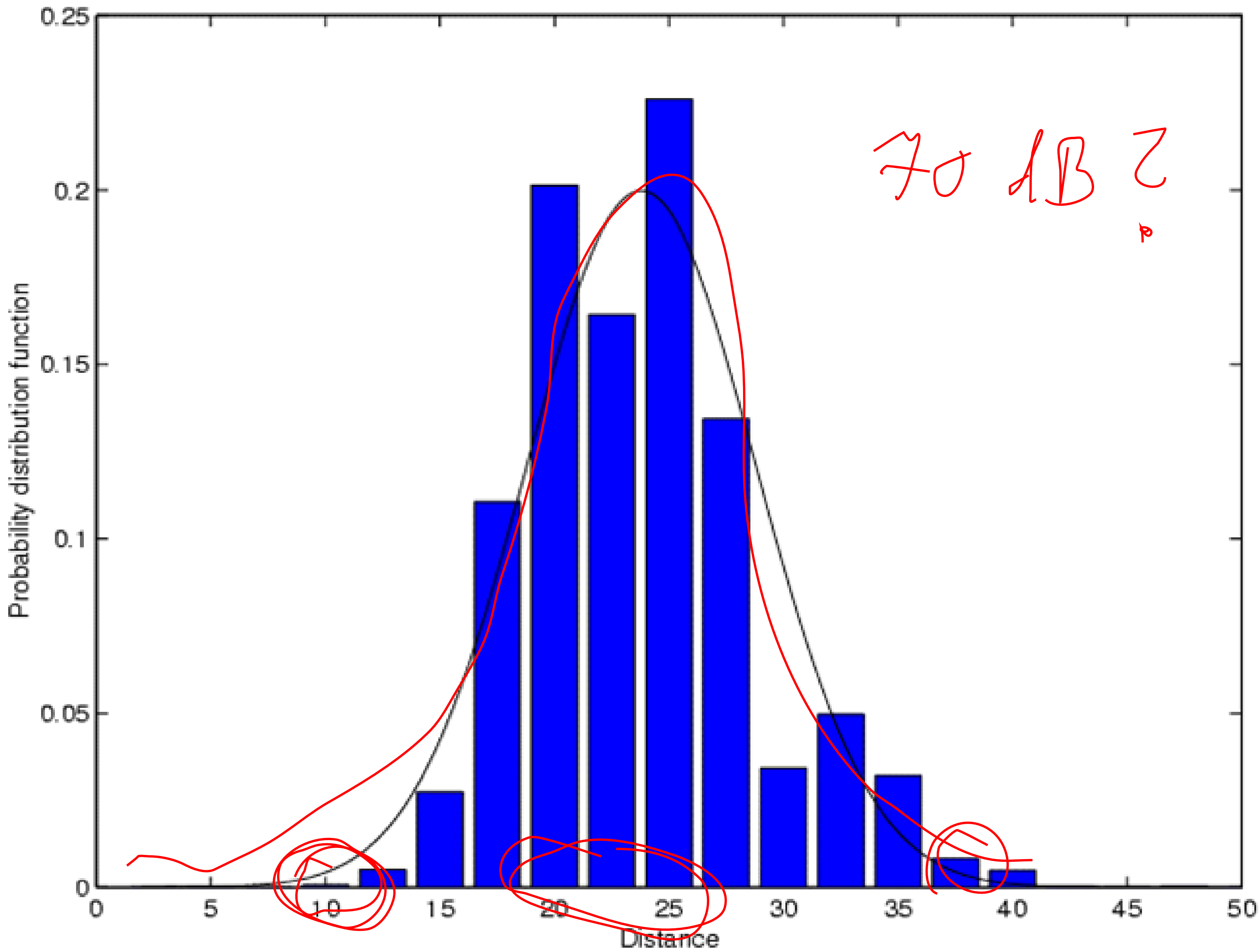
  - Path loss exponent α, transmission power $\mathbf{P}_{\text{tx}}$
  - Problem: High error rate



[Sichitiu and Ramadurai, MASS 2004]

RSSI

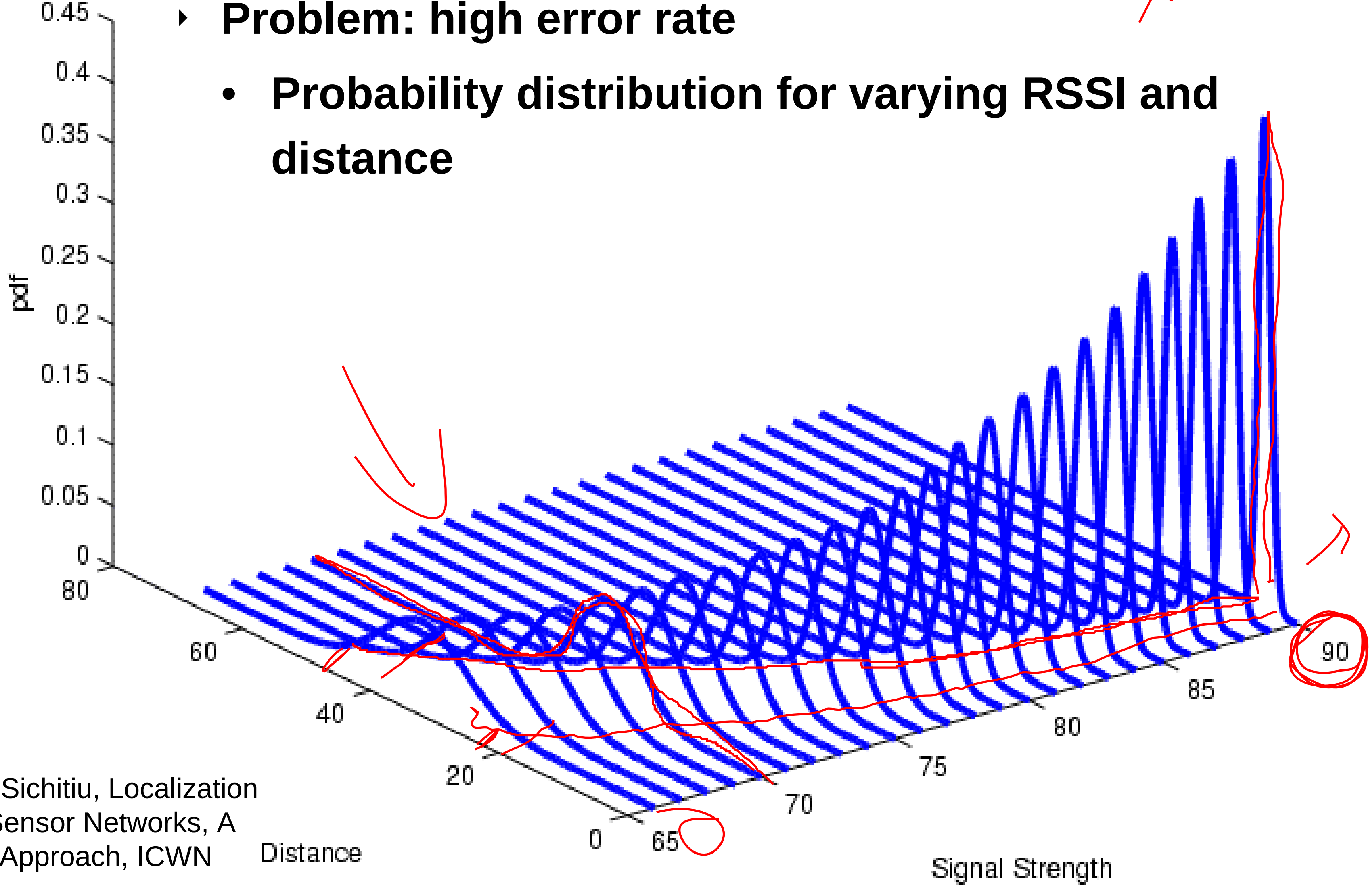
- **Problem: high error rate**
  - **Probability distribution for RSSI and given transmission power**



[Ramadurai, Sichitiu, Localization in Wireless Sensor Networks, A Probabilistic Approach, ICWN 2003]

RSSI

- **Problem: high error rate**
  - **Probability distribution for varying RSSI and distance**



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RSSI

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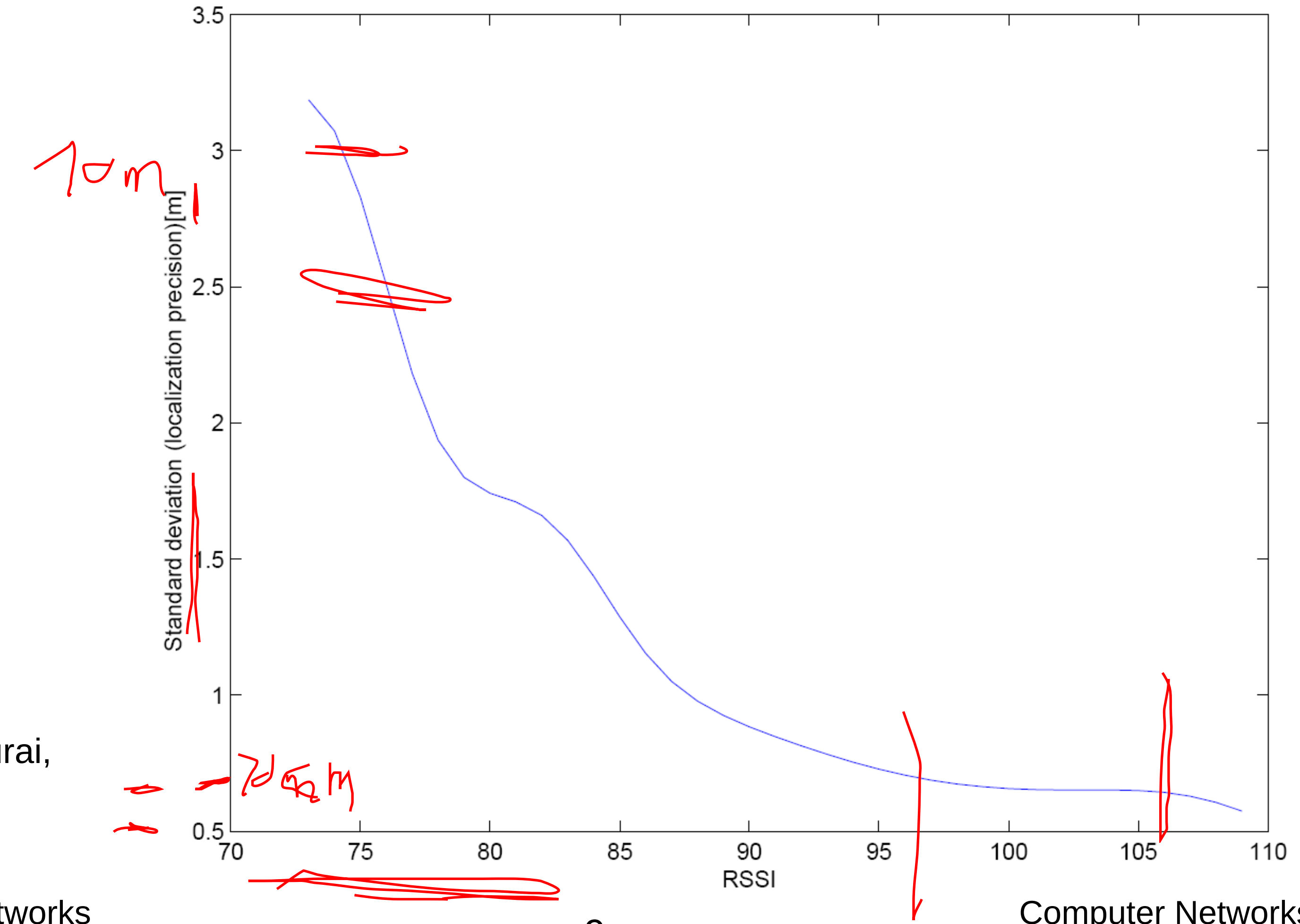

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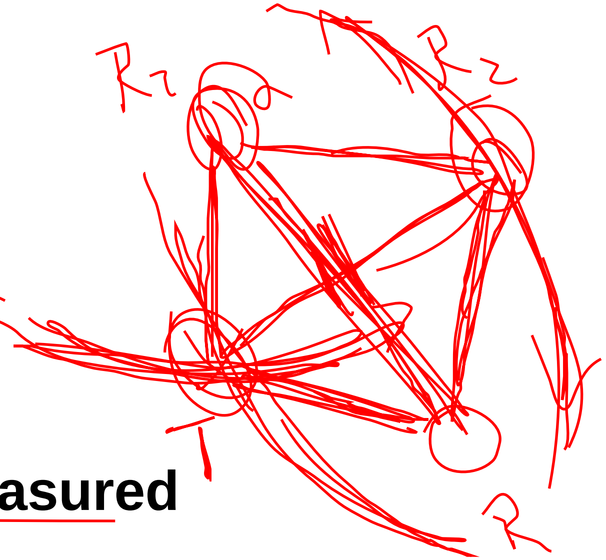
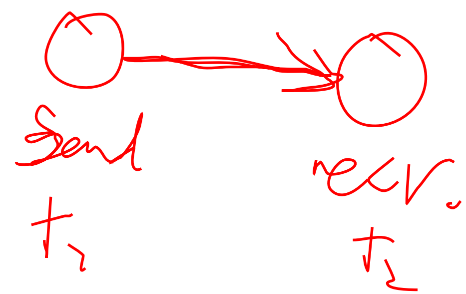
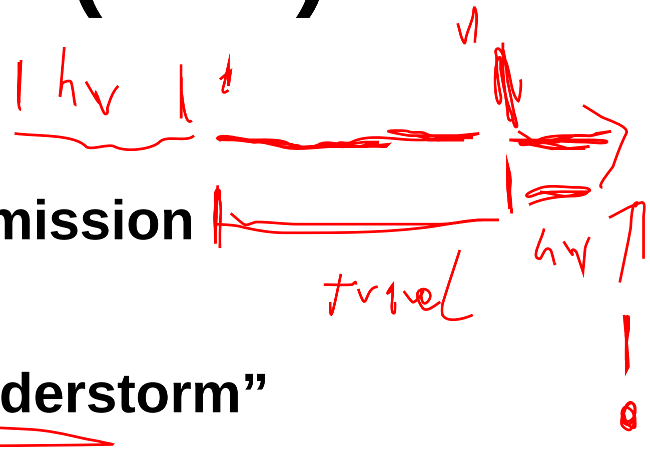
Time of Arrival



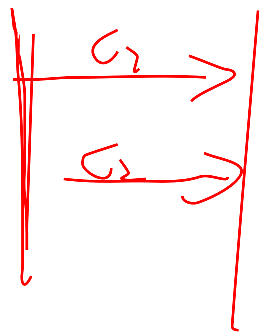
- Time of arrival (TOA)
  - Transmission time (“Time of flight”) is measured
  - Transmission time = Reception time – Send time
  - Results from the quotient:
    - Transmission time = distance / speed signal
- Problem
  - Positions of measurement points (anchors) must be known (usually...)
  - Accurate time measurement
  - Clock synchronization
  - Relative ranges require more anchors



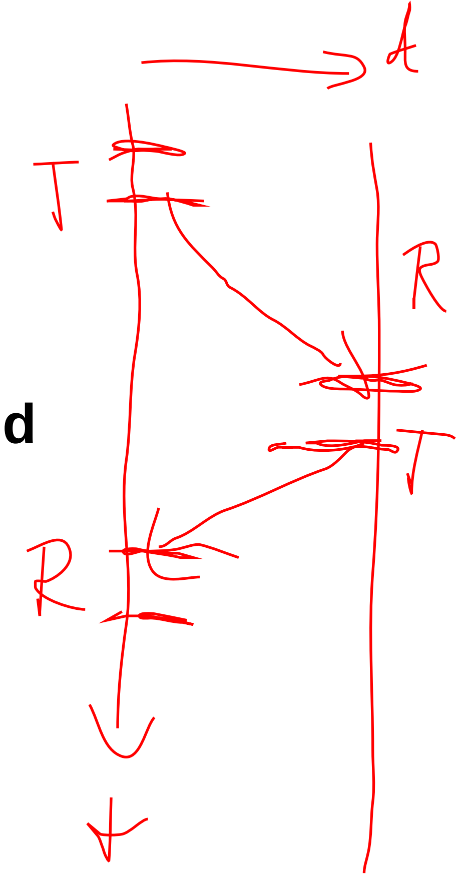
Time *Difference* of Arrival (ToA)



- **Two different signals with different transmission speeds**
  - **E.g. ultrasound and radio signal, “thunderstorm”**
  - **Main component of the speed of sound**
  - **Calculate the different arrival times is distance**
  - **If one signal is very fast (e.g. “light”), eliminate it**
- **Problems:**
  - **calibration (hardware delay)**
  - **special hardware is required**



Round Trip time (ToA)



- **Two way communication, send a signal back and forth between two transceivers**
  - **E.g. radio signal, sound signal**
  - **Distance = 1/2 * Round trip time / c**
- **Problems:**
  - **Again: calibration (hardware delay)**
  - **Requires two transmitters and two receivers**
- **Similar: Measure distance to an obstacle (reflection)**
  - **Distance measurement by Laser or ultrasound**

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