LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Praktikum Mobile und Verteilte Systeme

# Indoor Positioning Systems

## WLAN Positioning

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http://www.mobile.ifi.lmu.de

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# WLAN Positioning

**Today:**

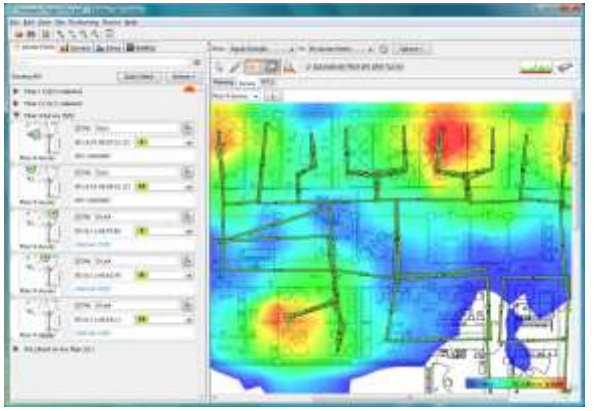
- Motivation
- Overview of different indoor positioning technologies/methods
- WLAN Positioning
- Sensor Fusion

# Why Indoor Positioning?

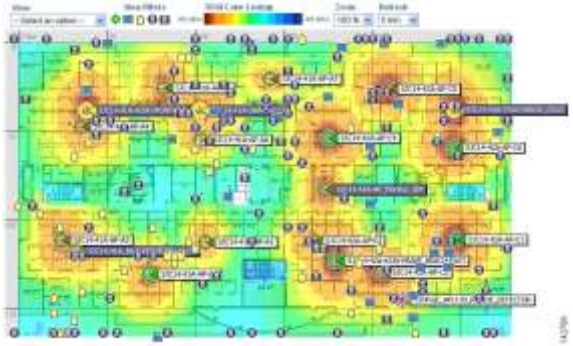
- Developement of Location-based Services
  *Value-added services that consider the position of a mobile target*
  - Navigation Systems
  - Information Systems
  - Emergency
  - Advertising
  - …
- Location-based Services require a positioning method
  - GPS / Galileo
  - GSM Cell-ID
  - Indoor?

# Indoor Positioning Systems

- Application examples
  - Object & asset tracking
  - Workflow optimization & maintenance
  - Information services
  - Healthcare & ambient living
  - Security & safety



Ekahau (www.ekahau.com)



Cisco (www.cisco.com)

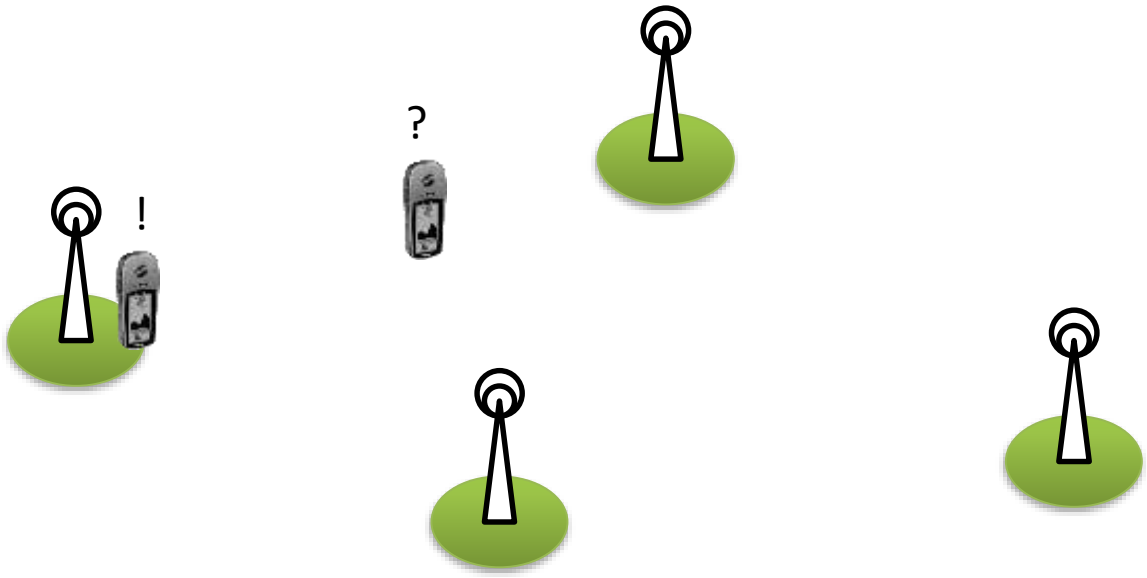
# Positioning Fundamentals

- Positioning is determined by
  - one or several parameters observed by measurement methods
  - a positioning method for position calculation
  - a descriptive or spatial reference system
  - an infrastructure
  - protocols and messages for coordinating positioning

| Positioning method | Observable | Measured by |
|---|---|---|
| Proximity sensing | Cell-ID, coordinates | Sensing for pilot signals |
| Lateration | Range or<br><br><br>Range difference | Traveling time of pilot signals<br>Path loss of pilot signals<br><br>Traveling time difference of pilot signals<br>Path loss difference of pilot signals |
| Angulation | Angle | Antenna arrays |
| Dead reckoning | Position and<br>Direction of motion and<br>Velocity and<br>Distance | Any other positioning method<br>Gyroscope<br>Accelerometer<br>Odometer |
| Pattern matching | Visual images or<br>Fingerprint | Camera<br>Received signal strength |

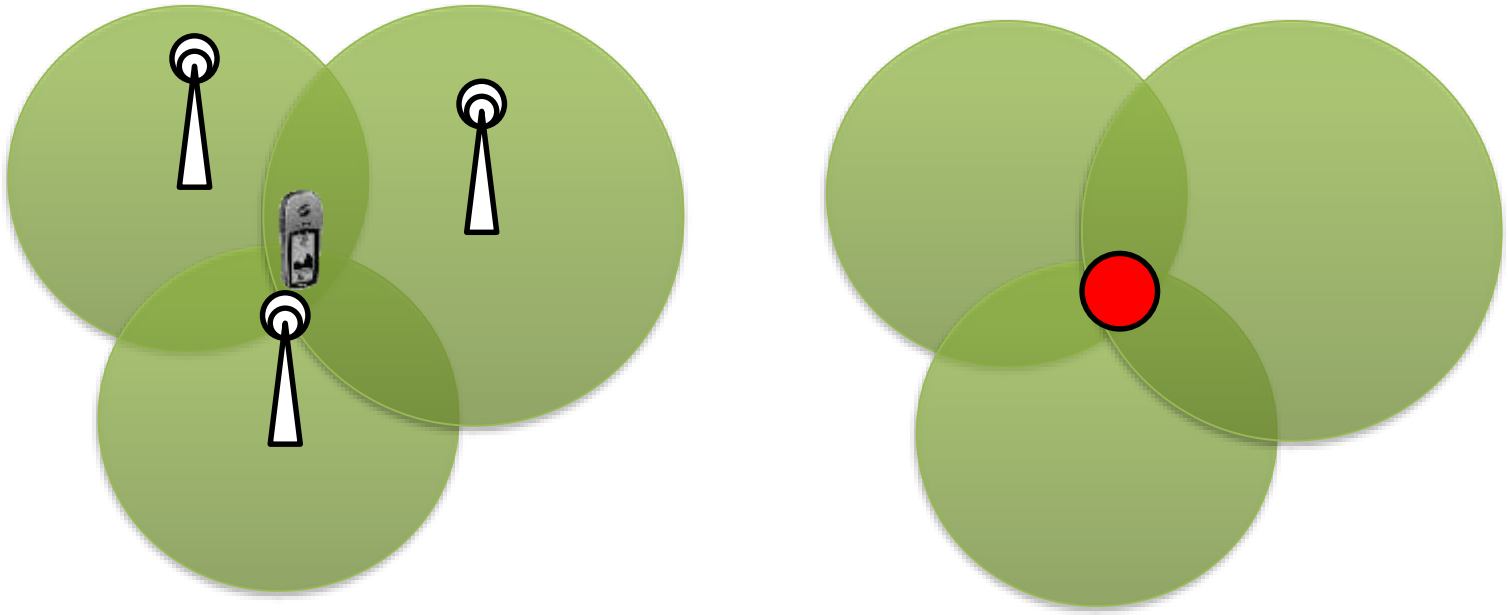
# Proximity Sensing

- Proximity is sensed by a station using (short) range pilot signals:



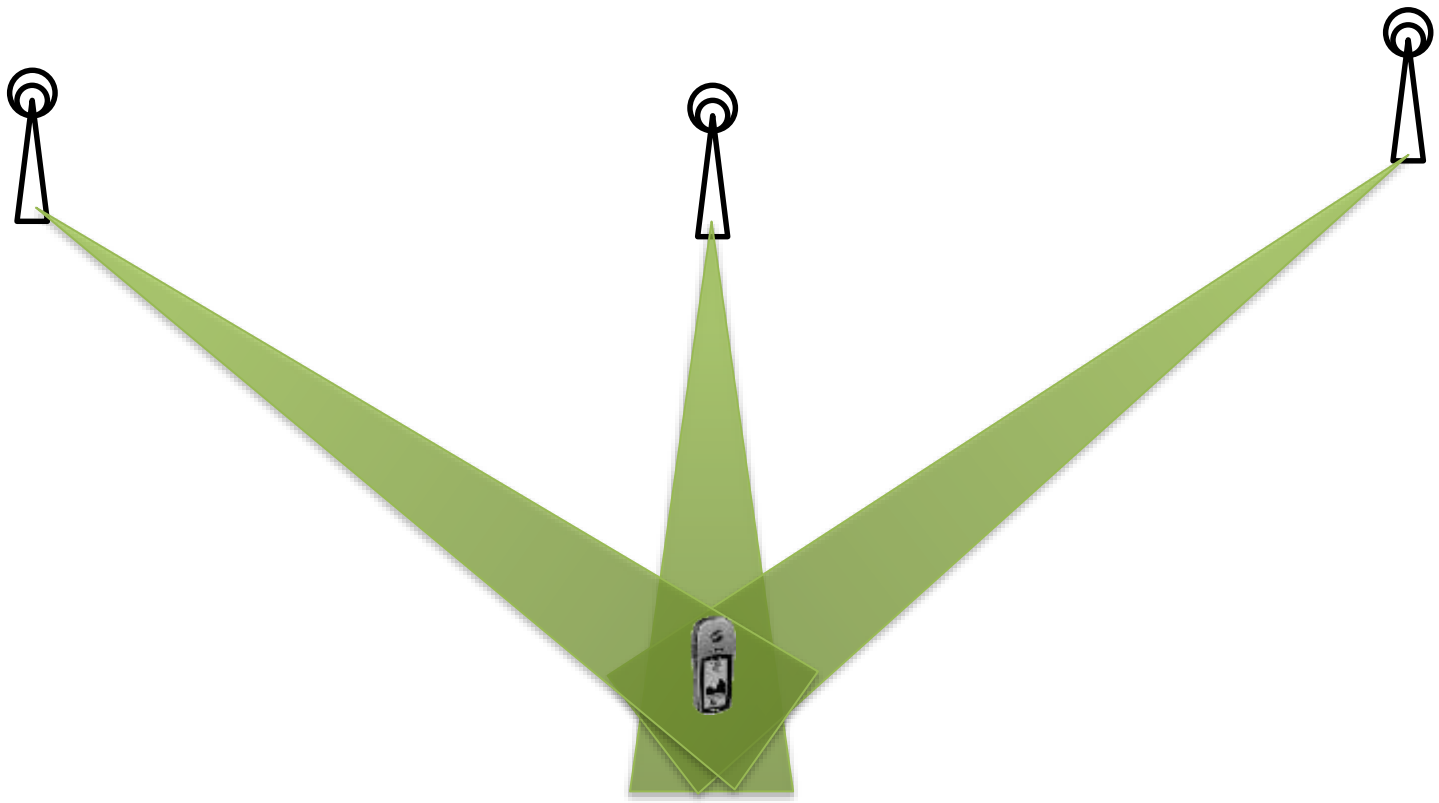
# Lateration

- Position is computed by a number of range measurements to known fix-points:



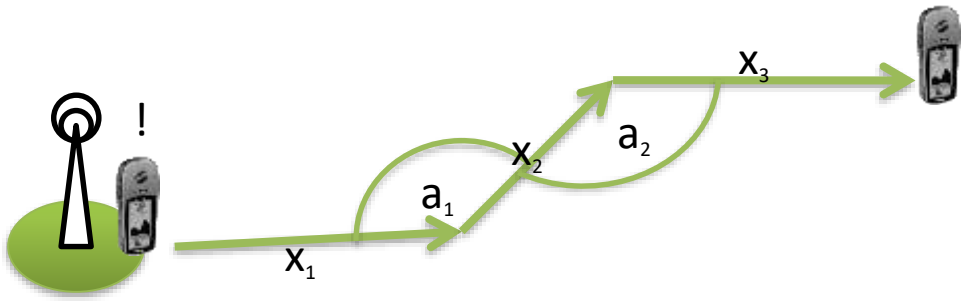
# Angulation

- Position is derived by the measured of the angle of an arriving signal by multiple stations at known fix-points:



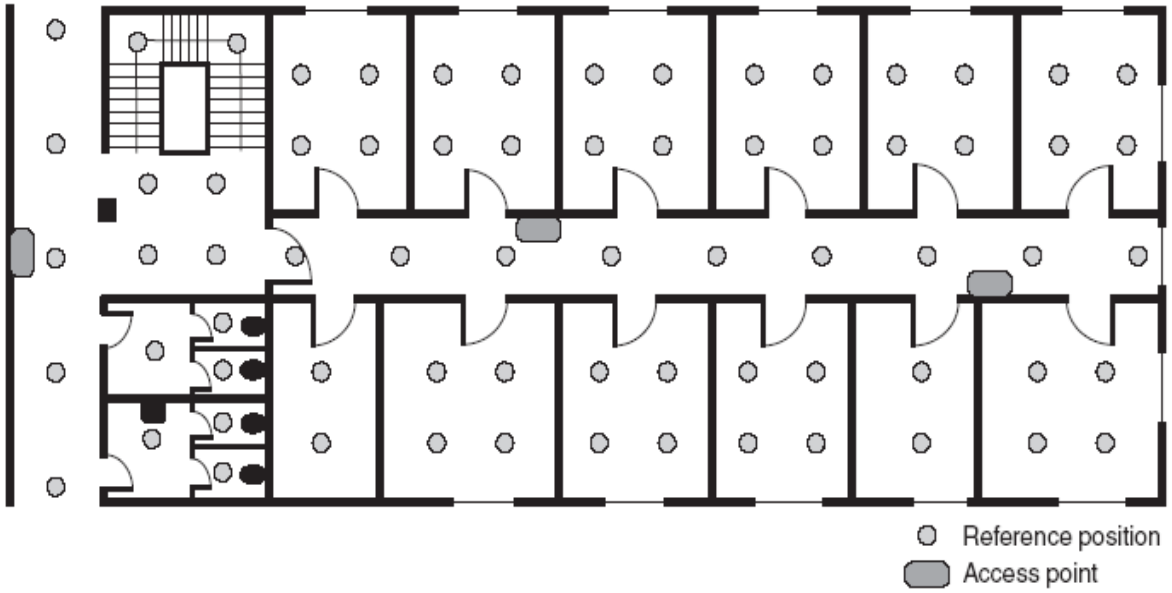
# Dead Reckoning

- From a fixed starting position, the movement of the mobile device is estimated (e.g., using velocity and direction of movement):



# Fingerprinting

- Position is derived by the comparision of location dependent online measurements with previously recoded data:



# Positioning systems: some examples

| Name | Signals | Observable | TB, NB, TA | Accuracy |
|---|---|---|---|---|
| Active Badge | Infrarot | CoO | NB | Cell (Room) |
| ActiveBat | Ultrasonic, Radio | TDoA | NB | 10cm |
| AeroScout | RFID & WLAN | TDoA & RSS | NB | 3 - 5m |
| Cisco WLA | WLAN | RSS | NB | ~ 3m |
| Cricket | Ultrasonic, Radio | Proximity sensing | TB | few cm |
| EasyLiving (Microsoft Research) | misc. | misc. | NB | 30cm |
| Ekahau | WLAN | RSS | TB | ~2m |
| GPS | Satellite | ToA | TB | ~2m |
| Horus (University of Maryland) | WLAN | RSS | | 1m |
| MagicMap | WLAN | RSS | TB, P2P | <10m |
| MetroGroup Future Store | RFID | TDoA & AoA | NB | 30cm |
| PARCTAB (Xerox Research Center) | Infrarot | CoO | NB | Cell (Room) |
| PlaceLab | WLAN, Bluetooth, GSM | RSS | TB | ~10m |
| PinPoint (Universität Maryland) | RFID | TDoA | | 1 - 3m |
| RADAR | WLAN | RSS | TA NB | 2 - 3m |
| Rosum: TV-GPS | GPS & TV-Signale | RSS | TA | ? |
| Rover (Universität Maryland) | WLAN & Bluetooth | RSS | | 2m |
| SmartFloor (Georgia Inst. of Techn.) | | Footprint profile | | 90% |
| SpotOn (Predecessor of PlaceLab) | Radio | RSS | NB | 3m |
| Tadlys: Topaz | Bluetooth | CoO | TA | 2 - 3m |
| UbiSense | Ultra Wide Band | TDoA & AoA | NB | 30cm |
| WhereNet | WLAN | TDoA | NB | 2 - 3m |
| WIPS | Infrarot, WLAN | CoO | TA NB | Cell (Room) |

AoA = angle of arrival
CoO = cell of origin
RSS = received signal strength
TDoA = time difference of arrival

TB = terminal based
TA = terminal assisted
NB = network based

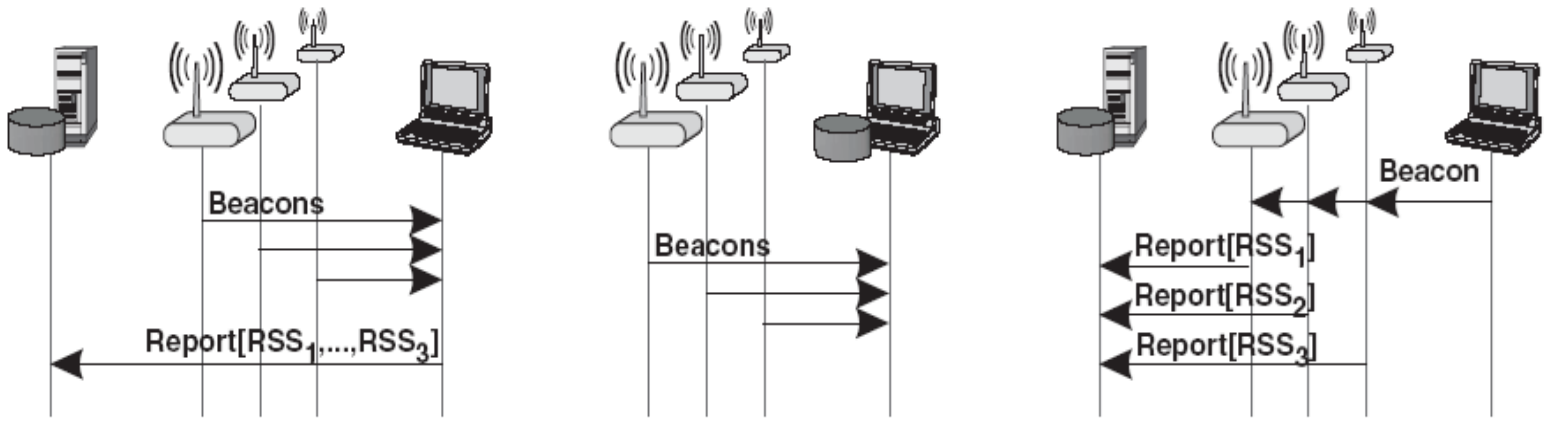
(without engagement)

# WLAN Positioning

Why use IEEE 802.11 components for indoor positioning?

- Widely deployed infrastructure
- Available on many mobile platforms
- 2,4 GHz → signal penetrates walls → no line-of-sight necessary
- A standard WLAN access point deployment is often already sufficient to achieve room-level accuracy

# WLAN Positioning – TA, TB, NB




(a) Terminal-assisted mode (b) Terminal-based mode (c) Network-based mode

## Terminal assisted (TA)

- Measurements are made at the terminal
- Position calculation happens at the server

## Terminal based (TB)

- Measurements and position calculation are made at the terminal

## Network based (NB)

- Beacons are emitted by terminal
- Measurements and calculation are done at the server

# WLAN Fingerprinting – Idea

**WLAN Fingerprinting**

- Derive position from **patterns of signals** received from/at several WLAN access points
- Observable: **received signal strength** (RSS)
- **Offline phase**
  - Record well-defined RSS patterns for well-defined reference positions and store them in a radio map
  - Due to line-of-sight conditions on the spot, it might be necessary to observe RSS patterns from several directions for each position
- **Online phase**
  - RSS patterns related to the target are recorded and compared with the RSS fields of the entries stored in the radio map
  - Position of the target is extracted from the reference position with the closest match

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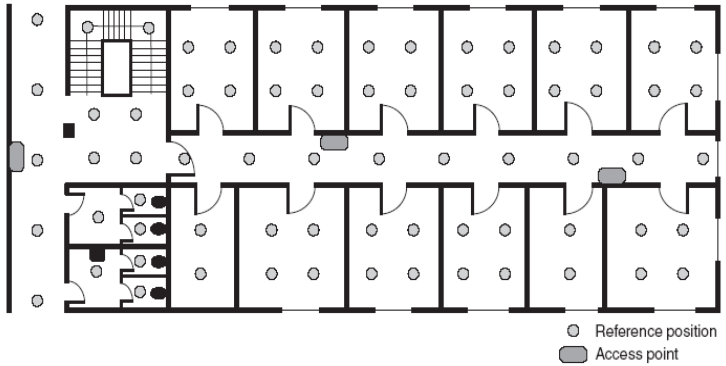

# WLAN Fingerprinting – Empirical vs. Modeling Approach

**Empirical approach**

- Create radio maps from measurements
- Disadvantages
  - Time consuming
  - Measurements must be repeated whenever the configuration of access points changes

**Modeling approach**

- Create radio maps from a mathematical model
  - Calculate the radio propagation conditions taking into account the positions of access points, transmitted signal strengths, free-space path loss, obstacles reflecting or scattering signals, …
- Disadvantages
  - Complexity and accuracy of mathematical models

# Sensor Fusion

Idea:

- Refine the WLAN positioning with additional measurements from other sensor sources
  - Accelerometer
  - Gyroskope
  - Compass

How to combine several sensors (Sensor Fusion):

- Probability distributions
  - Kalman Filter
  - Particle Filter