WiFi fingerprinting

Indoor Localization (582747), autumn 2015

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Seminar

- INTO seminar 27.11. in Pasila (FREE)
- You should have received email with instructions on registration
- Speakers from Here, Nimble, 9Solutions, KoppiCatch, IndoorAtlas, Quuppa, Elisa, EkaHau, Tekes, KTH, Sintef, Tampere University of Technology, VTT and FGI

Course issues

There will be two lectures:

1. A quick review of WiFi fingerprinting (today)
2. A short introduction to tracking and some industrial applications (next week)

The two weekly sessions following these will be used for supporting the project work.

Course issues

To complete the course, you need to submit two assignments

1. An indoor localization implementation that will resolve a given fingerprint into a location.
2. An indoor localization system or location based service

Localization “competition”

- This will be treated as a “competition”, thus submissions will be ranked based on accuracy and effort.
- Each student will submit their individual solution.
- Basically it should consist of a positioning function in your favorite programming environment, that will return co-ordinates (x,y,z) based on the fingerprint given as input (mac address - rssi -pairs).
- You will have to have trained the system yourself and include any labeled training data.
- 1 page report on your approach and findings.

Localization system or LBS

- This could be a complete localization system running (for example) on your mobile phone
- Or a LBS using the existing system
- Or a research project agreed upon separately
- Pair or individual submissions
- Report with description of project and findings.

Deadlines

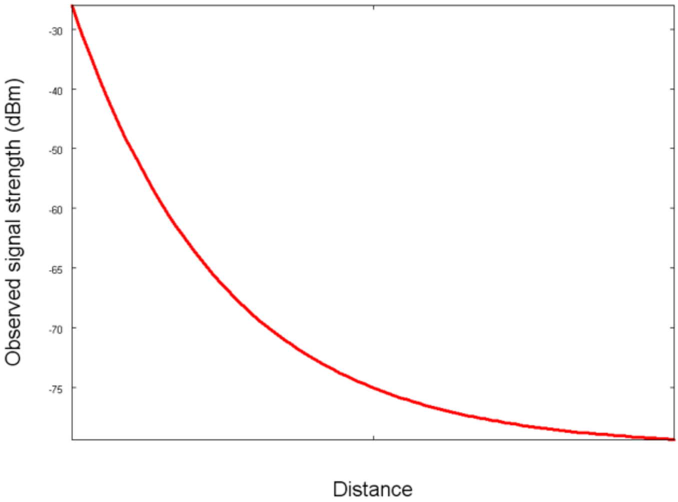
- Competition deadline could be during the course (maybe even get intermediate results?
- Project deadline 16.12. if you want the course to count this year, 10.1.2016 for grading in January.

Other

Why don't we just use trilateration?

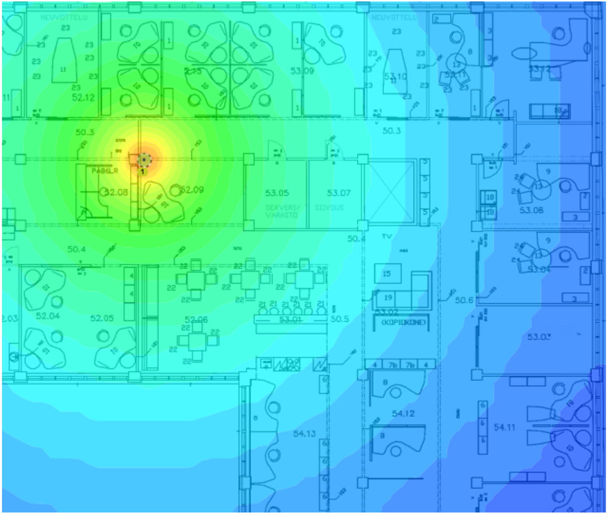
- Easy to trilaterate based on 3 signal sources

Signal propagation (approx)

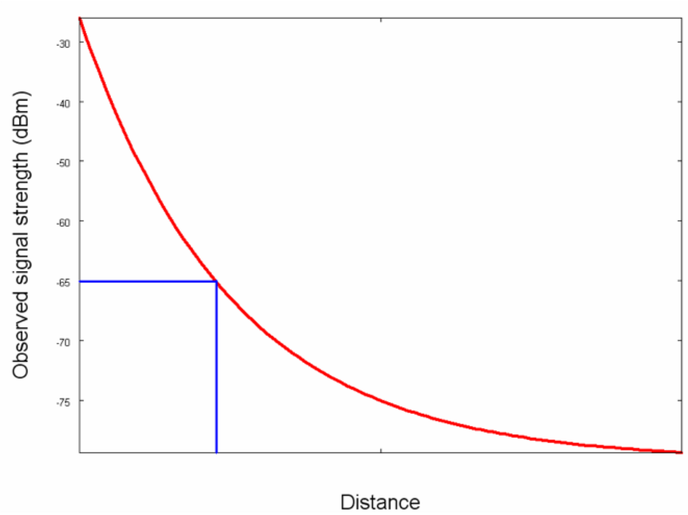


An office with a single AP

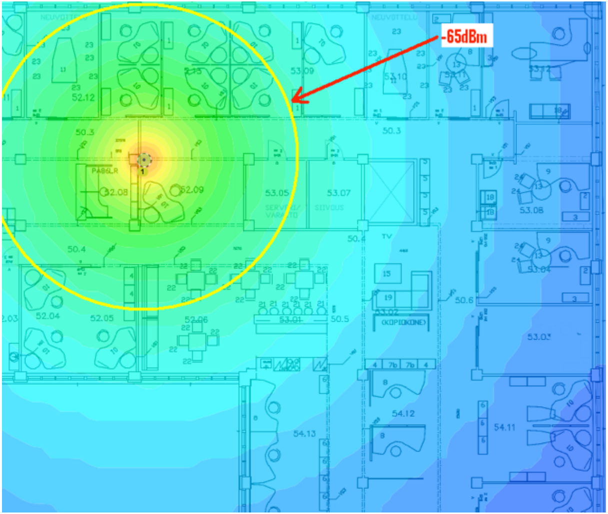
An office with a single AP and signals



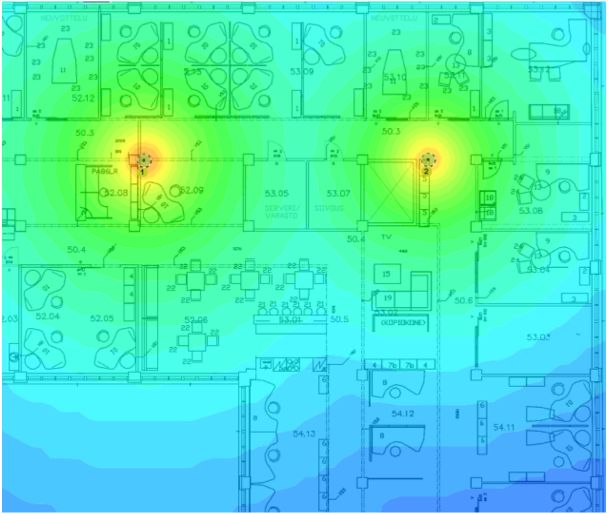
Let's estimate distance based on RSS



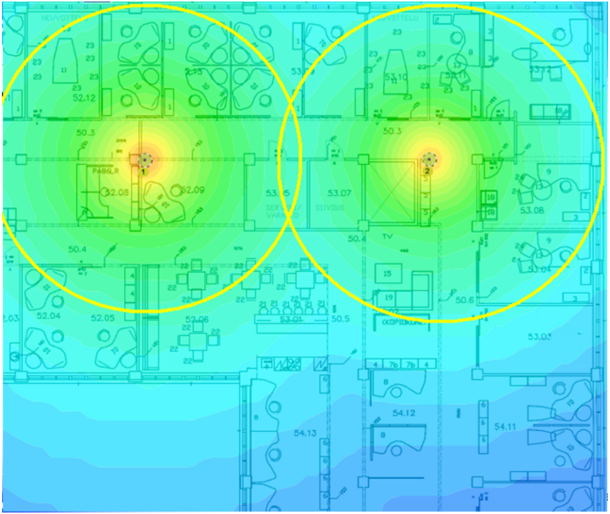
So we're somewhere on this circle



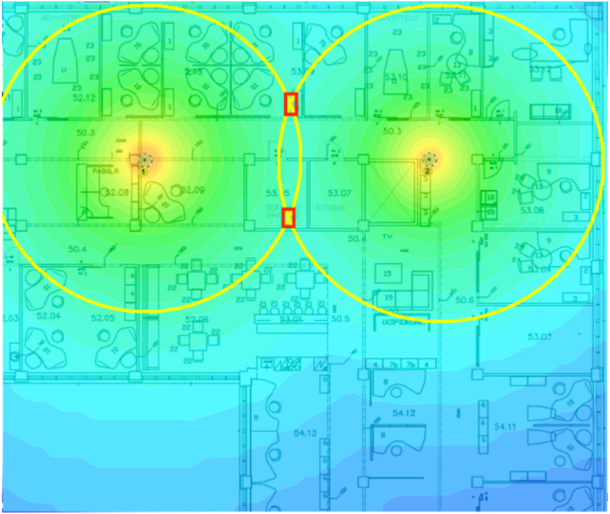
An office with two APs and signals



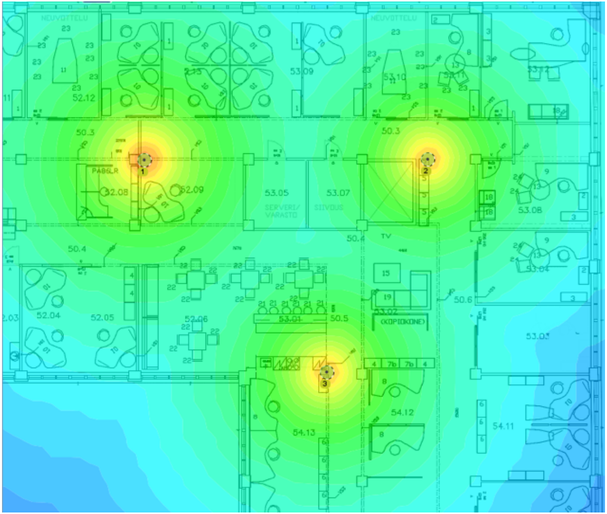
Using the distance estimated from both APs...



...we're on either of the two crossing points



Now with three APs...



..three distances...

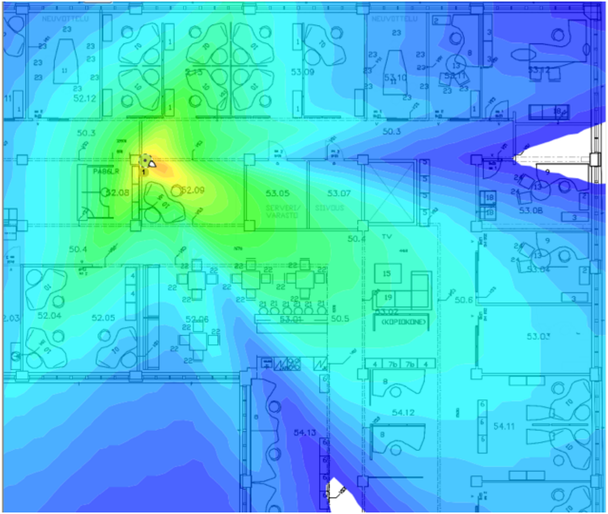
...problem solved!

Welcome to reality

Measured RSS is dependent on (amongst others):

- signal source height and antenna angle
- antenna radiation pattern

Actual radiation pattern

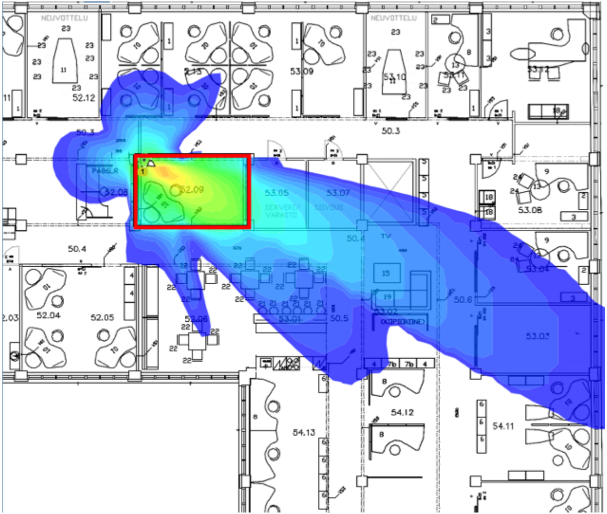


Welcome to reality #2

Signal propagation depends on (amongst others):

- material characteristics
- reflection
- refraction

Actual propagation



So what now?

- From Petteri's first lecture we learned that one requirement for fingerprinting was that the signal characteristics (RSS) are sufficiently distinctive
- This seems to be the case, given that we have a sufficient number of APs available for most of the area

Fingerprinting (recap)

- Two phases:
  - **Calibration** measure RSS of APs at different locations
  - **Estimation** measure RSS with device to be localized, compare to calibration measurements
- The collected fingerprint database can be described as a matrix, where each row corresponds to a single location and each column to an AP, each field containing the RSS measured (if any)

Fingerprint data format

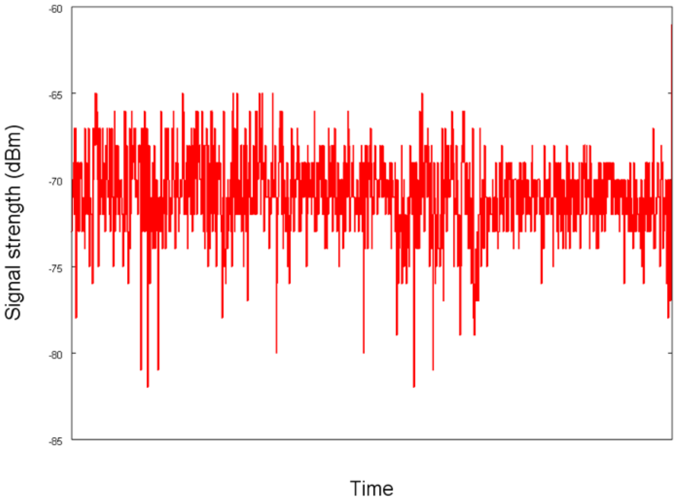
For exchanging fingerprints during this course we will use the following format

- One fingerprint per line, semicolon as separator (;)
- Each line begins with z,x,y -coordinates $\in \mathbb{N}$
- Coordinates are map pixels with the origin being the top-left corner (corresponding to screen coordinate systems)
- Following the coordinates we have 0 or more MAC-address & RSS -value pairs
- For readability complete MAC-addresses (90:72:40:13:b4:d4) and the absolute value of RSS measurements should be used

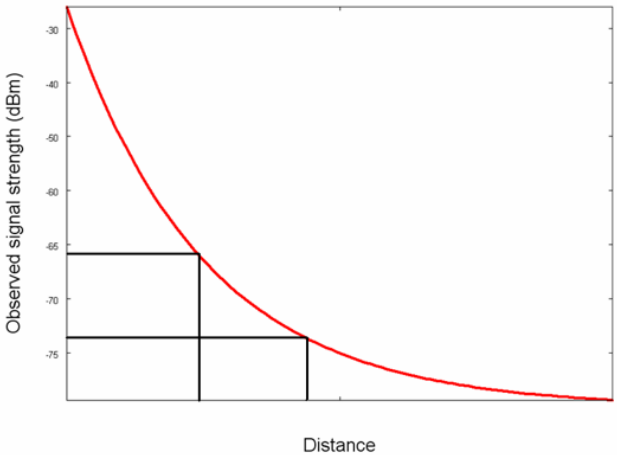
Platform examples

- Linux has a set of *wireless tools:*
  - *iwlist* can provide you with the information you need
    - ”sudo iwlist wlan0 scan”
    - Outputs a list of access points it can hear, and information related to them
    - ”Address: 00:1D:A2:83:8C:A2” = **MAC**
    - ”Signal level=-72 dBm” = **RSSI**
- Android devices are usually very forthcoming with this information as well
  - android.net.wifi.ScanResult
  - android.net.wifi.WifiManager ...
  - Code example?

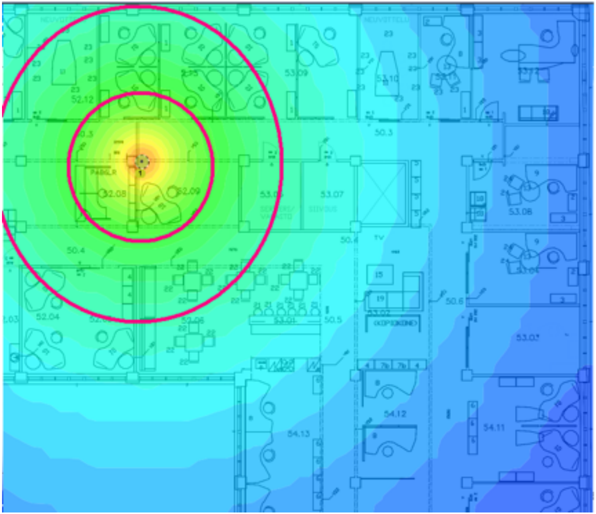
Noise!



Uncertainty in RSS



Uncertainty in location



What now?

- We can disregard noise when using deterministic methods for position estimation, hoping that the Euclidean distance will still be minimized to the correct position
- We can model noise when using probabilistic methods, but what kind of distribution should we use?
- How to parameterize said distribution?

RADAR [1] (very shortly)

- Collect 20 samples per location and orientation
- Use Nearest Neighbor using Euclidean distance to estimate location

Haeberlen [2] (very shortly)

- Discretize building into cells (one per room)
- Collect roughly 100 scans per cell
- Build graph connecting cells
- Use Markov chains for tracking (more next lecure)

Caveats with probabilistic models

- Variance?
- Missing items?
- CDF vs PDF & underflow?

Measuring errors [3]

- Euclidean error
- Route error
- Zone error

References I

- P. Bahl and V.N. Padmanabhan. "RADAR: an in-building RF-based user location and tracking system". In: *INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE*. Vol. 2. 2000, 775–784 vol.2. DOI: 10.1109/INFCOM.2000.832252.
- Andreas Haeberlen et al. "Practical Robust Localization over Large-scale 802.11 Wireless Networks". In: *Proceedings of the 10th Annual International Conference on Mobile Computing and Networking*. MobiCom '04. Philadelphia, PA, USA: ACM, 2004, pp. 70–84. ISBN: 1-58113-868-7. DOI: 10.1145/1023720.1023728. URL: http://doi.acm.org/10.1145/1023720.1023728.

References II

Teemu Pulkkinen and Johannes Verwijnen. "Evaluating Indoor Positioning Errors". In: *International Conference on ICT Convergence 2015*. 2015, pp. 167–169. URL: http://www.cs.helsinki.fi/u/jverwijn/ICTC_2015.pdf.