IT-JIM
signal and image processing

Advanced Indoor Navigation

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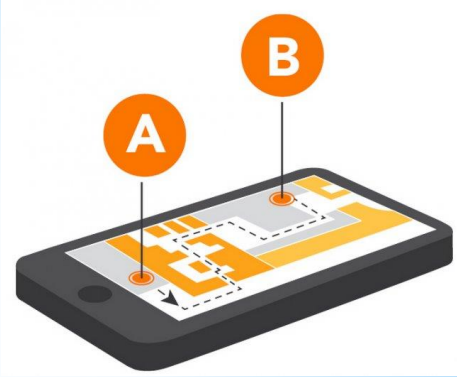
AI UKRAINE'16
III International conference on practical use of Artificial Intelligence and Data Science

OUTLINE

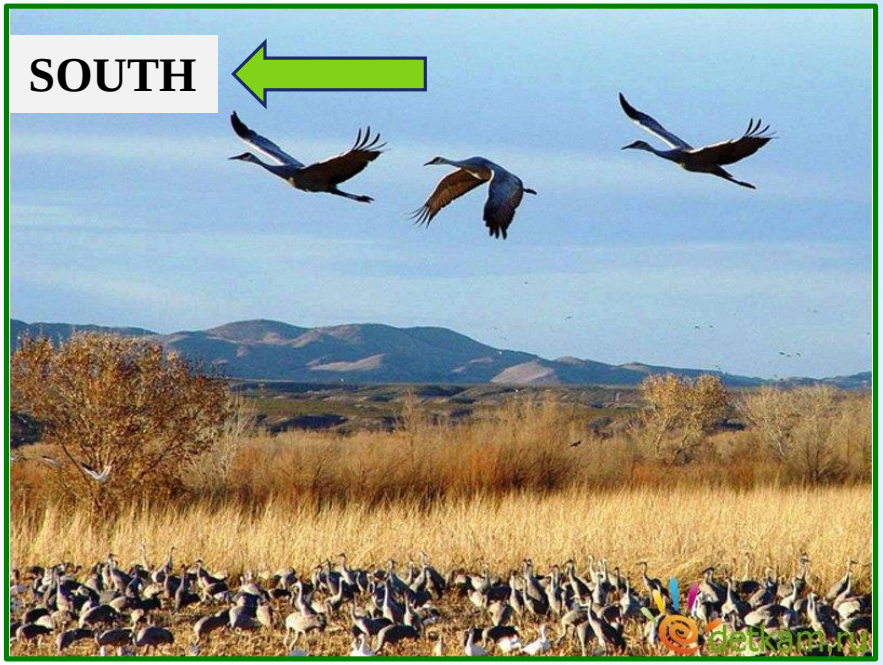


- Introduction to Navigation
- User Location in Buildings
- Indoor navigation: Tracking and Routing
- Real Scenarios and Experimental Results
- Conclusions and Future Work

What is Navigation?

1) Determine your location

2) Indicate the route



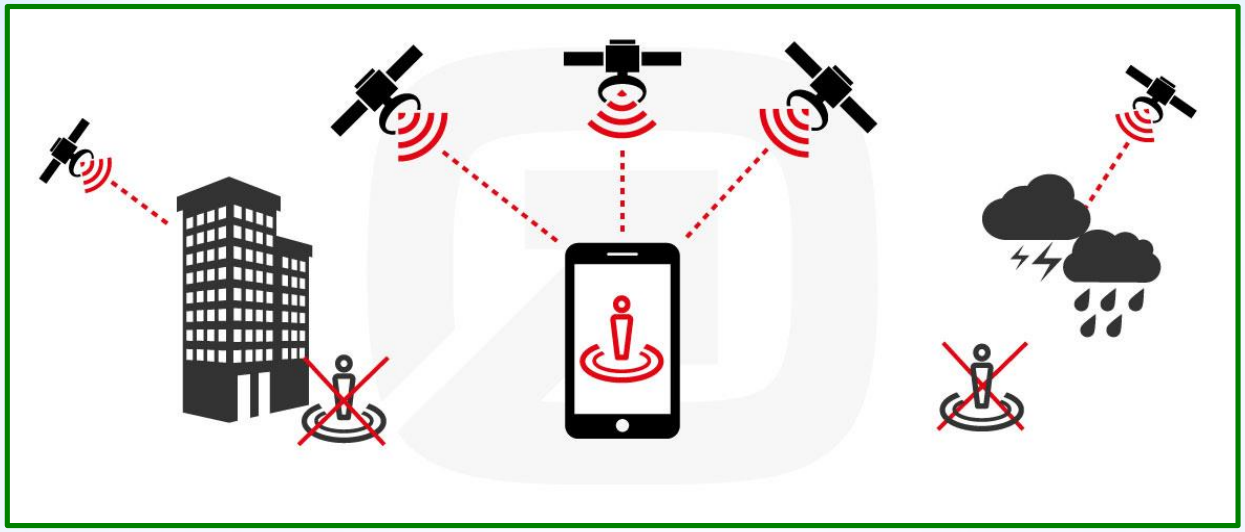
Global Positioning System (GPS)

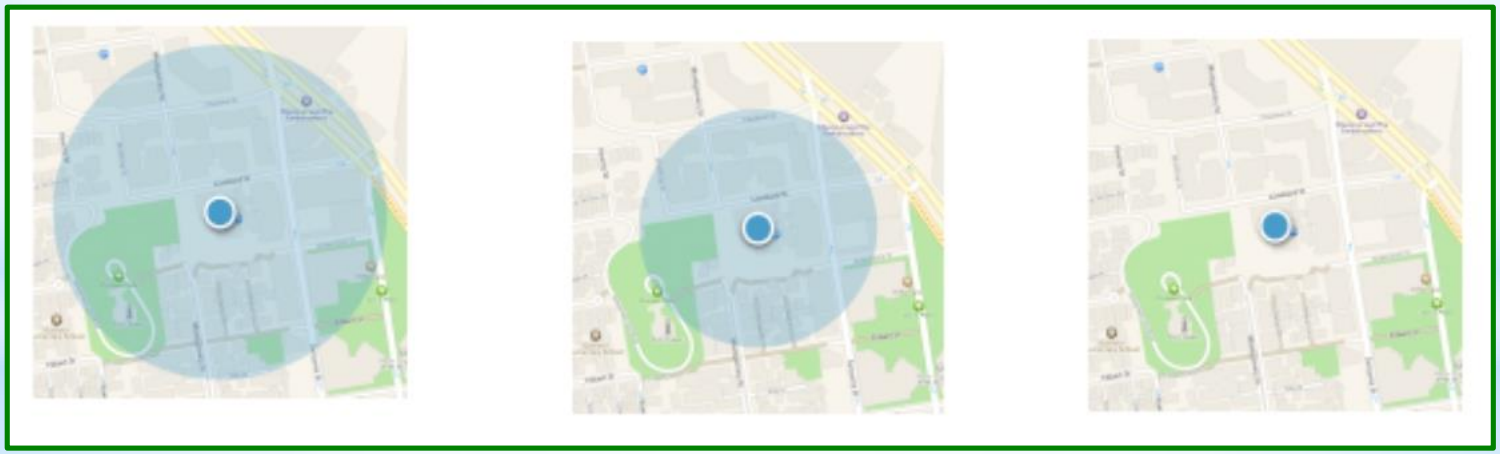
- Provides positioning and navigation services
- There are currently 72 satellites (Feb 2016)

GPS principle

- We need to receive signals from at least 3-4 satellites

GPS: Weak Points



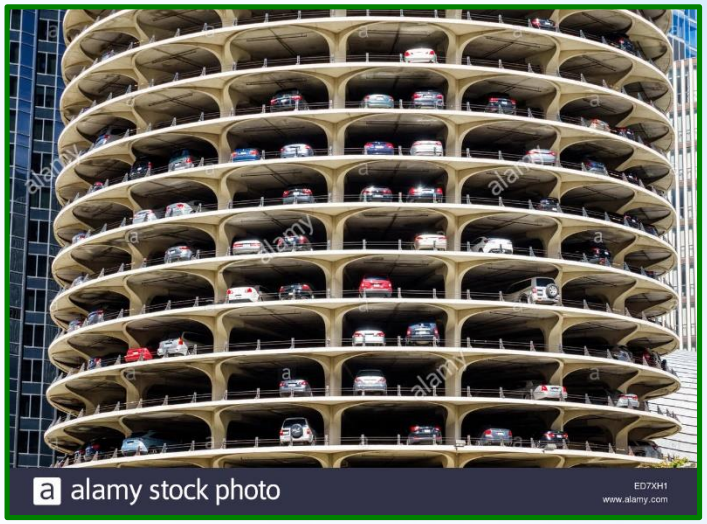


- The more sky view, the more accuracy one can get

GPS does not work in buildings → **INDOOR NAVIGATION**

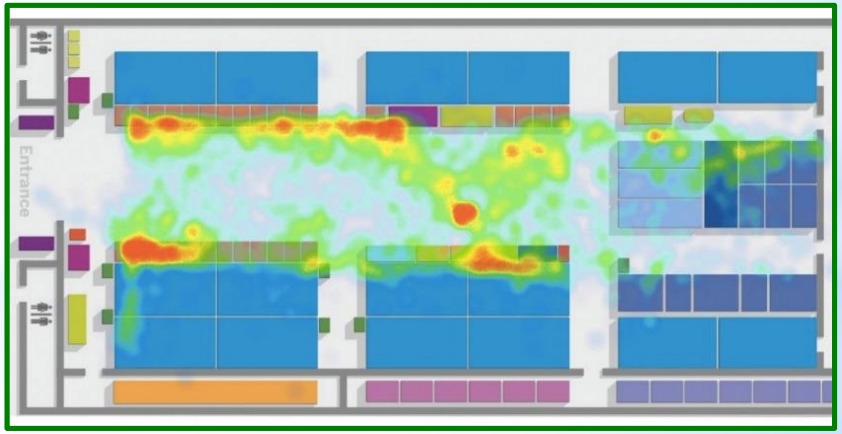
Indoor Navigation: Interesting Use Cases

Museum



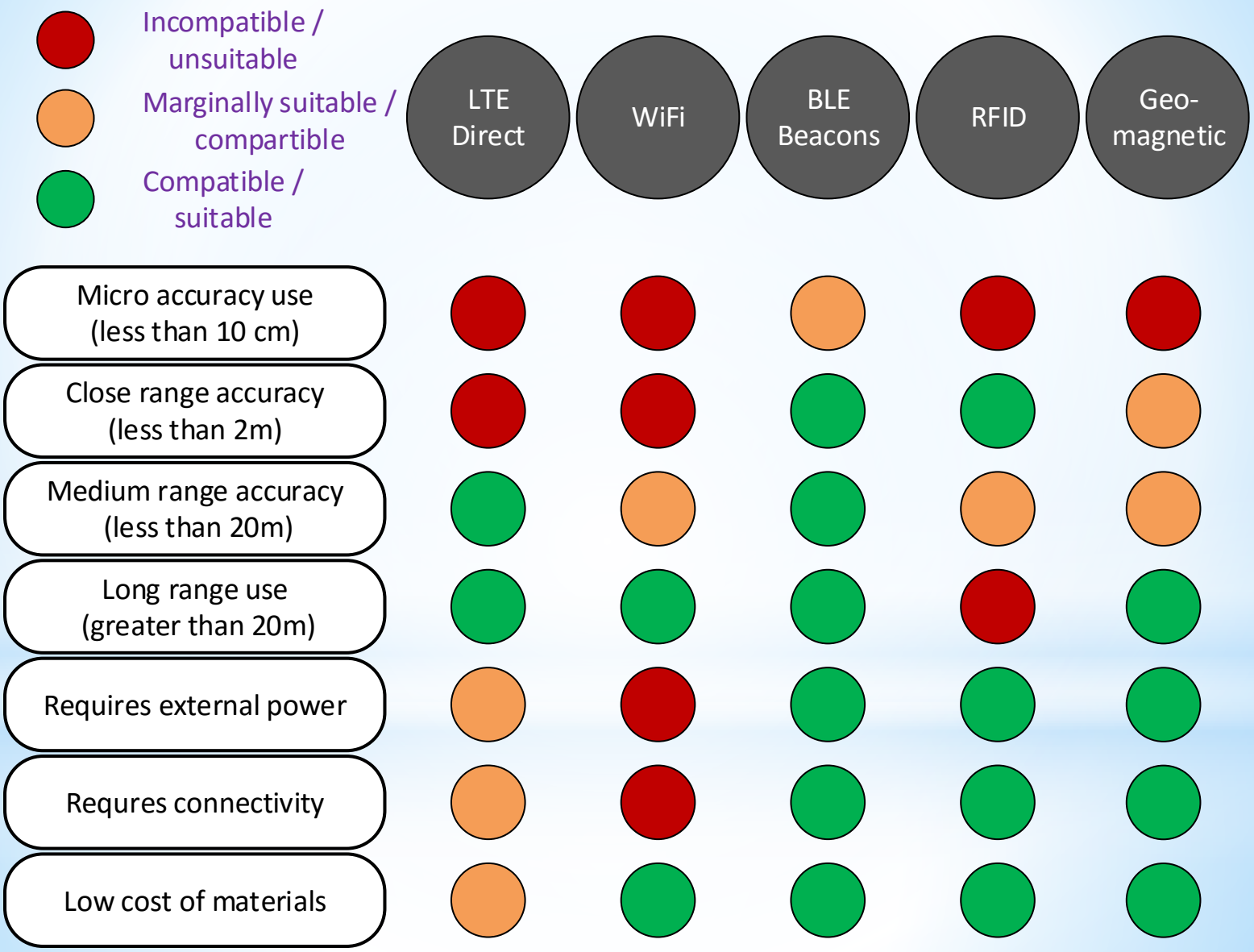
High-level parking

Airport



Heat map

Possible sources

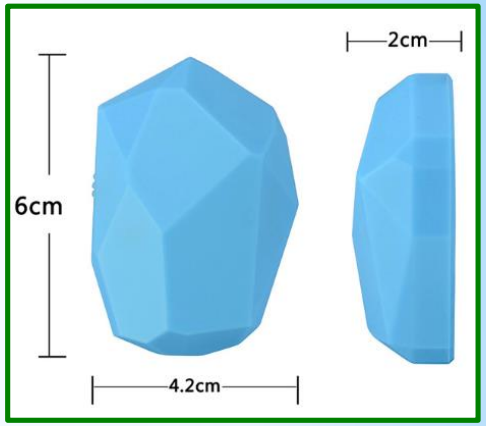


Examples of Beacons

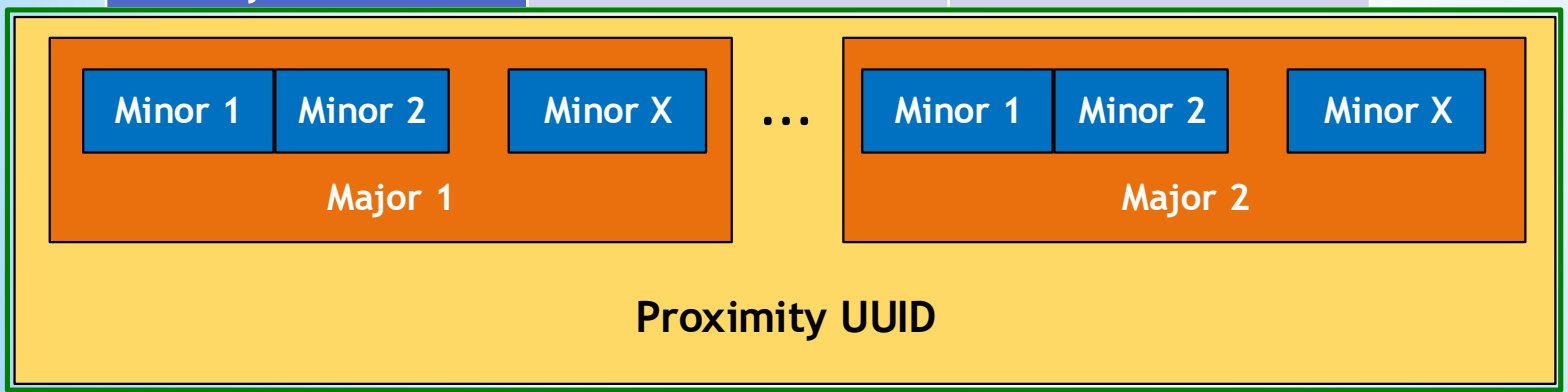
- BLE – Bluetooth Low Energy

Beacon Parameters and Package Structure

Name	Data format	Range
Set UUID	16 BYTE	16bytes of data
Set Major	UINT 16	2bytes of data
Set Minor	UINT 16	2bytes of data
Set Name character	20 BYTE	20 BYTE
Set contact	BOOL	NO -YES
Set Broadcast Interval	UINT 16	0-1600
Set measured power	UINT8	0~-129
Connect/disconnect	BOOL	NO~YES
Password paring	UNIT 12	“654321”(ASCII)
Temperature and humidity ON/OFF button	1 Byte	1 BYTE
Temperature and humidity read	1 Byte	1 BYTE

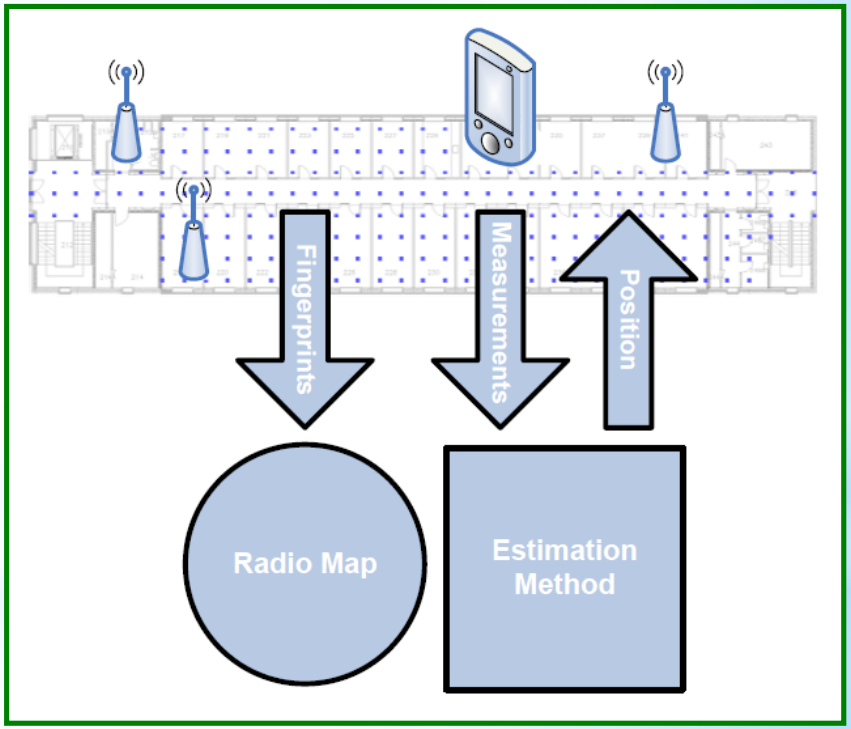


Sky beacons



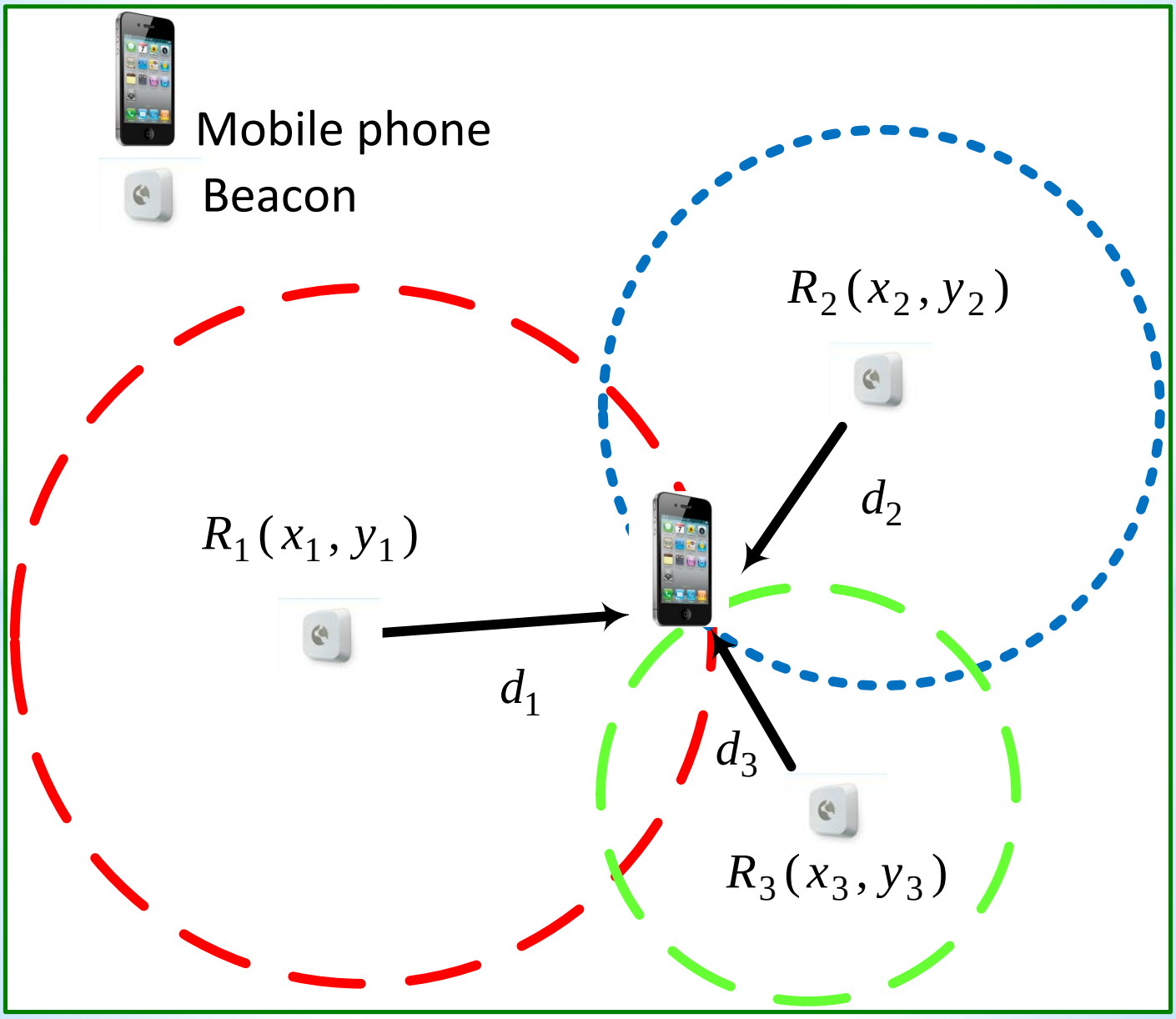
Indoor Positioning: Fingerprinting

Saving of radio map → Measurement and estimation



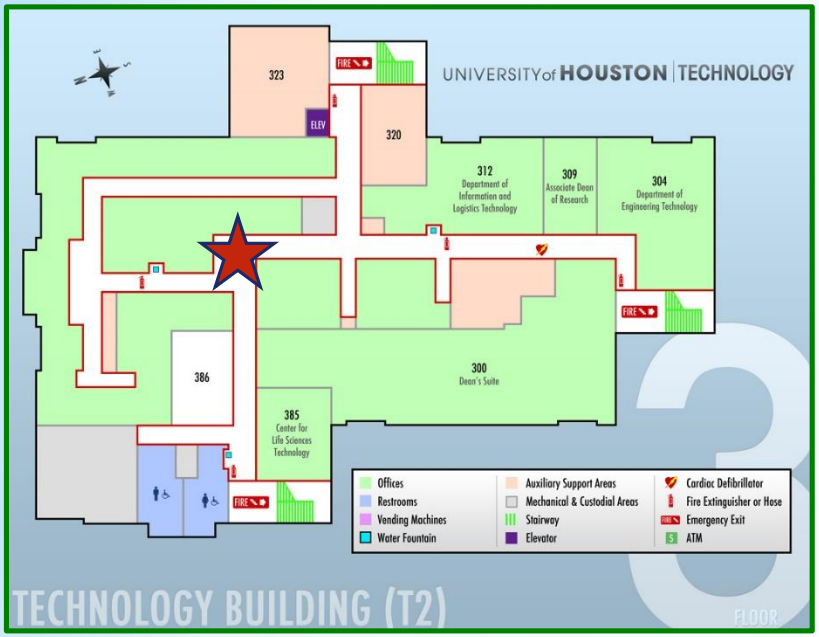
Principle of fingerprinting

Indoor Positioning : Trilateration

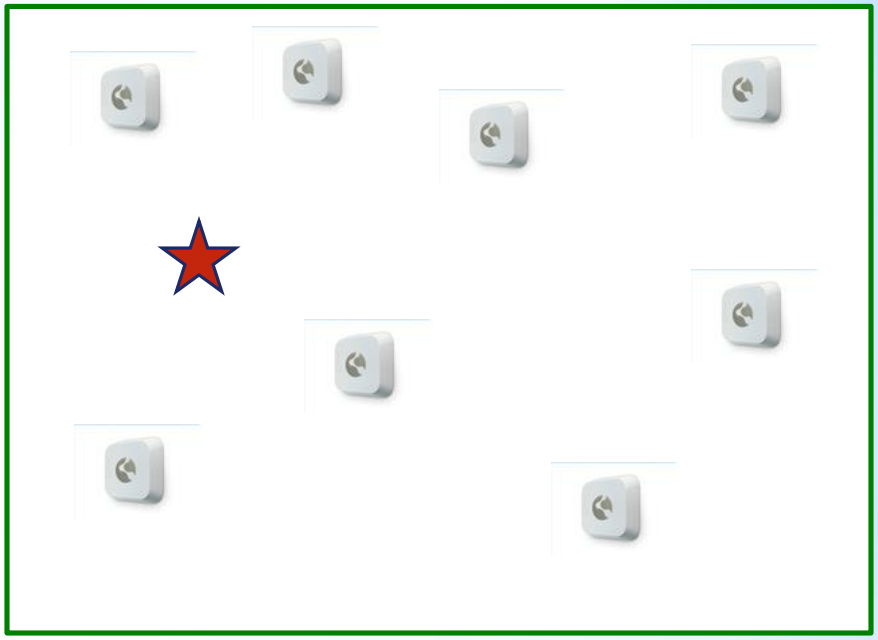


User Location in Buildings

High-Level Description of User Location Algorithm



Building Map

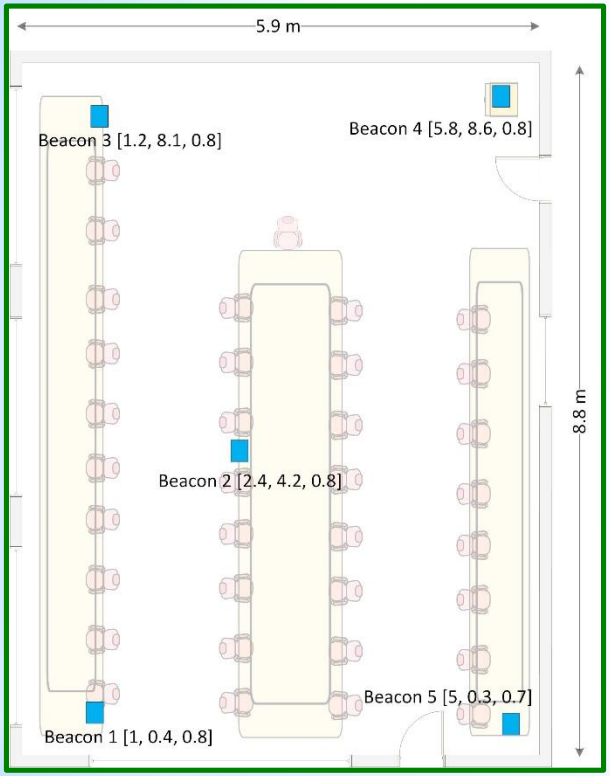


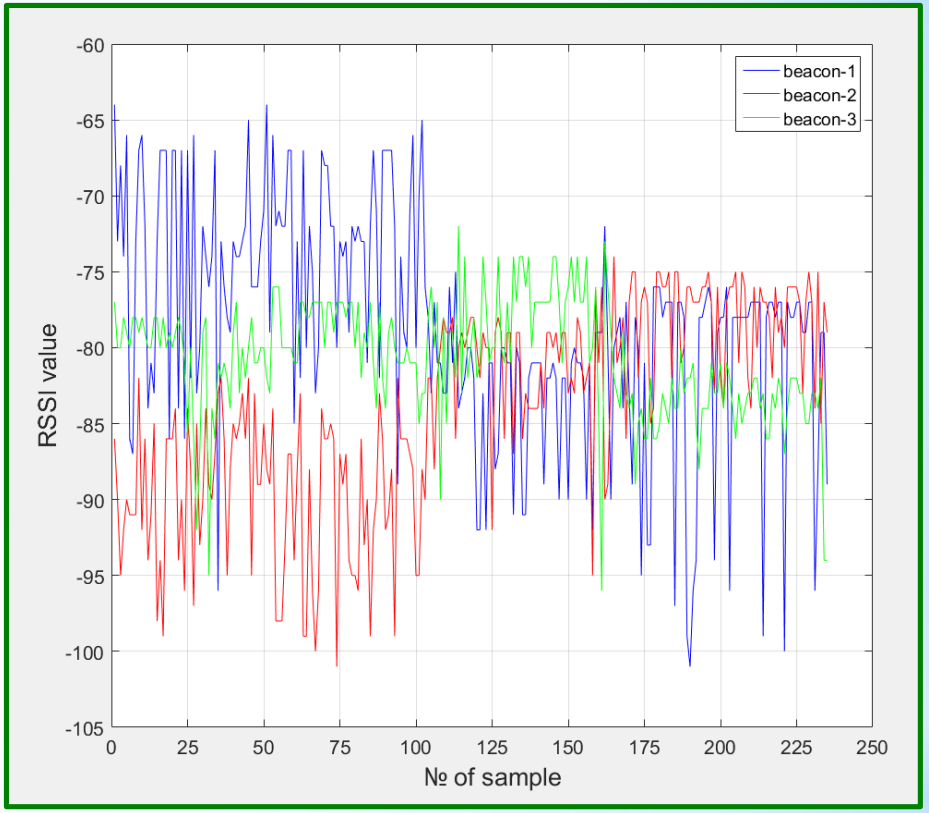
Beacons locations

RSSI measurements → Distances calculation → Location estimation

RSSI from Beacons

- RSSI – received signal strength indicator





Example of RSSI from 3 beacons

Sensoro 4AA

- Power supply by 4 x AA batteries (changeable).
- 4000 mAh(Alkaline) ~ 6000 mAh(Lithium), battery life is 5+ years with common configuration.
- Dual-Antenna, signal range 0.15m - 80m.
- Consumer-electronic level designs, white beauty.
- Embedded Temperature sensor.
- Length: 64.0 mm ; Width : 64.0 mm ; Depth : 23.5 mm.
- Dust-proof ; Anti-vibration.
- Broadcasting interval: 100 ms ~ 1285 ms.
- Download PDF specification of 4AA.

- Fluctuations are very high
- RSSI is sensitive to environment

Range vs RSSI: Propagation Models

- All electromagnetic waves demonstrate inverse-square relationship between RSSI and distance

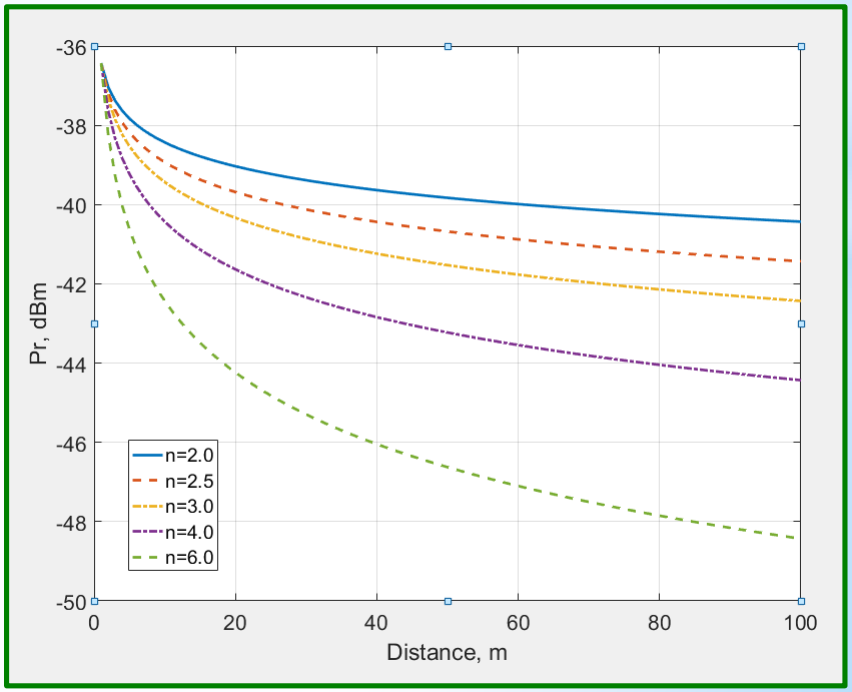
$$P_r \propto \frac{1}{d^2}$$

- Difference between transmitted and received power is described via "path loss"

$$P_r = \frac{P_{(d0)}}{(d/d_0)^n}$$

- Typically d0 is set to 1m
- Parameter **n** depends on environment

higher RSSI not always better



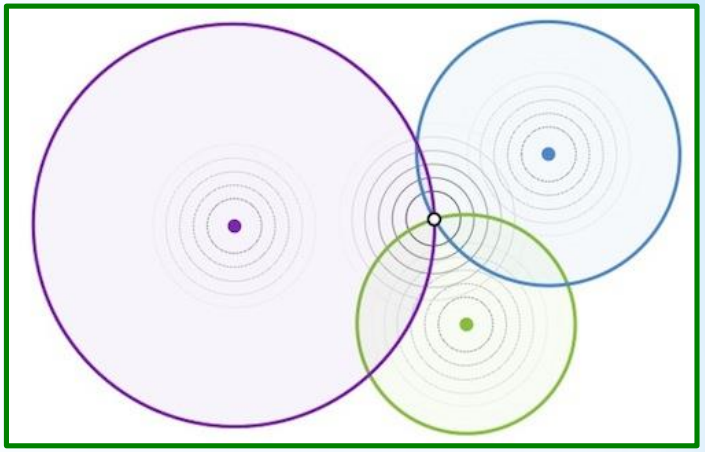
RSSI vs distance

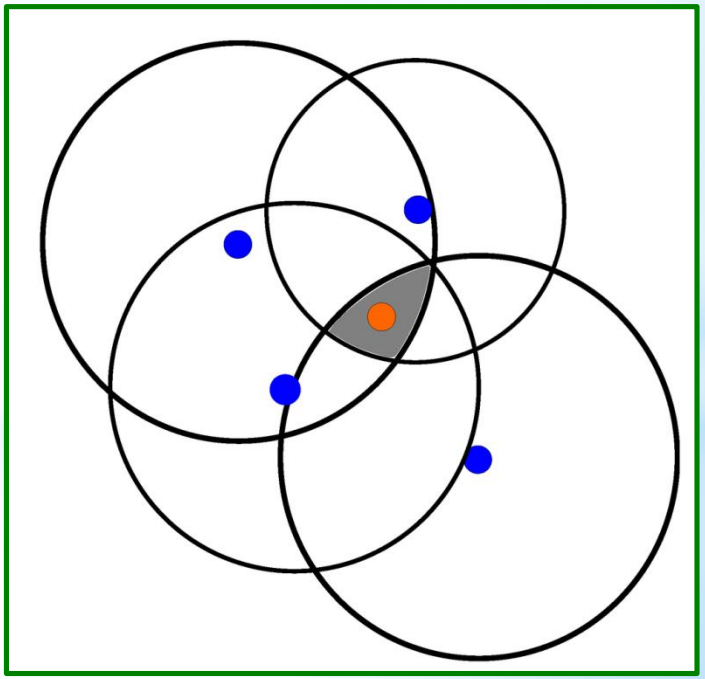
[1] Indoor Location Tracking Using Received Signal Strength Indicator
By Chuan-Chin Pu, Chuan-Hsian Pu and Hoon-Jae Lee
DOI: 10.5772/10518

Multilateration

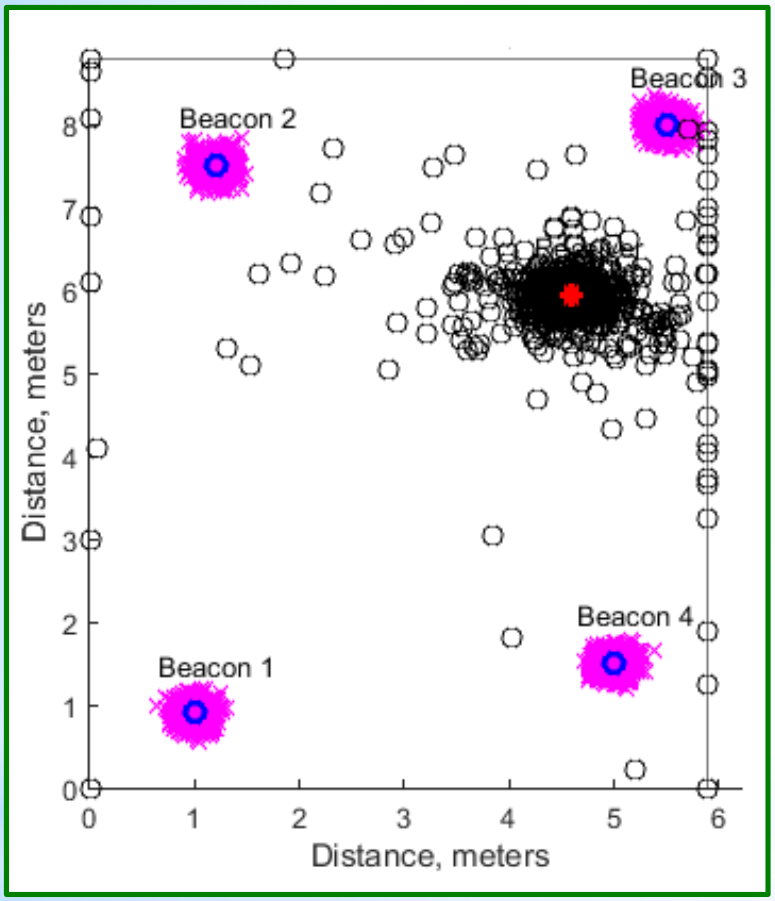
```
if (  == 3 ) {
    doTrilateration();
}

if (  > 3 ) {
    doMultilateration();
}
```

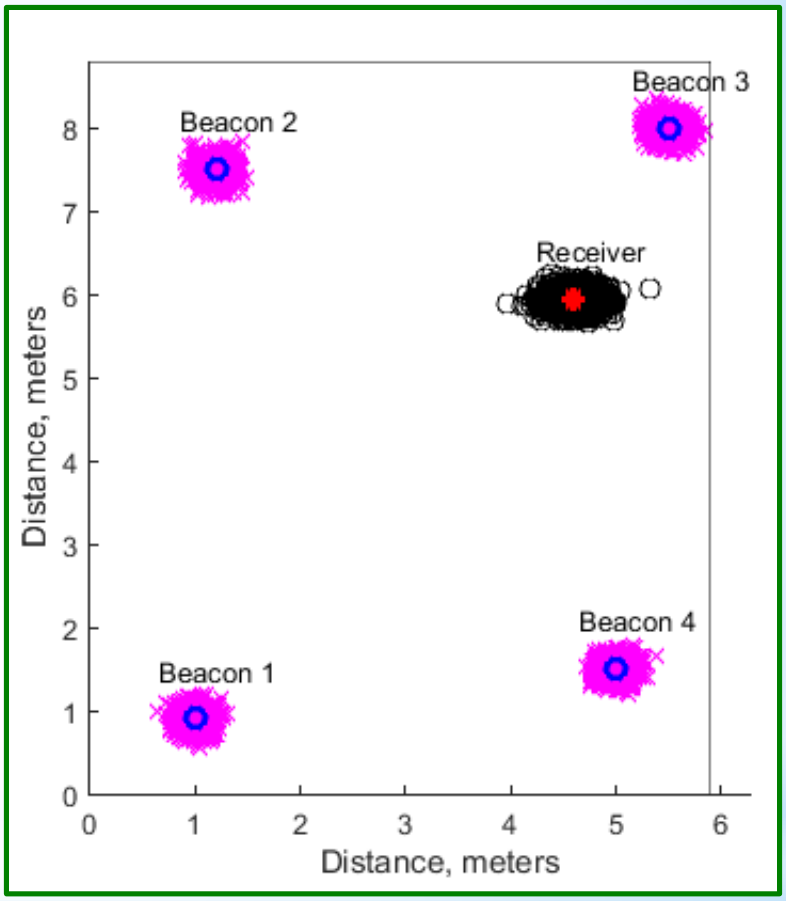




Trilateration vs Multilateration (Simulation)



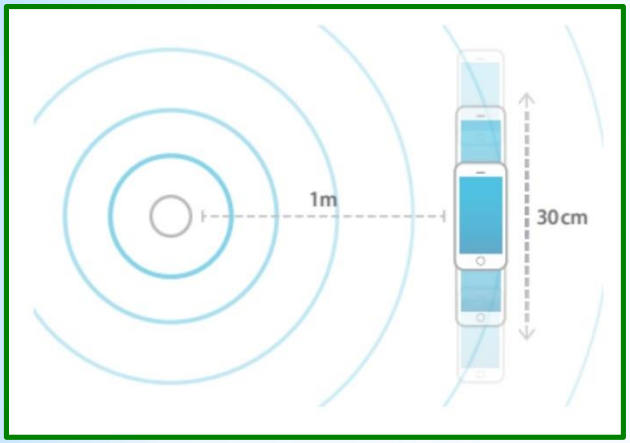
*Application of **Trilateration** for 3 beacon signals with the greatest power*



*Application of **Multilateration***

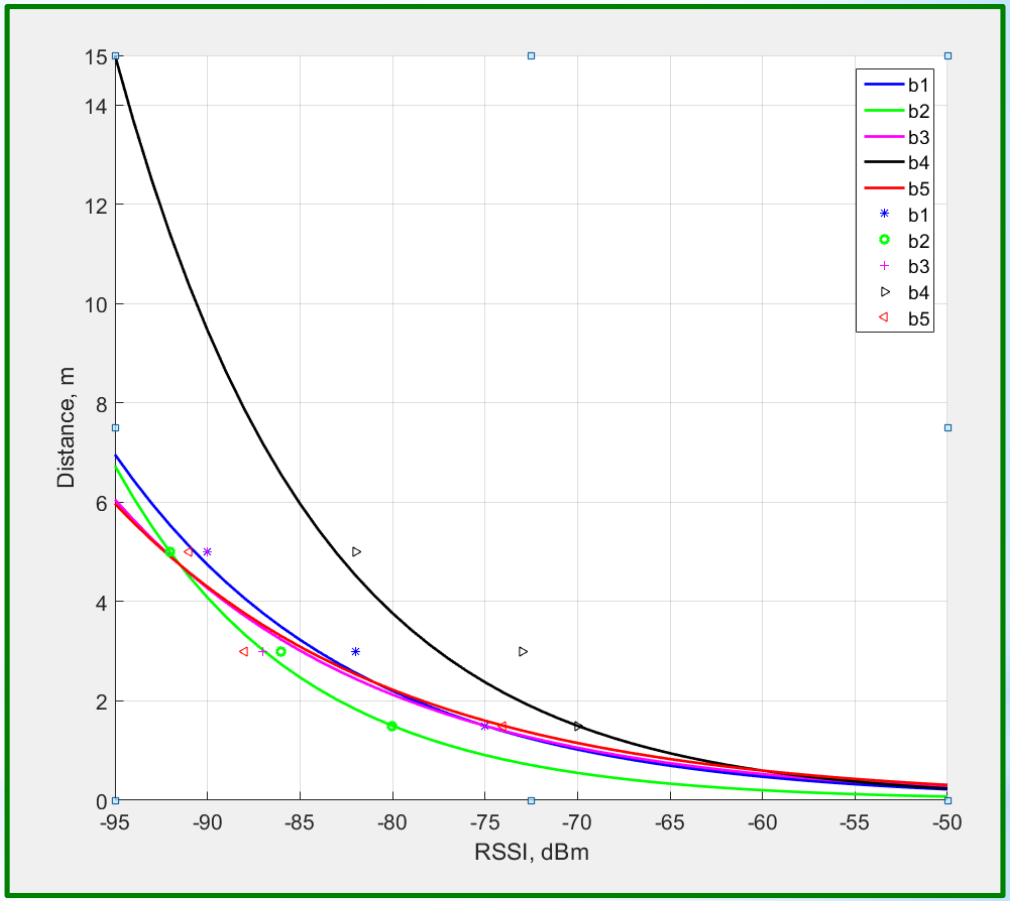
Calibration Procedure

Beacons are different



Calibration principle

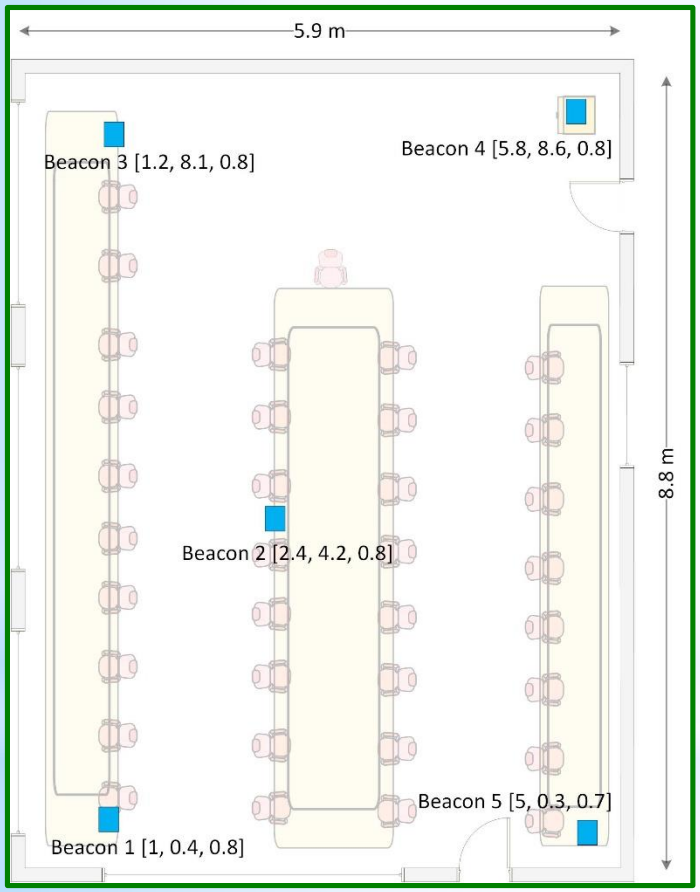
1. ***tx_power*** = measurement of *rssi* on distance of 1m from a beacon → obtaining a statistical sample → averaging.
2. **Path loss exponent *n*** = rssi measurement at several fixed distances from a beacon → comparison with the theoretical values → calculation of *n* to "adjust" the calibration curve to experimental data



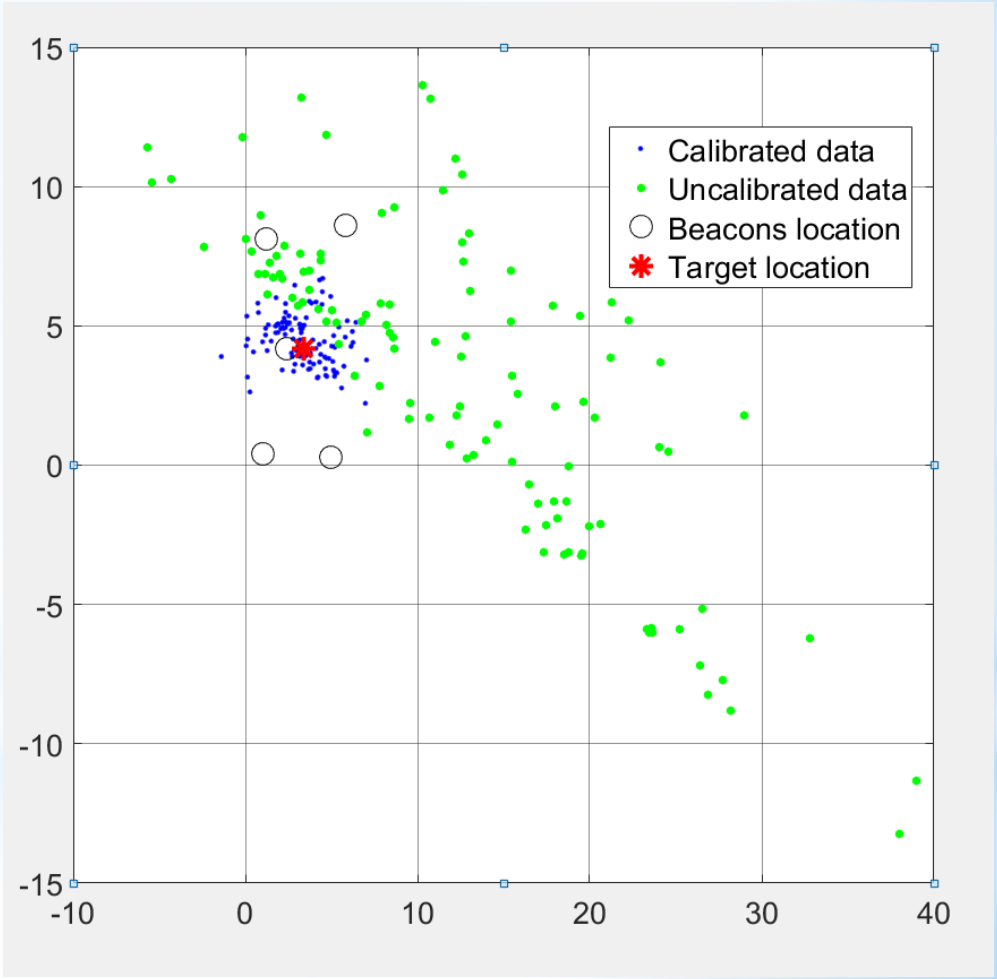
Example of adjusted calibration curves (rssi is measured at 1.5, 3 and 5 m from each beacon)

Calibration Effect

$\sigma_{x\ calbr} = 1.6472$	$\sigma_{x\ uncalbr} = 10.2921$
$\sigma_{y\ calbr} = 0.8888$	$\sigma_{y\ uncalbr} = 6.1412$

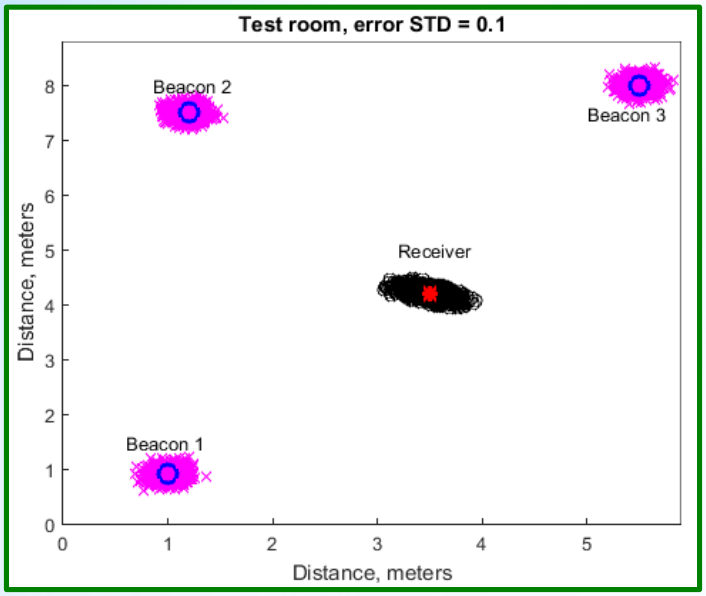


Map

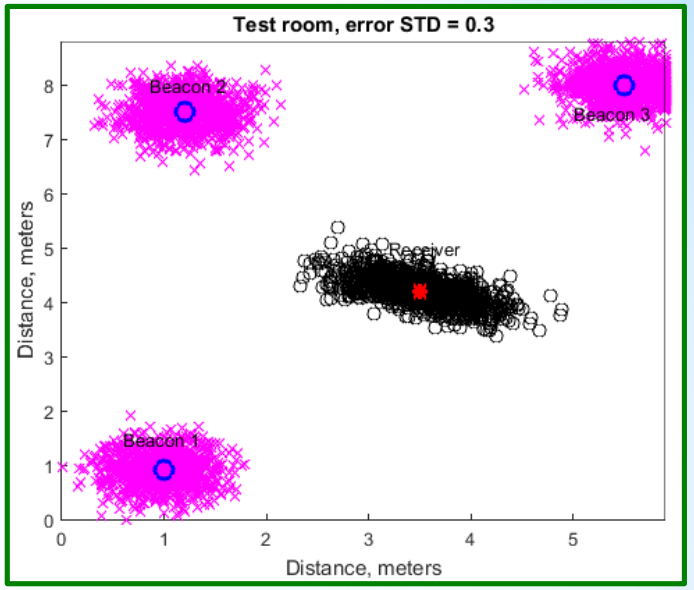


Estimated user location (static position)

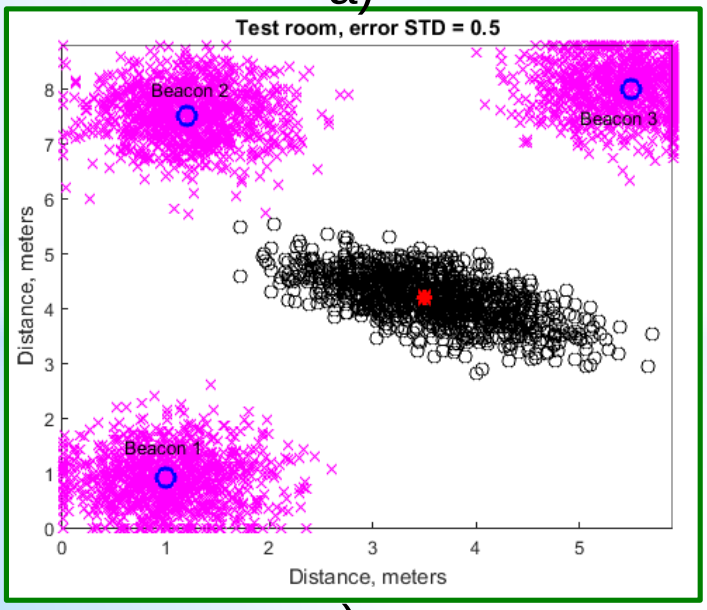
Effect of Beacon Location Error (Simulation)



a)



b)

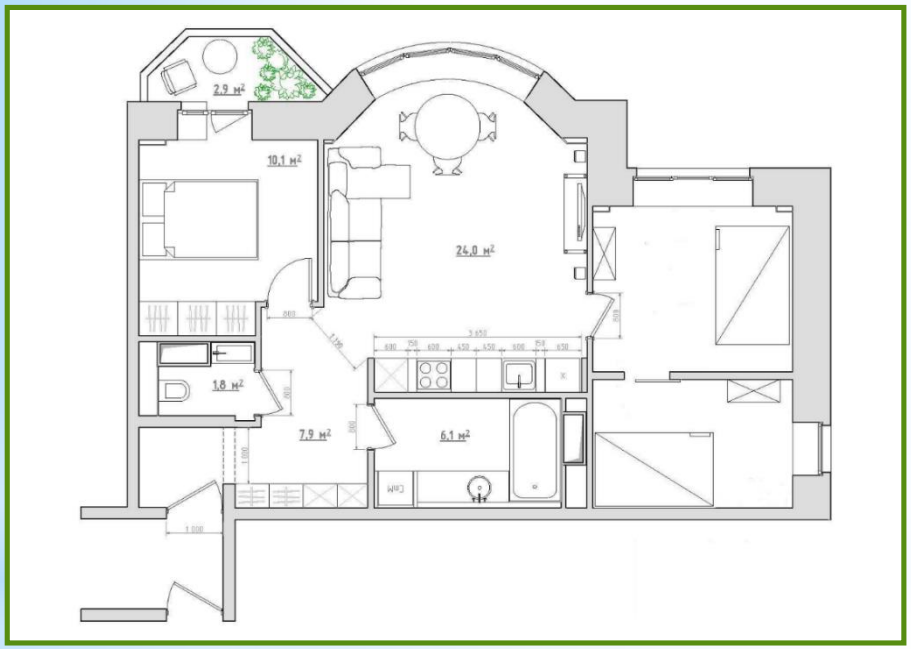


c)

Effects of errors in beacon coordinates up to about:
±0,3 m (case **a**),
±1 m (case **b**),
±1.5 m (case **c**)

Indoor Navigation: Tracking and Routing

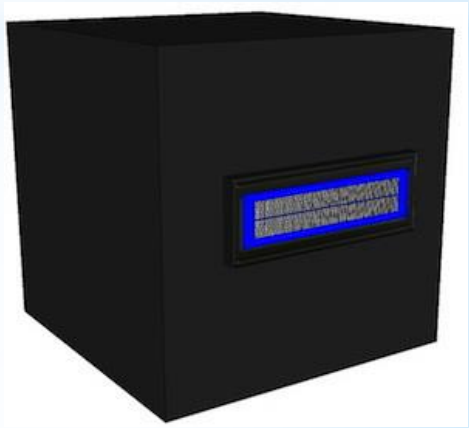
Indoor Navigation:Required Inputs



Building Map

Inputs
Configuration data
Beacons locations
Allowed zones
Building Map

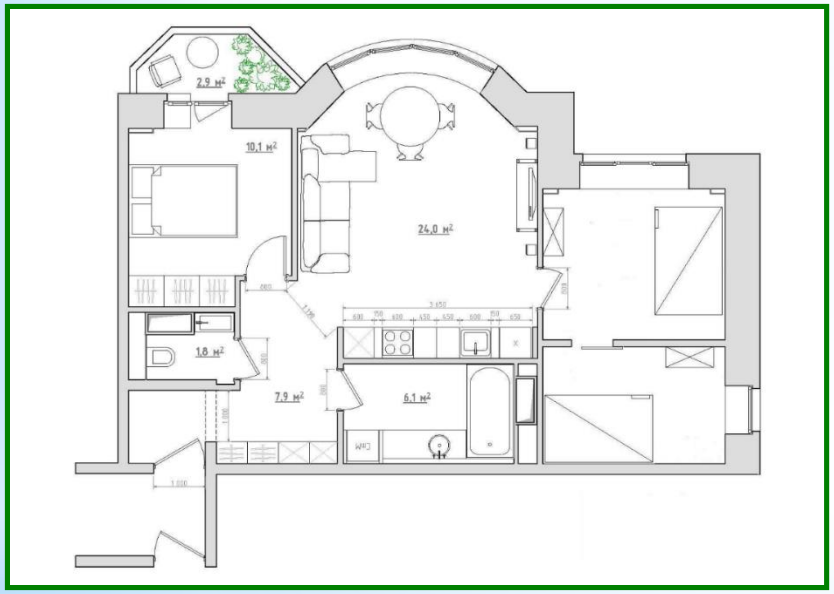
- User should know only about map!
- We need to know locations of beacons



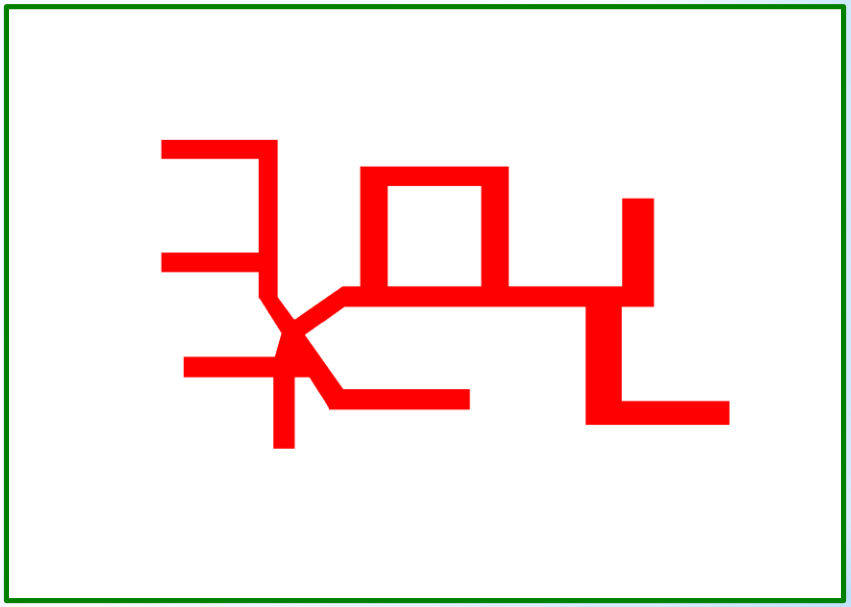
Black box

Building Map and Mask

- We can mark the allowed areas with simple mask



Building map

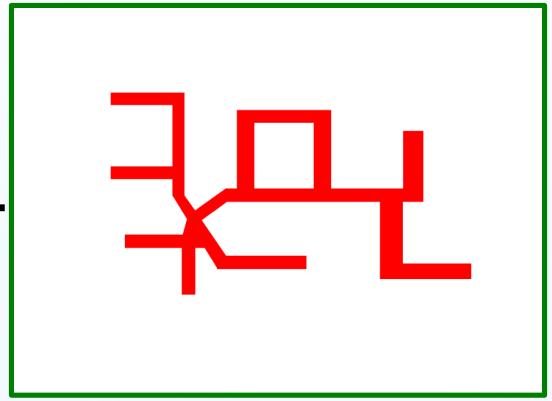


Binary mask

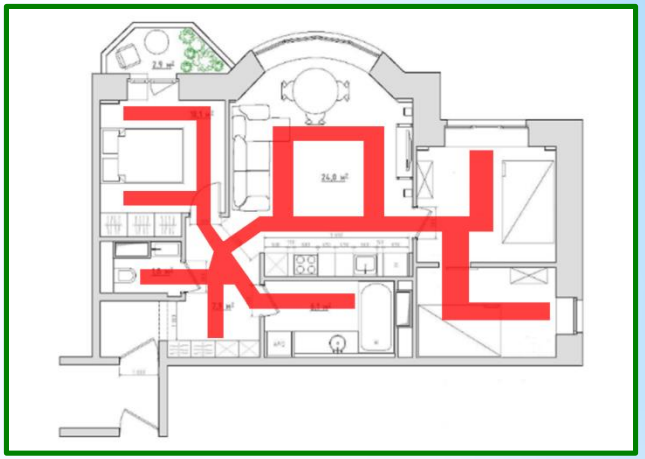
- Possible user locations are determined

Map and Graph for Routing

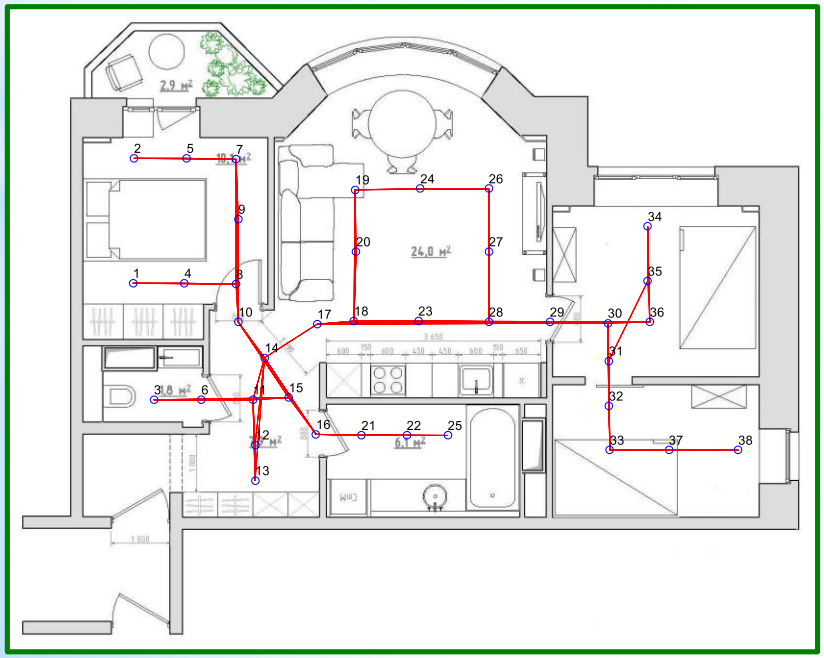
Building map



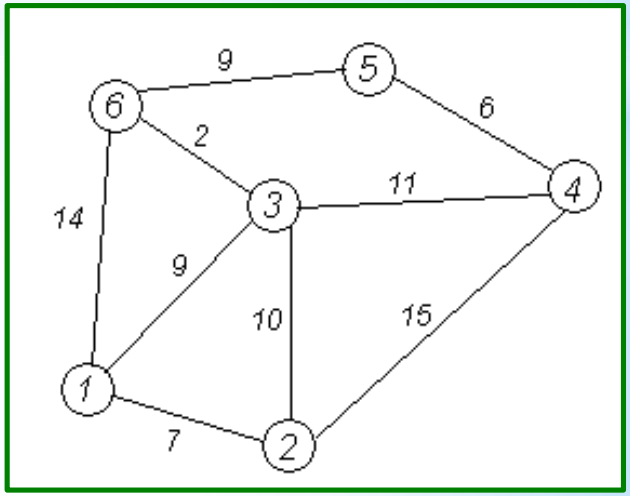
Binary mask



Map + Mask

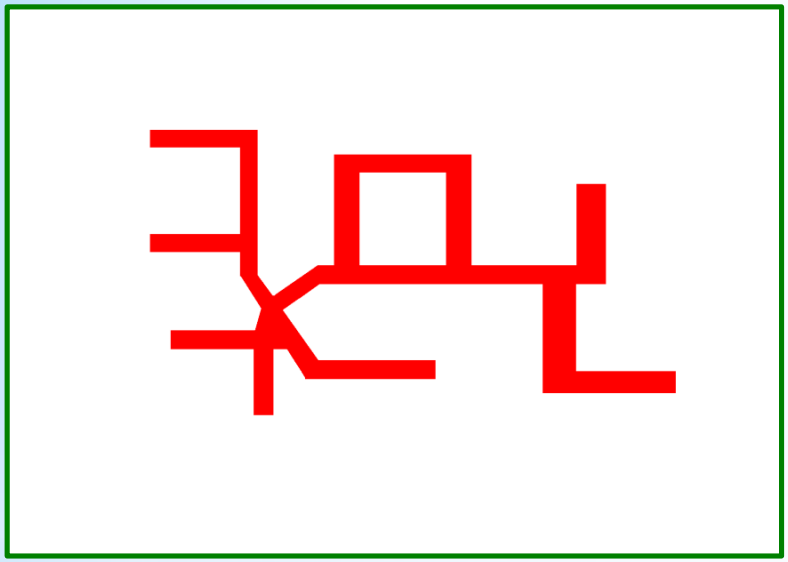


Building map

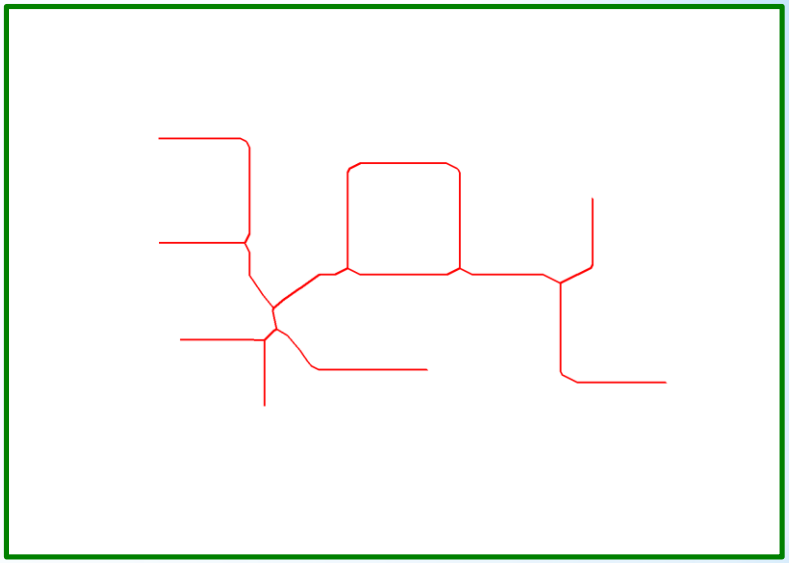


Simple graph example

Mask Skeletonization and Graph Extraction

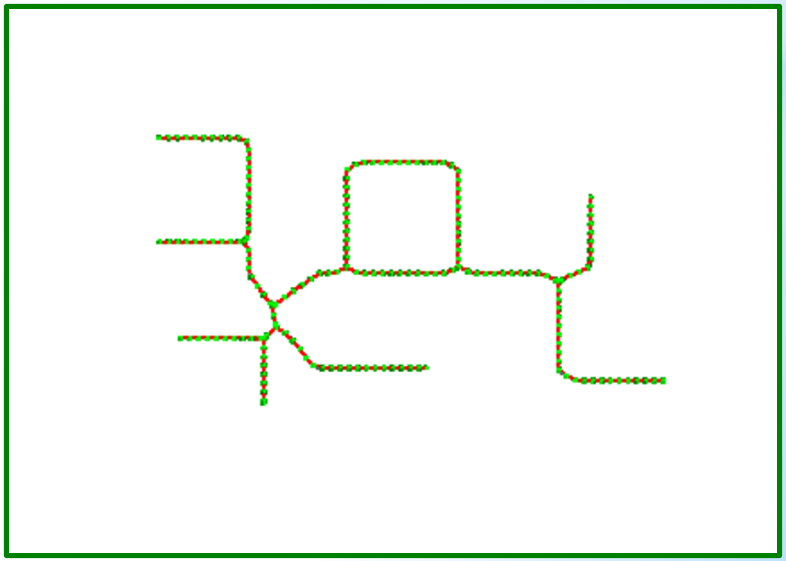


Mask



Mask skeleton

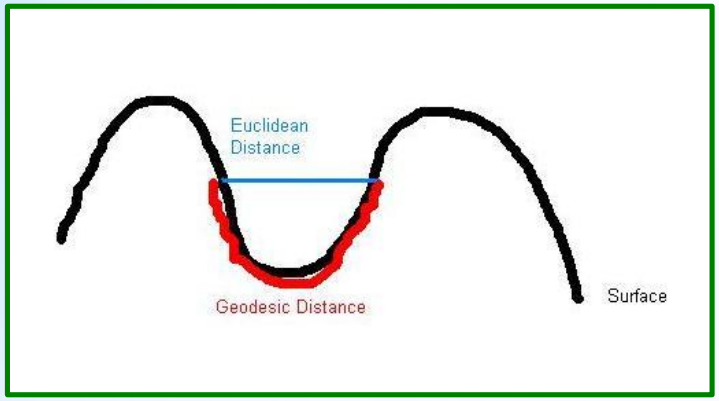
- Thinning algorithm can be applied
- Graph is easily obtained from skeleton
- In the case of large maps we really can save time



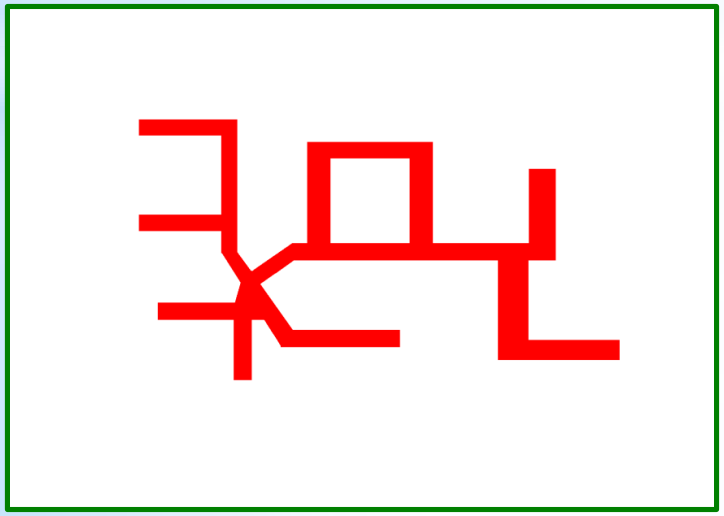
Extracted graph

Geodesic Distance

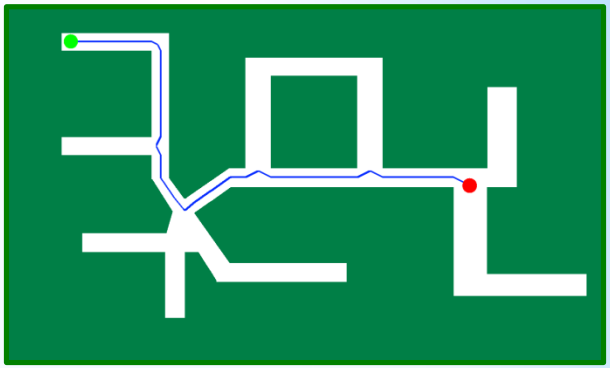
- Geodesic distance is determined as a shortest distance between the given pair of pixels within the image mask



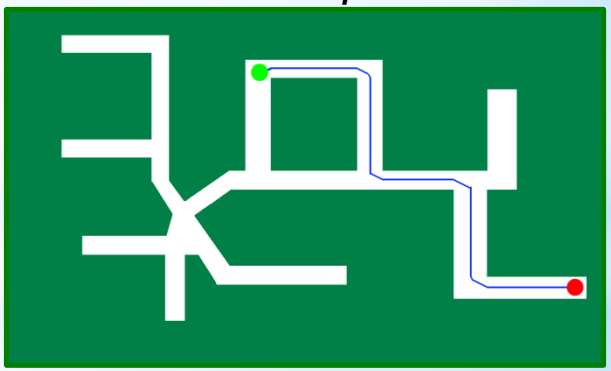
Geodesic distance



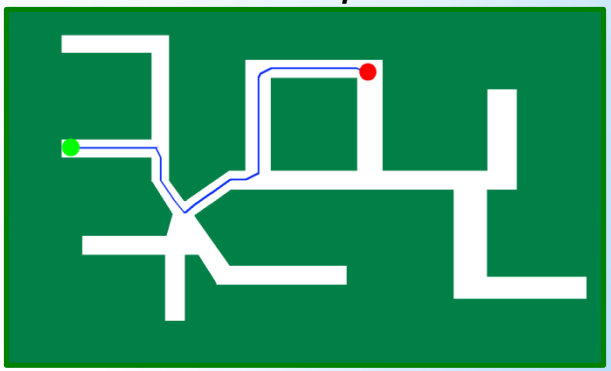
Binary mask



Route example 1



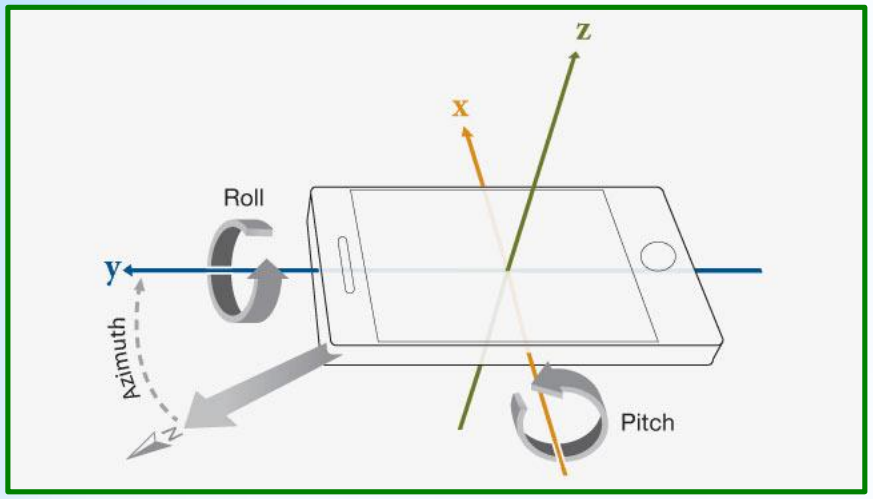
Route example 2



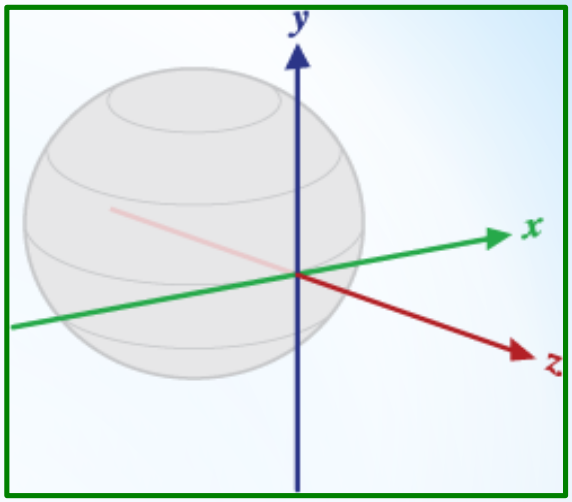
Route example 3

- Shortest path can be extracted directly from the mask!

Mobile Sensors and Orientation



Device orientation



Earth coordinate system

Get device angles with respect to the ECS

↓

getRotationMatrix(gData, mData)

↓

getOrientation(RMatrix)

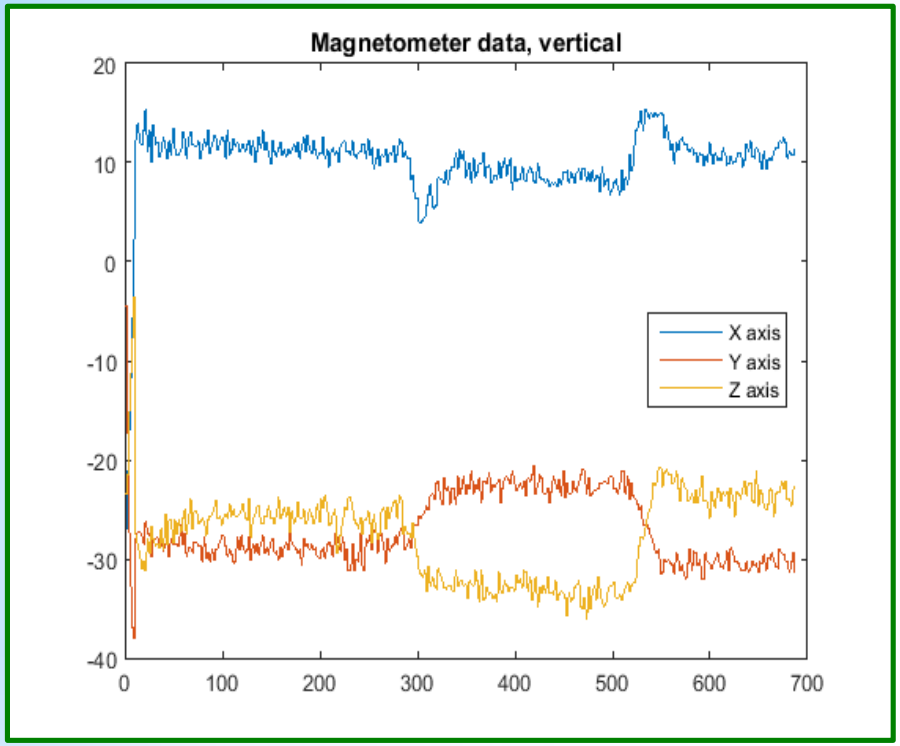
gData – **Gravity sensor** data

mData – **Magnetometer** data

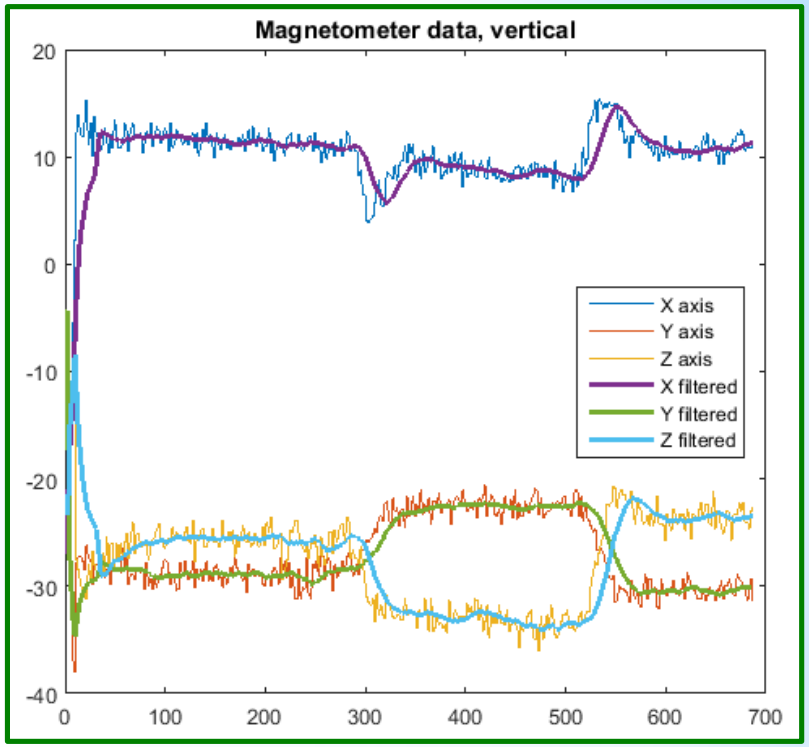
return – **Rotation Matrix**

return – **Roll, Pitch** and **Azimuth** angles

Filtering of Sensor Data Example



Magnetometer sensor data



Filtering effect

- Fluctuations in sensors data affect on data augmentation quality
- Sensors are crucial for user navigation

Real Scenarios and Experimental Results

System Setup

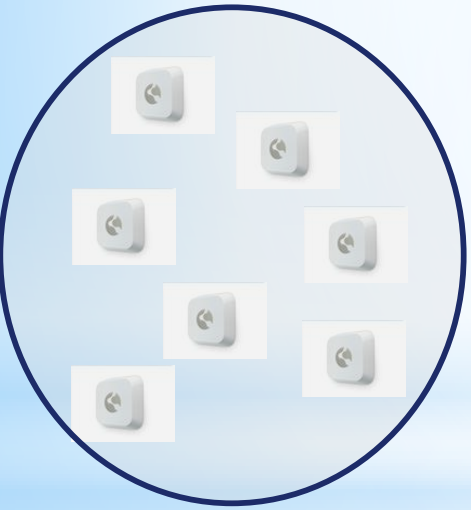
Mobile SDK

Indoor map

Server

Building ID

Config data



Beacons locations

Mobile phone (client)

1) User installs SDK

2) Map and configuration data are loaded from server

3) We are ready!

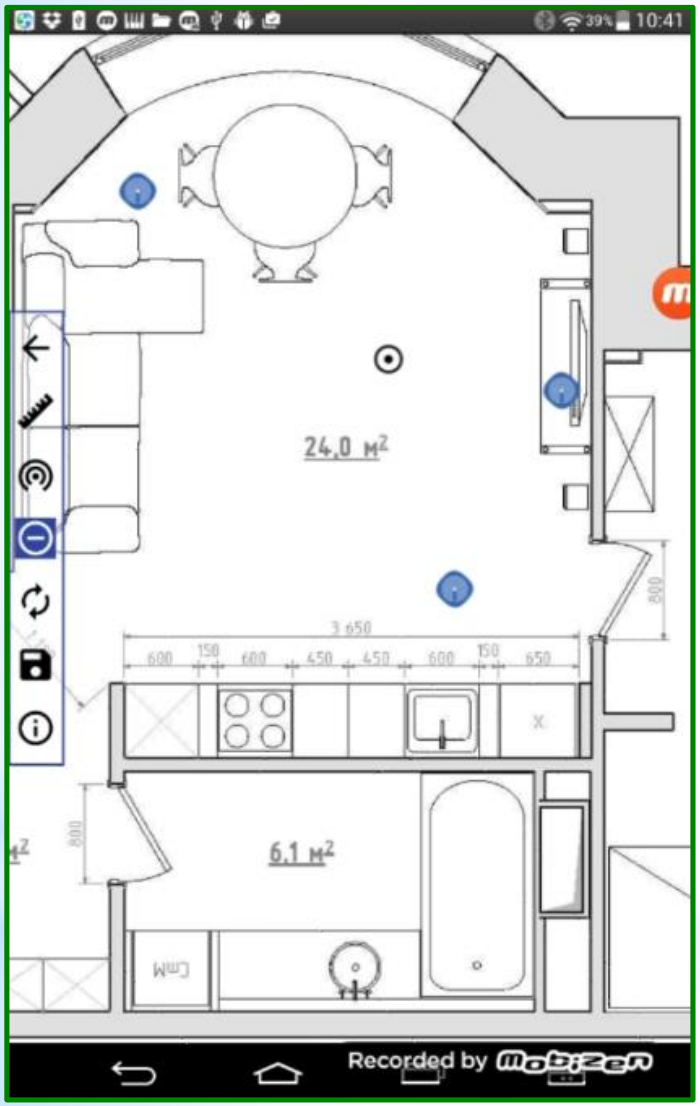
iBeacon and Eddystone

- Developed by **Apple**.
- Has deep integration with the **iOS** Works out of the box with CoreLocation framework.
- Broadcasts **1 advertising packet** (UUID, Major and Minor)

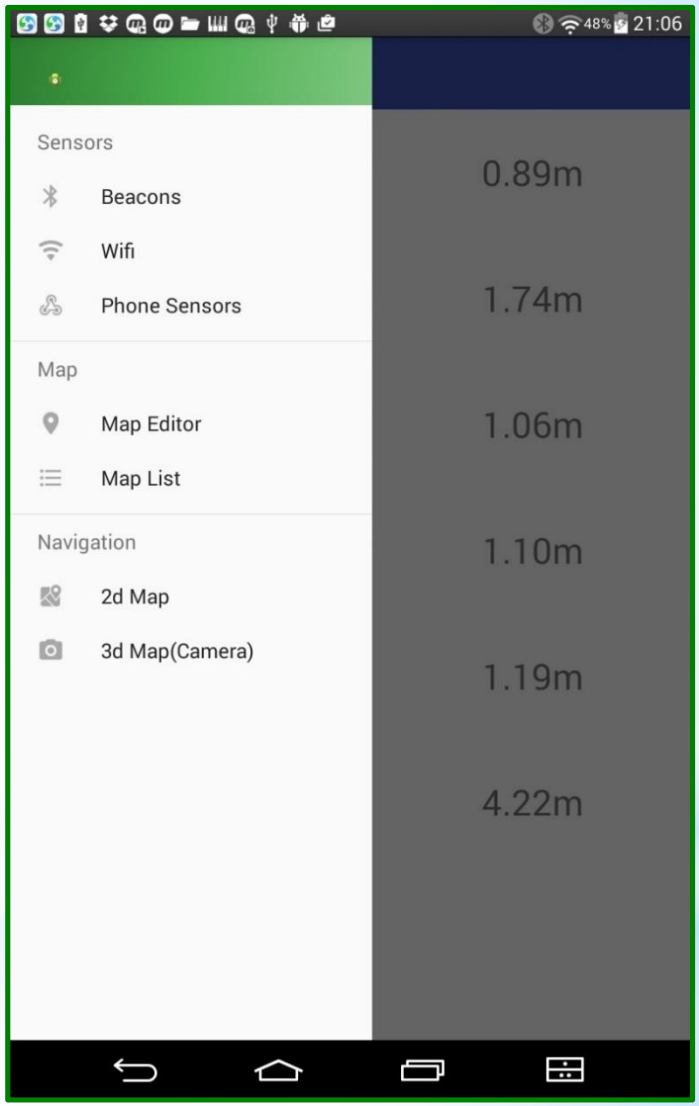
- Developed by **Google** and open to extension
- Works on **Android** and **iOS**.
- There are a lot of manufactures and SDKs available for both mobile platforms.
- Broadcasts **3 advertising packets** (frame types):
  - Eddystone-UID (similar to iBeacon)
  - Eddystone-URL
  - Eddystone-TLM

Google

Configuration Tool

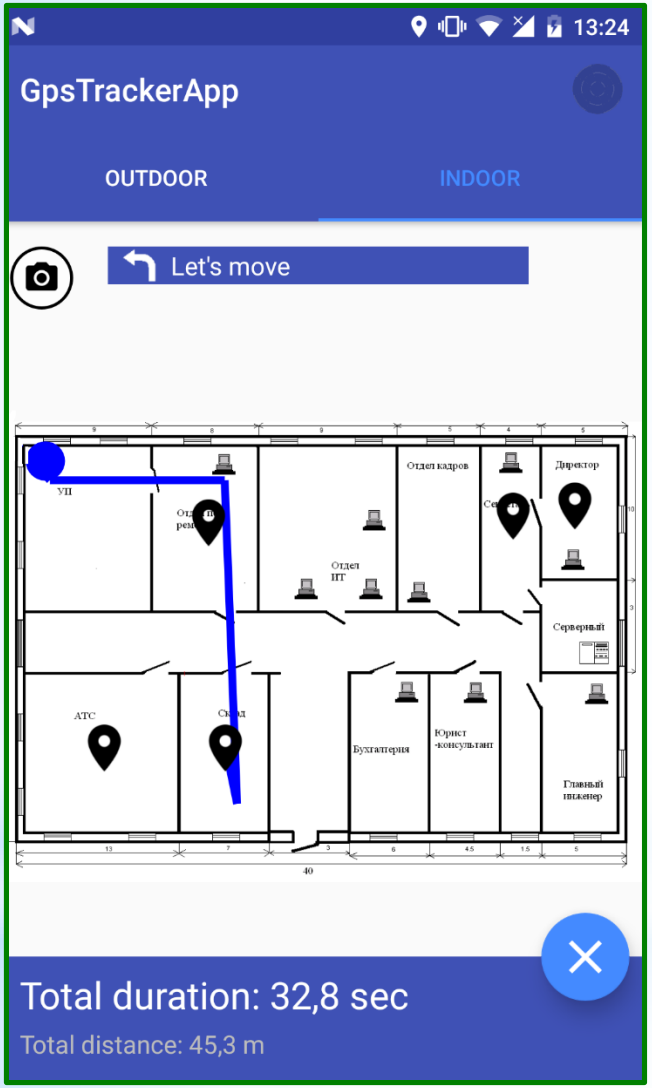


Building map in tool



Control panel

Map and Stream Modes



Map mode

Stream mode

Conclusions and Future Work

- Indoor navigation is very promising direction
- Proper signal processing allows to achieve a competitive localization accuracy
- Beacons are low cost and easy to use
- Areas of application are extensive and the market is growing

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- System performance optimization
- SLAM technologies
- Accuracy improvements

Thank you!