Low-Power, Long-Range, Precise Localization

Nextech 2014, Rome - 28 August 2014

Prof. Maarten Weyn
maarten.weyn@uantwerpen.be

CoSys-Lab
Constrained Systems Lab
University of Antwerp

CoSys-Lab
Constrained Systems Lab
University of Antwerp

Maarten Weyn

Research:

- Localization: from *Opportunistic* to *Just Enough*
- Low-power communication
- Low-power firmware development
- Simultaneous Localization and Mapping

Courses:

- Mobile Communication
- Digital Communication
- Real-Time Localization Systems (Eng)
- Ambient Intelligence (Eng): interaction between low-power communication, sensors, actuators, low-power hardware and algorithms

CoSys-Lab
Constrained Systems Lab
University of Antwerp

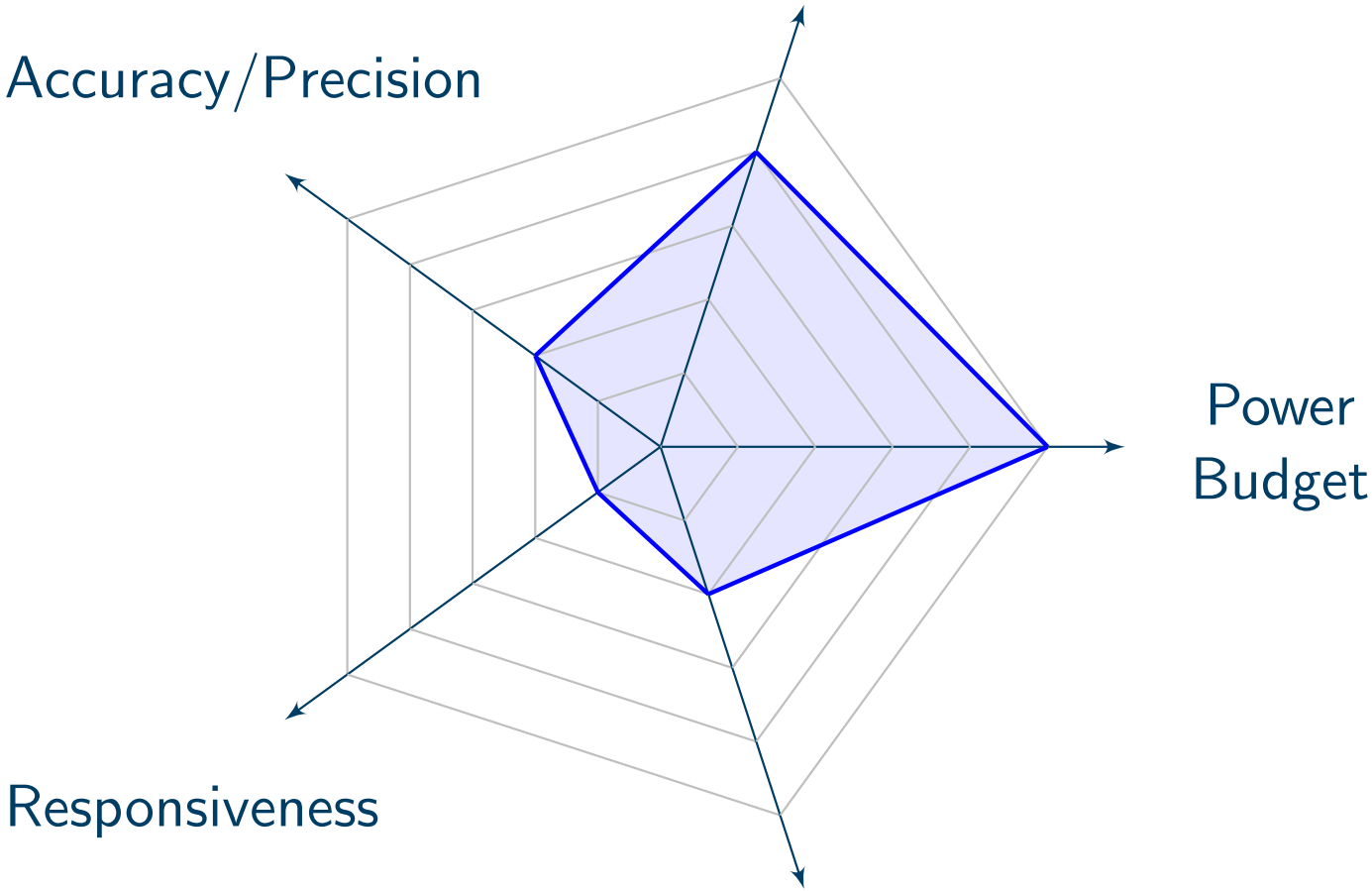
What I'm not going to do...

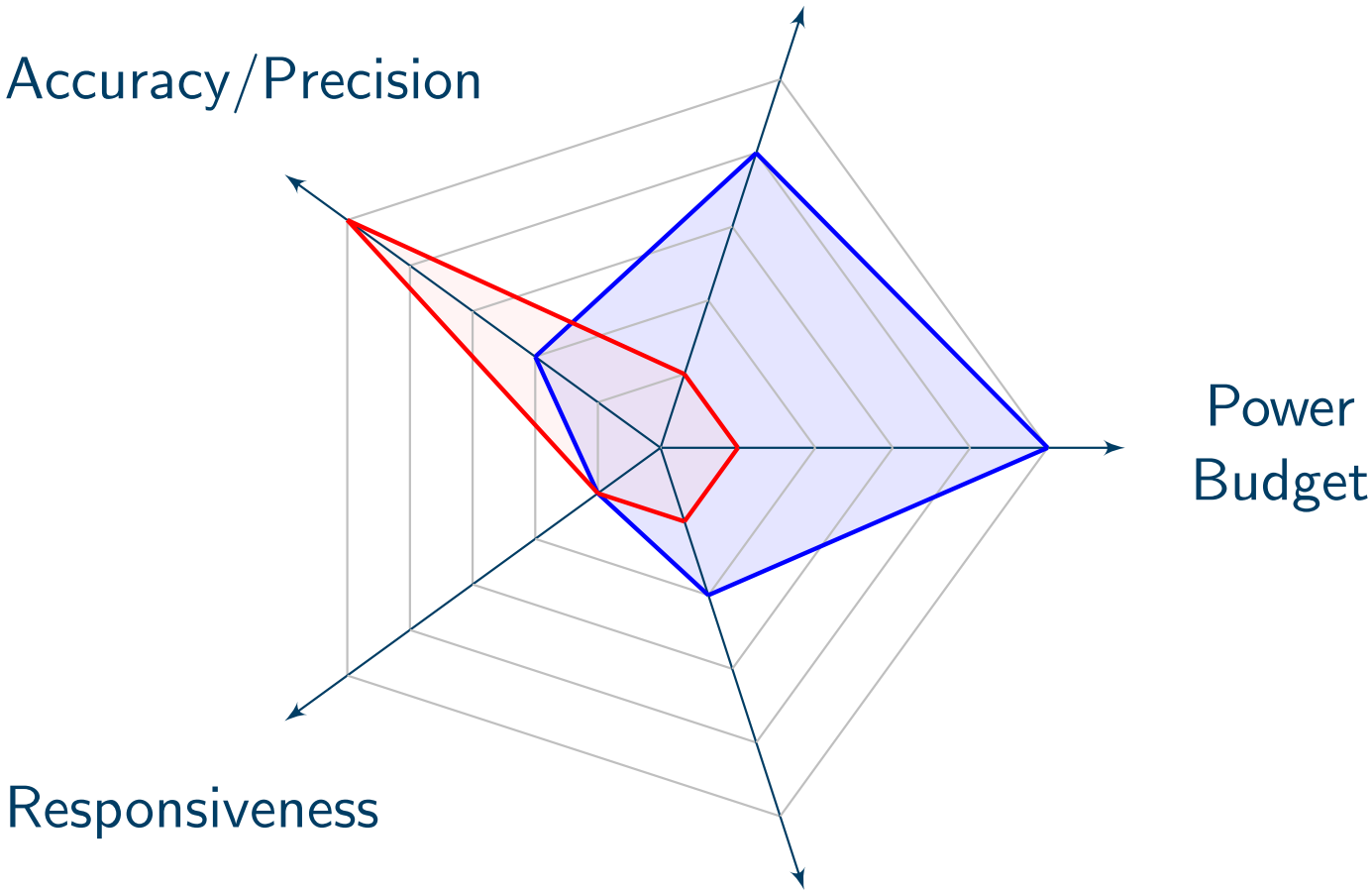
- No sales talk
- No academic formula's and equations
- No futuristic foresights
- No "You should's"

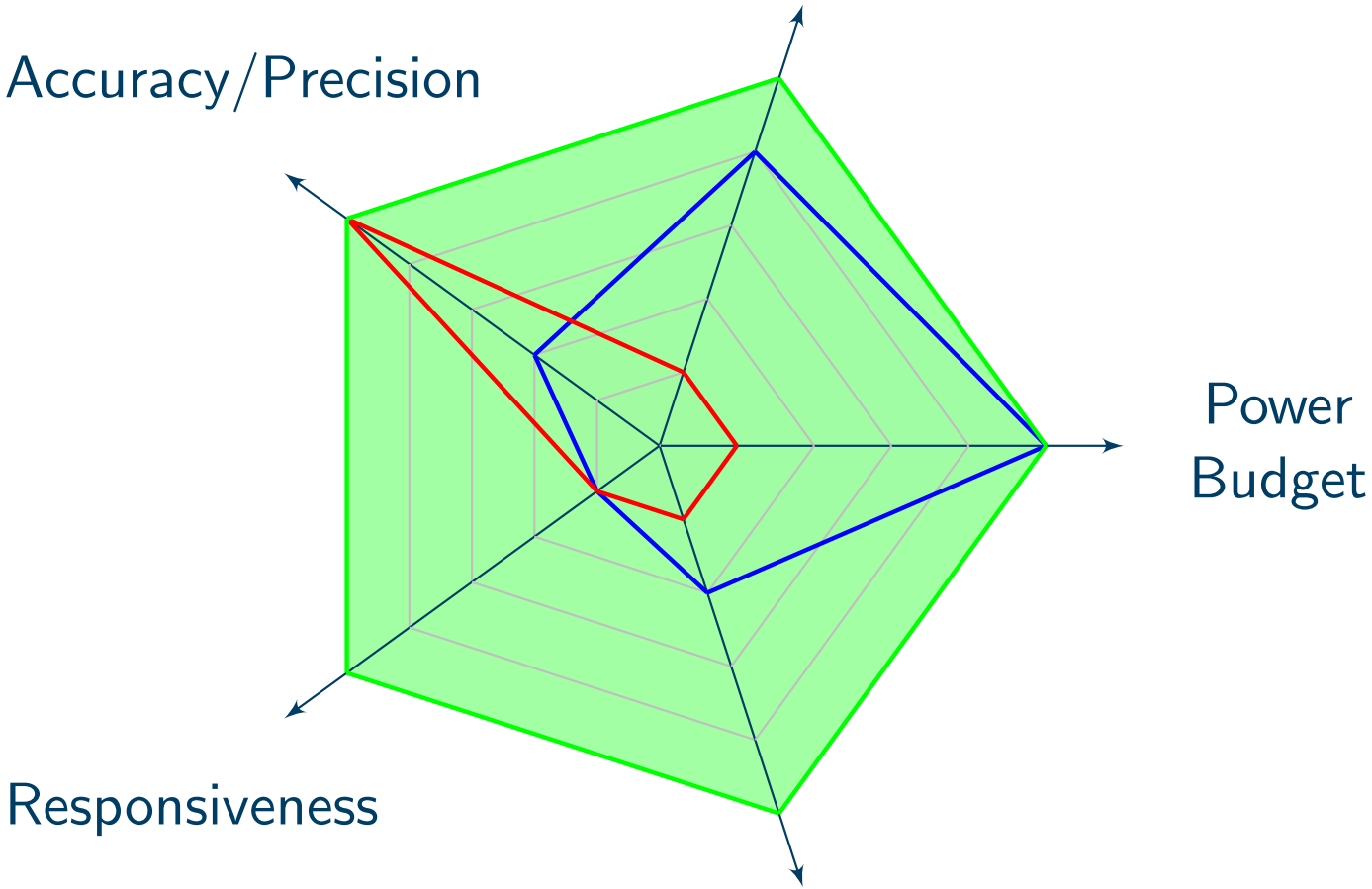
CoSys-Lab
Constrained Systems Lab
University of Antwerp

Low-Power, Long-Range, Precise Localization

Range




Range
Accuracy/Precision
Power
Budget
Responsiveness
Tag Size


Range
Accuracy/Precision
Power
Budget
Responsiveness
Tag Size

Power Budget

Low Power?:

- LG Nexus 5: 2300 mAh / day ?!!!
- Raspberry pi: 500 mAh
- TelosB

CoSys-Lab
Constrained Systems Lab
University of Antwerp

Power Budget

Low Power?:

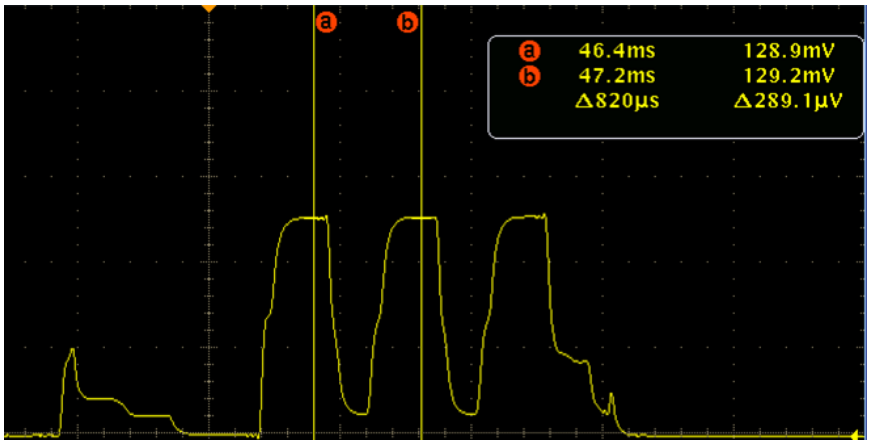
- LG Nexus 5: 2300 mAh / day ?!!!
- Raspberry pi: 500 mAh
- TelosB

Application Driven:

- e.g.: 1 year on coin cell (220 mAh)
- e.g.: "the lifetime of the bird and weight $\leq$ 1 gram"
- e.g.: 2 year on 1/2 AA 3.6V battery (1100 mAh) $\rightarrow 62\mu Ah/day$

CoSys-Lab
Constrained Systems Lab
University of Antwerp

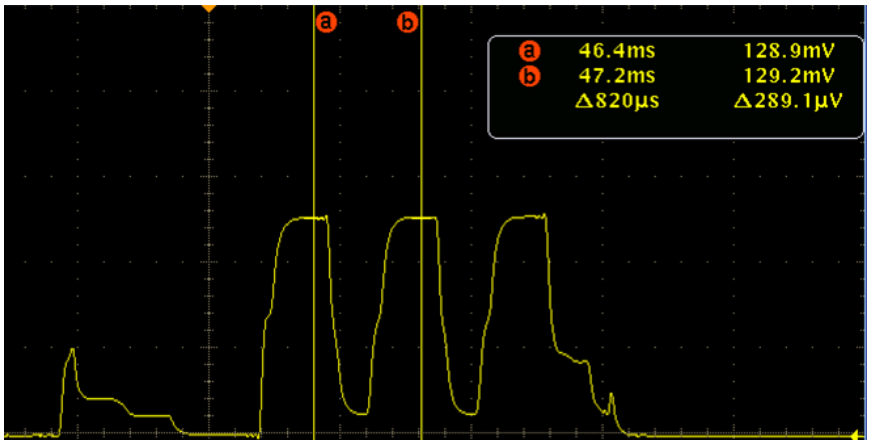
Power Consumption: e.g. BLE



- 3 x 12.8 mA x 660 μs (0 dBm)
- 0.00704 μAh / beacon

CoSys-Lab
Constrained Systems Lab
University of Antwerp

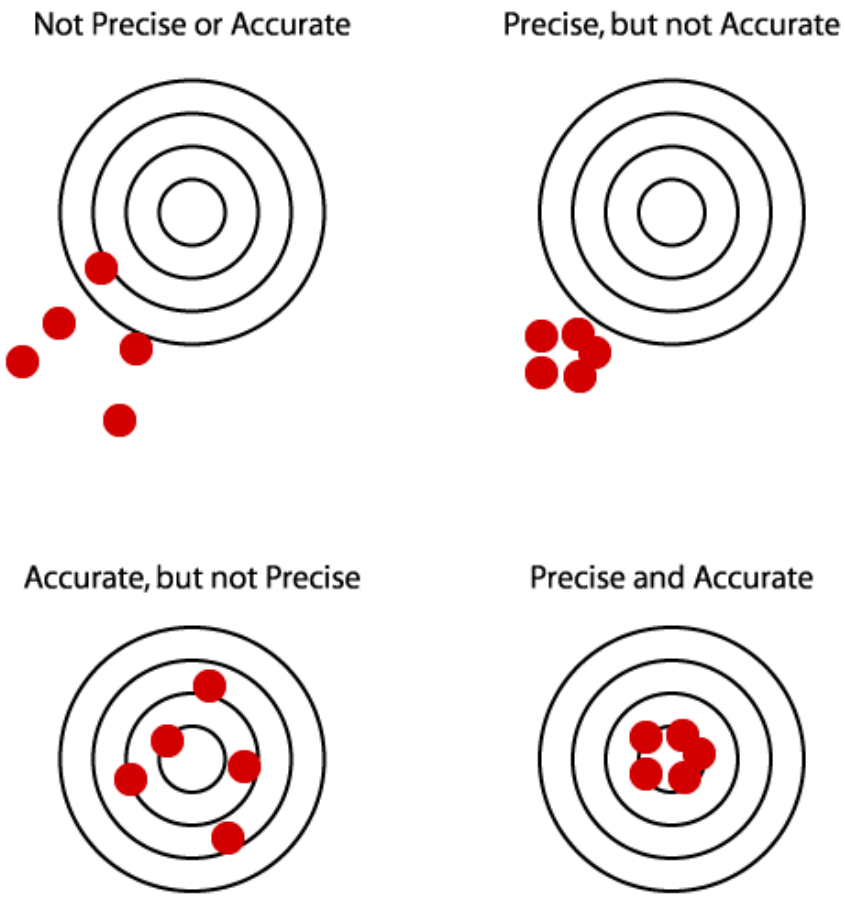
Power Consumption: e.g. BLE



- 3 x 12.8 mA x 660 μs (0 dBm)
- 0.00704 μAh / beacon
- iBeacon: 10 msg/s
- $\rightarrow$ 253.44 μAh

$\rightarrow \pm$ 1 month with a coincell battery

Accuracy vs Precision



CoSys-Lab
Constrained Systems Lab
University of Antwerp

Accuracy vs Precision

Source: Versus Technology, Inc.

CoSys-Lab
Constrained Systems Lab
University of Antwerp

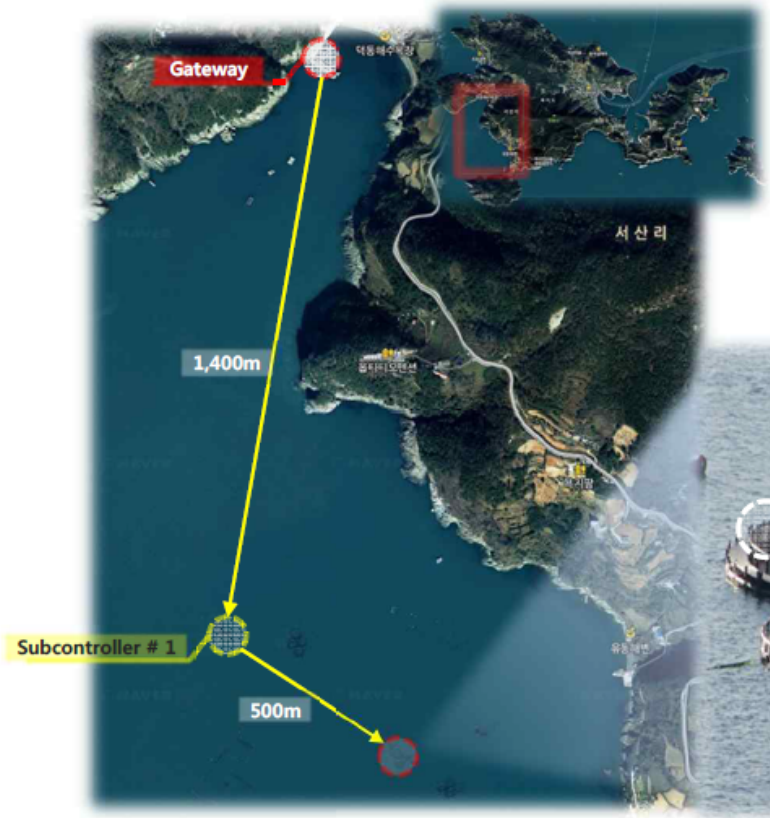
Range

CoSys-Lab
Constrained Systems Lab
University of Antwerp

Range

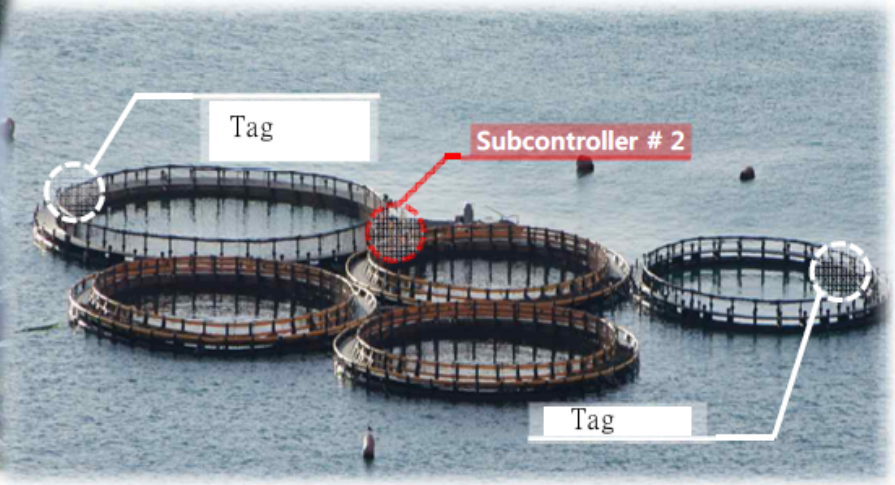
CoSys-Lab
Constrained Systems Lab
University of Antwerp

Range



Source: Pusan National University

r



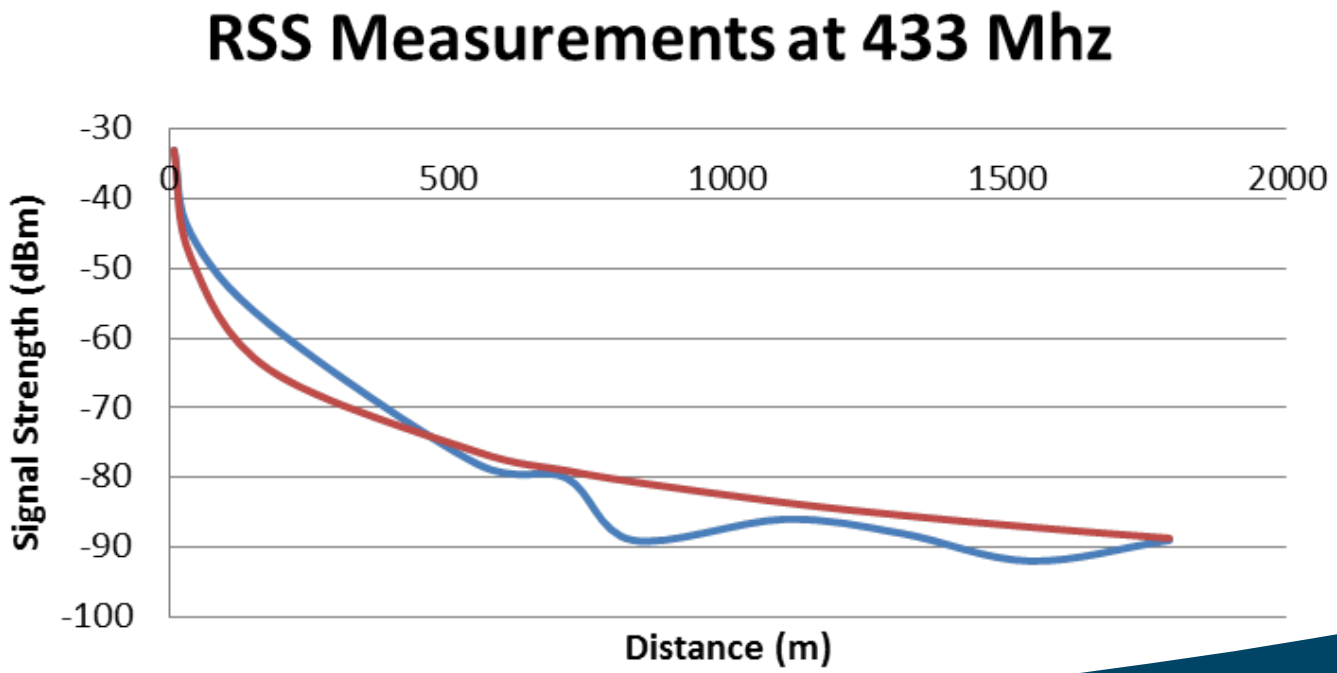
Techniques

- Signal Strength:
  - Attenuation
  - Pattern Matching (Fingerprinting)
  - Presence / Proximity
- Time (Ranging):
  - Time of Flight - Time Difference of Arrival
  - Round Trip Time
- Direction Finding / Angle of Arrival

CoSys-Lab
Constrained Systems Lab
University of Antwerp

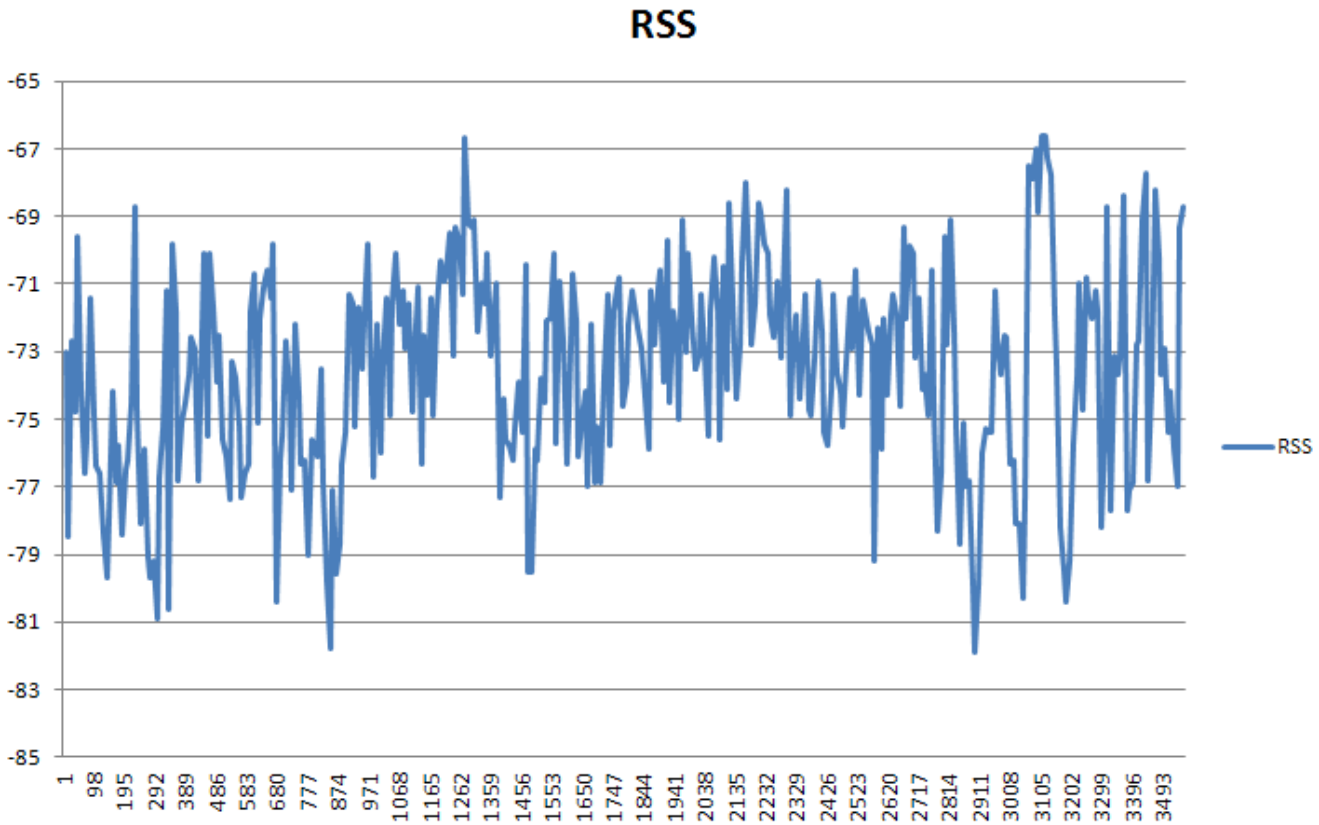
Signal Strength

$$RSS_d = P_{rdBm} = 10 \log P_r(d_0) - 10 n_p \log \frac{d}{d_0} + X$$



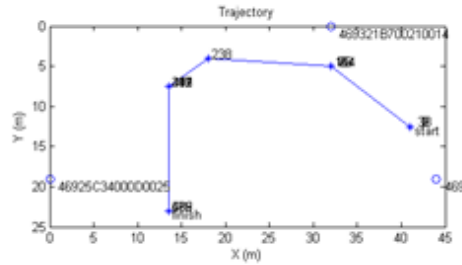
CoSys-Lab
Constrained Systems Lab
University of Antwerp

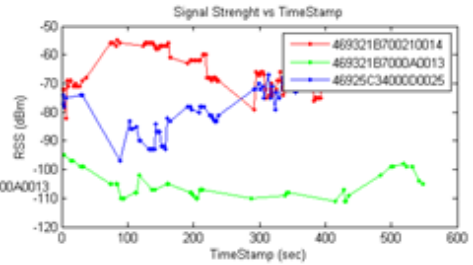
Attenuation

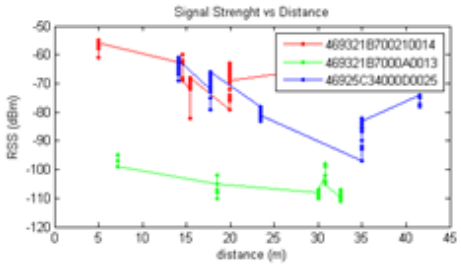


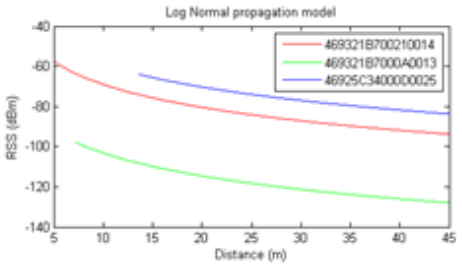
CoSys-Lab
Constrained Systems Lab
University of Antwerp

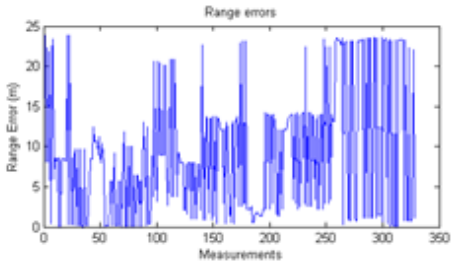
Attenuation

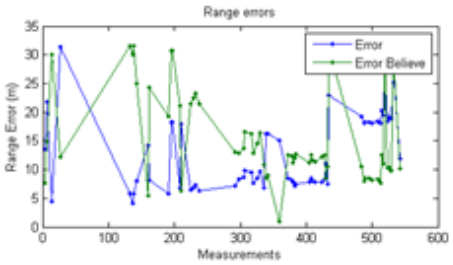


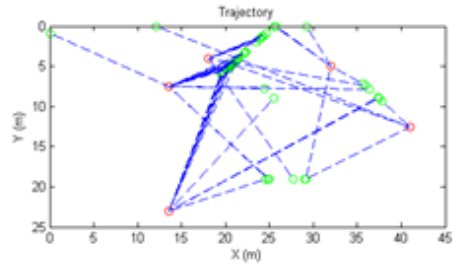






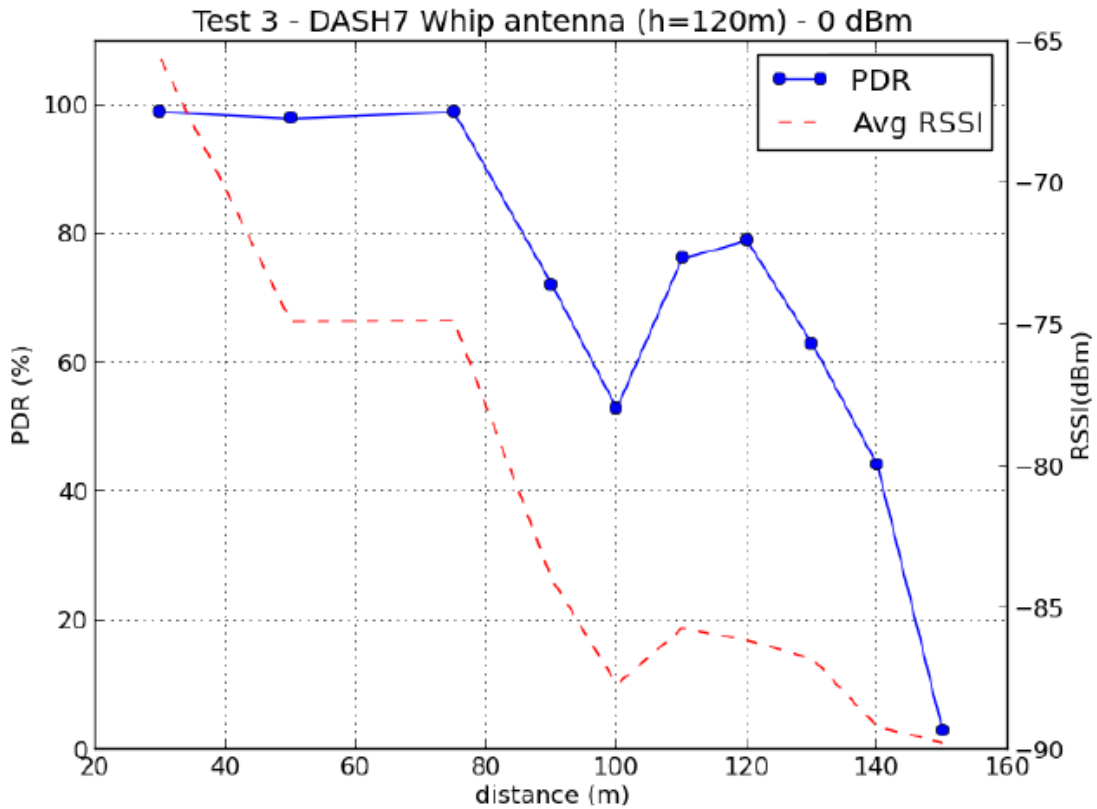






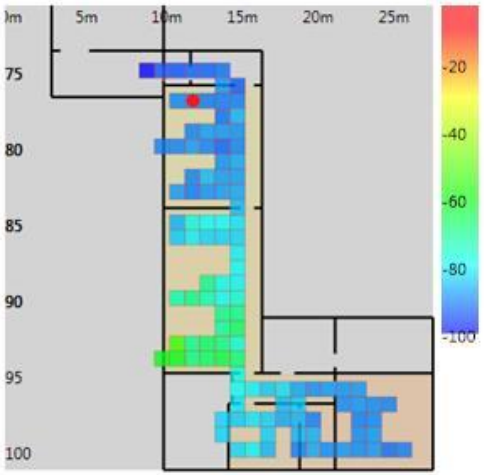
CoSys-Lab
Constrained Systems Lab
University of Antwerp

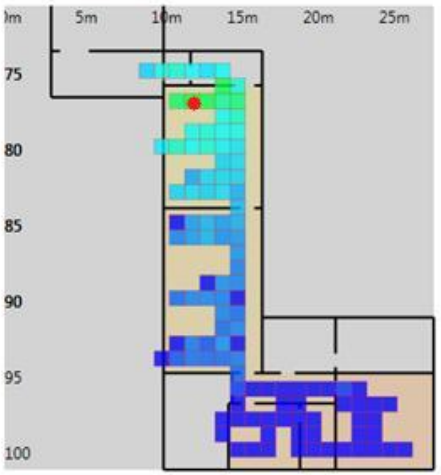
Attenuation

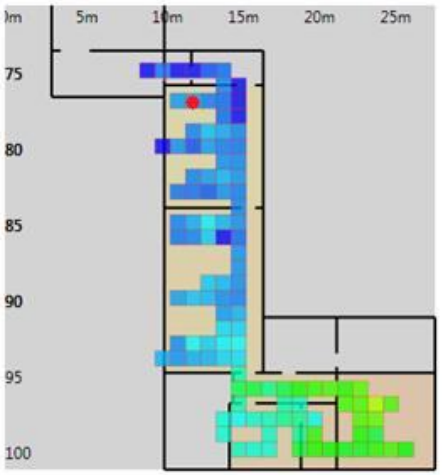


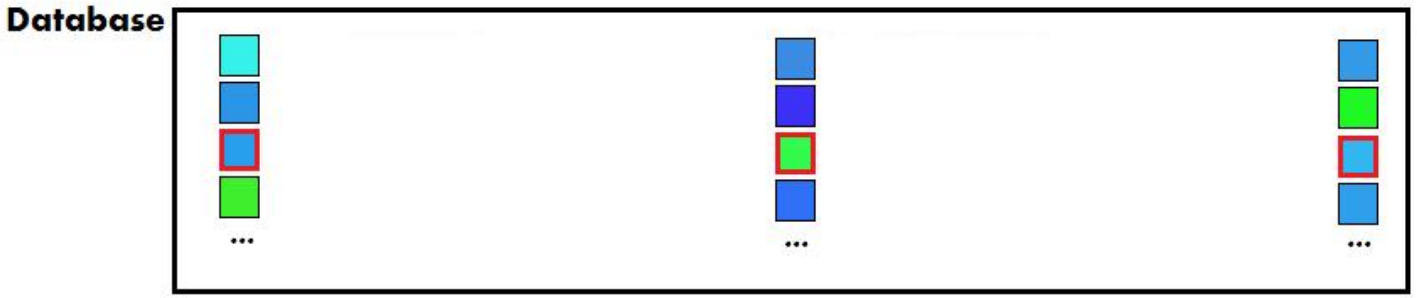
CoSys-Lab
Constrained Systems Lab
University of Antwerp

Pattern Matching



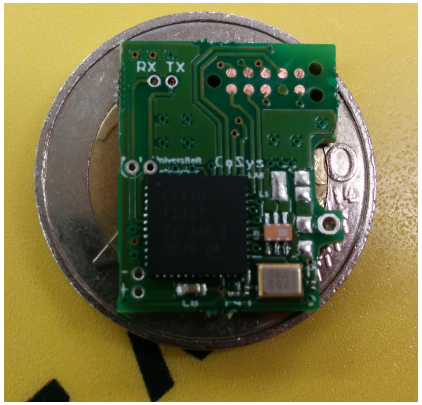


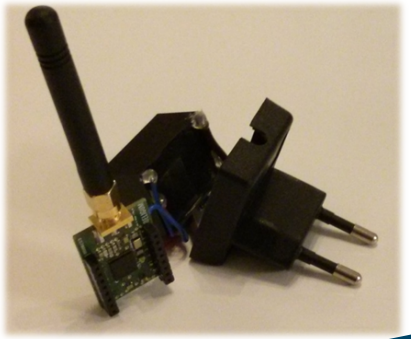




CoSys-Lab
Constrained Systems Lab
University of Antwerp

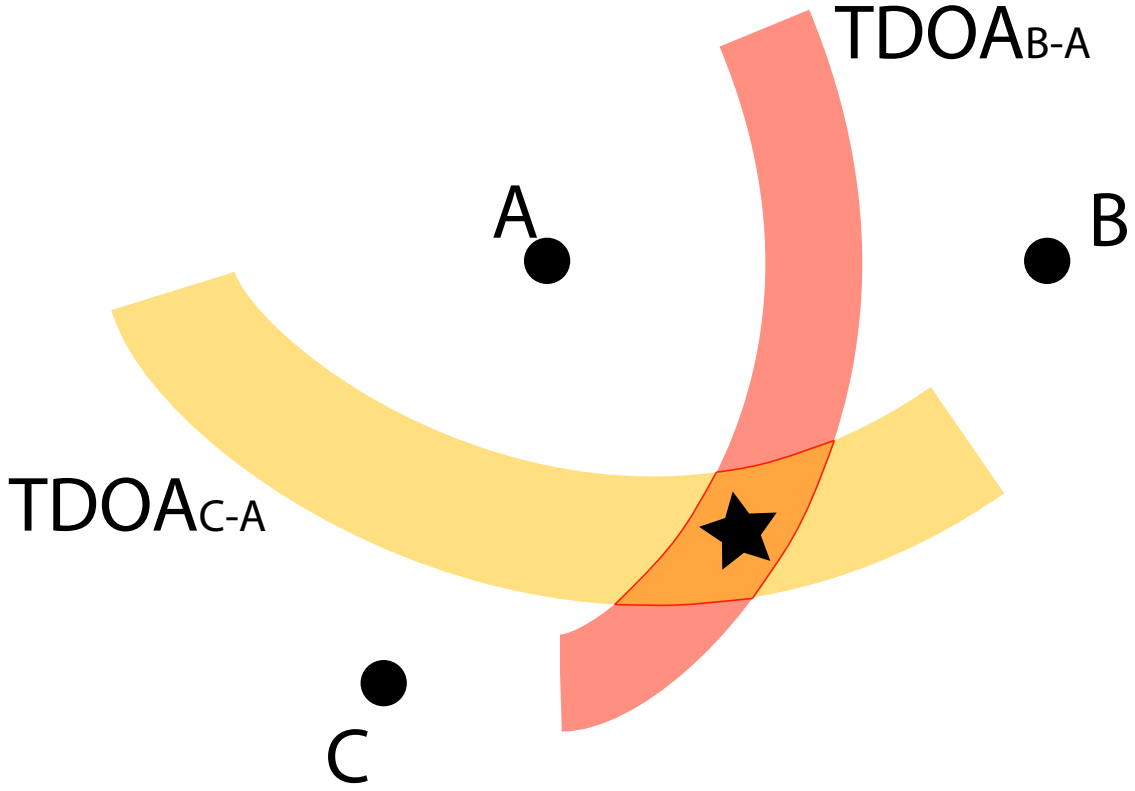
Presence Detection





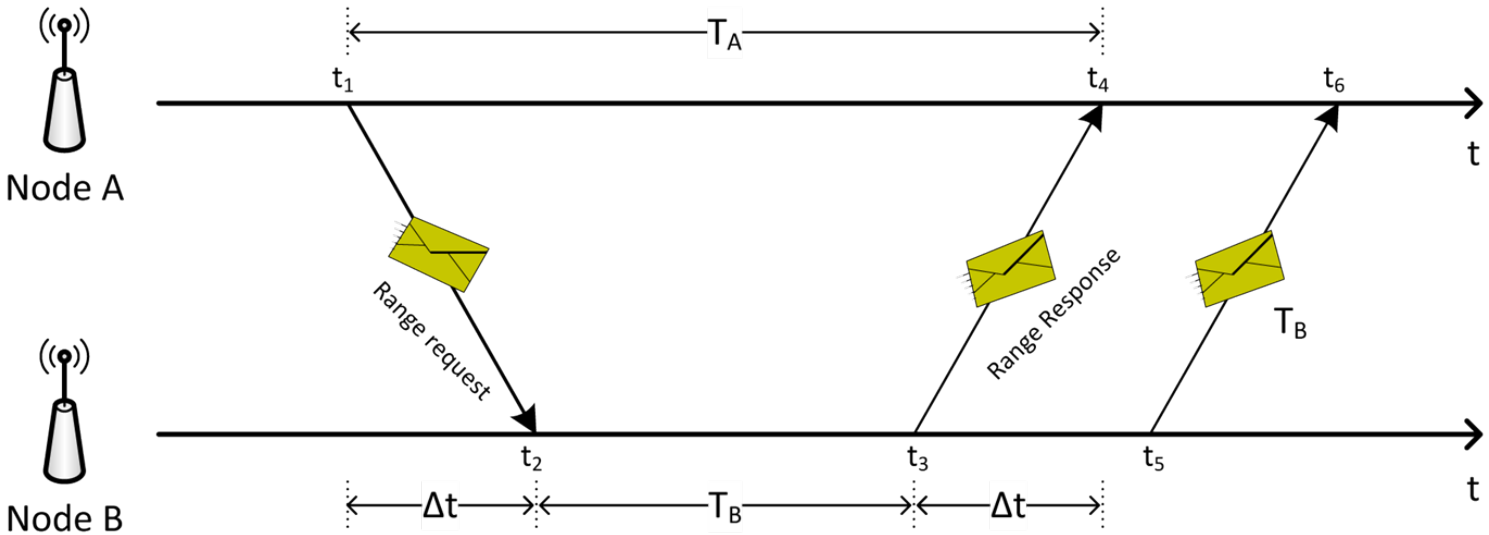
CoSys-Lab
Constrained Systems Lab
University of Antwerp

Time of Flight: Time Difference of Arrival



CoSys-Lab
Constrained Systems Lab
University of Antwerp

Time of Flight: Round Trip Time



CoSys-Lab
Constrained Systems Lab
University of Antwerp

Time of Flight: Cramer Rao Bound

$$\sigma_{\hat{r}}^2 \geq \frac{c^2}{\frac{4\pi^2 B^2 E_s}{N_0}}$$

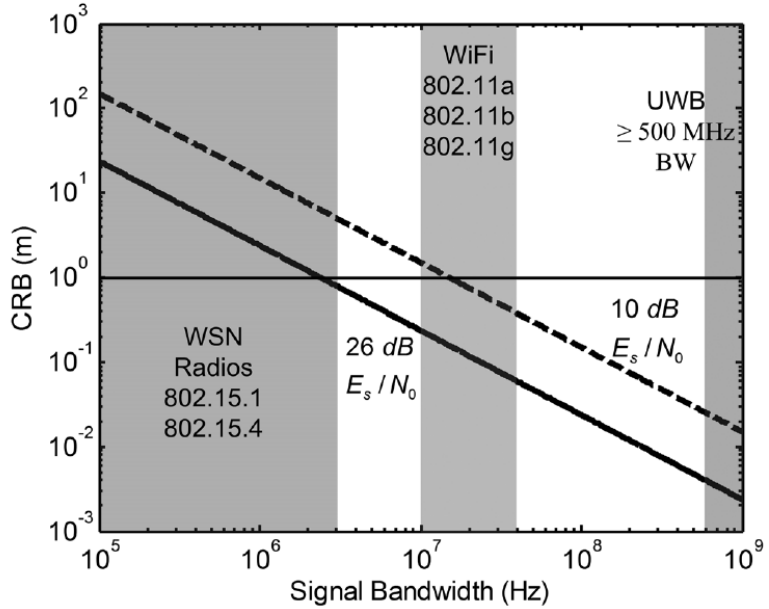
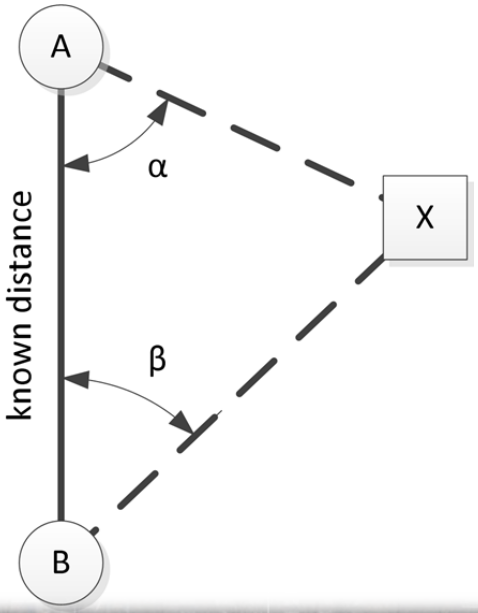


Fig. 2. CRB as a function of bandwidth.

Source: Lanzisera et al.: Radio Frequency Time-of-Flight Distance Measurement

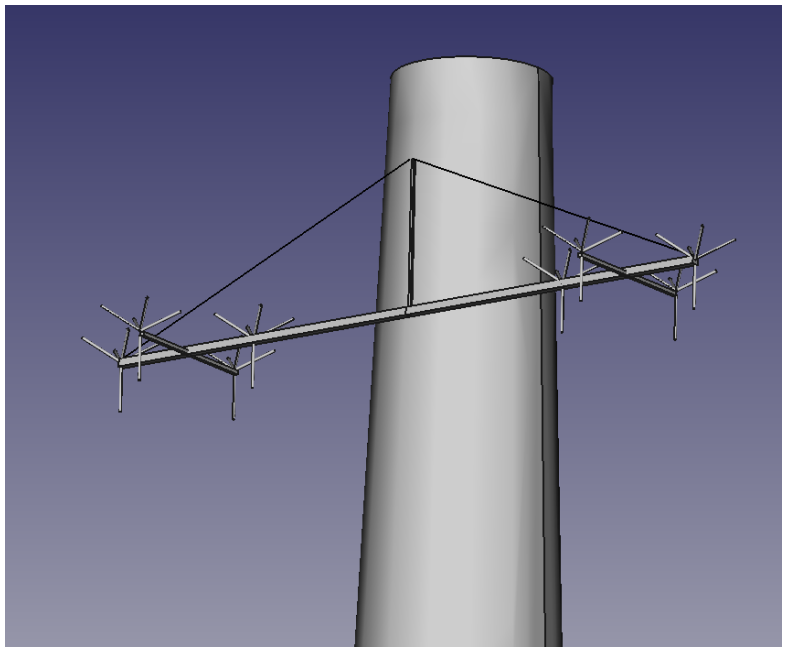
CoSys-Lab
Constrained Systems Lab
University of Antwerp

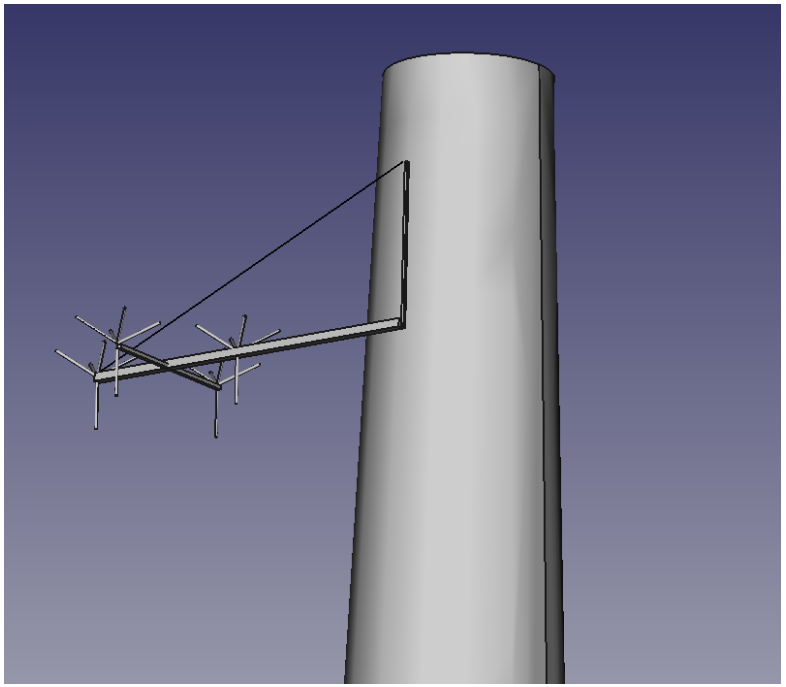
Direction Finding

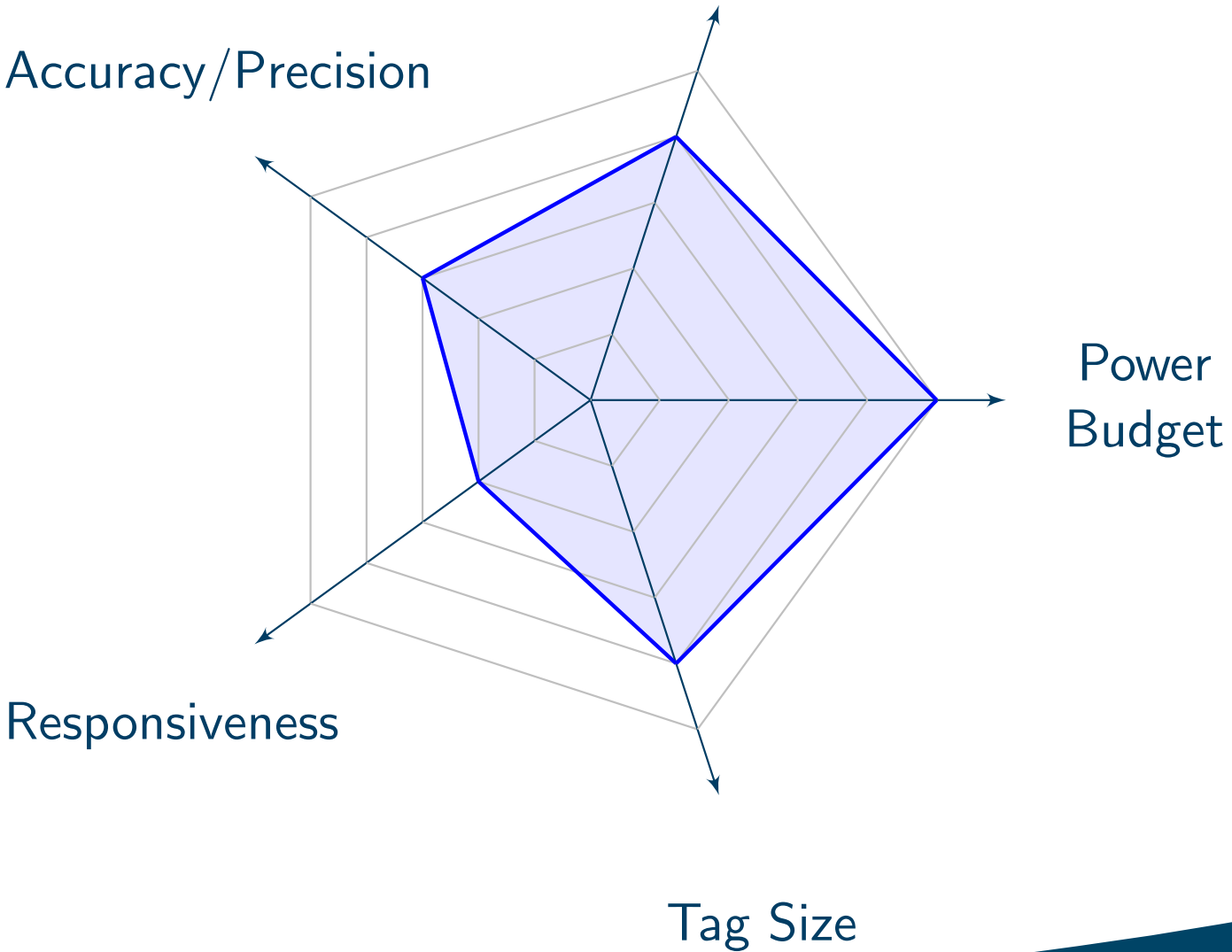


CoSys-Lab
Constrained Systems Lab
University of Antwerp

Direction Finding






Range
Accuracy/Precision
Power
Budget
Responsiveness
Tag Size


CoSys-Lab
Constrained Systems Lab
University of Antwerp


DASH7™
ALLIANCE

DASH7

Active RFID Standard for 433 MHz.

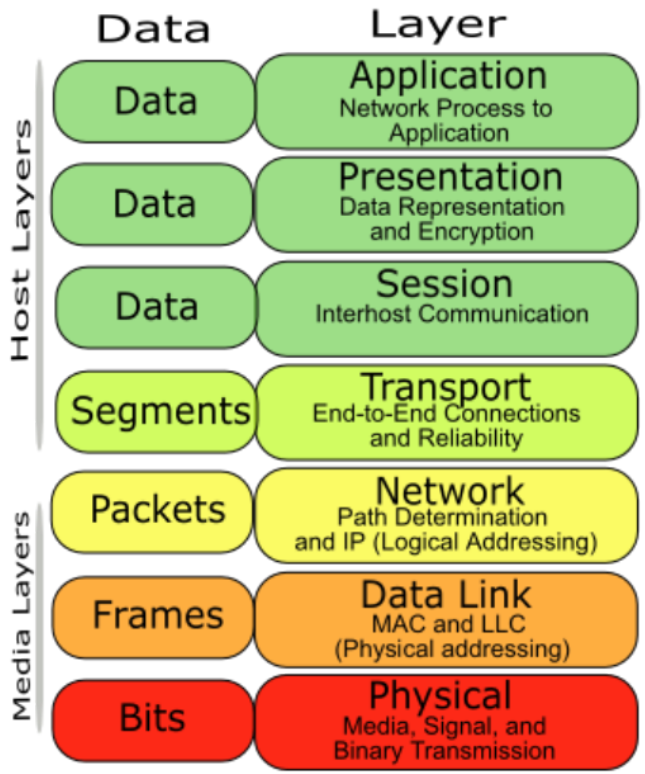
- Build on top of asynchronous WSN MAC.
- High level functionality optimized for RFID.
- Defines full functional RFID tag.
- Can be extended to non RFID applications.

Supports Tag to Tag communication.
DASH7 Alliance Protocol is designed to support fixed and mobile nodes that need to upload or retrieve small chunks of information

CoSys-Lab
Constrained Systems Lab
University of Antwerp

DASH7

DASH7 Alliance Protocol

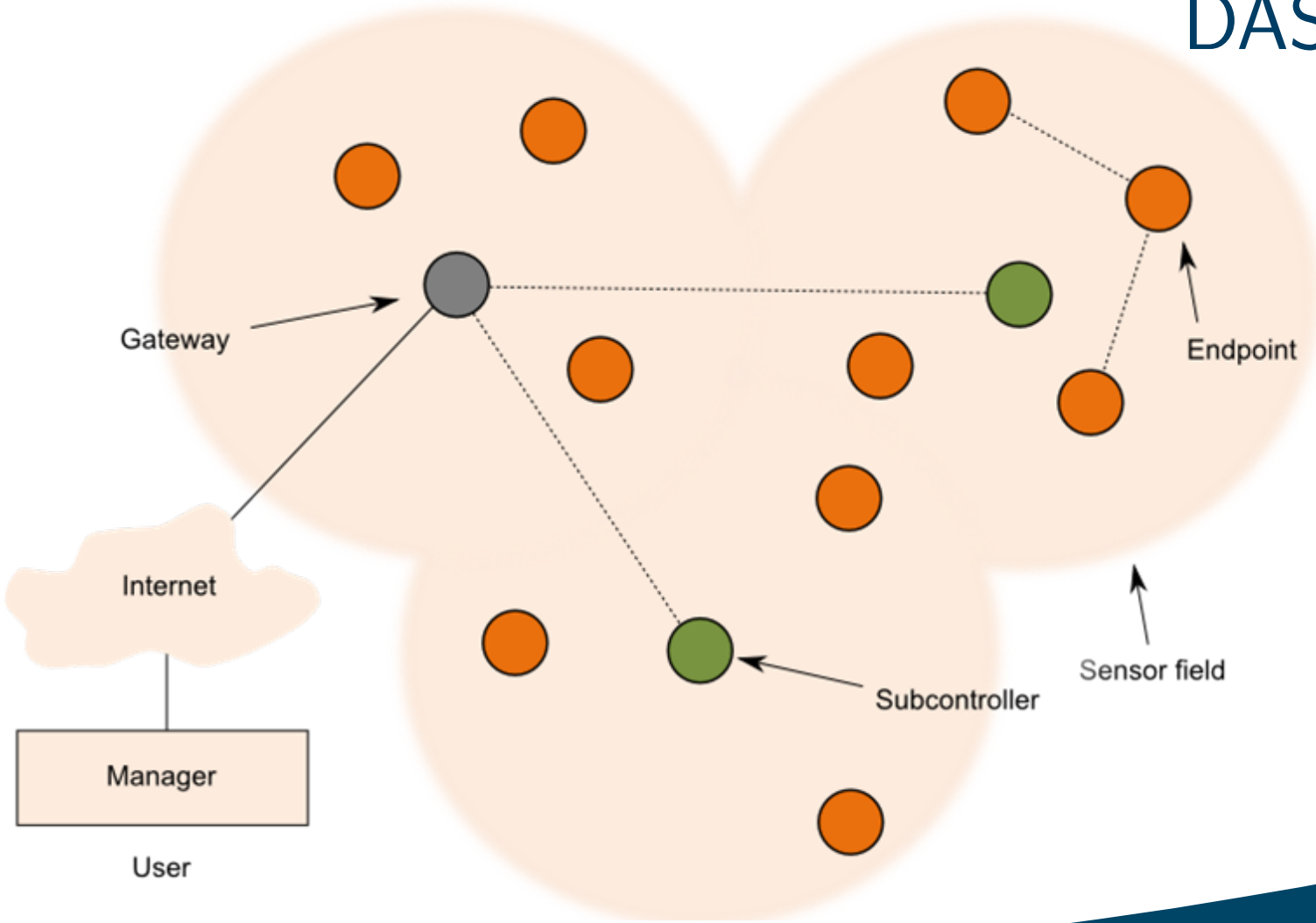


ZigBee
WirelessHart
ISA100.11a

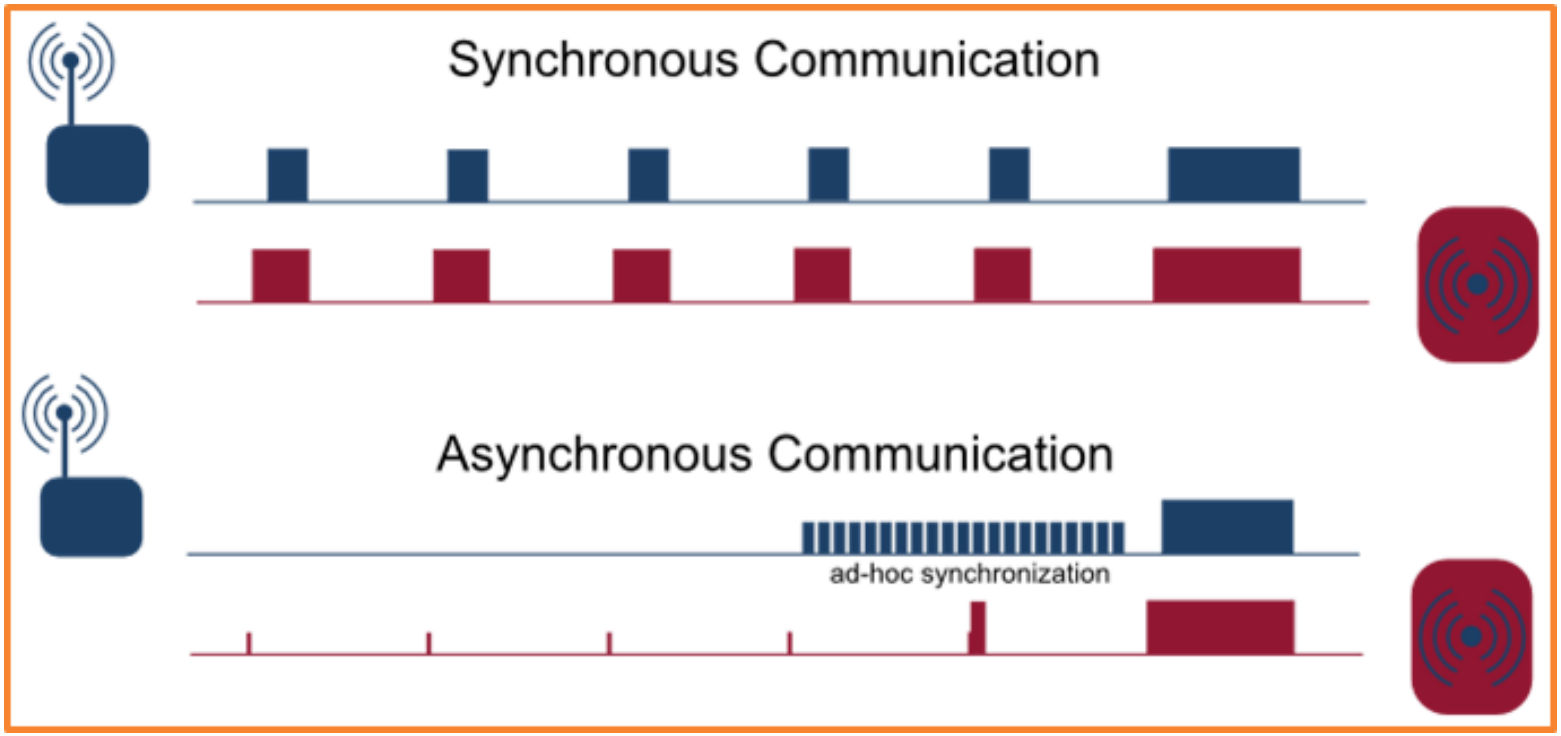
IEEE 802.15.4

CoSys-Lab
Constrained Systems Lab
University of Antwerp

DASH7



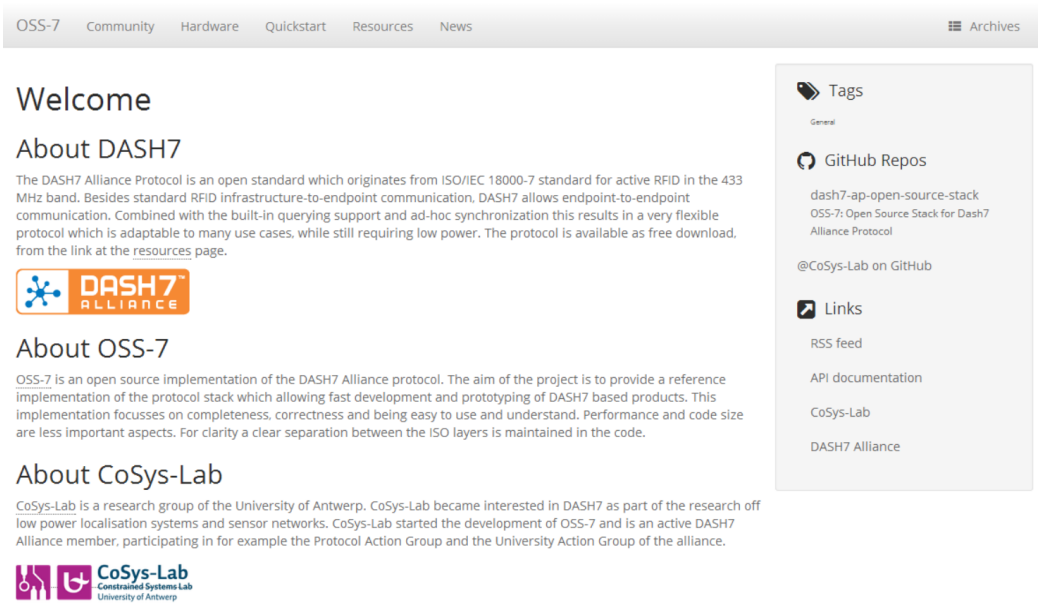
DASH7


Synchronous Communication
Asynchronous Communication
ad-hoc synchronization

CoSys-Lab
Constrained Systems Lab
University of Antwerp

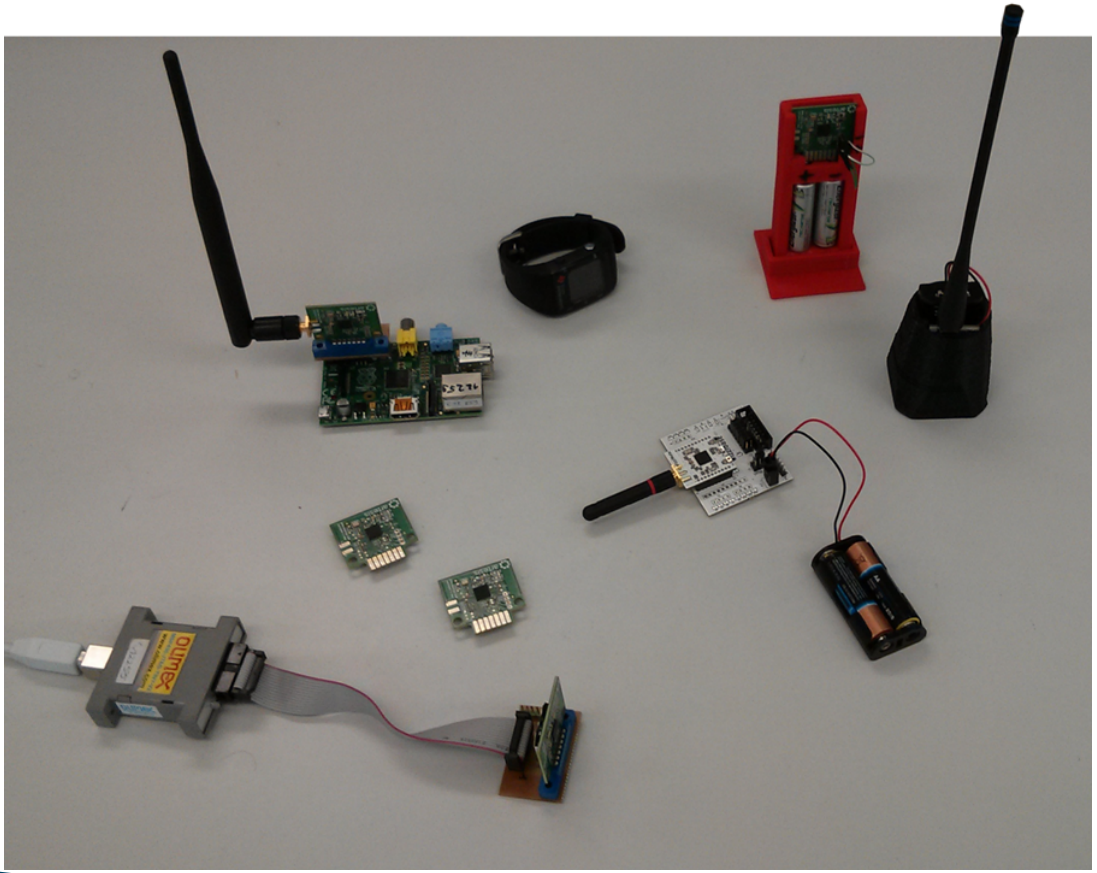
Open Source Stack for DASH7

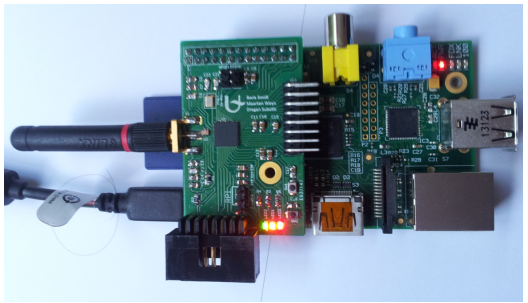
http://oss-7.cosys.be
LGPL v2.1



CoSys-Lab
Constrained Systems Lab
University of Antwerp

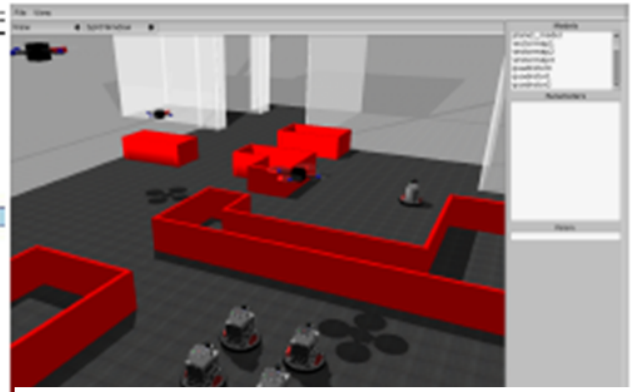
Open Source Stack for DASH7

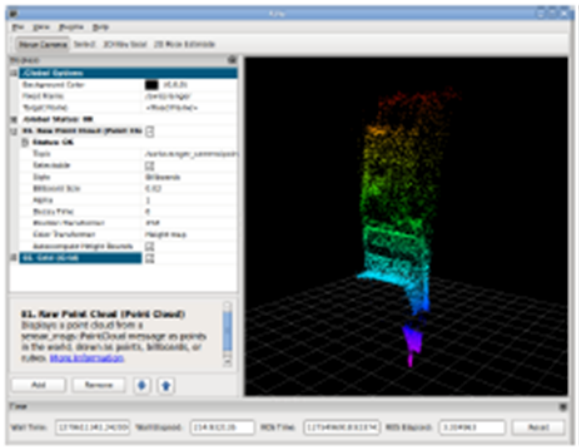


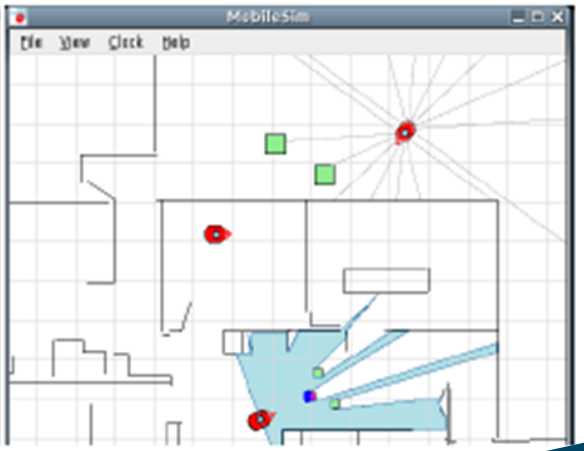


CoSys-Lab
Constrained Systems Lab
University of Antwerp

Localization Benchmarking

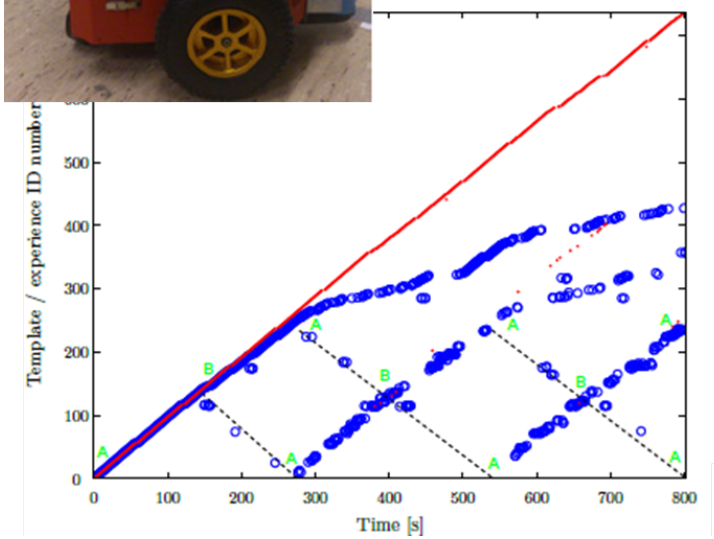


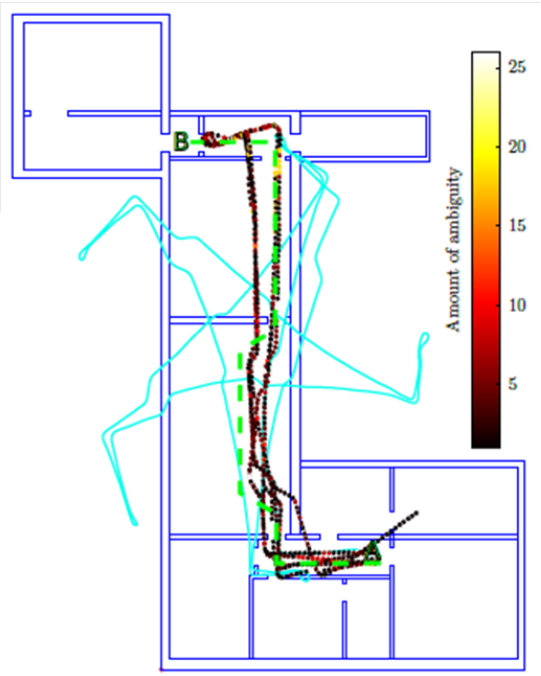




CoSys-Lab
Constrained Systems Lab
University of Antwerp

RF-based RatIsam





CoSys-Lab
Constrained Systems Lab
University of Antwerp

Questions?

maarten.weyn@uantwerpen.be