

# 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





## Research:

Maarten Weyn

- ▶ 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



## What I'm not going to do...

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



# Low-Power, Long-Range, Precise Localization

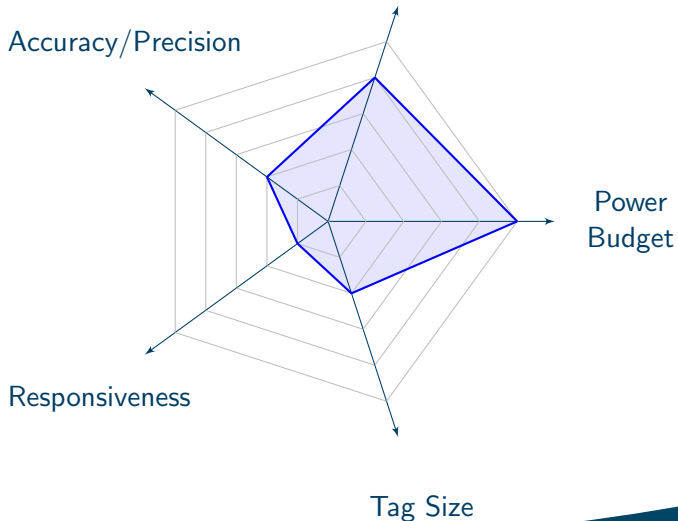




Range



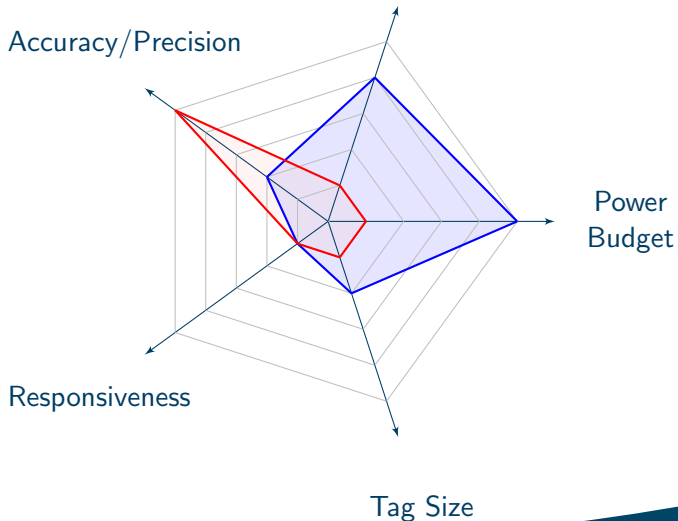
**CoSys-Lab**  
Constrained Systems Lab  
University of Antwerp



Range



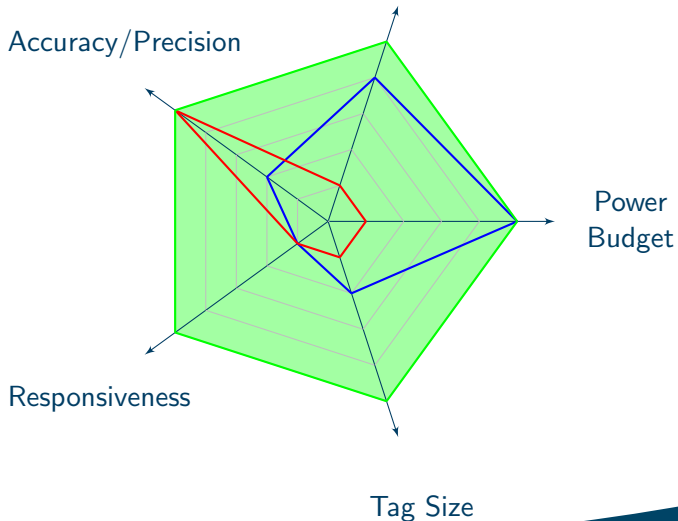
**CoSys-Lab**  
Constrained Systems Lab  
University of Antwerp



Range



**CoSys-Lab**  
Constrained Systems Lab  
University of Antwerp





## Power Budget

Low Power?:

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



## Power Budget

Low Power?:

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

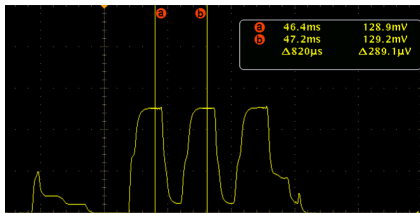
Application Driven:

- ▶ 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)  $\rightarrow 62\mu\text{Ah}/\text{day}$





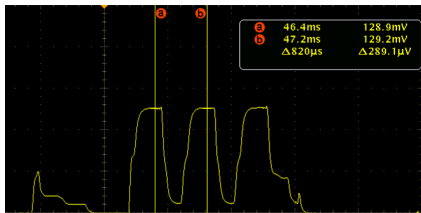
## Power Consumption: e.g. BLE



- ▶  $3 \times 12.8 \text{ mA} \times 660 \mu s$  (0 dBm)
- ▶  $0.00704 \mu\text{Ah} / \text{beacon}$



## Power Consumption: e.g. BLE



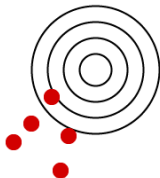
- ▶  $3 \times 12.8 \text{ mA} \times 660 \mu s$  (0 dBm)
- ▶  $0.00704 \mu\text{Ah} / \text{beacon}$
- ▶ iBeacon: 10 msg/s
- ▶  $\rightarrow 253.44 \mu\text{Ah}$

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



## Accuracy vs Precision

Not Precise or Accurate



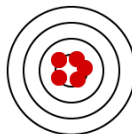
Precise, but not Accurate



Accurate, but not Precise



Precise and Accurate







# Accuracy vs Precision



Source: Versus Technology, Inc.



# Range





# Range

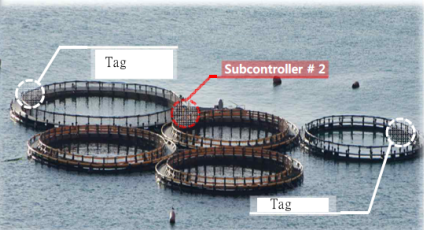




# Range



Source: Pusan National University





# Techniques

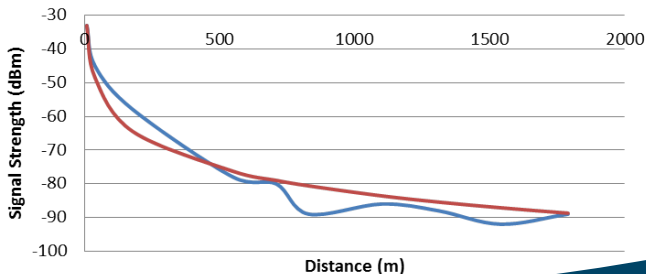
- ▶ Signal Strength:
  - ▶ Attenuation
  - ▶ Pattern Matching (Fingerprinting)
  - ▶ Presence / Proximity
- ▶ Time (Ranging):
  - ▶ Time of Flight - Time Difference of Arrival
  - ▶ Round Trip Time
- ▶ Direction Finding / Angle of Arrival



## Signal Strength

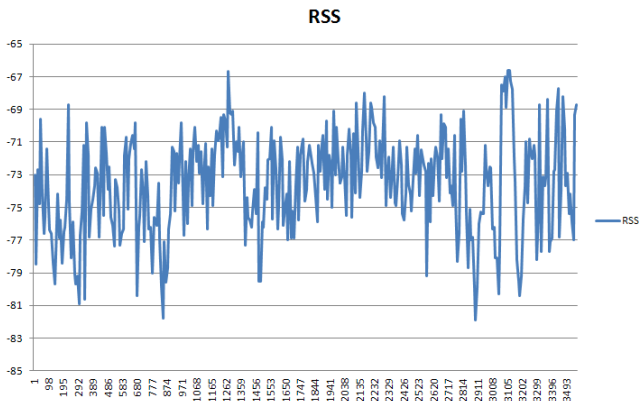
$$RSS_d = P_{rdBm} = 10 \log P_r(d_0) - 10n_p \log \frac{d}{d_0} + X$$

### RSS Measurements at 433 Mhz



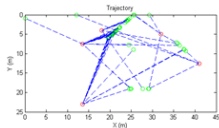
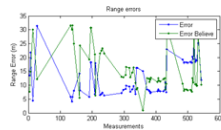
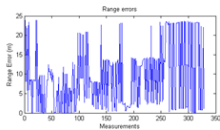
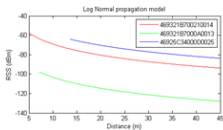
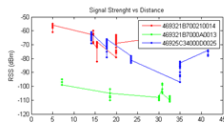
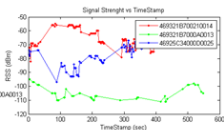
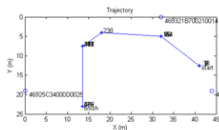


# Attenuation





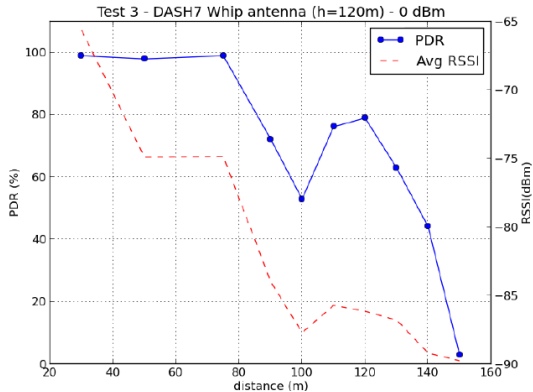
# Attenuation



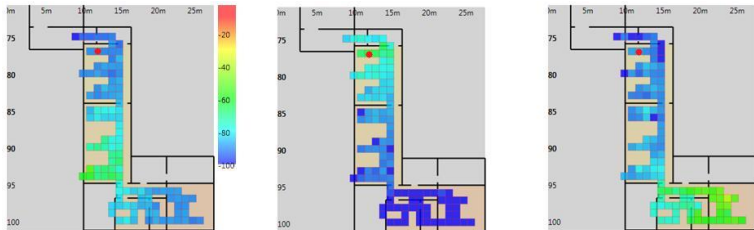




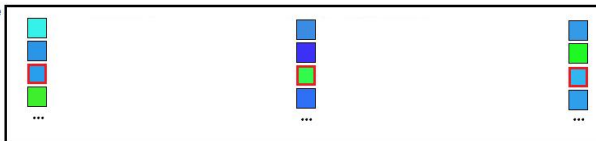
# Attenuation



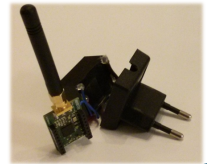
# Pattern Matching



**Database**

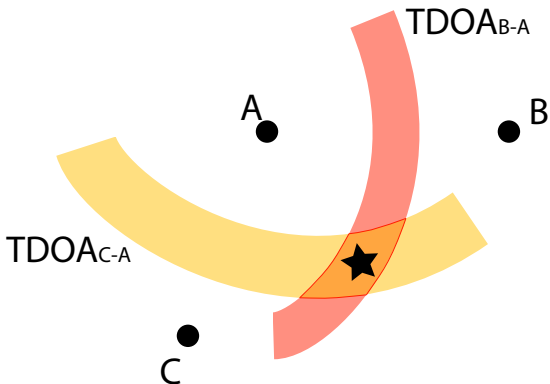


# Presence Detection



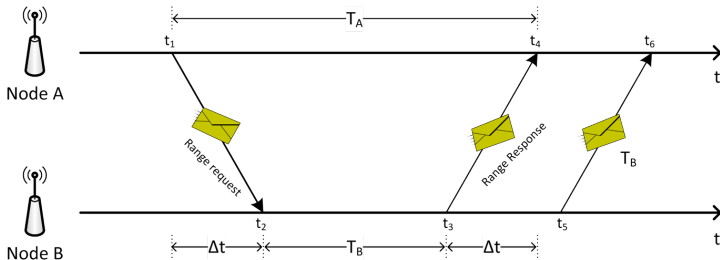


## Time of Flight: Time Difference of Arrival





# Time of Flight: Round Trip Time



# Time of Flight: Cramer Rao Bound

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

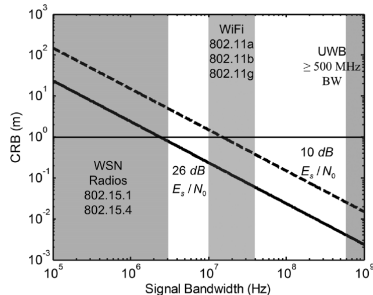
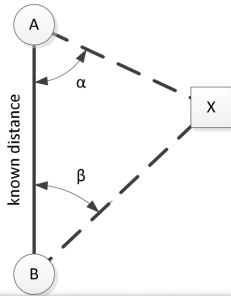


Fig. 2. CRB as a function of bandwidth.

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

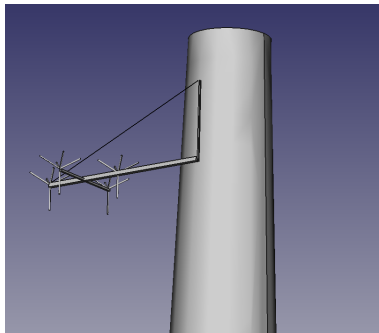
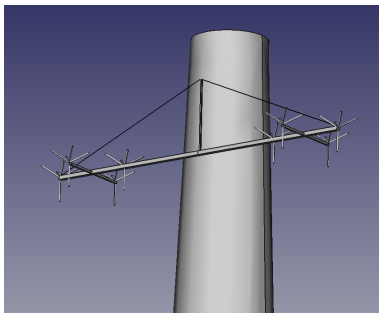


## Direction Finding





## Direction Finding

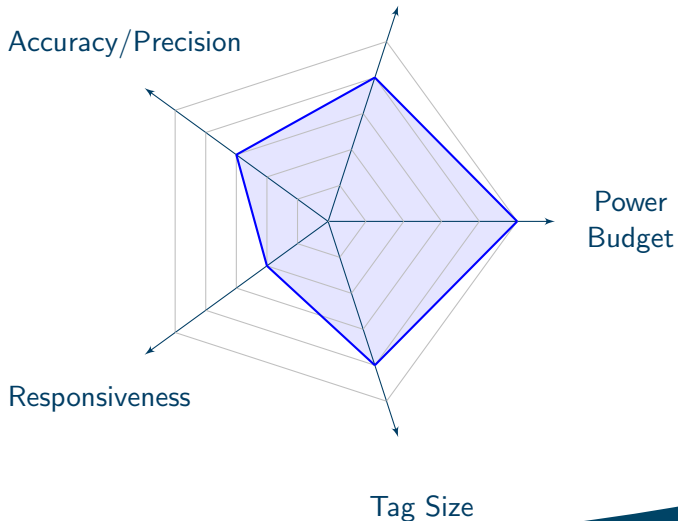




Range



**CoSys-Lab**  
Constrained Systems Lab  
University of Antwerp





**CoSys-Lab**  
Constrained Systems Lab  
University of Antwerp





## DASH7

Active RFID Standard for 433 MHz.

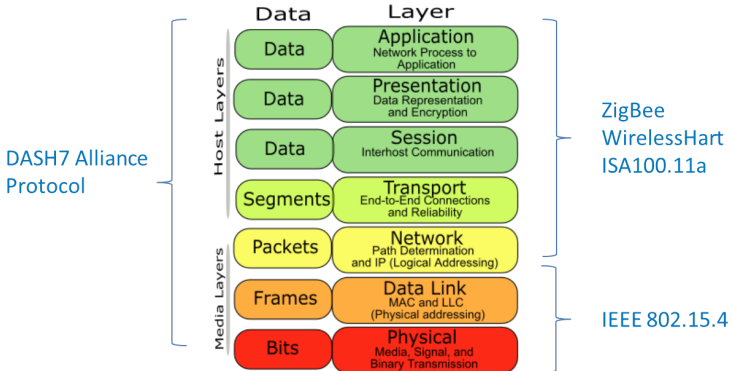
- ▶ Build on top of asynchronous WSN MAC.
- ▶ High level functionality optimized for RFID.
- ▶ Defines full functional RFID tag.
- ▶ Can be extended to non RFID applications.

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

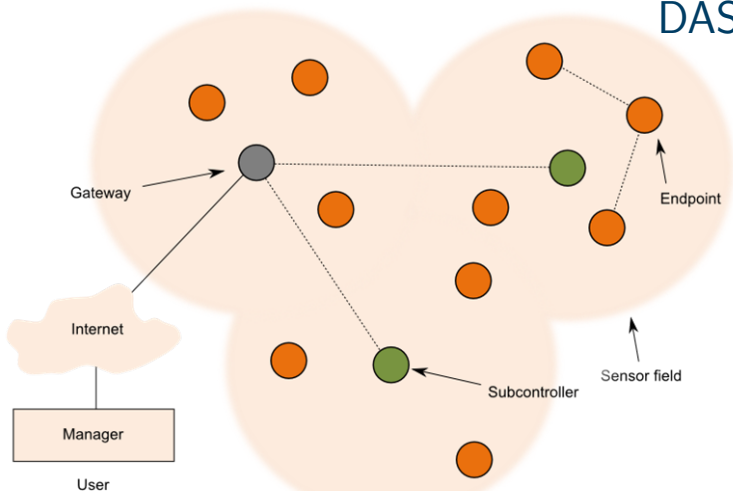


# DASH7



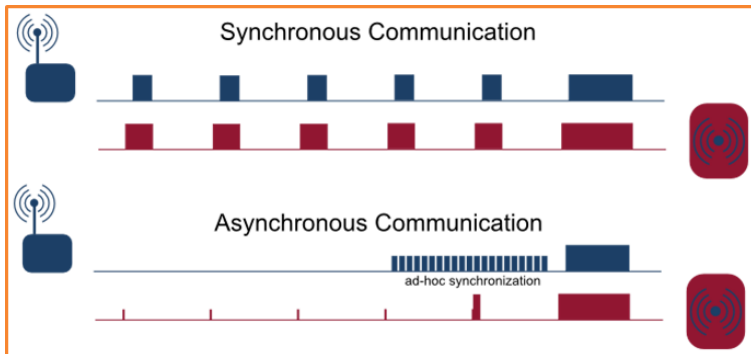


## DASH7





# DASH7





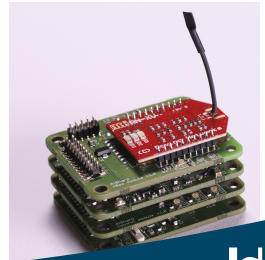
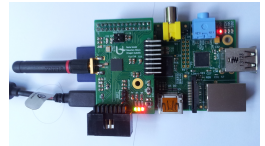
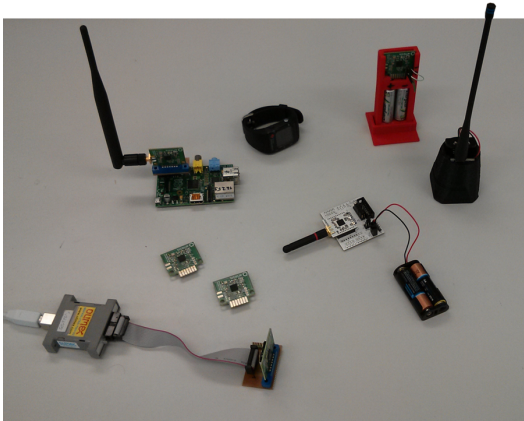
# Open Source Stack for DASH7

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

The screenshot shows the homepage of the OSS-7 project. At the top, there is a navigation bar with links for OSS-7, Community, Hardware, Quickstart, Resources, News, and Archives. The main content area is titled "Welcome" and "About DASH7". It describes the DASH7 Alliance Protocol as an open standard originating from ISO/IEC 18000-7, designed for active RFID in the 433 MHz band. Below this is the DASH7 Alliance logo. The "About OSS-7" section explains that OSS-7 is an open source implementation of the DASH7 Alliance protocol, aimed at providing a reference implementation for fast development and prototyping. The "About CoSys-Lab" section states that CoSys-Lab is a research group at the University of Antwerp, interested in DASH7 as part of their research on low-power localization systems and sensor networks. On the right side, there is a sidebar with "Tags" (General), "Git-Hub Repos" (dash7-4ip-open-source-stack, OSS-7: Open Source Stack for Dash7 Alliance Protocol), "@CoSys-Lab on GitHub", "Links" (RSS feed, API documentation, CoSys-Lab, DASH7 Alliance).



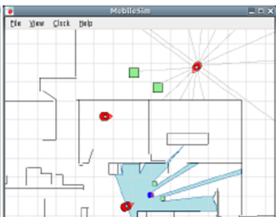
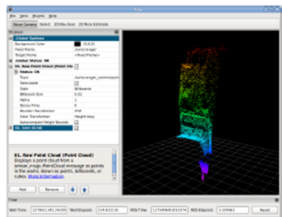
# Open Source Stack for DASH7





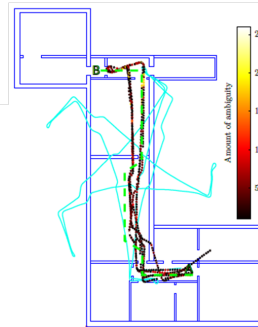
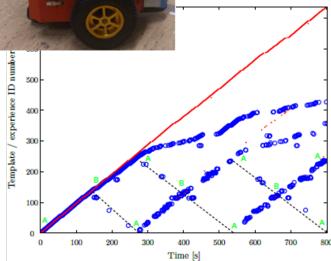


# Localization Benchmarking





## RF-based Ratsam





## Questions?

**1**

**Birth**

Form question in  
your mind



**2**

**Evaluate**

Is it a reasonable  
question?



**3**

**Remember**

Until you can  
ask the question



**4**

**Courage**

To ask the  
question out loud



[maarten.weyn@uantwerpen.be](mailto:maarten.weyn@uantwerpen.be)