Ambient Intelligence

Smart Patient Monitoring

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II-Ambient Intelligence
2016-2017

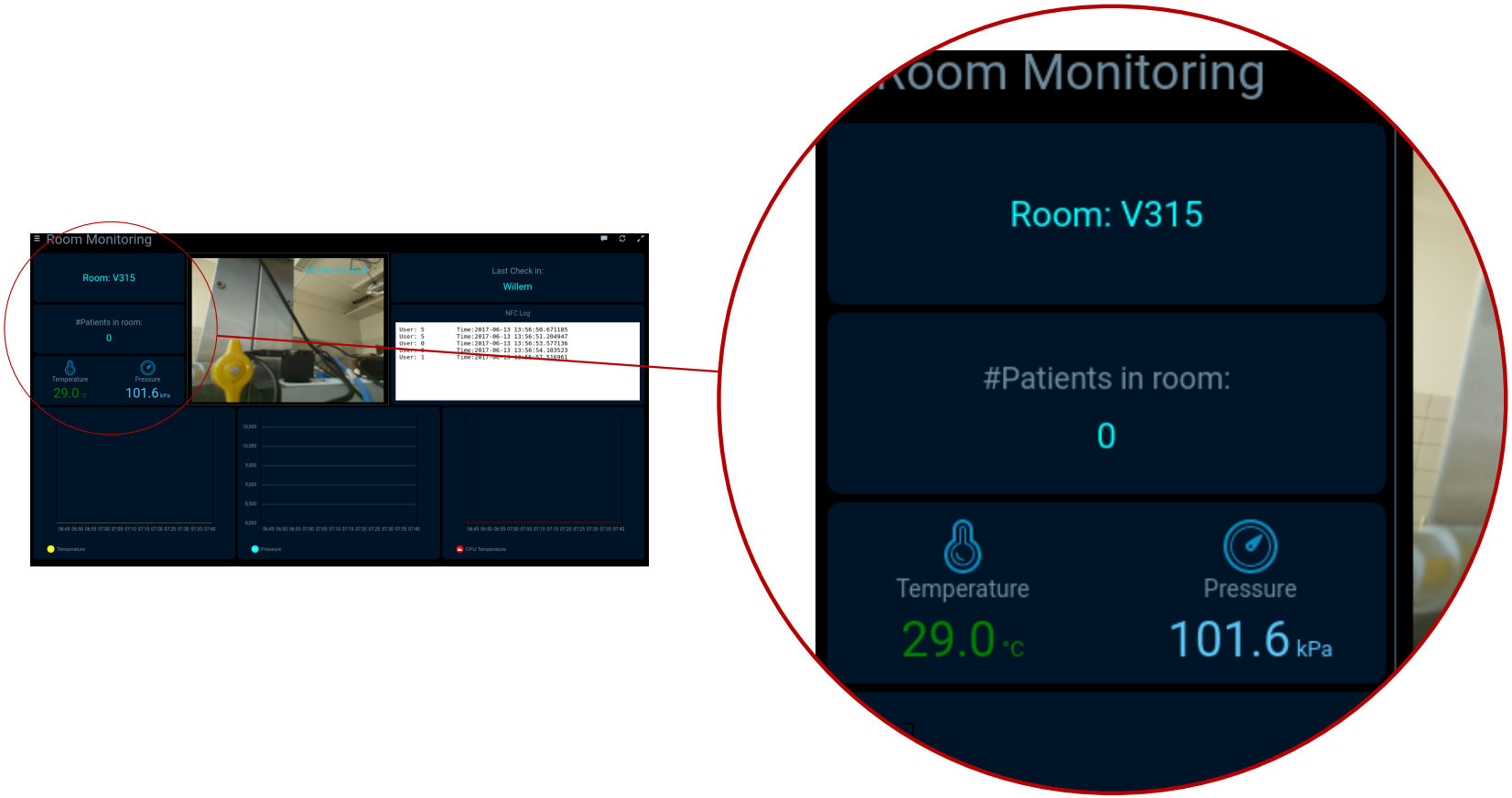
The Product

Smart Patient Monitoring

- Room monitoring
  - CO^2 levels
  - Humidity
  - Temperature
  - Camera
- Patient identification
- Localization
  - DASH7
  - Magnetometer
- Fall detection

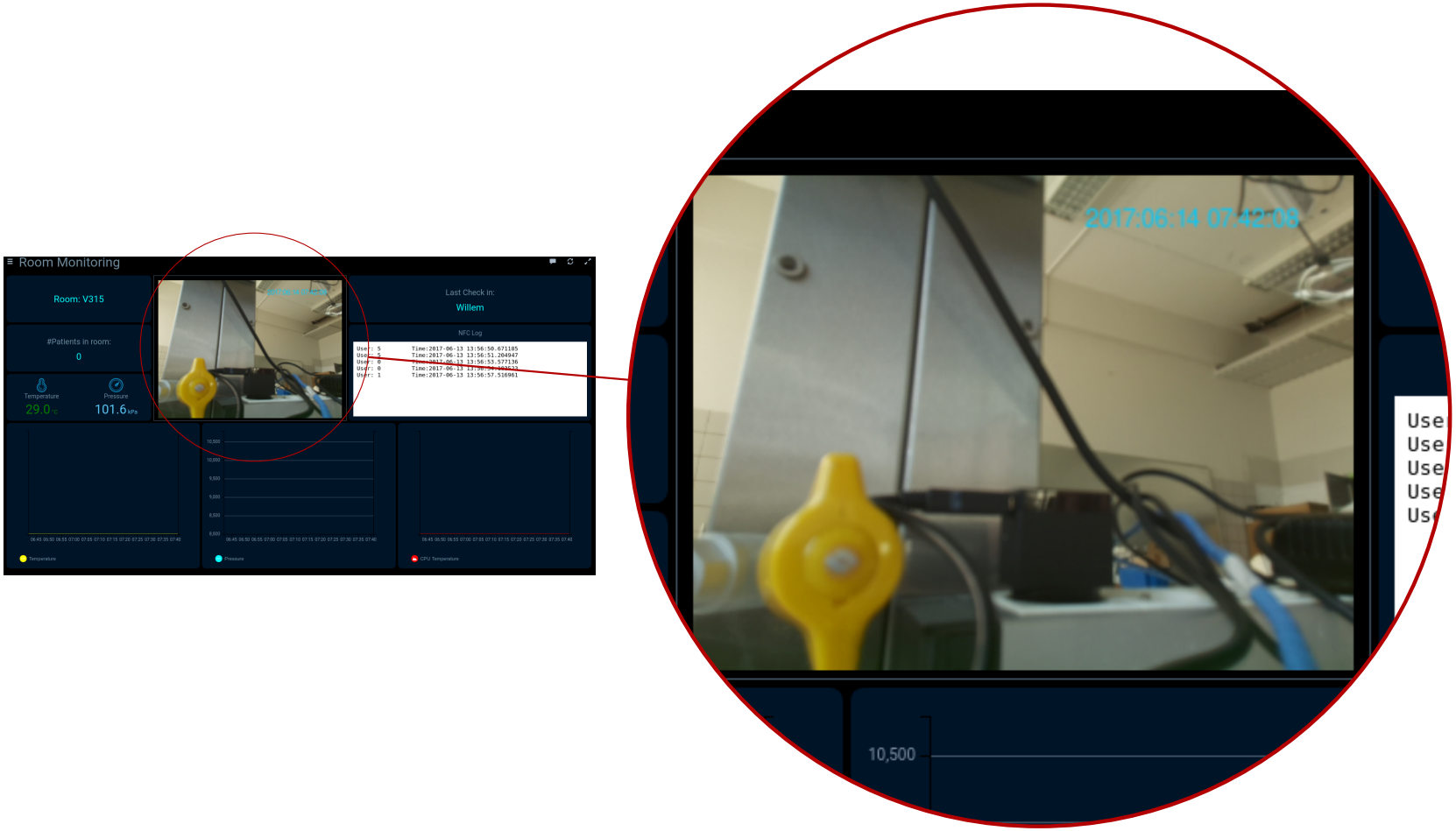
OpenHAB

Room Monitoring - Localization



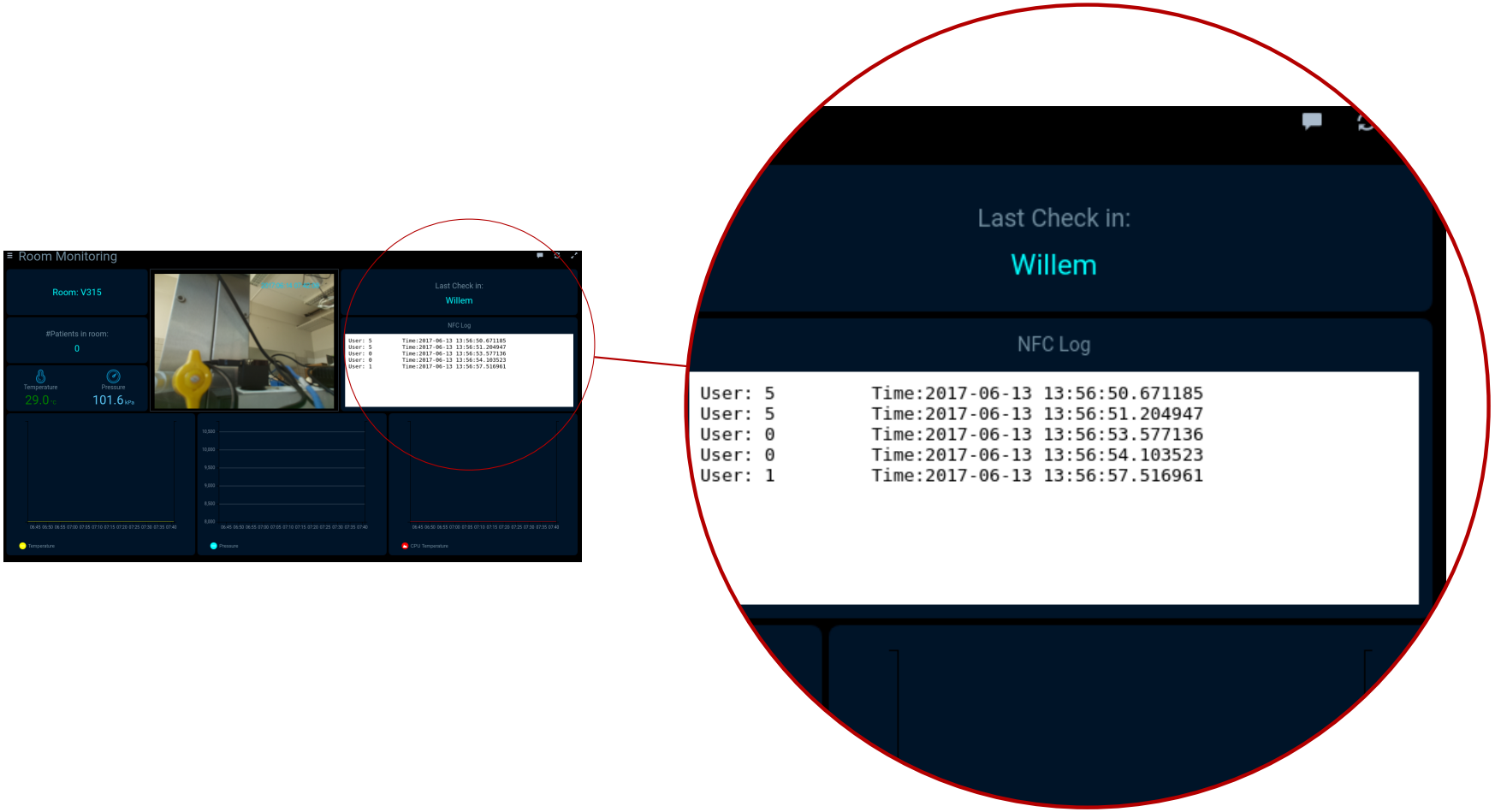
OpenHAB

Room Monitoring - Camera feed



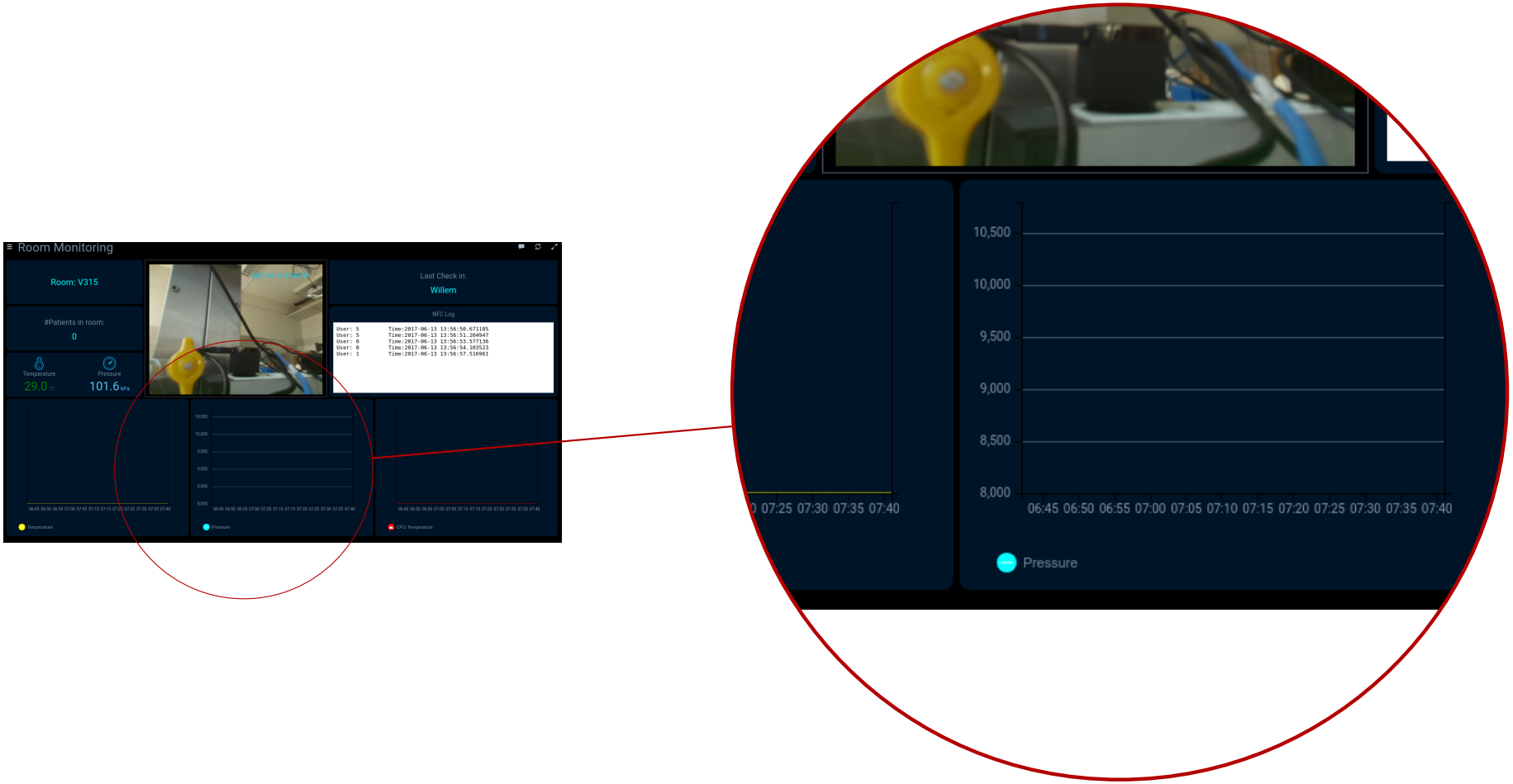
OpenHAB

NFC identification



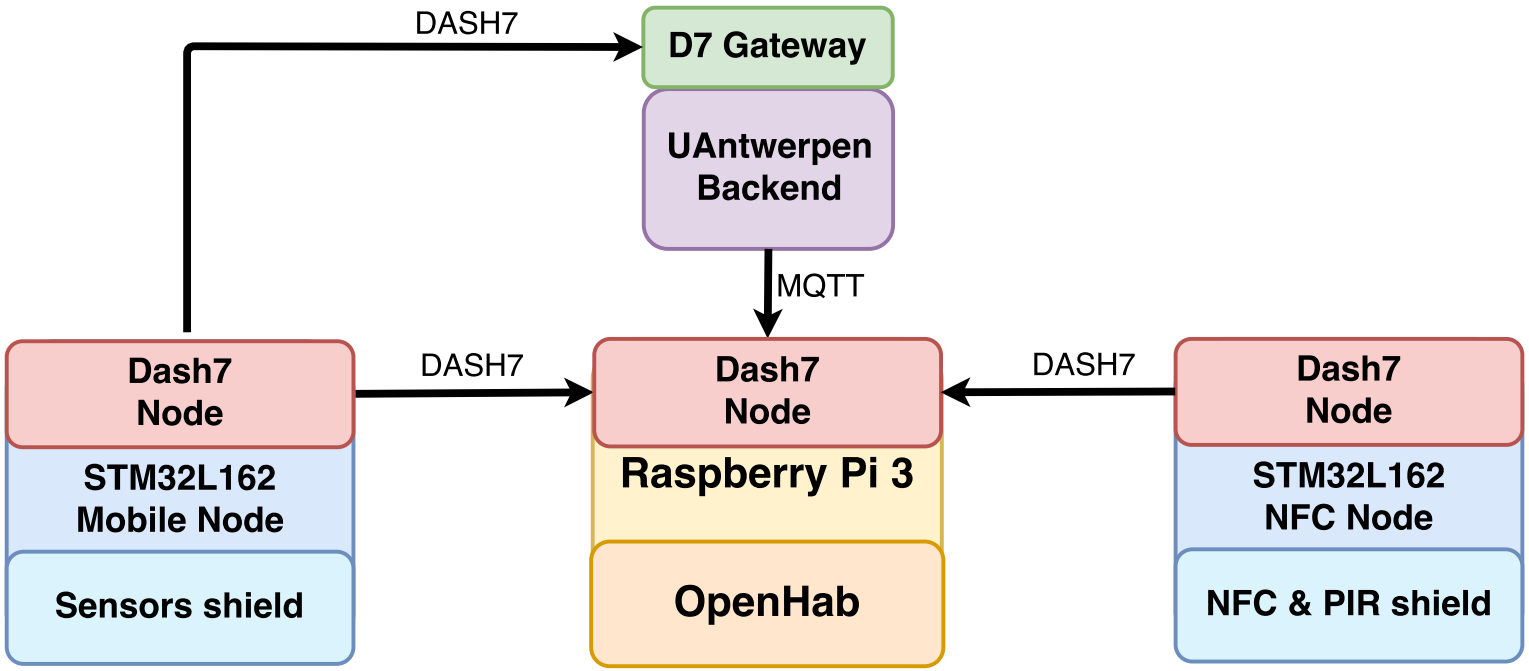
OpenHAB

Sensor data graphs



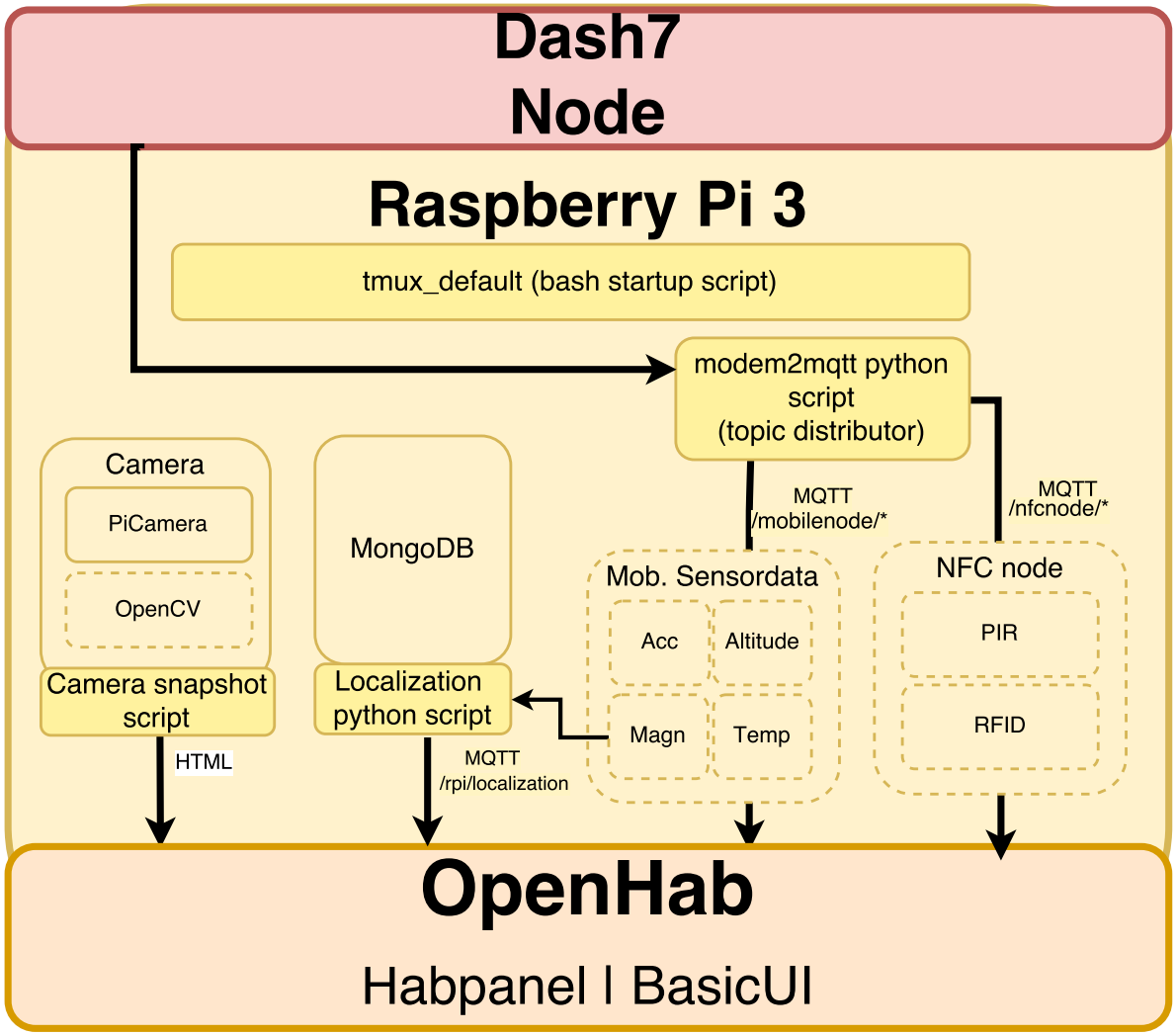
Architecture

Global Architecture



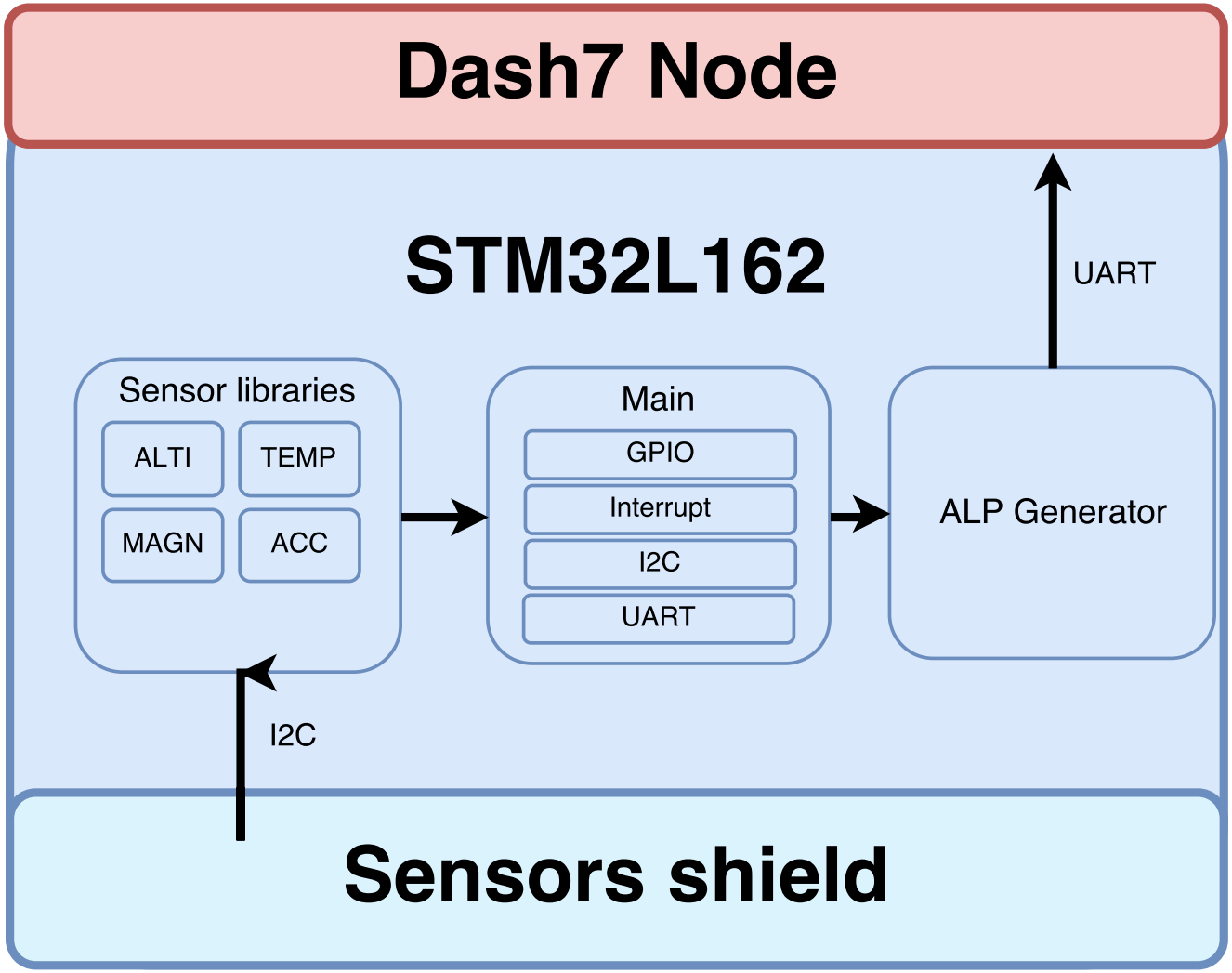
Architecture

RPi Architecture



Architecture

Mobile node architecture

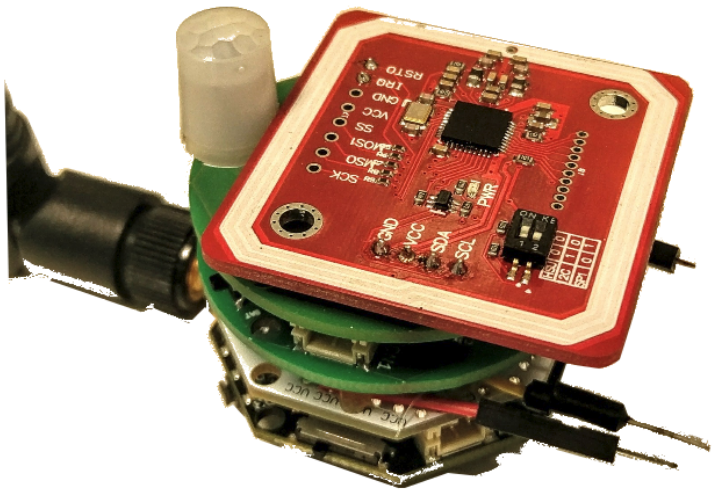


Hardware

Design & Redesign

NFC node with PIR sensor
Top to bottom :

- NFC shield
- Sensor board with PIR
- Microcontroller board with low power STM32 (L162RD)
- Adapter breakout board
- Mini Octa DASH7 gateway

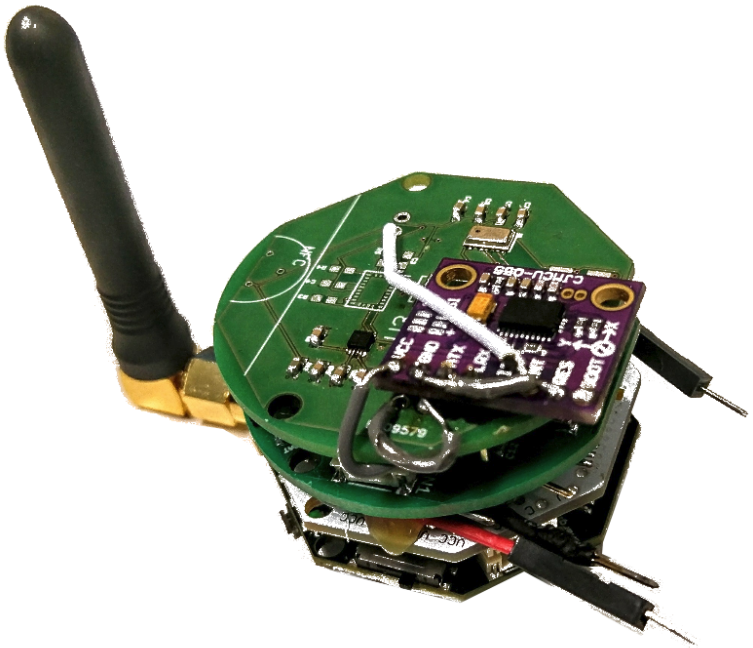


Hardware

Design & Redesign

Mobile node
Top to bottom :

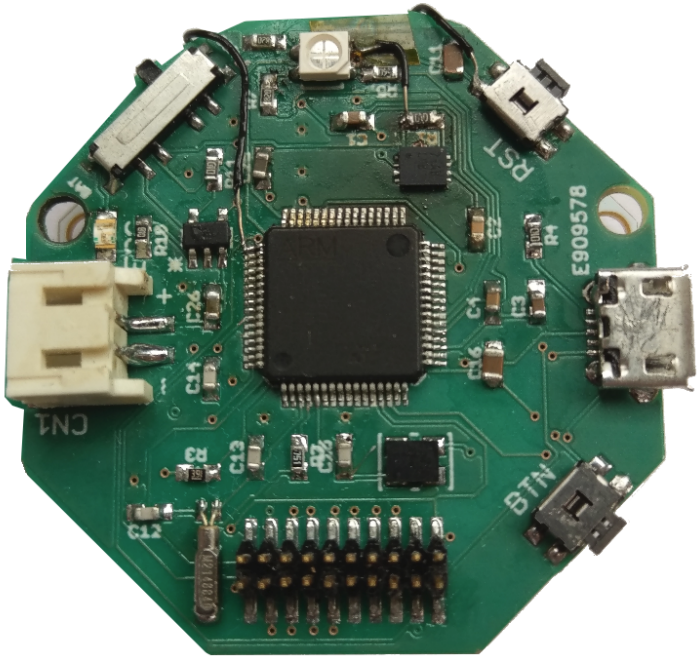
- BNO055 breakout board
- Sensor board
- Microcontroller board
- Adapter breakout board
- Mini Octa DASH7 gateway

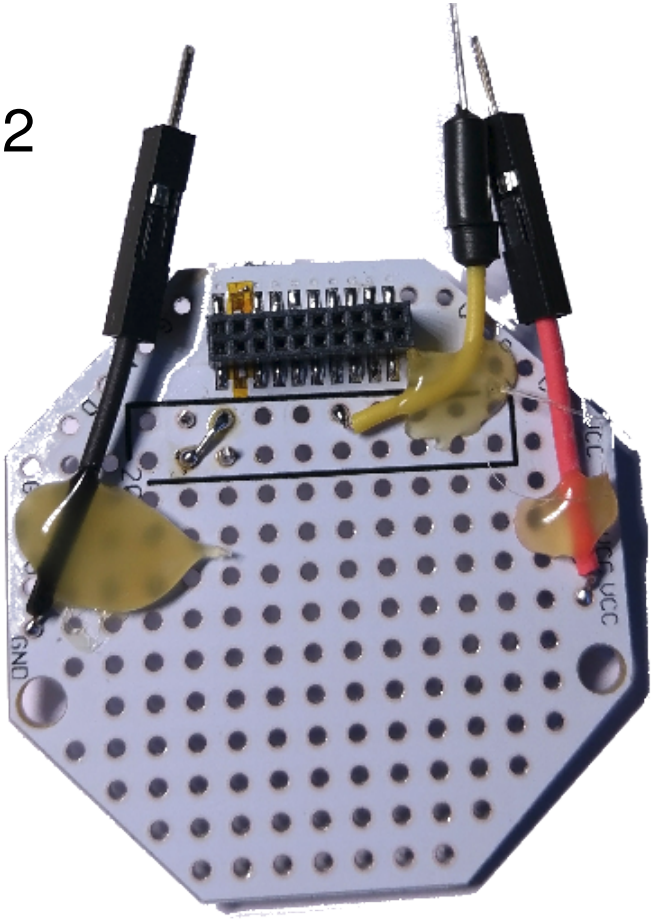


Hardware

Design & Redesign

Microcontroller board with STM32L162





Power Consciousness

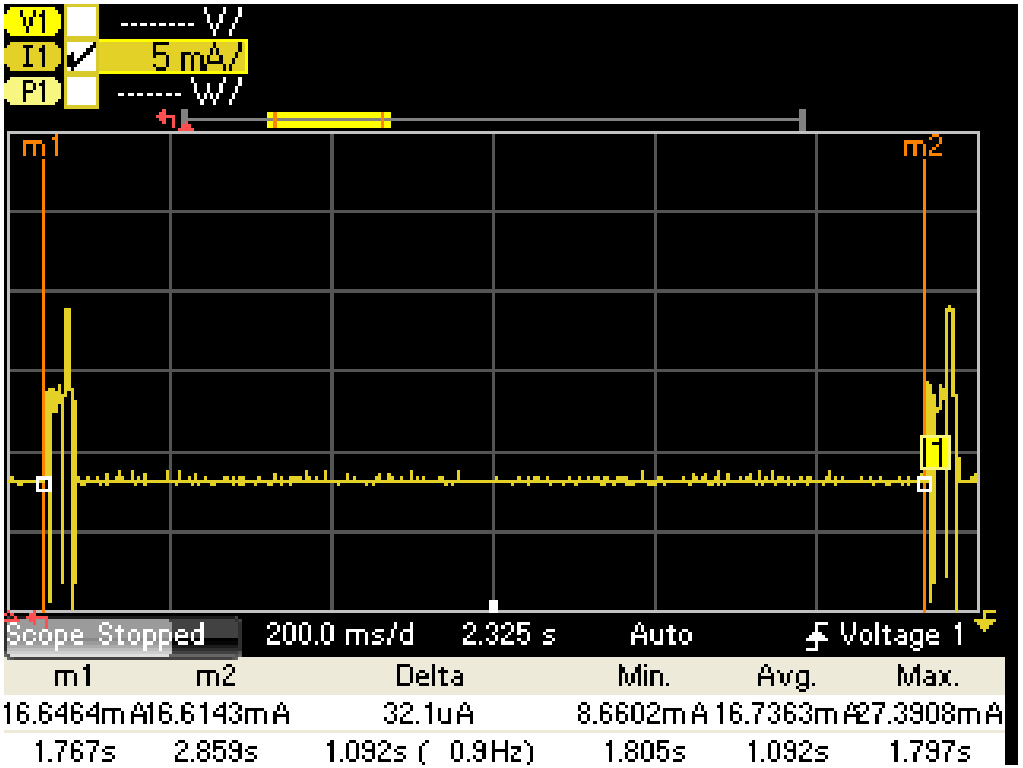
Low Power NFC node

NFC node PIR interrupt → Read RFID → D7ALP → WFI stop mode

Power Consciousness

Current Measurements

- Average current drawn: 16.73mA
- 1Ah LiPo battery would only last approx. 62 hours

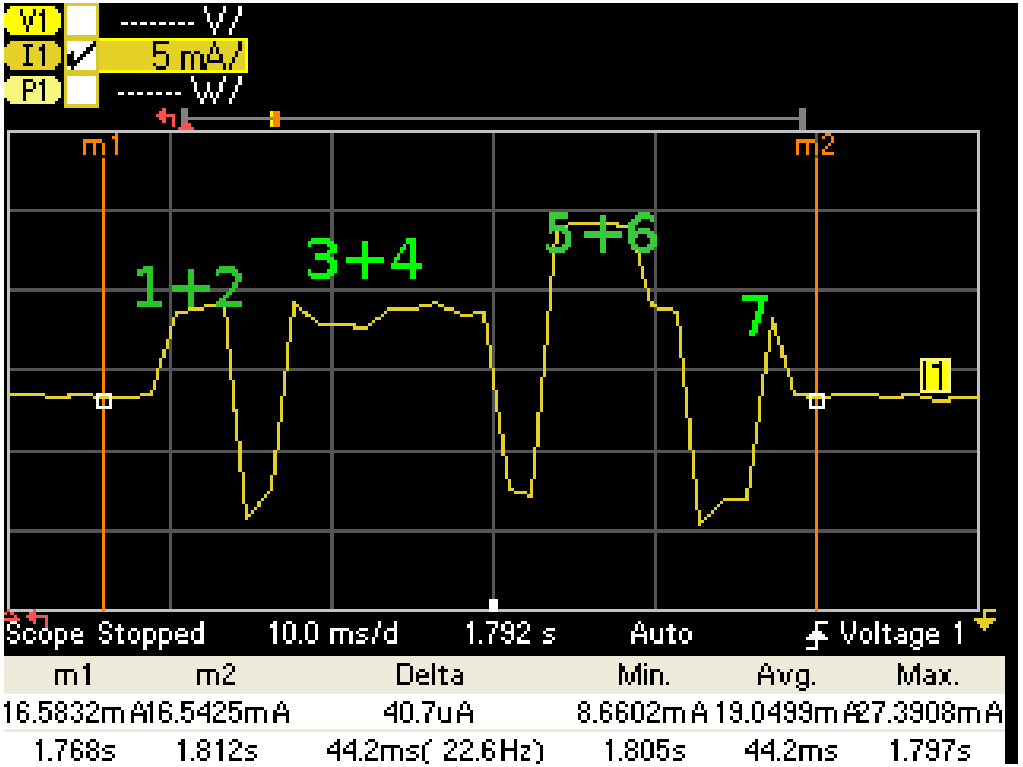


Expected minimal current drawn to be less than 1mA, especially in stop mode. SysCLK interrupt may be the issue.

Power Consciousness

Low Power NFC node?

1. initialize
2. flash leds 1/4 s
3. check firmware
4. Read RFID for 1 s
5. D7ALP Tx
6. Enter stop mode
   - suspend sysClk tick
   - WFI



Power Consciousness

Low Power Mobile node

Attempted using basic timer update event to wake from sleep mode.

$$UpdateEvent = \frac{Timer_{clock}}{(Prescaler + 1) \cdot (Period + 1)}$$

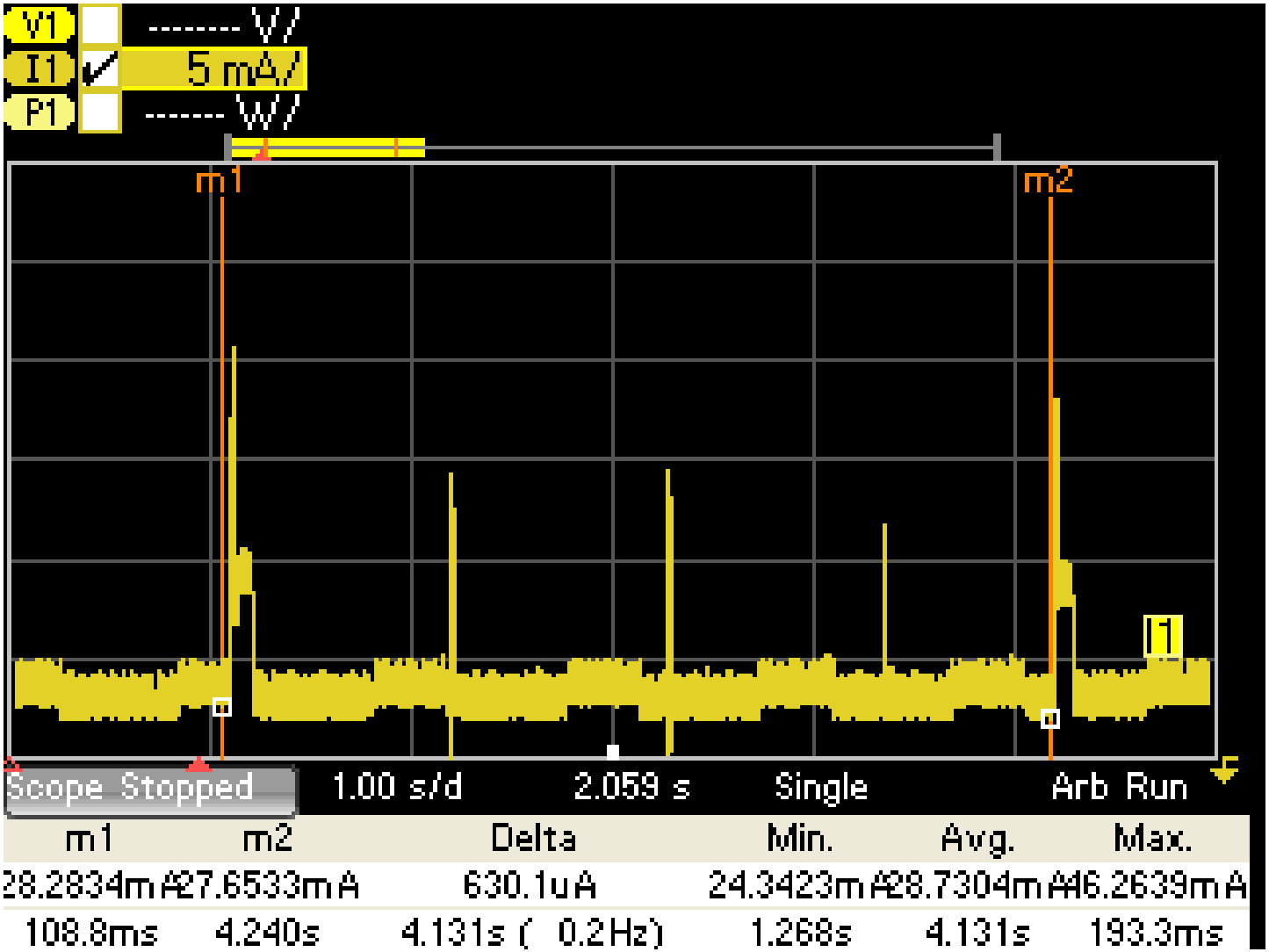
Which gives

$$\frac{2,000,000Hz}{(1999 + 1) \cdot (9999 + 1)} = .1Hz$$

Timer update event every 10 seconds.
Likely better: RTC wakeup alarm for periodic & independent tx.

Power Consciousness

Current Measurements



Power Consciousness

Currrent Measurements

- sysClk frequency: 2MHz
- Average current drawn: 28.73mA
- 1Ah LiPo battery would only last approx. 35 hours

Sleep mode for sysClk at 16MHz for this microcontroller would draw 1mA on avg.
STOP mode with RTC wakeup would even be better.

DASH7

ALP Message

- Serial frame
- ALP command
  - TAG
  - FORWARD
  - RETURN FILE DATA

Serial Frame	Tag	Forward	Return File Data
[41 54 24 44 c0 00 0e]	[34 af]	[32 d7 01 00 10 01]	[20 01 00 02 00 01]

DASH7

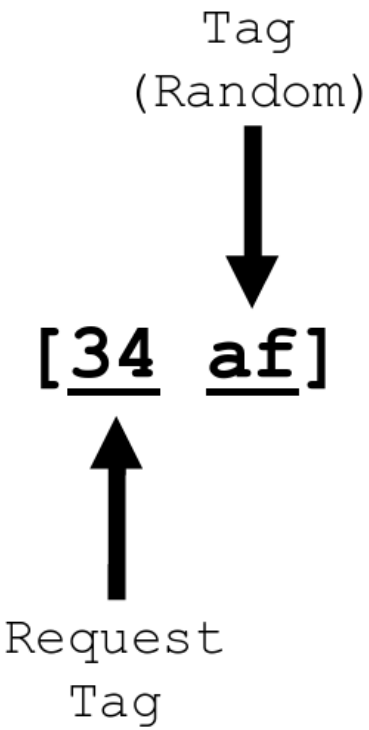
Serial Frame

- Constant values
- Length
- ALP does not contain length

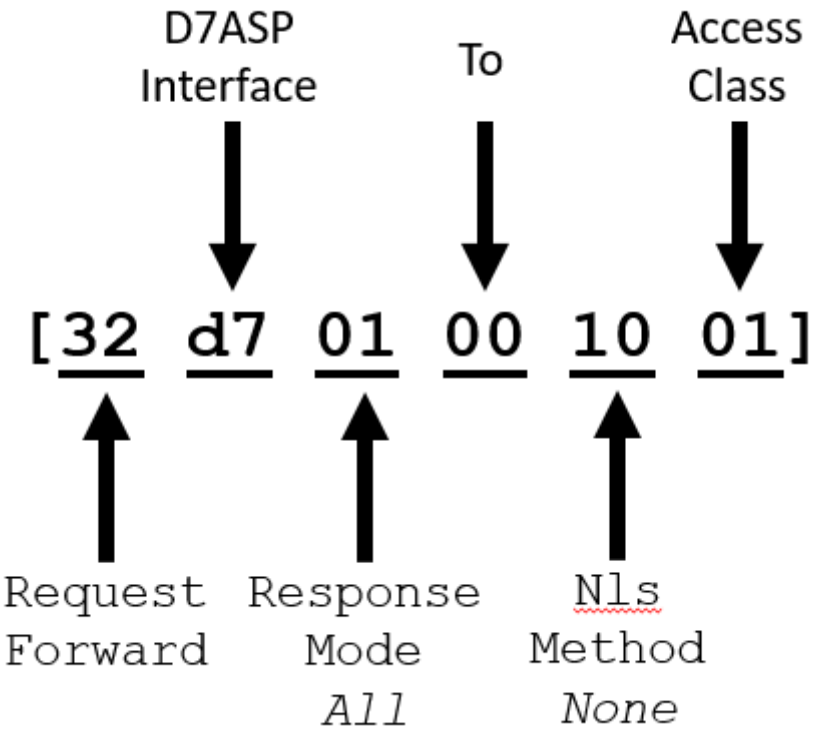
[41 54 24 44 c0 00 0e]

Length

- Request Tag
- Tag Value

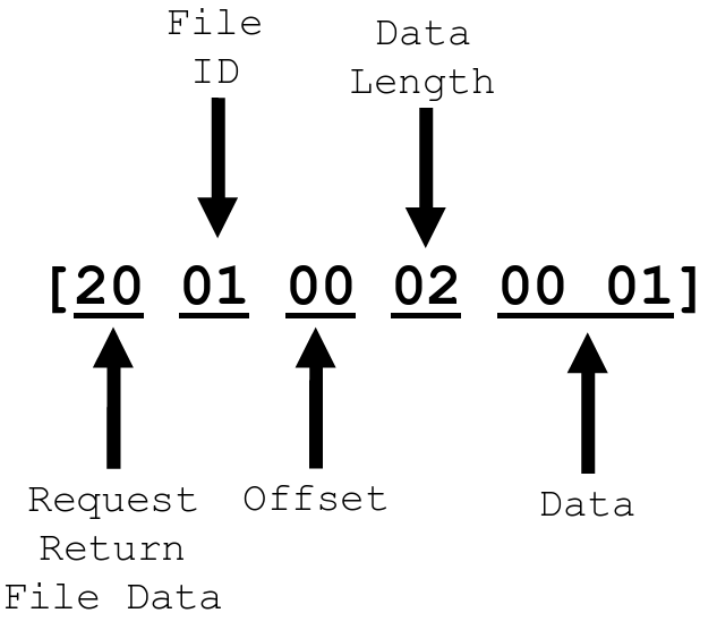


- Forward Operation
- D7ASP



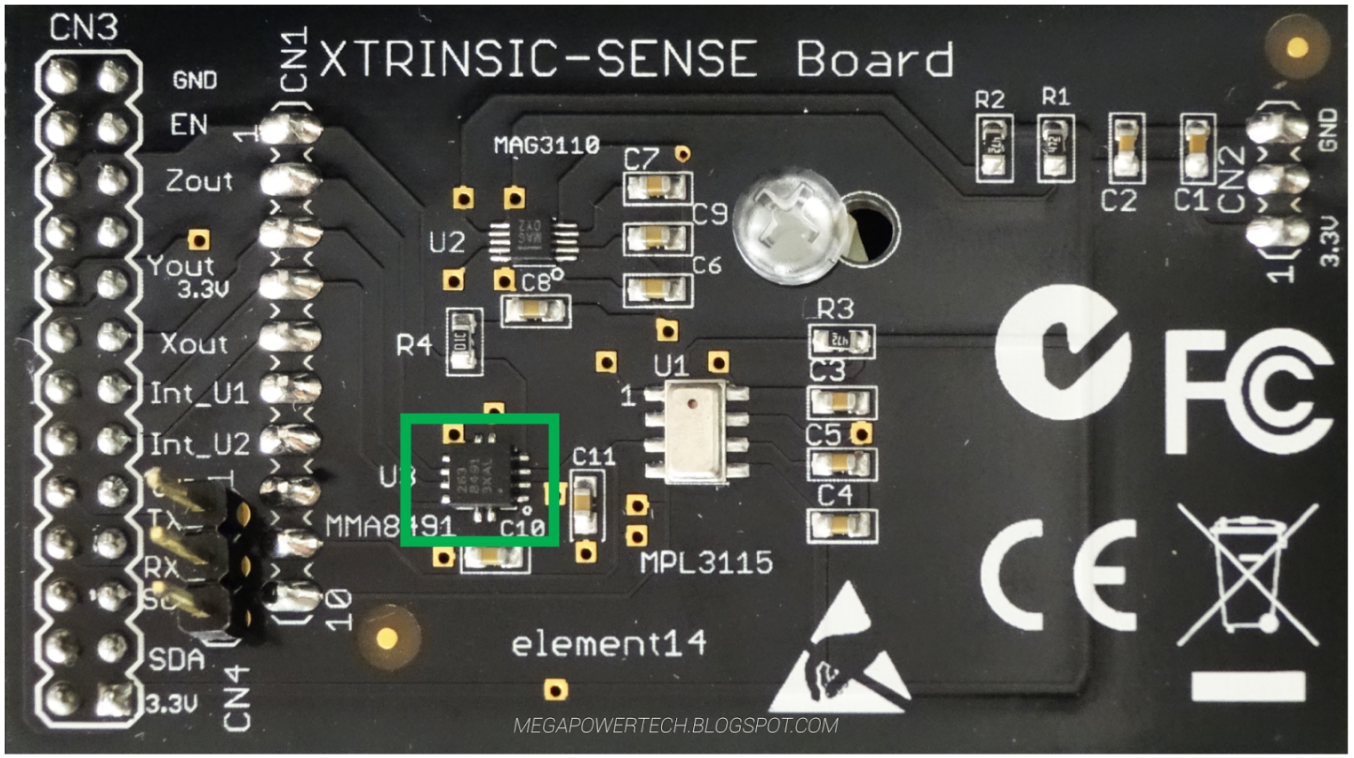
ALP Command - RETURN FILE DATA

- Request Return File Data
- File ID
- Data Length
- Data



Sensor derived features

Fall detection



Sensor derived features

Fall detection

- Accelerometer IC: MMA8491Q
- Every x seconds a sample is sent to the RPI
- RPI uses a fall detection algorithm
  - Threshold based: compare new sample to previous one

Sensor derived features

Height measurements

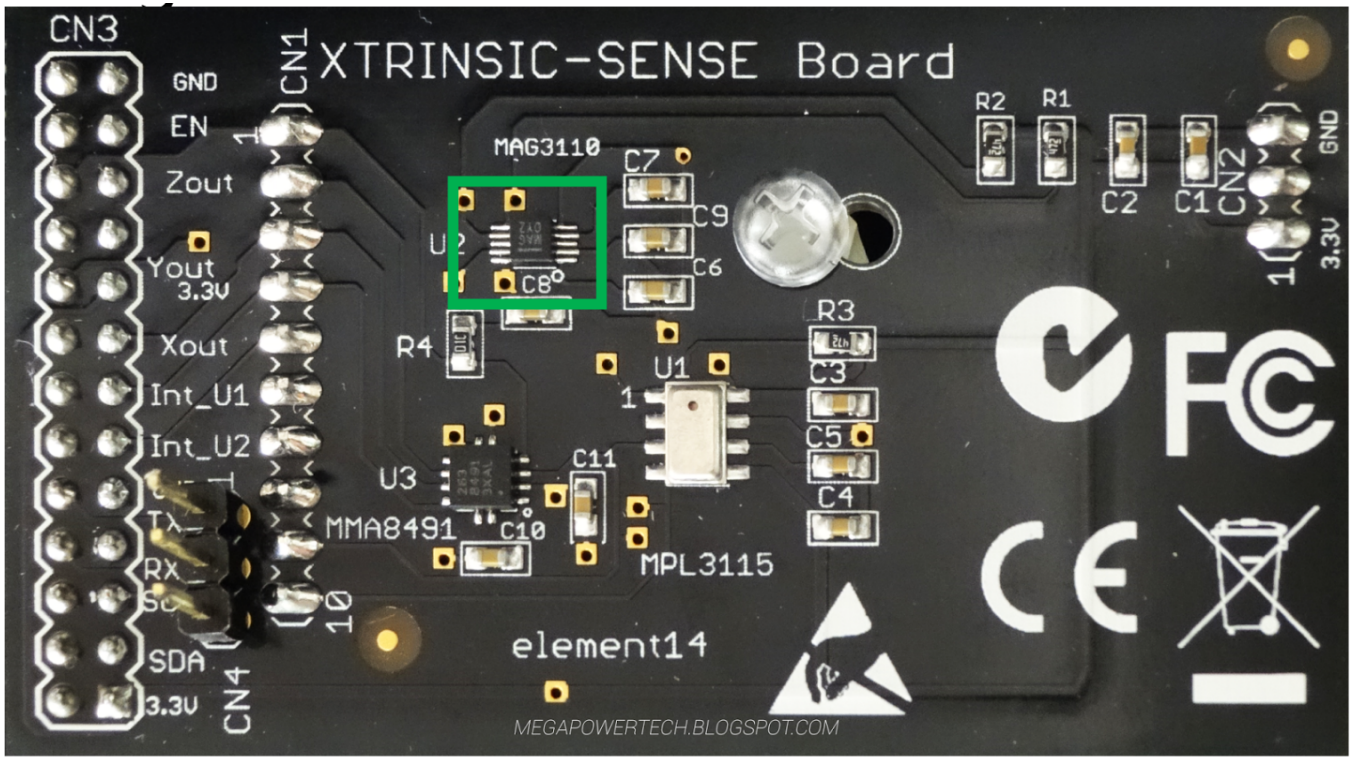
Sensor derived features

Height measurements

- Sensor: MPL3115A2
- Pressure / altimeter
- Two independent interrupt signals
- Programmable for autonomous data acquisition (1s $\rightarrow$ 9h)

Sensor derived features

Magnetometer



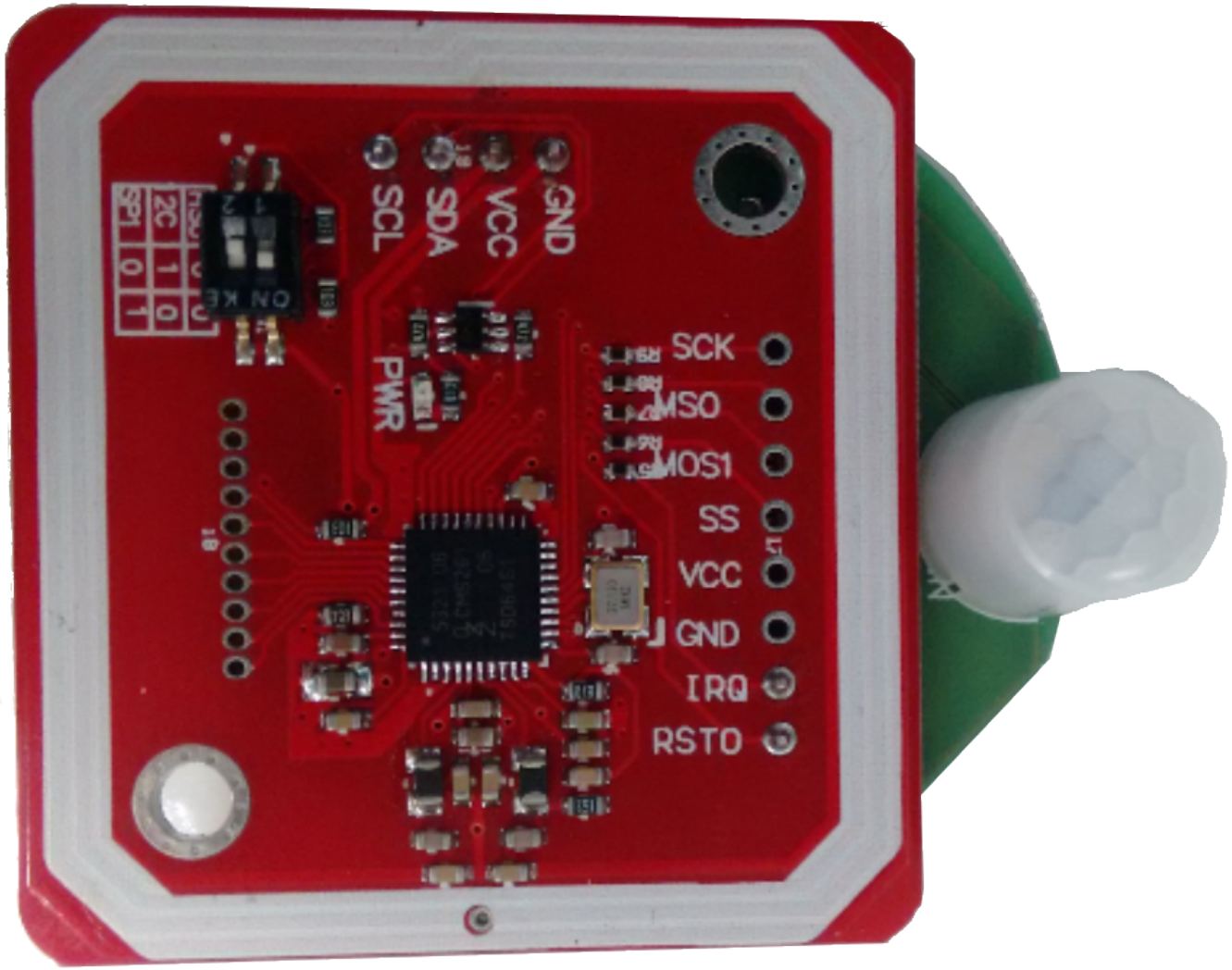
Sensor derived features

Magnetometer

- Mag3110 IC low power magnetometer
- Measures magnetic field strength in x-y-z directions
- The sensor data can be used to increase the accuracy of the dash7 localization
- IC can be in standby until it receives a trigger to take a measurement
- Can trigger an interrupt when new data is ready

Sensor derived features

Presence detection - PIR



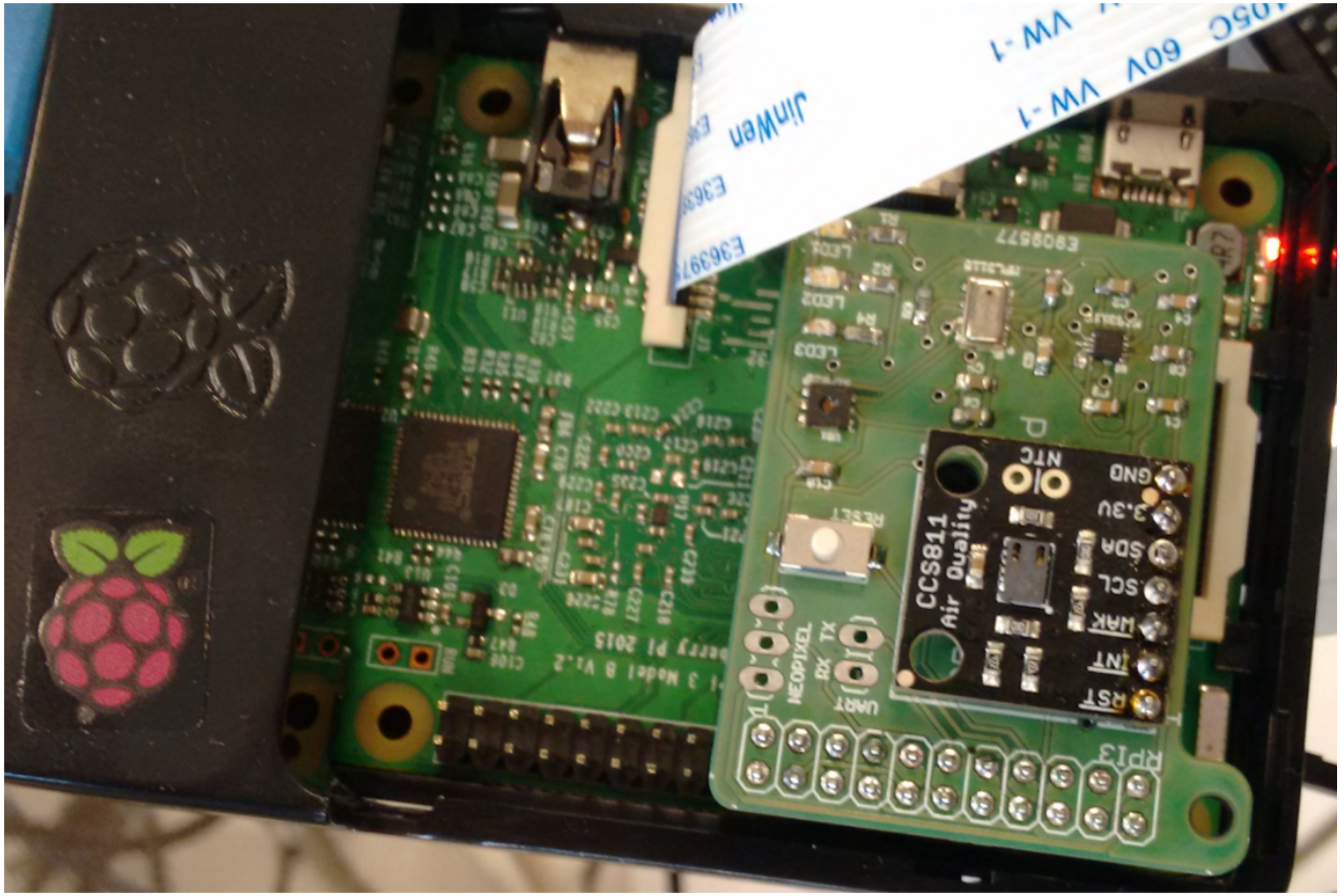
Sensor derived features

Presence detection - PIR

- Passive Infrared sensor
- Detects human presence by measuring infrared light radiating from them

Sensor derived features

Room monitoring



Sensor derived features

Room monitoring

- Air quality
- Humidity
- Temperature $\rightarrow$ Sensor shield on the RPI

Sensor derived features

Room monitoring - Air Quality

Sensor derived features

Room monitoring - Air Quality

- Sensor: CCS811
- Detects wide range of Volatile Organic Compounds (VOCs)
- Can use interrupts
- 5 different modes of operation:
  - Mode 0: Idle
  - Mode 1: Constant power mode
  - Mode 2: Pulse heating mode
  - Mode 3: Low power pulse heating mode
  - Mode 4: Constant power mode (RAW data)

Sensor derived features

Room monitoring - Humidity

Sensor derived features

Room monitoring - Humidity

- Sensor: Si7021
- Polling for measurement
- Convert reading to Relative Humidity percentage:

$$\%RH = \frac{125 * RH_Code}{65536} - 6$$

Sensor derived features

Room monitoring - Temperature

Sensor derived features

Room monitoring - Temperature

- Sensor: Si7021
- Polling for measurement
- Convert the sensor output to degrees Celsius:

$$\text{Temperature } (^\circ\text{C}) = \frac{175.72 * \text{Temp_Code}}{65536} - 46.85$$

- Temperature reading is performed at the same time as a humidity reading.

Sensor derived features

I^2C

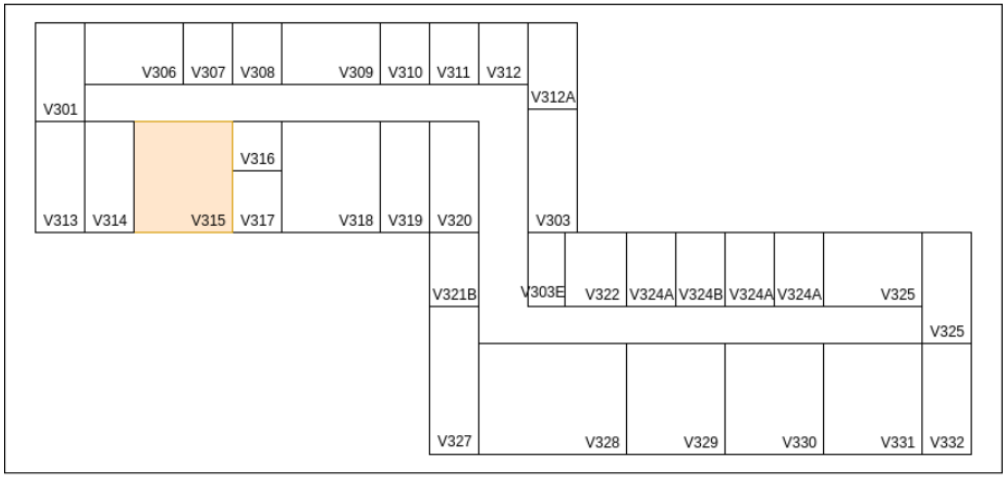
Sensor derived features

I^2C

- Multi-master multi-slave bus
- Two bidirectional open-drain lines
  - Serial Data Line (SDA)
  - Serial Clock Line (SCL)
- 7-bit addressing, LSB of the address byte is used for R/W
- Used by all sensors
- Each sensor has a unique address

Localization

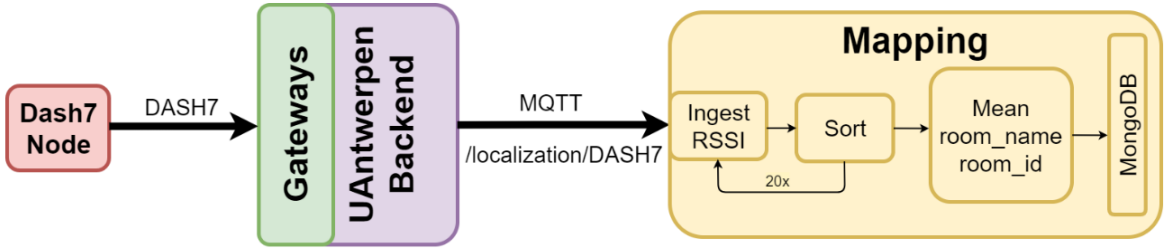
- Mapping
- Localization
- OpenHAB



Localization

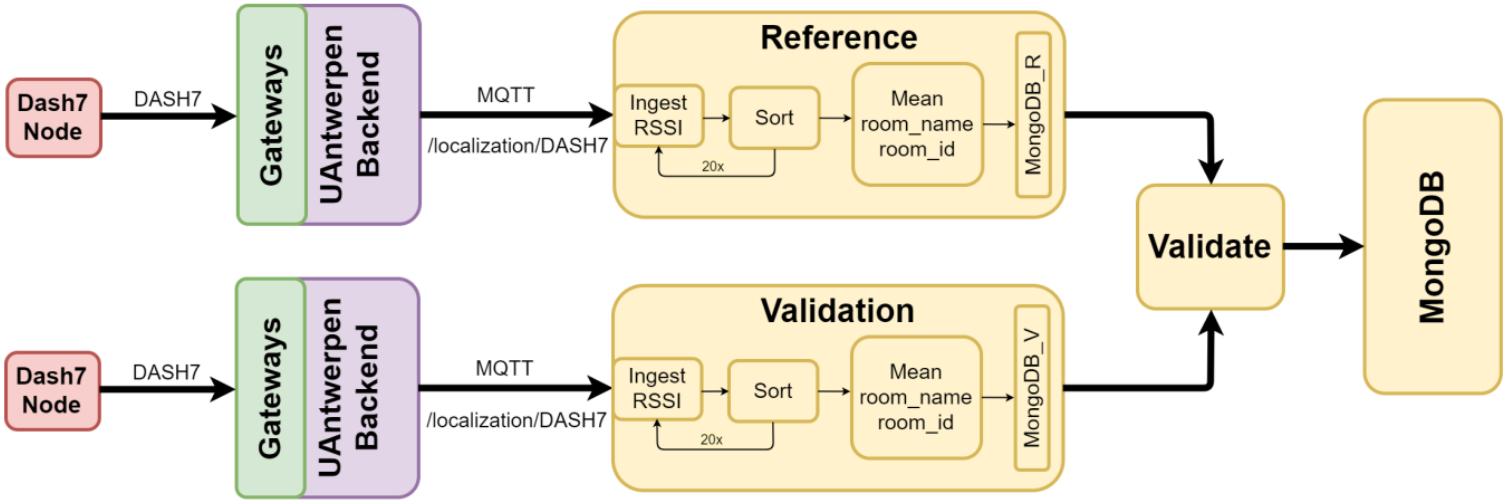
Mapping - ArchitectureV1

- RSSI1, RSSI2, RSSI3, ...
- room_name (prompted first launch)
- room_id (incremented)



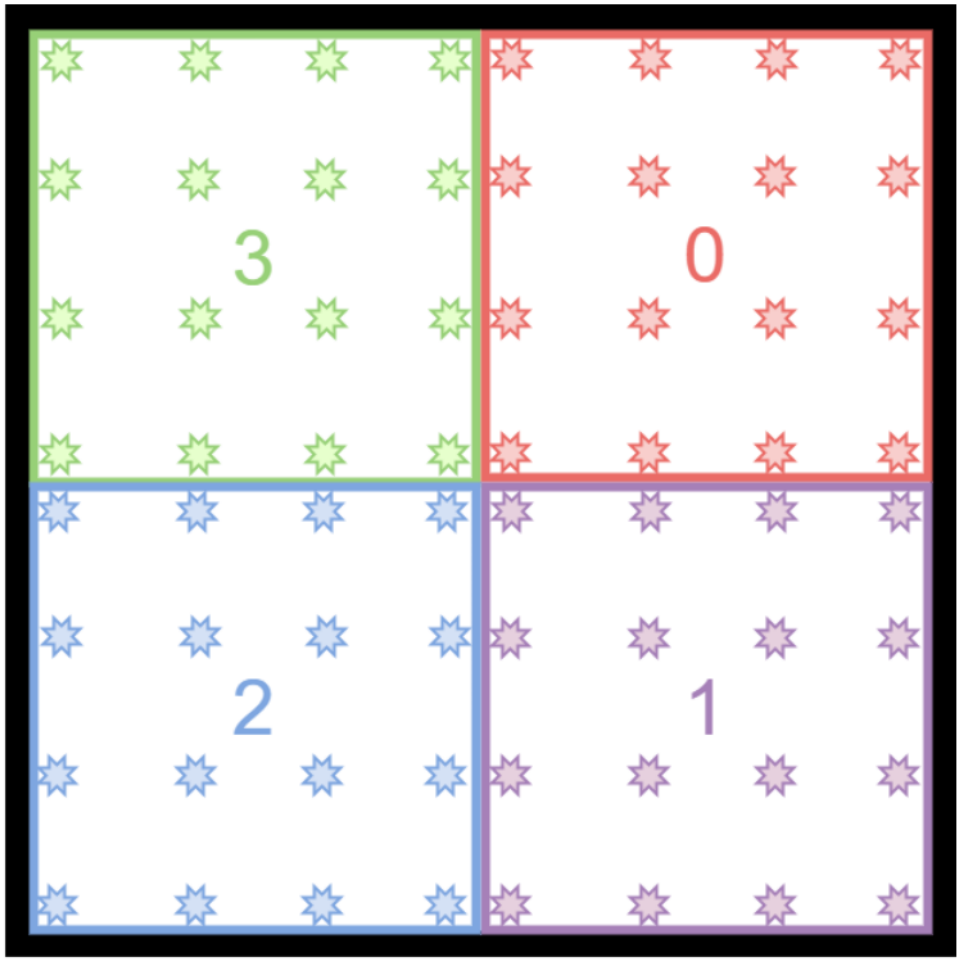
Localization

Validation - Architecture



Localization

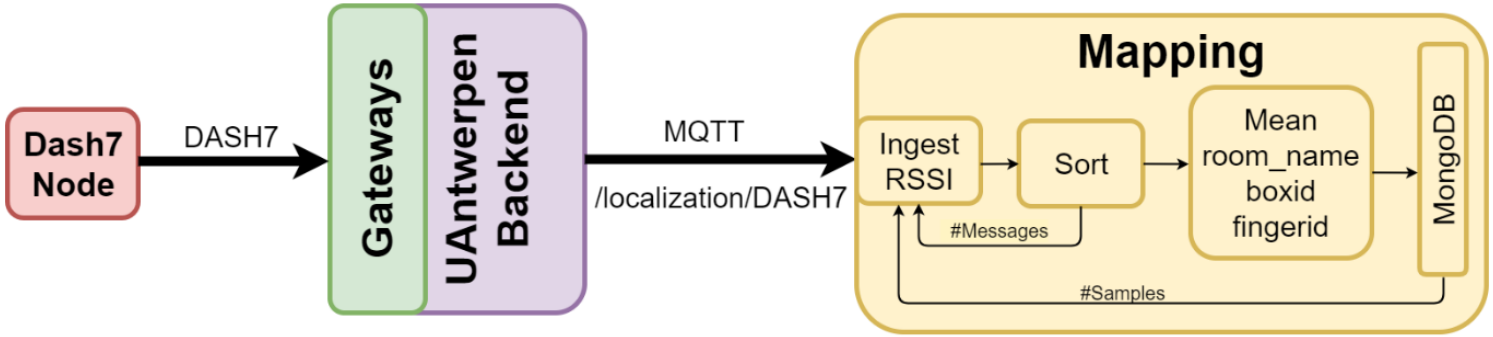
Mapping - LogicV2



Localization

Mapping - ArchitectureV2

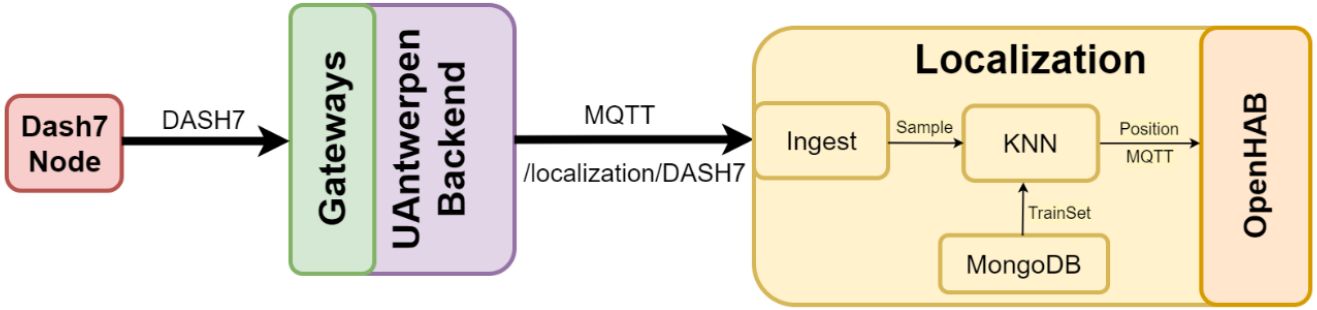
- RSSI1, RSSI2, RSSI3, ...
- room_name (prompted first launch)
- boxid (prompted first launch)
- Fingerid (incremented)



Localization

Localization - Architecture

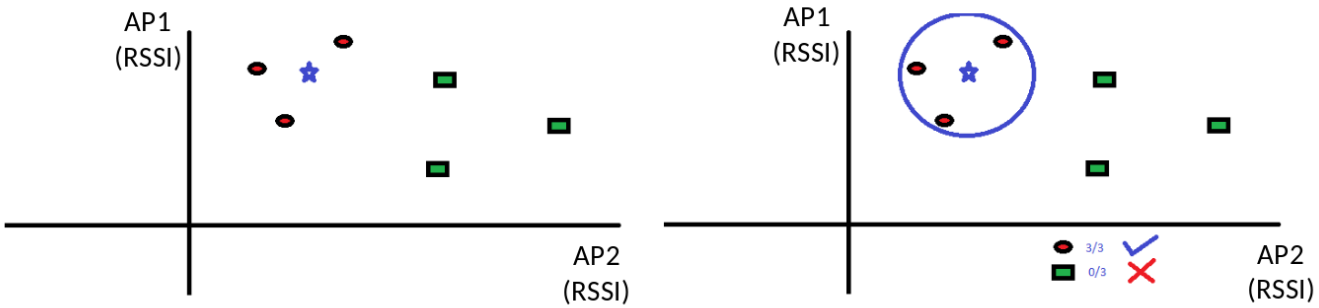
- Sample : [RSSI1, RSSI2, ...]
- Mapping Sample : [RSSI1, RSSI2, ..., room_name, room_id]



Localization

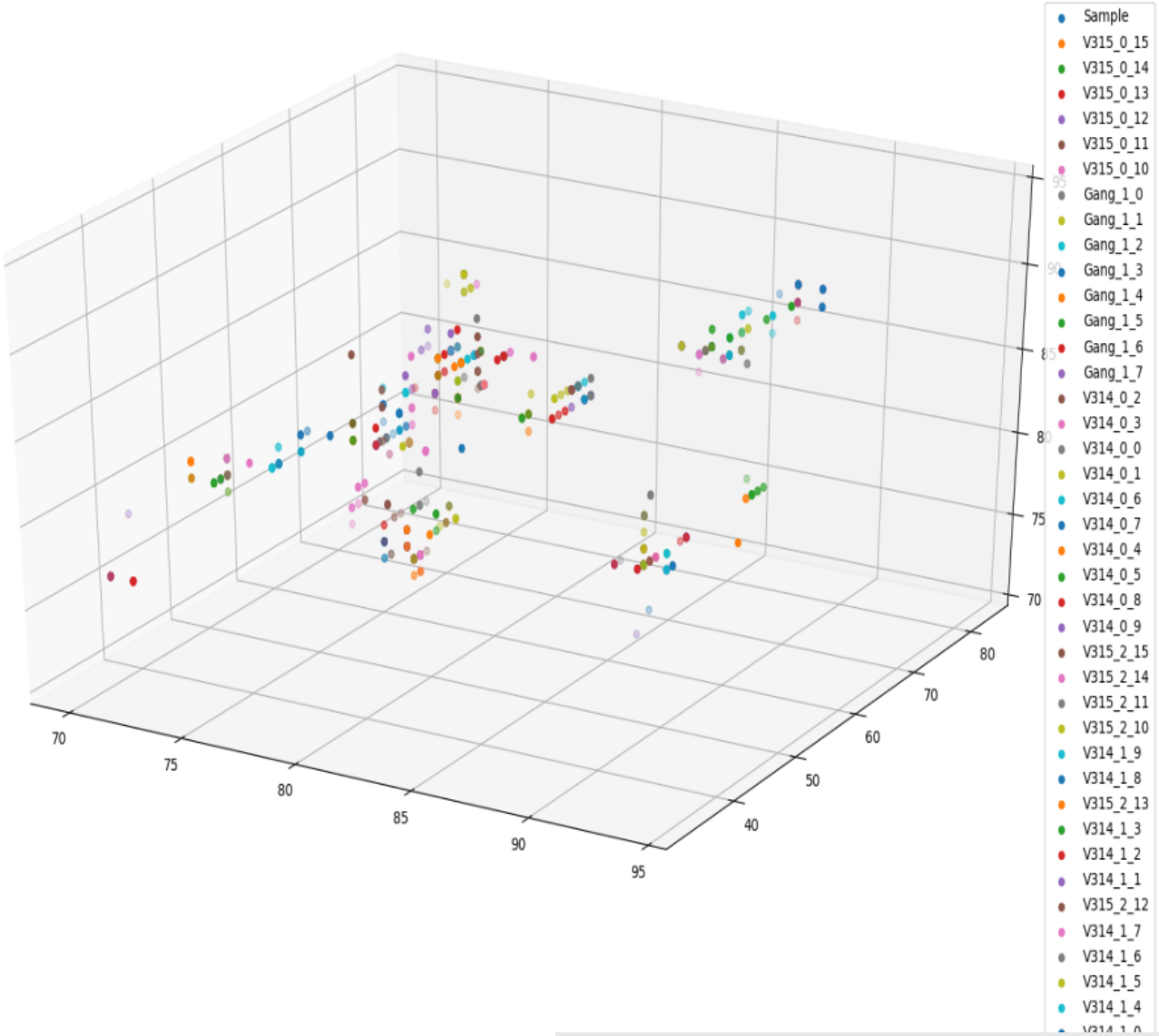
KNN (K-Nearest Neighbors)

- K : smoother boundaries
- K ↑ : Error ↑



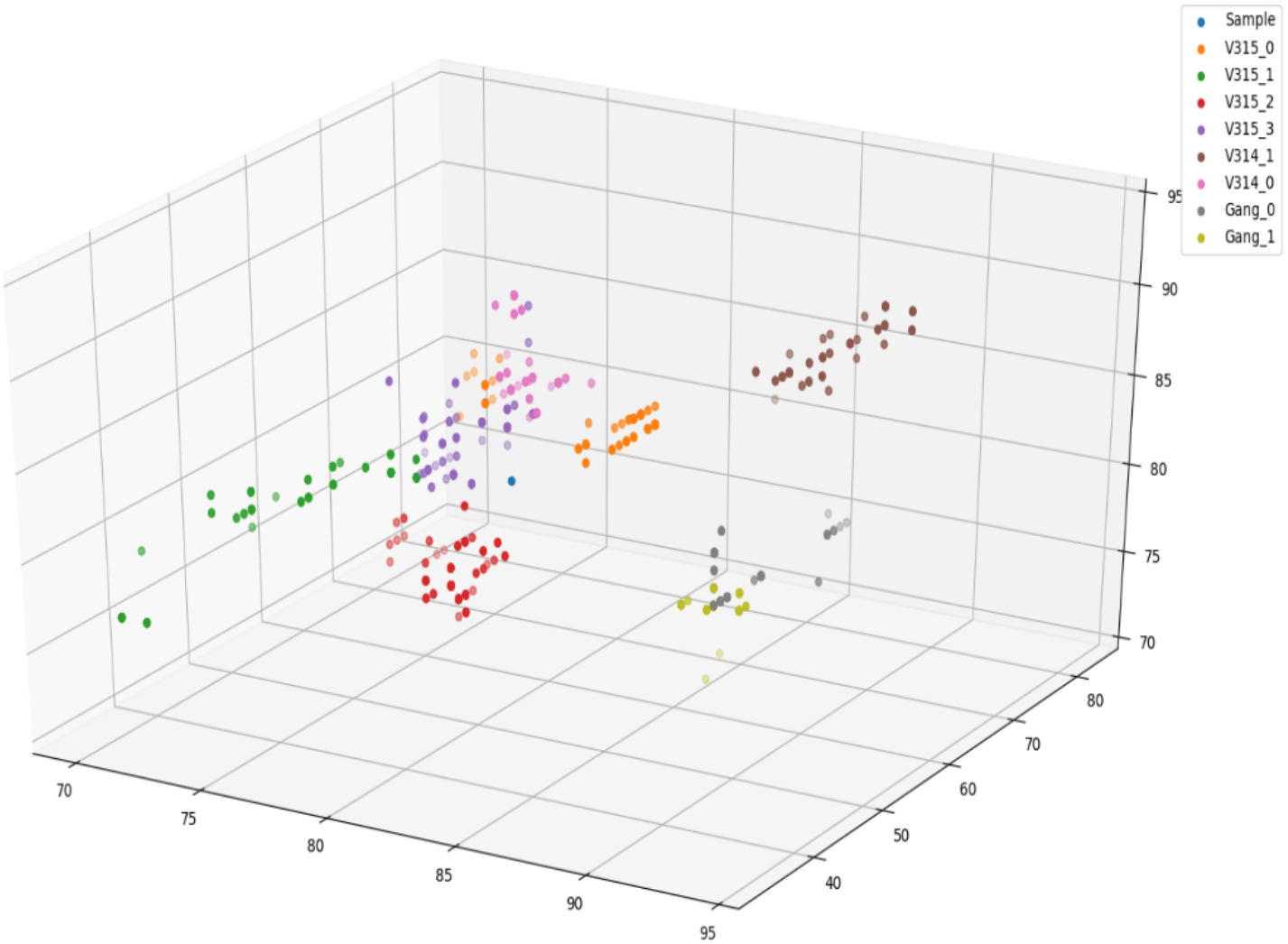
Localization

Visualization - FingerID



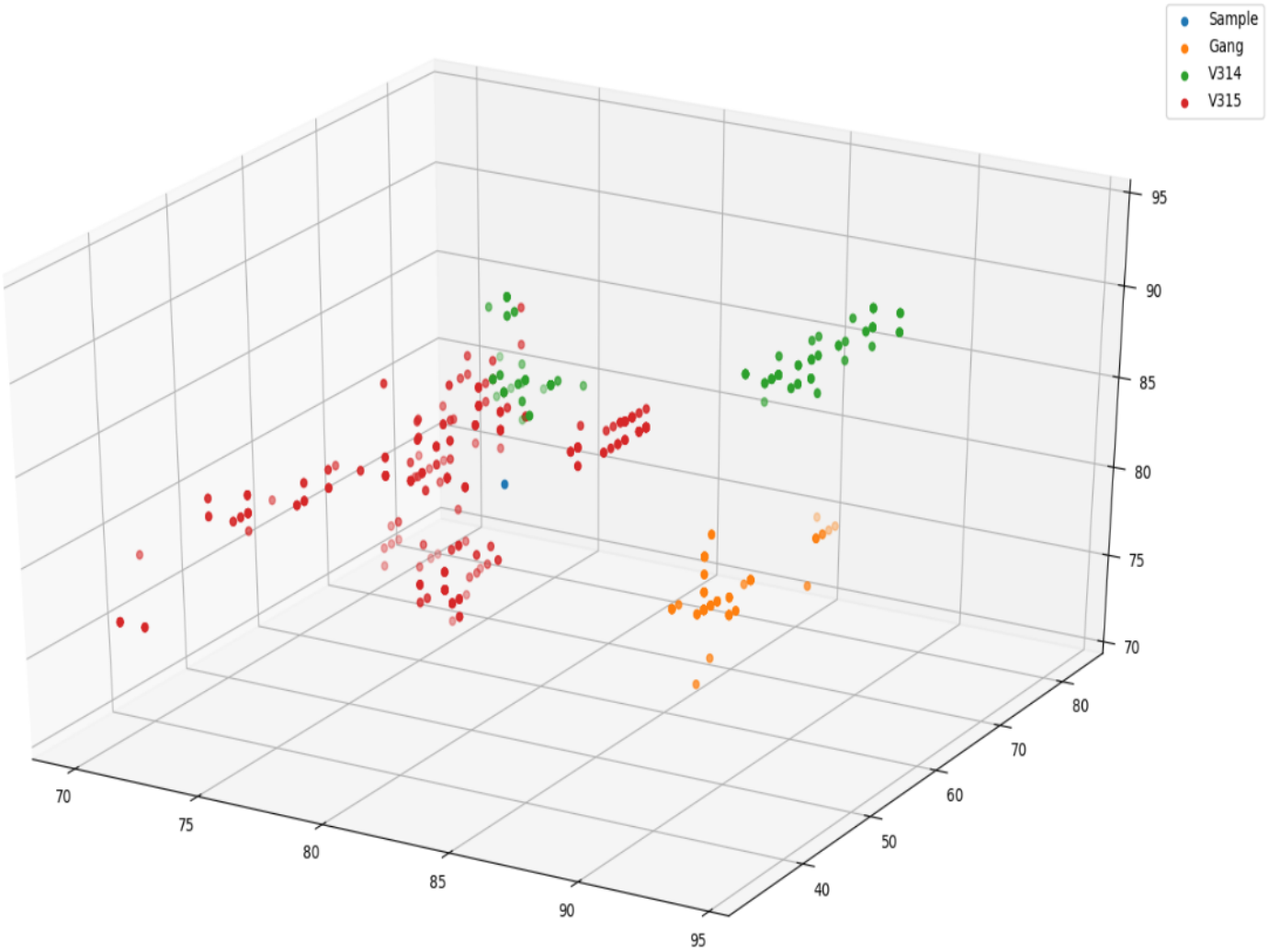
Localization

Visualization - BoxID



Localization

Visualization - Room

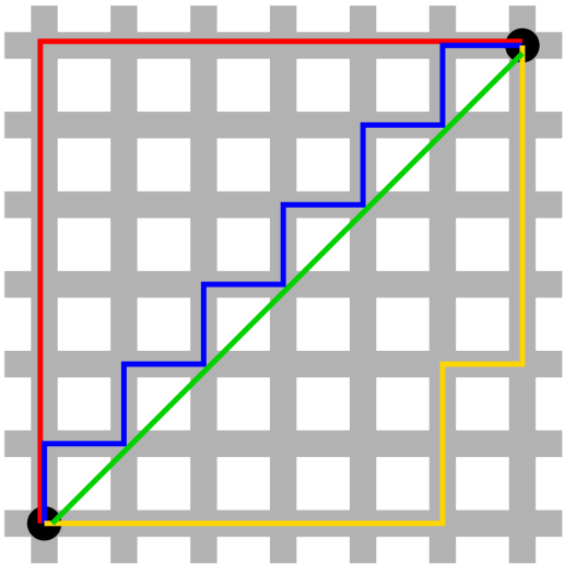


Localization

Why Manhattan?

- High Dimensional data

$$\sum \sqrt{(a-b)^2}$$



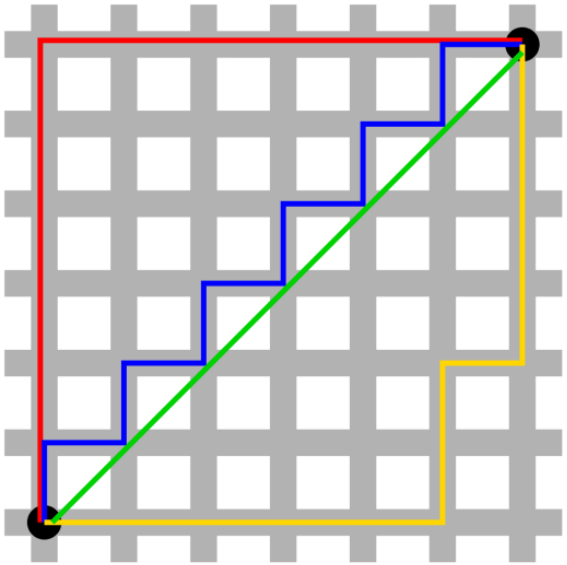
https://www.quora.com/What-is-the-difference-between-Manhattan-and-Euclidean-distance-measures
http://www.ijsr.net/archive/v4i7/SUB156942.pdf

Localization

Why Euclidian

- Renders better results

$$\sqrt{\sum (a-b)^2}$$



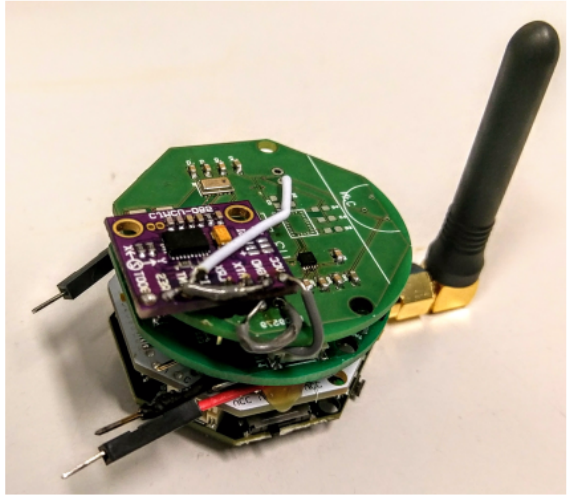
Localization

Problems?

- Fluctuations : No validation
  - Windows/Metal objects
- Gateway covering
- Gateway crashes

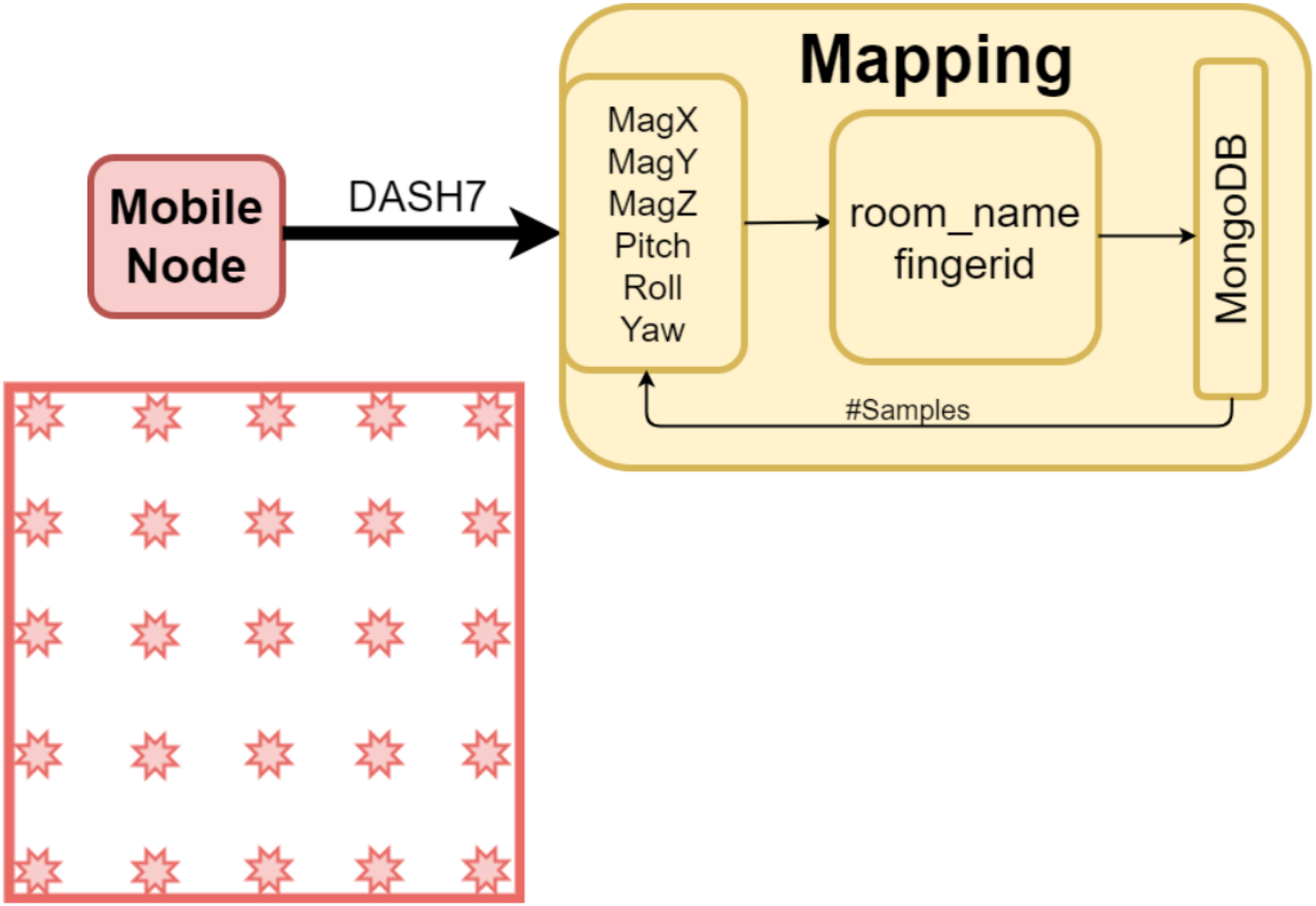
Localization - Magnetometer

- Proof of concept
- Same concept → DASH7
- OpenHAB



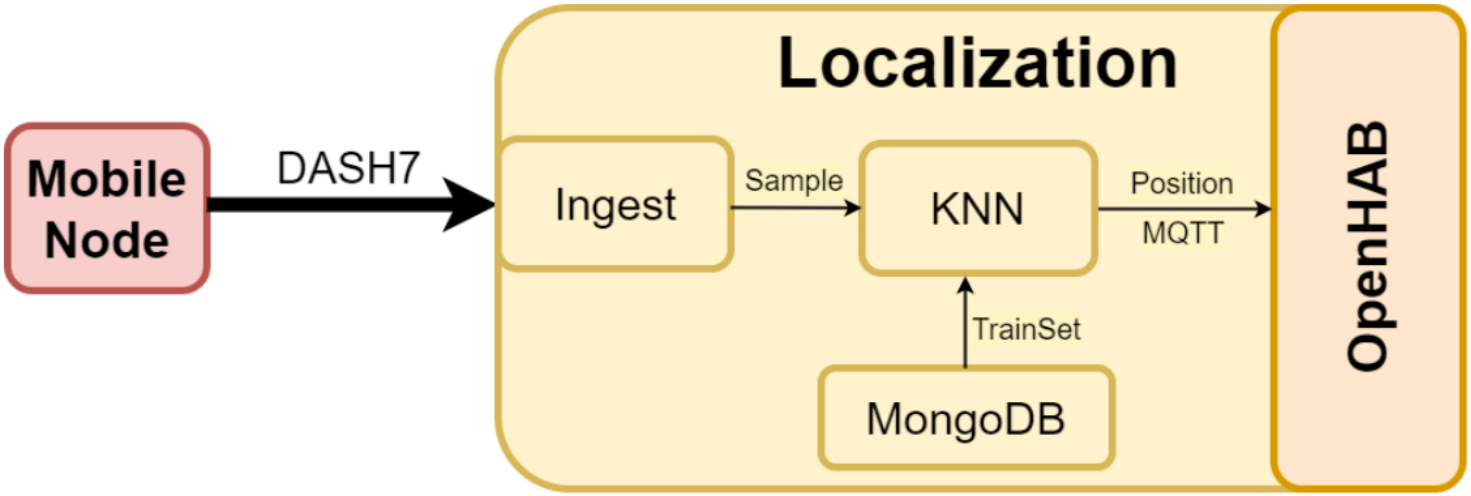
Localization - Magnetometer

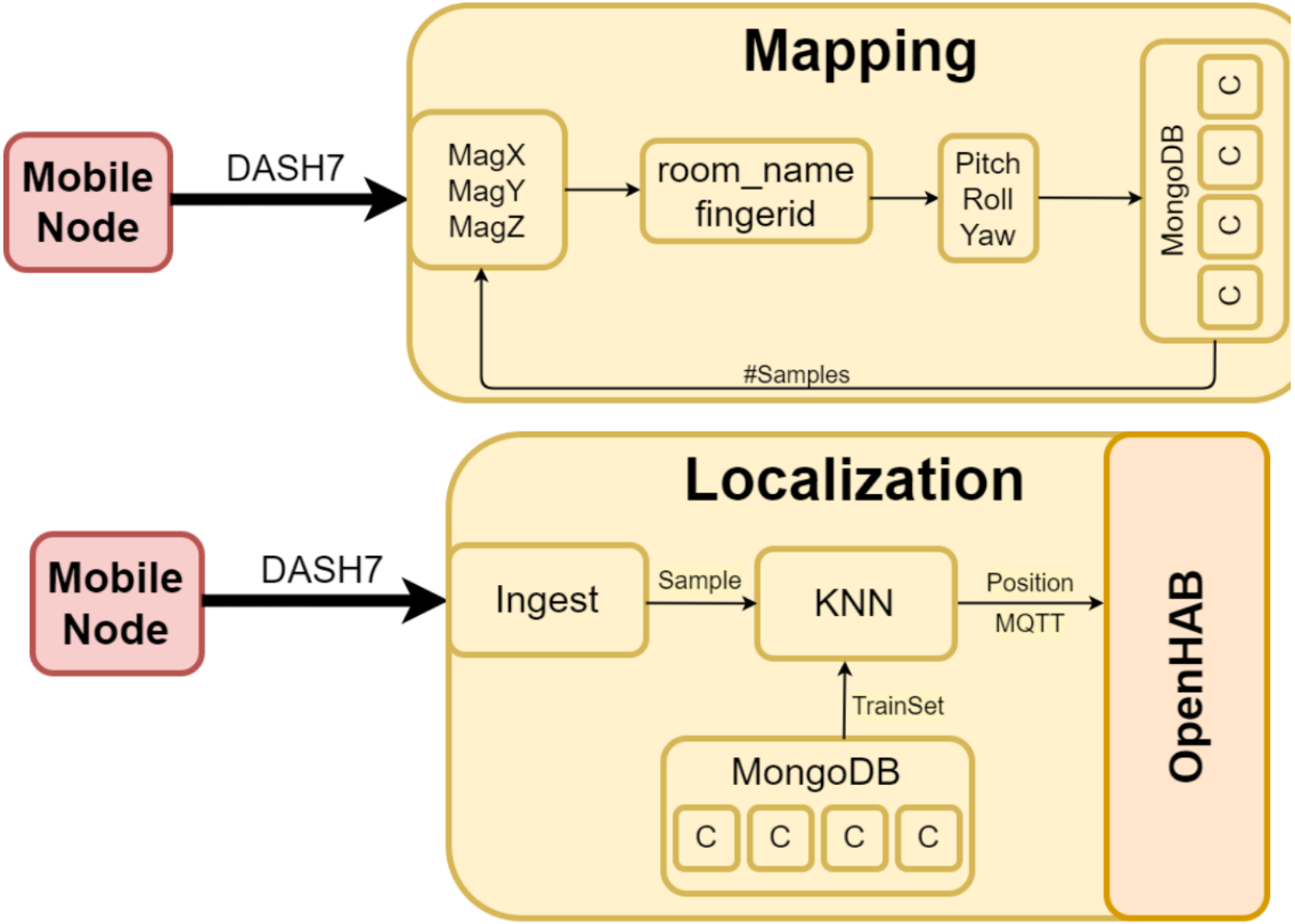
Current Architecture - Mapping



Localization - Magnetometer

Current Architecture - Localization



Localization - Magnetometer

Future Work