Fabrication and Prototyping in the LearningLab

ProtoFabStats

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Overview

Motivation

Motivation - 1/2

- record information about changes in
    - number of occupants
    - status of the door
        - locked/unlocked
        - open/closed
- graphic visualization

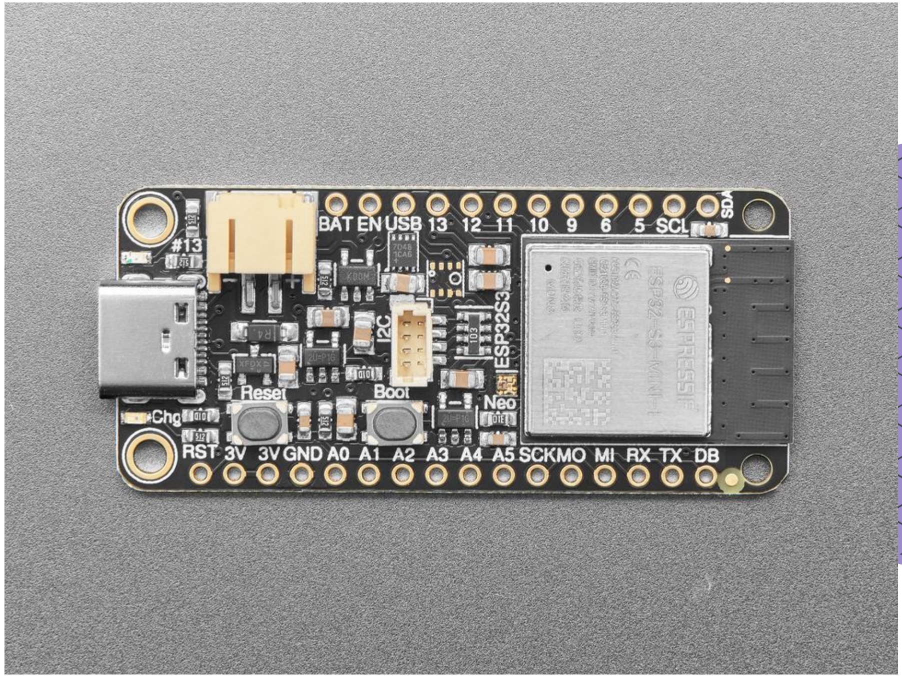
Motivation - 2/2

- compute statistics about the space usage
    - average number of users
        - per day
        - per hour
    - busiest day in the past 7 days

Hardware

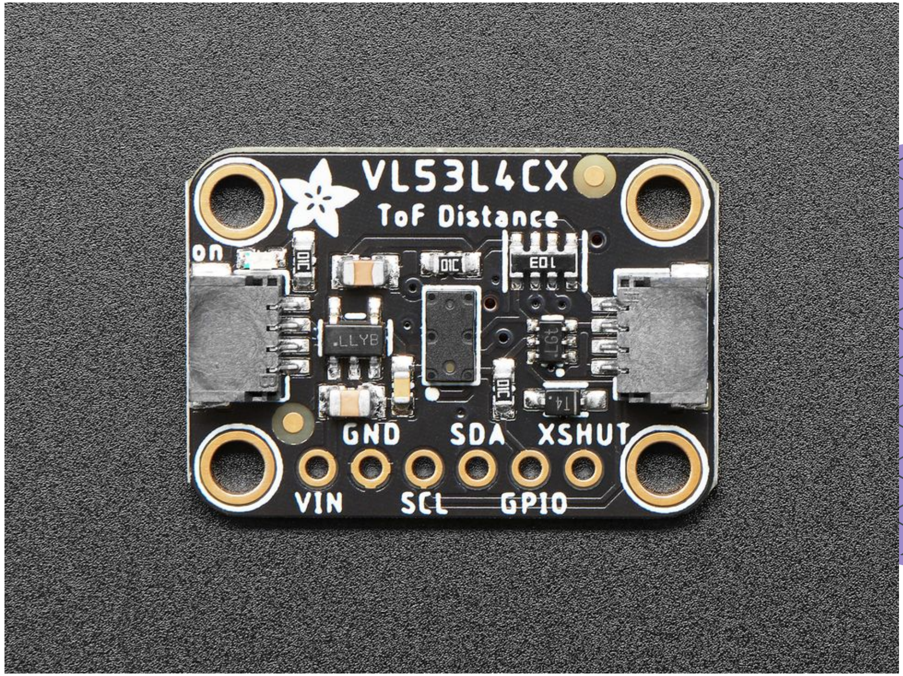
Adafruit ESP32-S3 Feather

- connected to distance & gesture sensors
- publishes measurements using MQTT


BAT EN USB 13 12 11 10 9 6 5 SCL SDA
#13
I2C
ESP32S3
ESPRESSIF
ESP32-S3-MINI-1
Reset
Boot
Neo
Chg
RST 3V 3V GND A0 A1 A2 A3 A4 A5 SCK MO MI RX TX DB

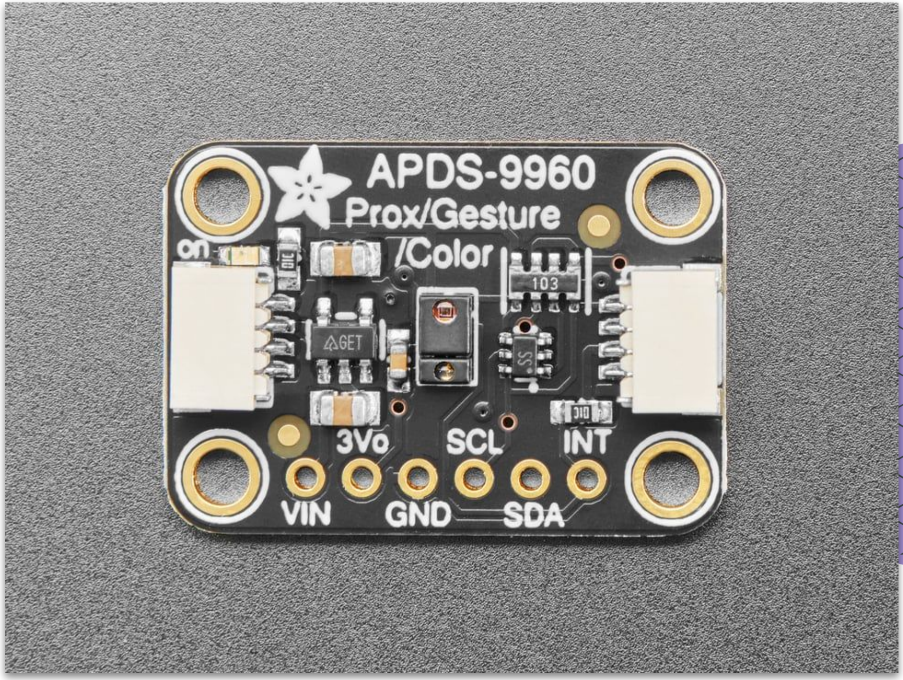
Time of Flight Distance Sensor

- Adafruit VL53L4CX
- 0 mm up to 6 m
- multi-object detection
  - keep only the closest one
- replacement for VL53L0X
  - which most of the times was not working



Proximity, Light, RGB, and Gesture

- Adafruit APDS9960
- direction of movement
  - up
  - down
  - left
  - right

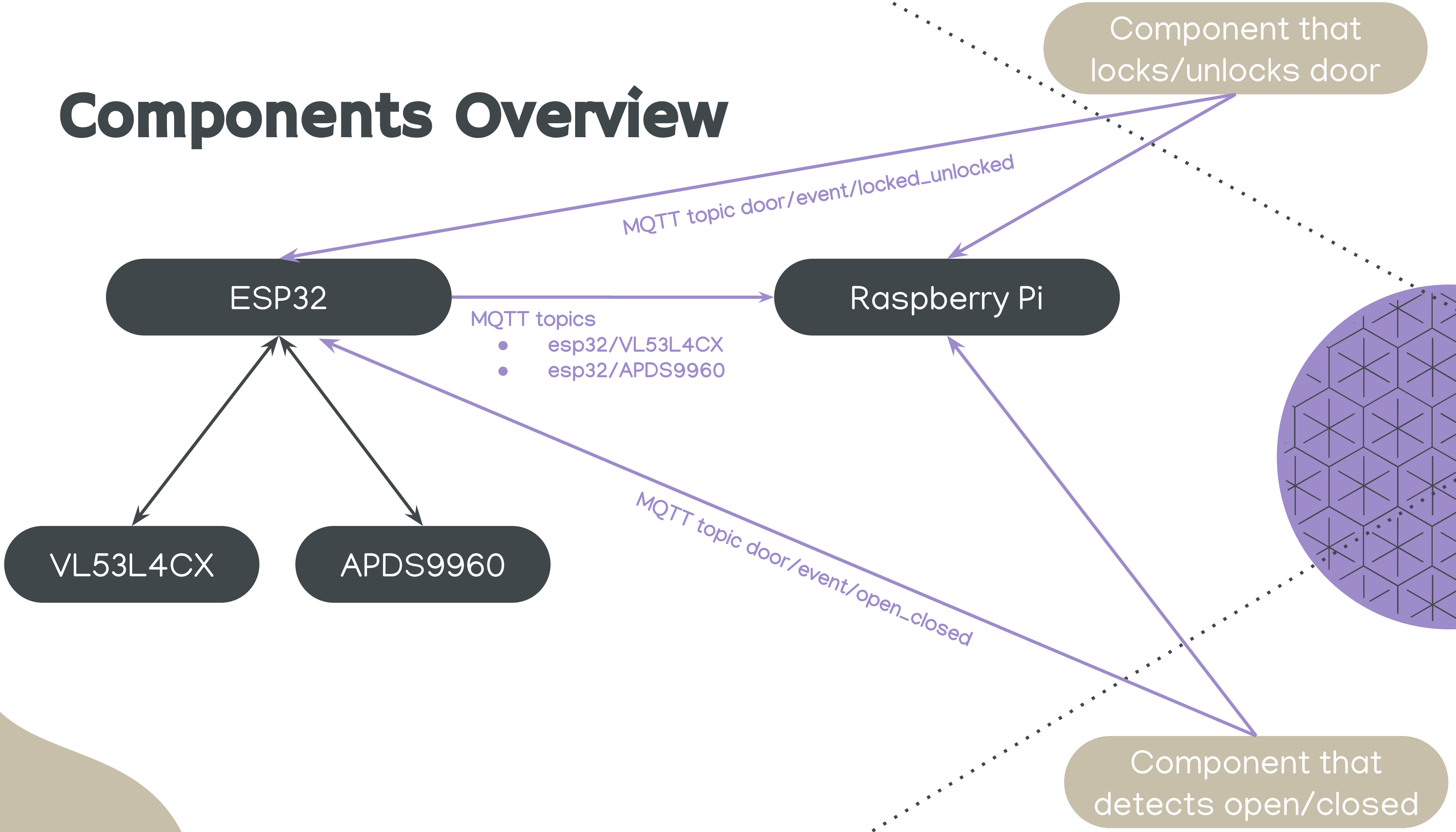


Raspberry Pi Zero

- acts as server
- subscribes to all MQTT topics
- can be accessed by anyone on the network

Methodology

Components Overview


Component that locks/unlocks door
MQTT topic door/event/locked_unlocked
ESP32
Raspberry Pi
MQTT topics
● esp32/VL53L4CX
● esp32/APDS9960
VL53L4CX
APDS9960
MQTT topic door/event/open_closed
Component that detects open/closed

ESP 32

- ESP32 subscribed to MQTT topics
  - door/event/open_closed
  - door/event/locked_unlocked
- status of the door is known => read data less often if we have an indication that the door is not open
  - every 50ms when door is open
  - every 0.1 seconds when door is unlocked but closed
  - every second when door is locked

Raspberry Pi

- 4 Linux Services
  - Grafana
  - Preprocessing Service
  - Days of Week Stats Service
  - Hour Stats Service
- Docker Container
  - Mosquitto
  - Telegraf
  - InfluxDB V1
  - Flask Service

Grafana

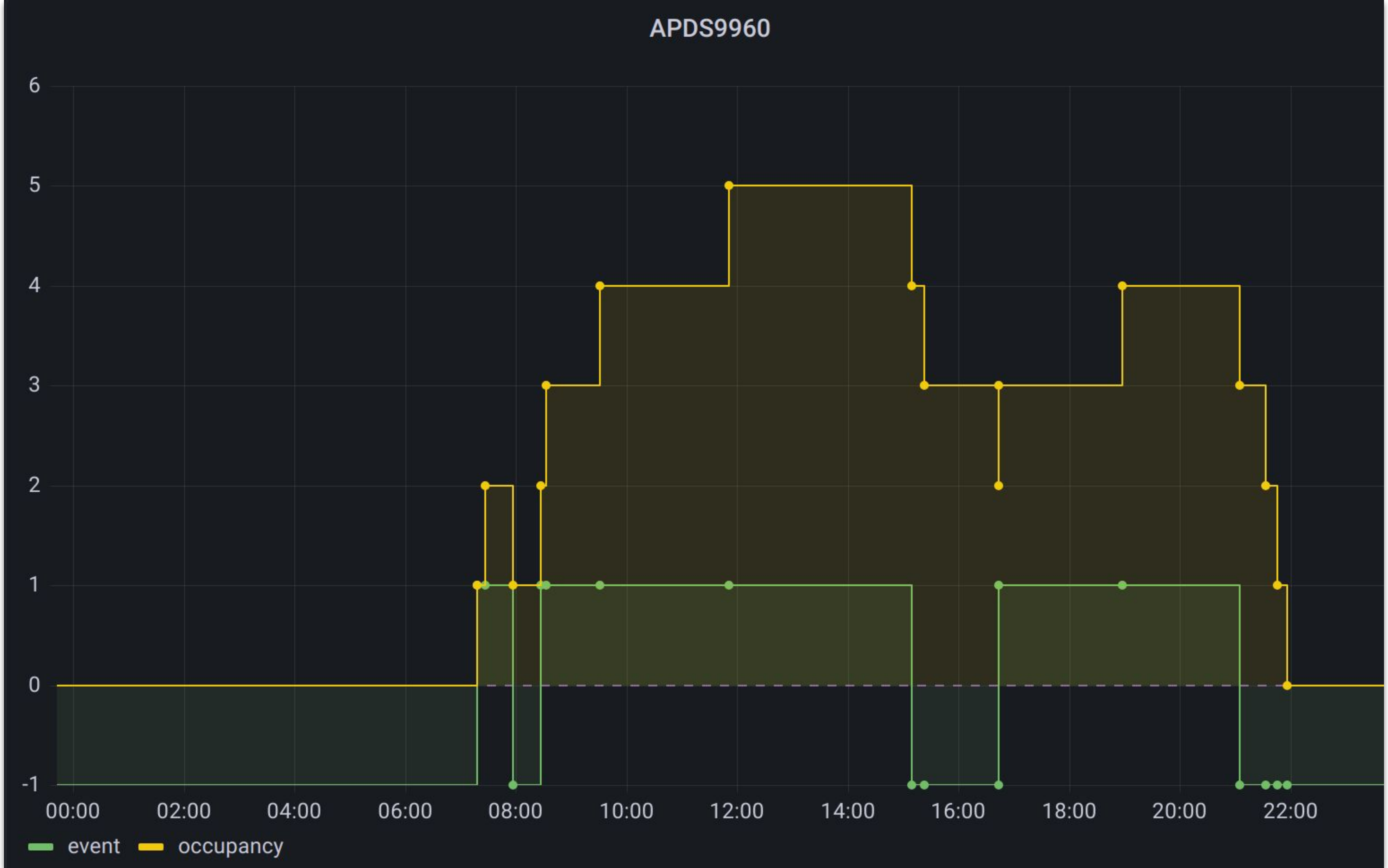
- live data for
  - locked/unlocked
  - closed/open
  - esp32/APDS9960
    - enter/leave
  - esp32/VL53L4CX
    - distance to closest target within range
- no live data for average occupancy/occupancy per week

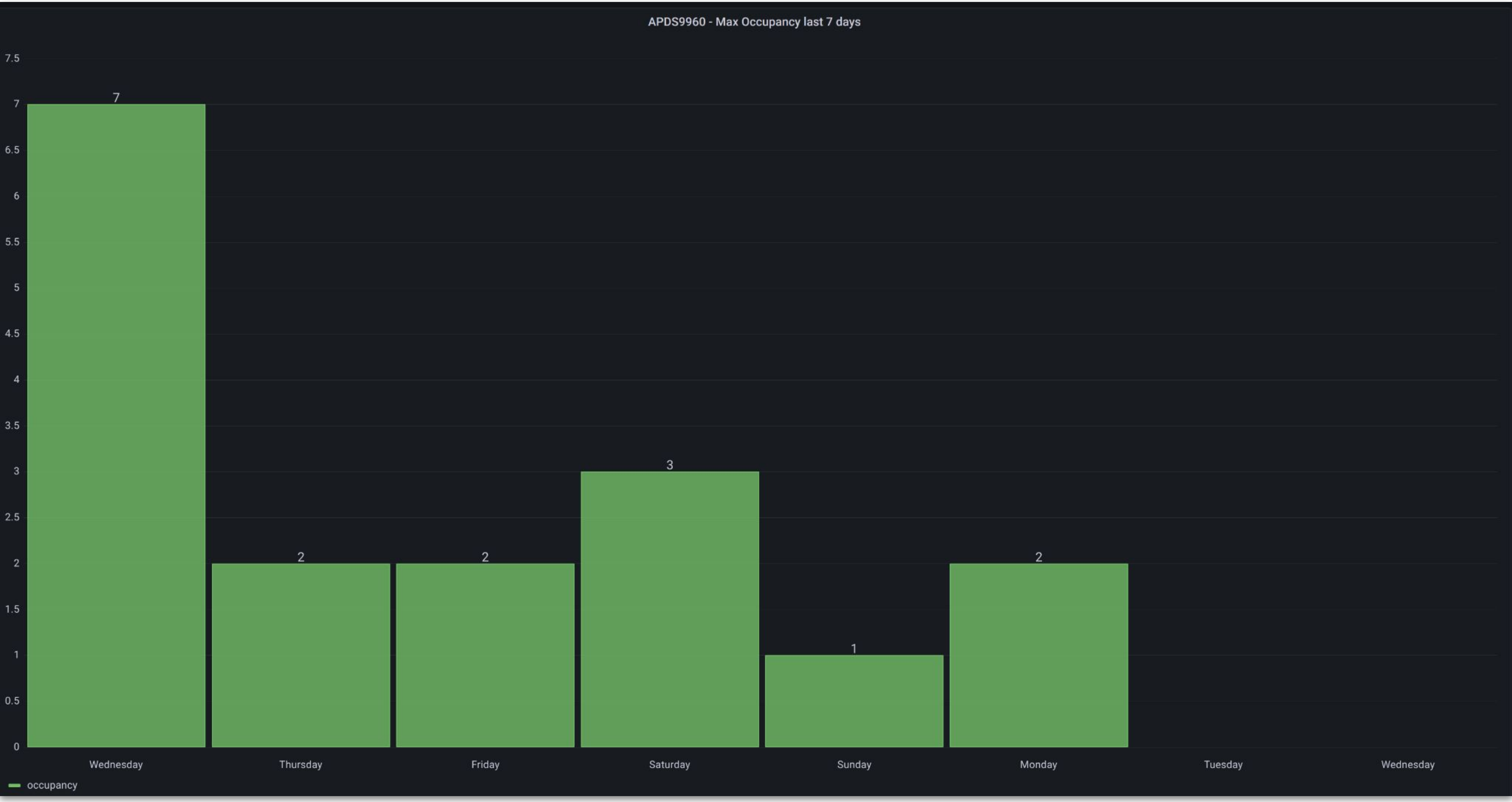
Data Processing Service - 1/2

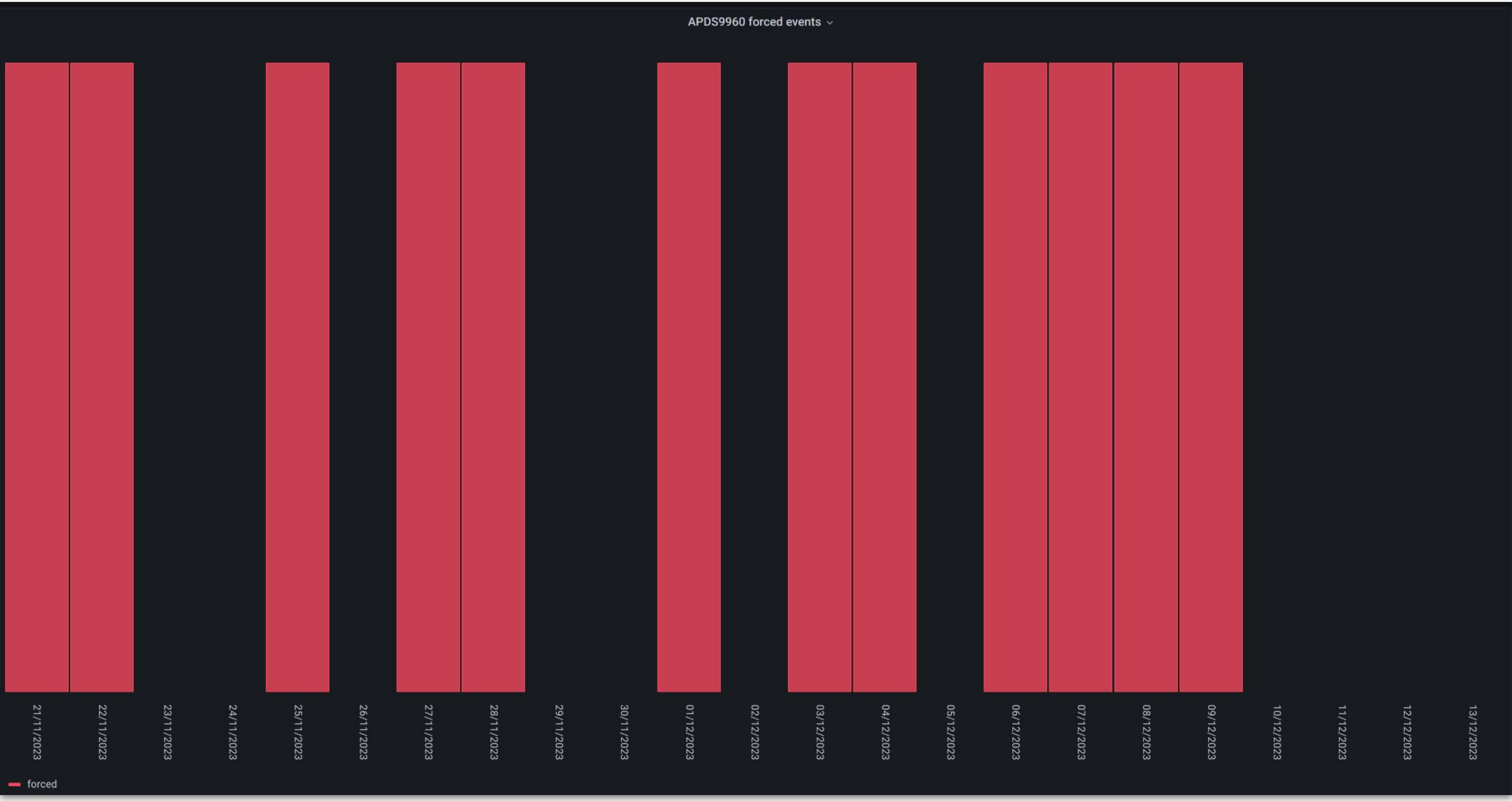
- updates InfluxDB measurement APDS9960_processed every 10 minutes
- computes occupancy metric based on enter/leave events
  - when does the number of people change?

Data Processing Service - 2/2

- validates data
  - based on certain assumptions
    - room is accessed only when the building is open (e.g. 7:00 – 22:00)
    - nobody is there at midnight
    - adds dummy data at midnight if events(enter) != events(leave)
      - missing/wrong data
      - signal these findings

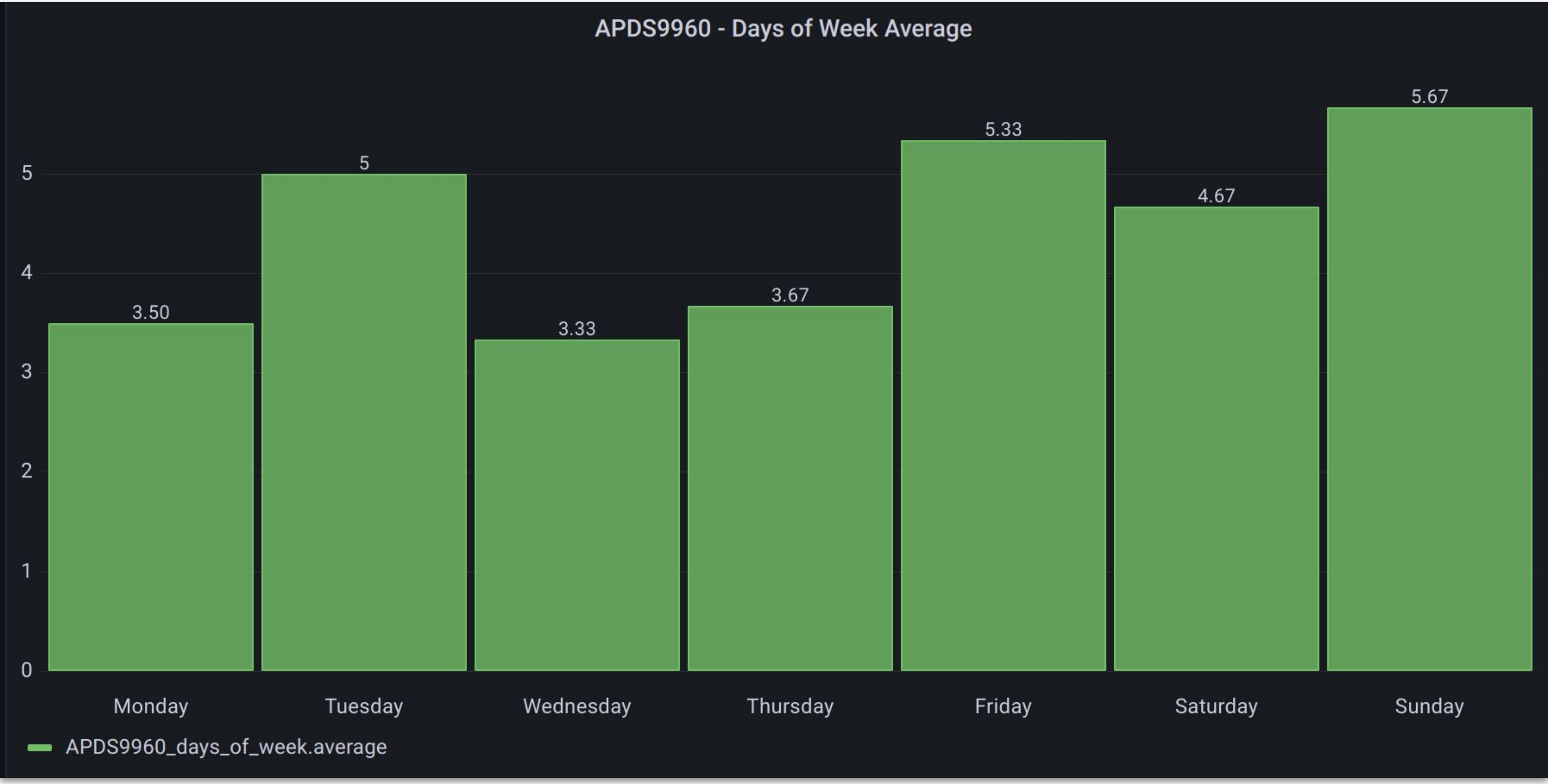

APDS9960
6
5
4
3
2
1
0
-1
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
event
occupancy


APDS9960 - Max Occupancy last 7 days
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
7
2
2
3
1
2
Wednesday
Thursday
Friday
Saturday
Sunday
Monday
Tuesday
Wednesday
occupancy


APDS9960 forced events
21/11/2023
22/11/2023
23/11/2023
24/11/2023
25/11/2023
26/11/2023
27/11/2023
28/11/2023
29/11/2023
30/11/2023
01/12/2023
02/12/2023
03/12/2023
04/12/2023
05/12/2023
06/12/2023
07/12/2023
08/12/2023
09/12/2023
10/12/2023
11/12/2023
12/12/2023
13/12/2023
🟥 forced

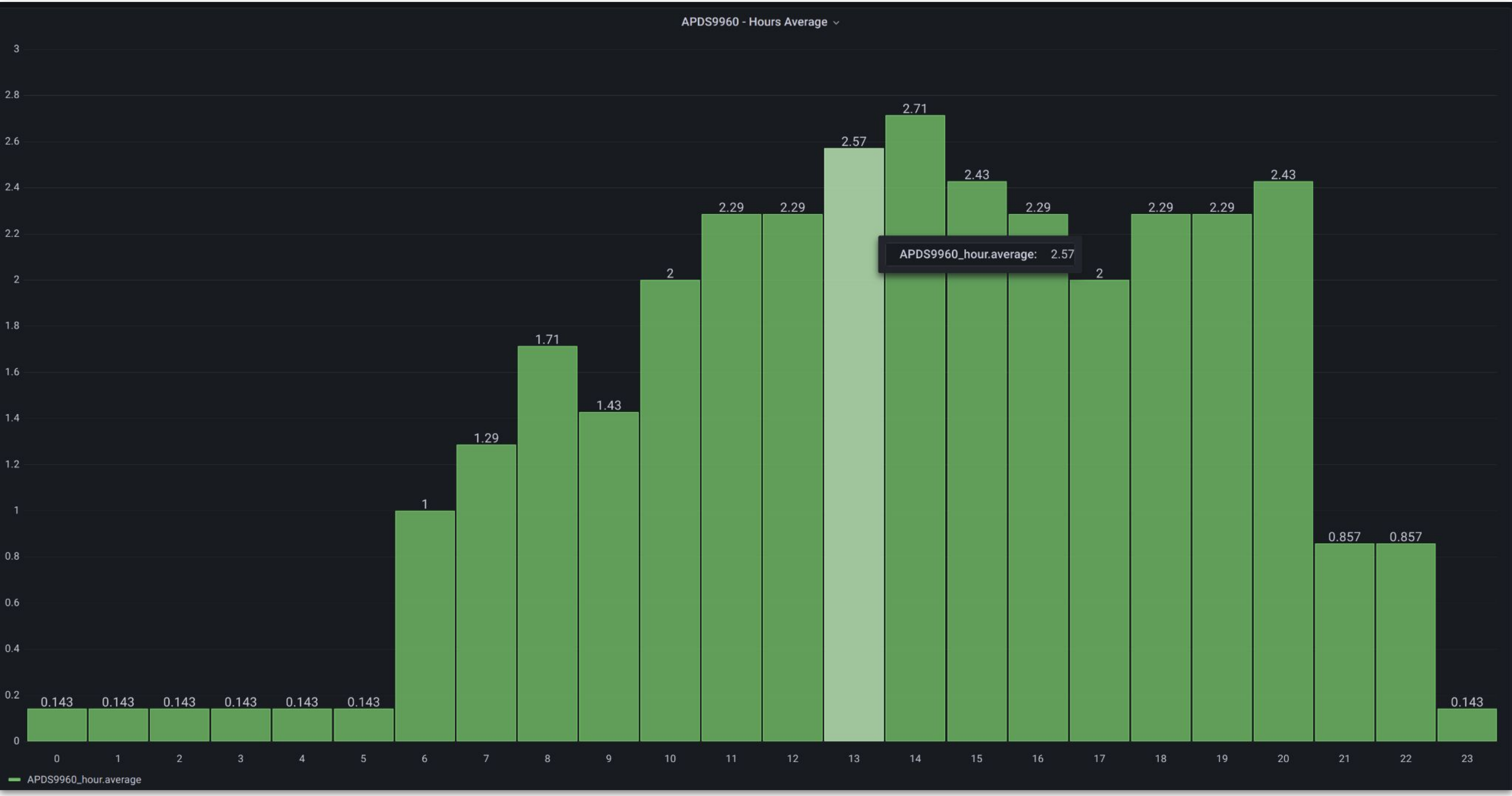
Day of Week Stats Service

- updates InfluxDB measurement APDS9960_days_of_week
- computes average occupancy metric based on weekdays
  - removes everything else => never more than one value / weekday
- intended to run daily at 4:00
  - for testing, runs every 5 mins


APDS9960 - Days of Week Average
0
1
2
3
4
5
3.50
5
3.33
3.67
5.33
4.67
5.67
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
🟩 APDS9960_days_of_week.average

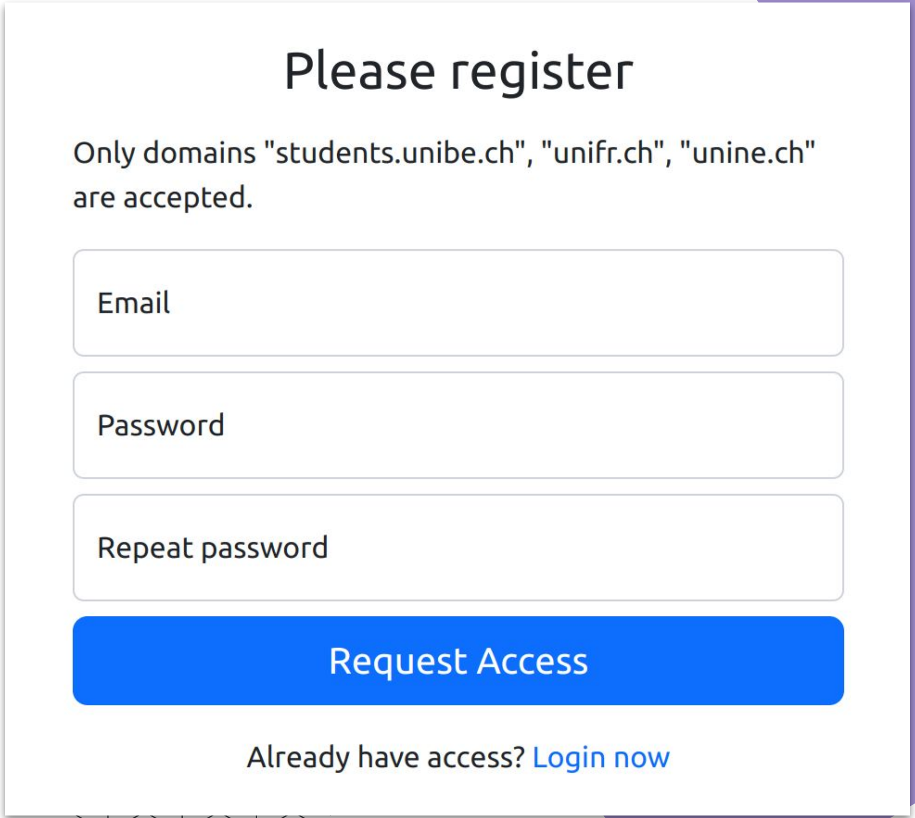
Hour Stats Service

- updates InfluxDB measurement APDS9960_hour
- computed for the last 7 days
- computes average occupancy metric based on hour
- intended to run every hour
    - for testing, runs every 5 mins


APDS9960 - Hours Average
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.143
0.143
0.143
0.143
0.143
0.143
1
1.29
1.71
1.43
2
2.29
2.29
2.57
2.71
2.43
2.29
2
2.29
2.29
2.43
0.857
0.857
0.143
APDS9960_hour.average: 2.57
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
APDS9960_hour.average

Flask Service - 1/2

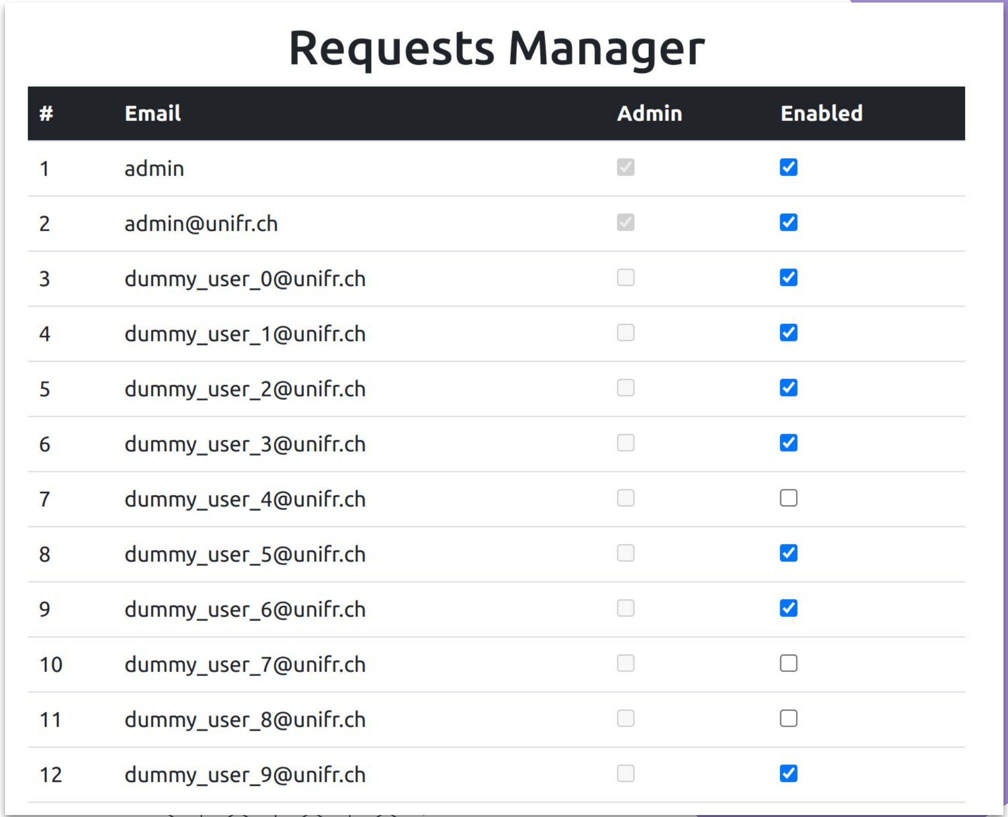
- anyone with university email can request access


Please register

Only domains "students.unibe.ch", "unifr.ch", "unine.ch" are accepted.

Flask Service - 2/2

- access can be granted/revoked by admins

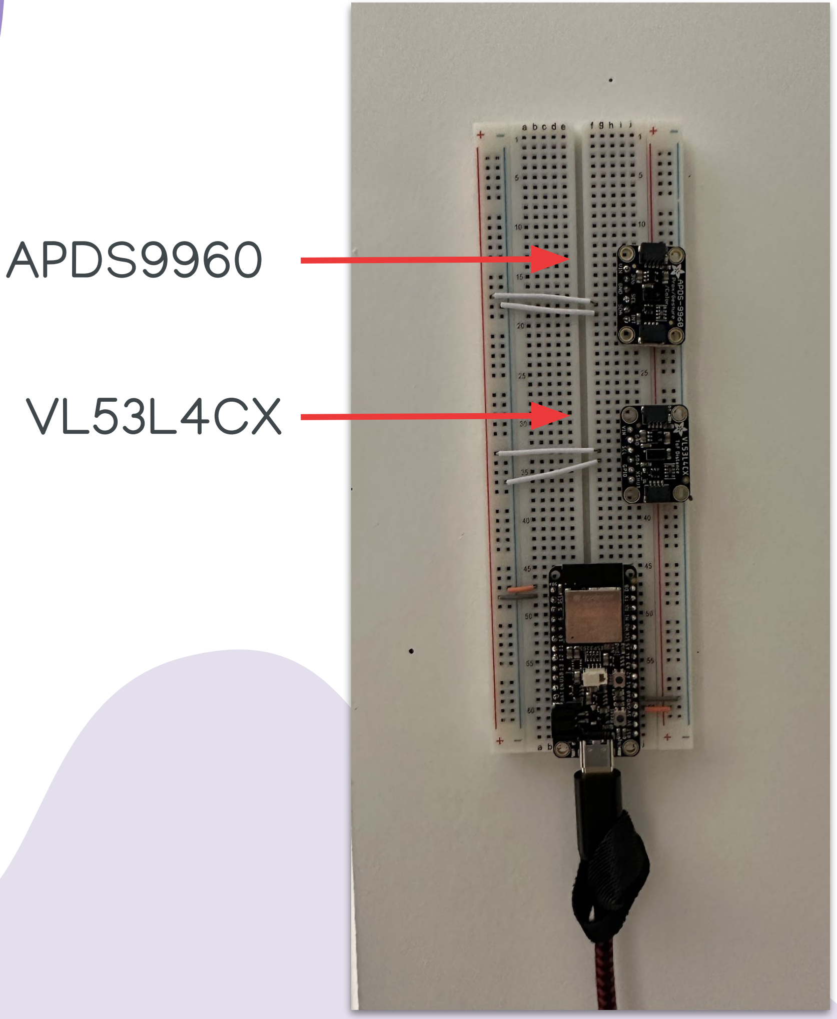


Requests Manager

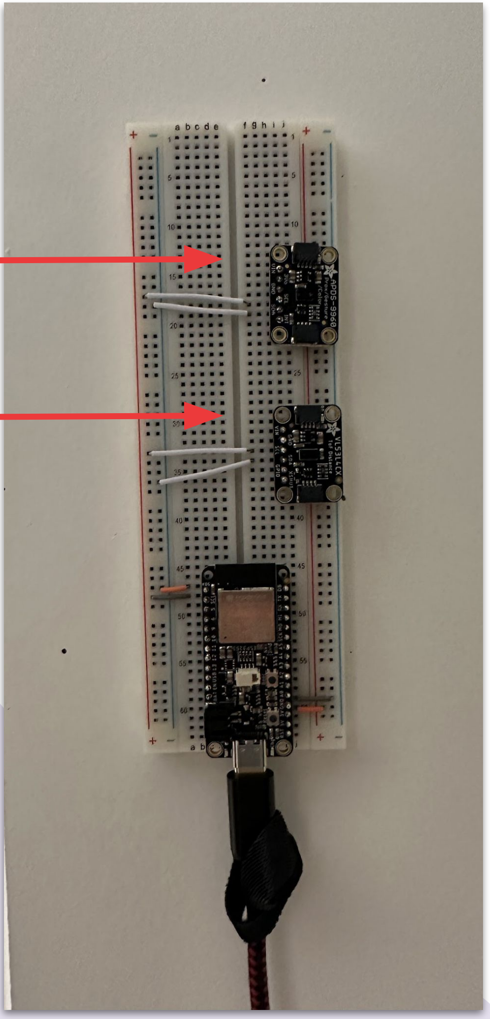
#	Email	Admin	Enabled
1	admin	✓	✓
2	admin@unifr.ch	✓	✓
3	dummy_user_0@unifr.ch	☐	✓
4	dummy_user_1@unifr.ch	☐	✓
5	dummy_user_2@unifr.ch	☐	✓
6	dummy_user_3@unifr.ch	☐	✓
7	dummy_user_4@unifr.ch	☐	☐
8	dummy_user_5@unifr.ch	☐	✓
9	dummy_user_6@unifr.ch	☐	✓
10	dummy_user_7@unifr.ch	☐	☐
11	dummy_user_8@unifr.ch	☐	☐
12	dummy_user_9@unifr.ch	☐	✓

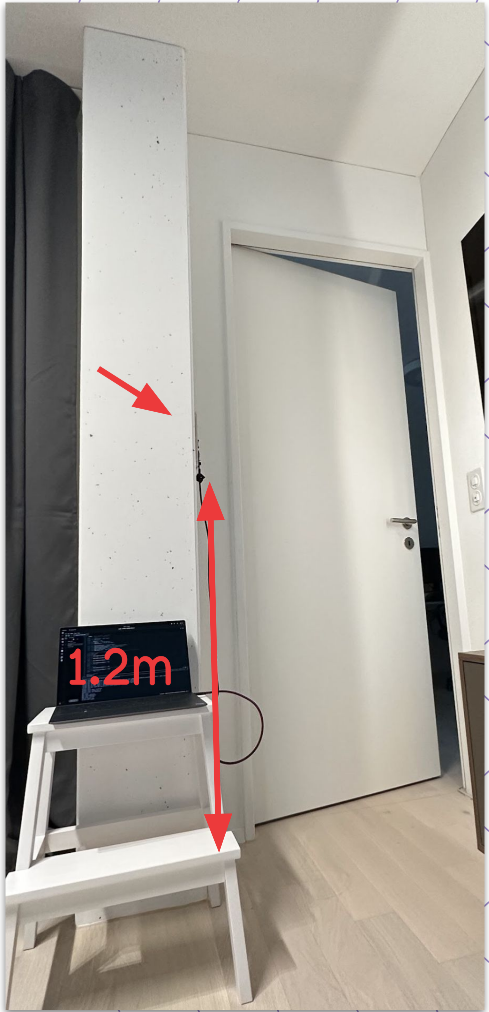
Experiment Setup

Setup

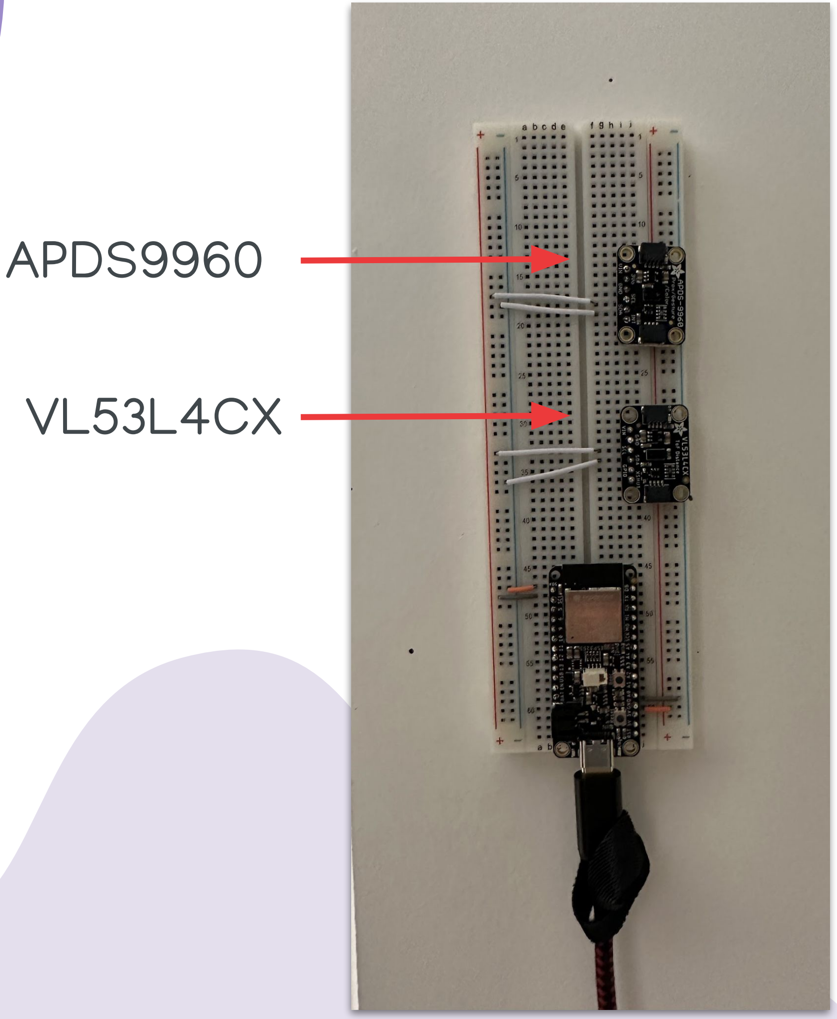


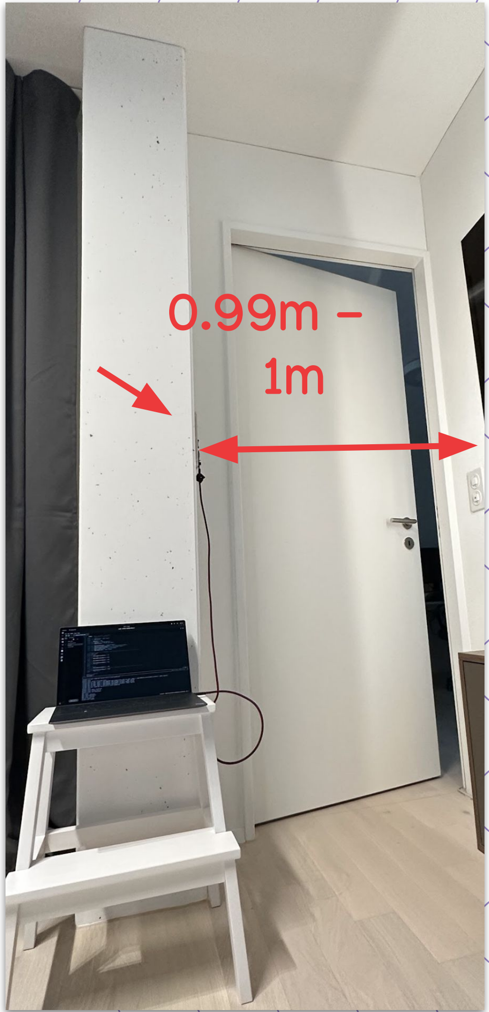
Setup

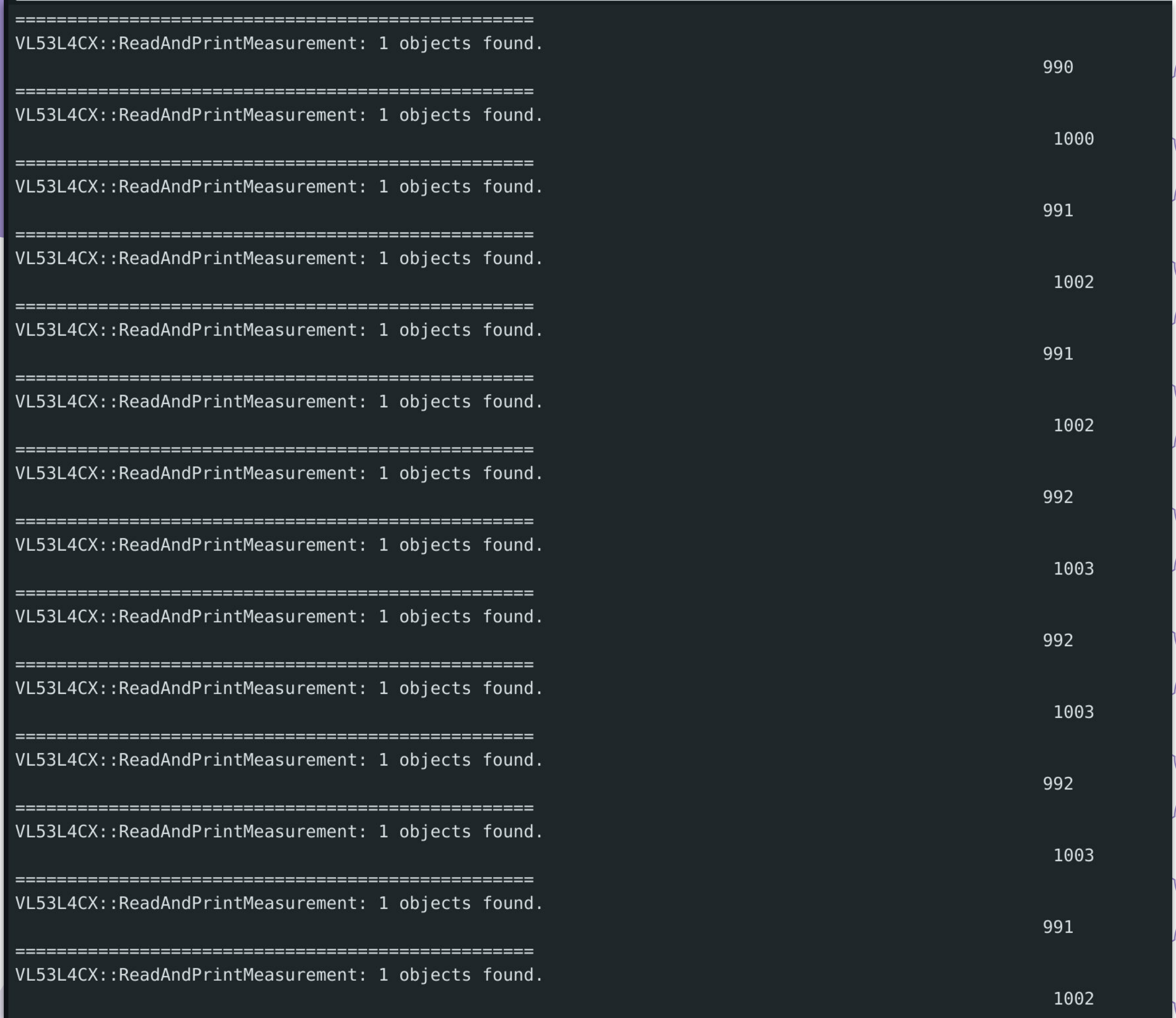




Setup

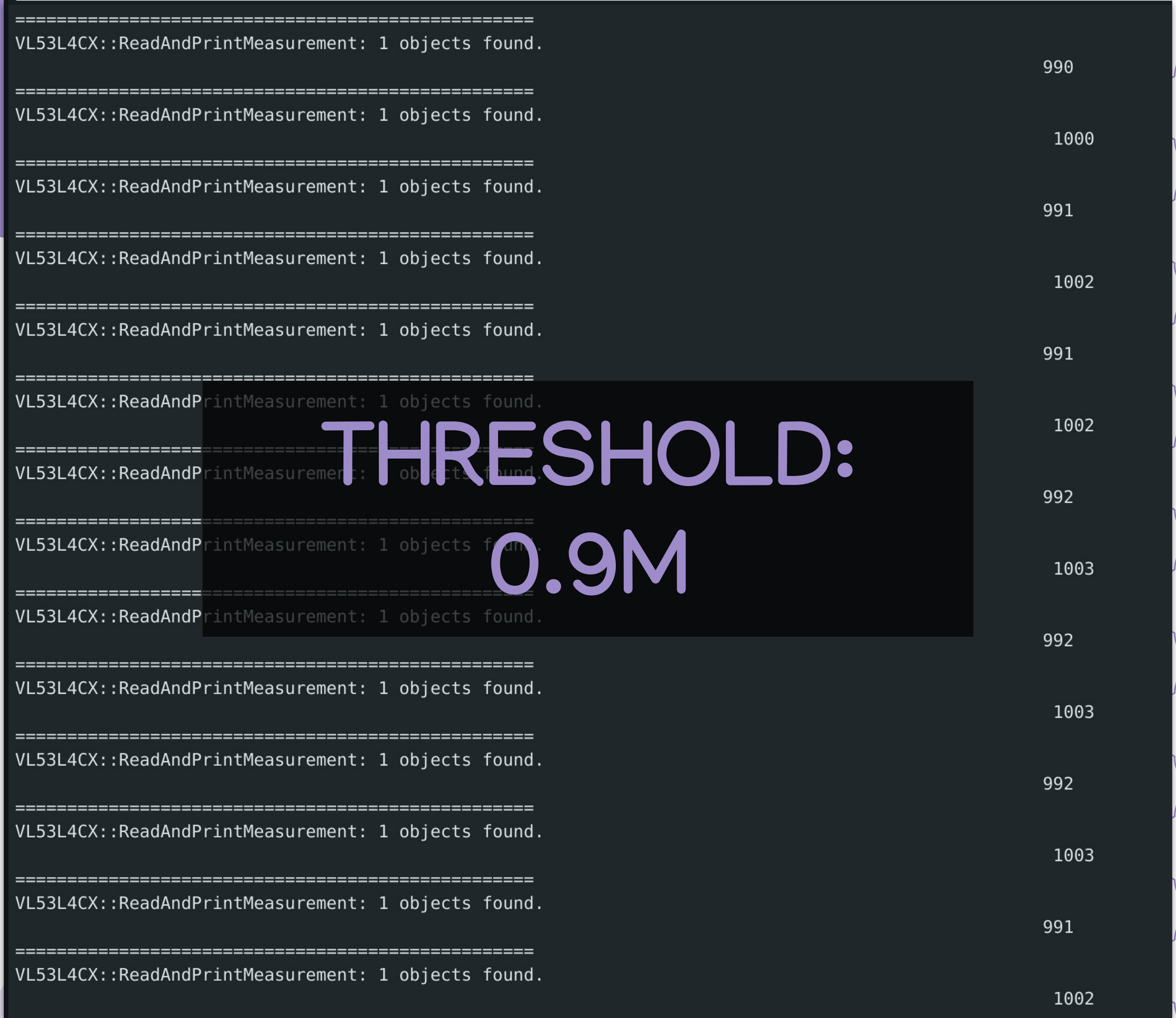






```
==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                    990

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                     1000

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                    991

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                     1002

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                    991

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                     1002

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                    992

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                     1003

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                    992

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                     1003

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                    992

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                     1003

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                    991

==================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                                     1002
```

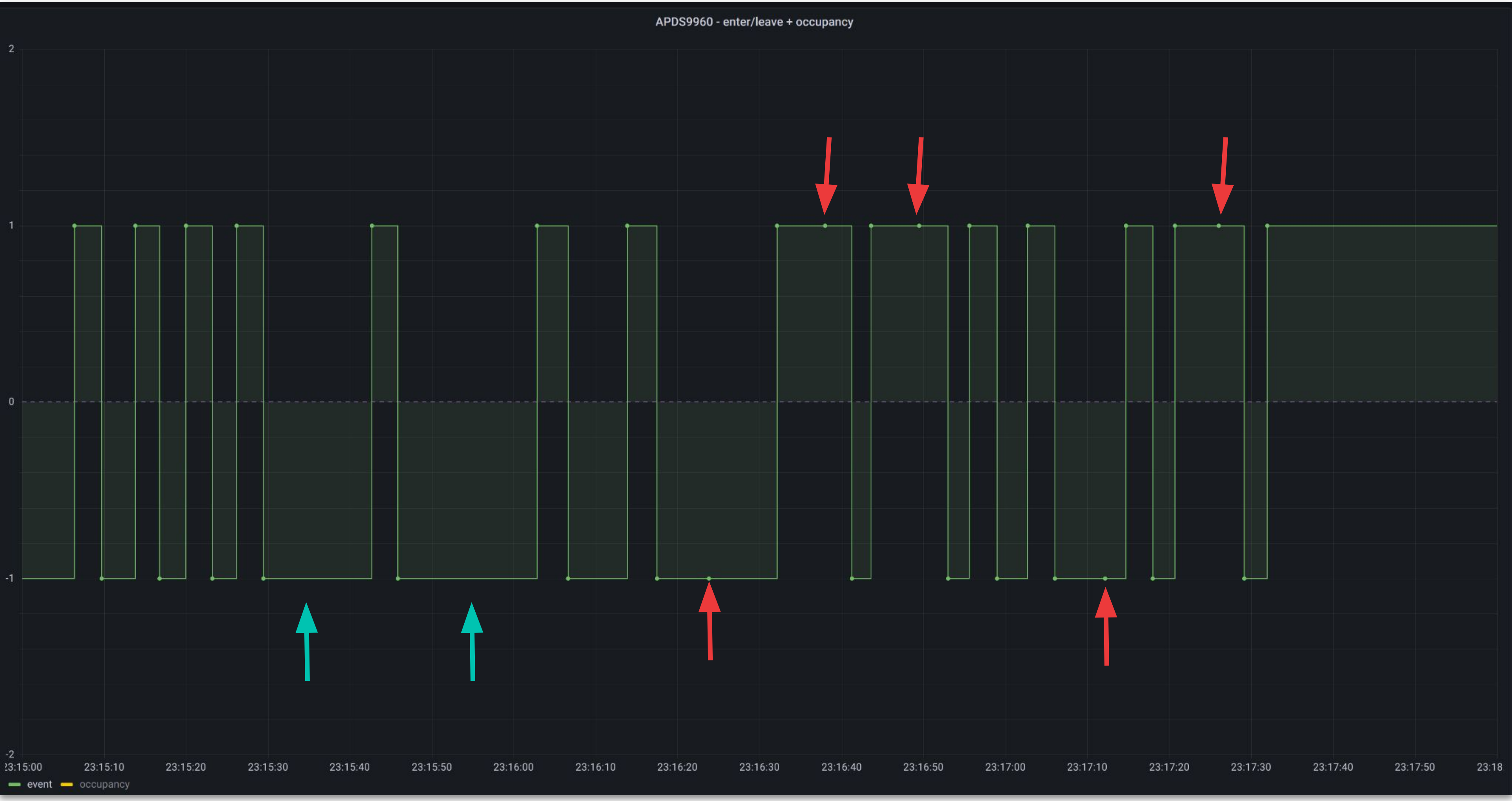
THRESHOLD: 0.9M

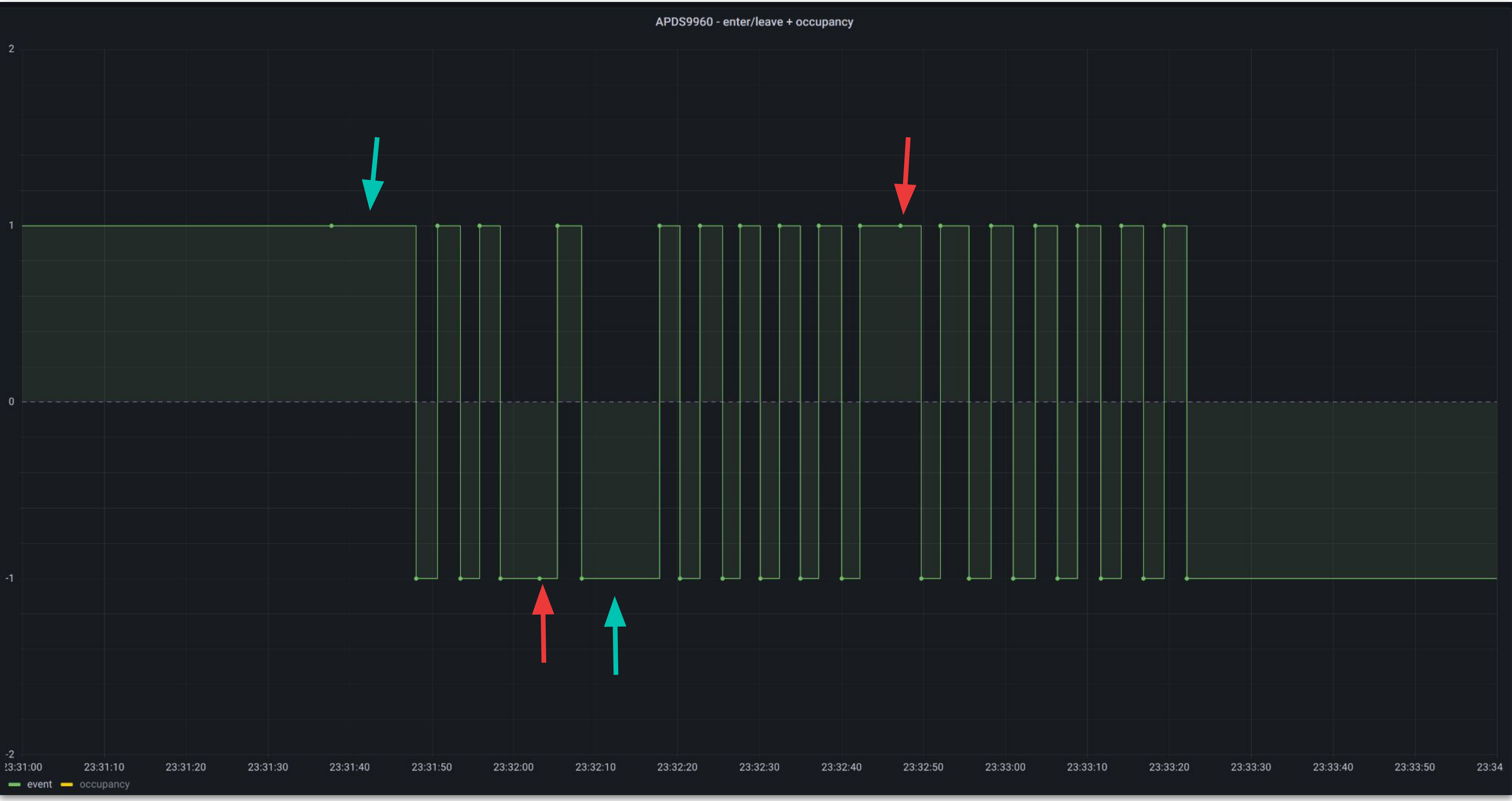


```
===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                              990

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                               1000

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                              991

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                               1002

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                              991

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                               1002

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                              992

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                               1003

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                              992

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                               1003

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                              992

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                               1003

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                              991

===================================================
VL53L4CX::ReadAndPrintMeasurement: 1 objects found.
                                                                               1002
```

APDS9960 Testing

- 20 times entering/leaving the room => 40 recordings
- Test 1
  - Start time 23:15
  - End time 23:18
  - 32 recorded (80%)
- Test 2
  - Start time 23:31
  - End time 23:34
  - 34 recorded (85%)


APDS9960 - enter/leave + occupancy
2
1
0
-1
-2
23:15:00
23:15:10
23:15:20
23:15:30
23:15:40
23:15:50
23:16:00
23:16:10
23:16:20
23:16:30
23:16:40
23:16:50
23:17:00
23:17:10
23:17:20
23:17:30
23:17:40
23:17:50
23:18
event
occupancy


APDS9960 - enter/leave + occupancy
2
1
0
-1
-2
23:31:00
23:31:10
23:31:20
23:31:30
23:31:40
23:31:50
23:32:00
23:32:10
23:32:20
23:32:30
23:32:40
23:32:50
23:33:00
23:33:10
23:33:20
23:33:30
23:33:40
23:33:50
23:34
event
occupancy

VL53L4CX Testing

-

Data Generation

- need data for multiple days to test statistics
  - 21 days
  - 0–30 events/day
  - 80% of days are valid
    - events(enter) == events(leave)
    - sum(events(enter)) >= sum(events(leave)) at any given point

Demo

Conclusions & Future Work

Conclusions

- working with sensors (and various pieces of hardware in general) can be tricky

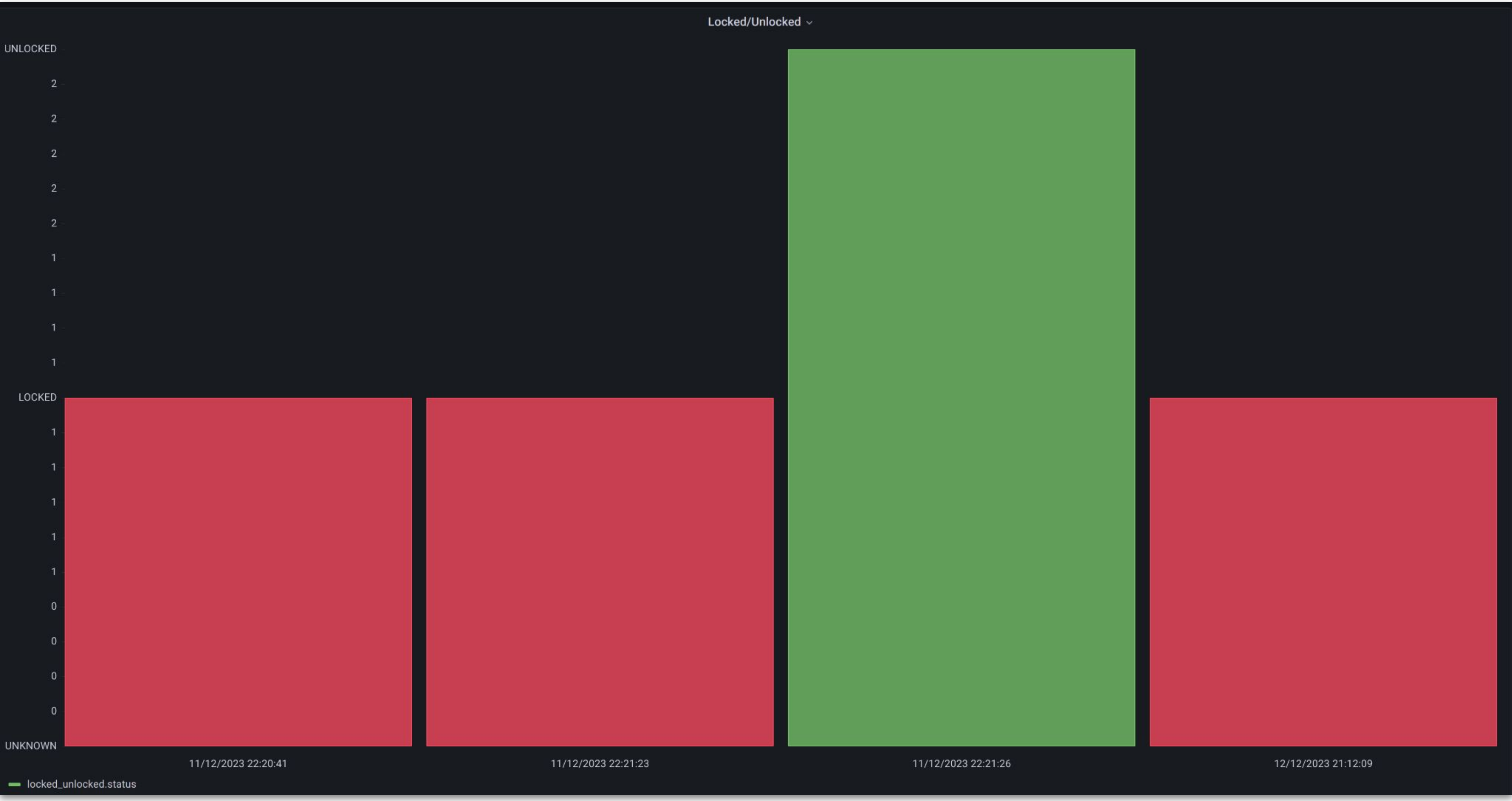
Future Work

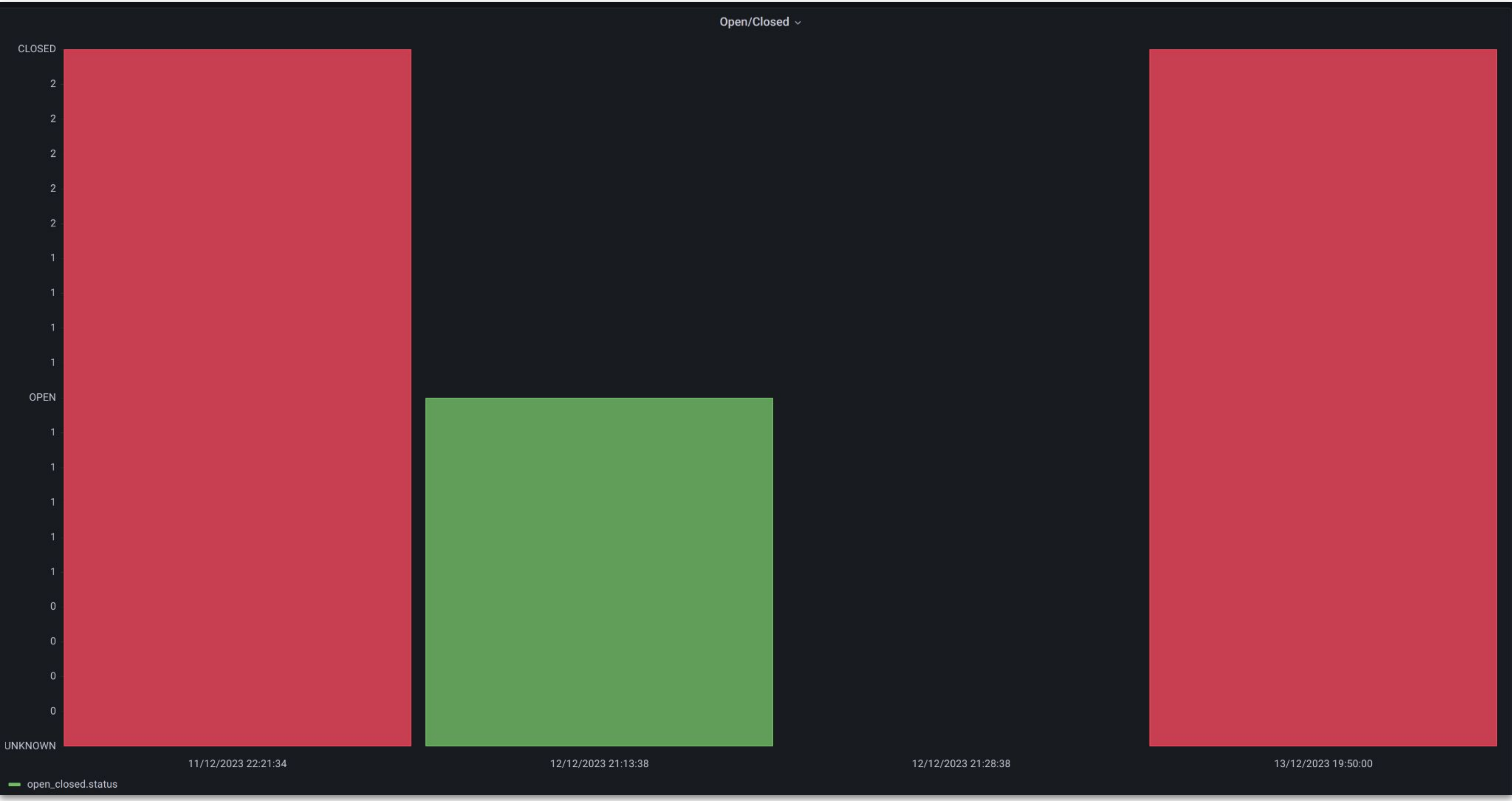
- connect with the other 2 projects
- look into using alerts in Grafana
- send confirmation email when permission is requested/granted

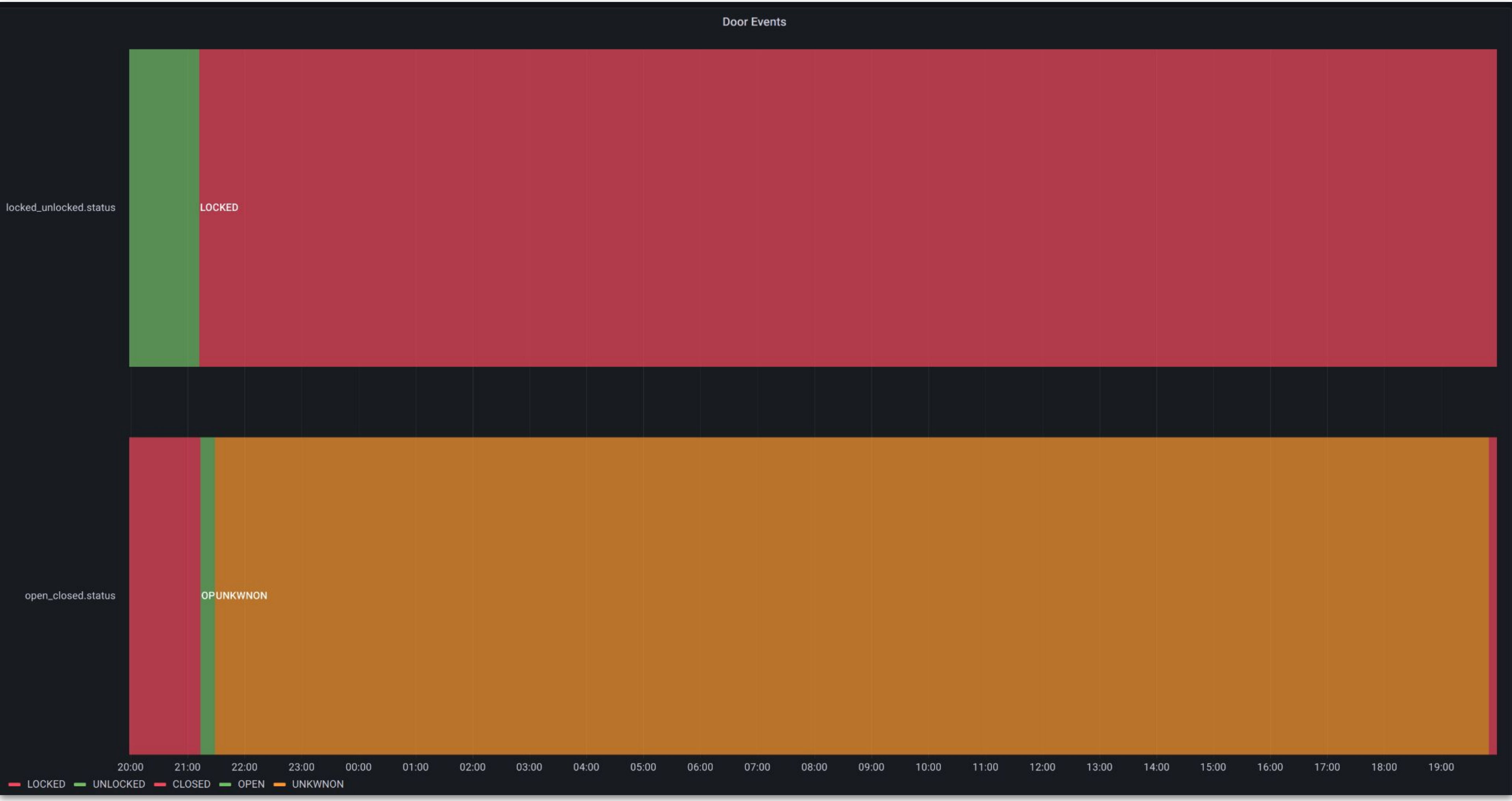
Thank you!

Appendix

Grafana - Door Events


Locked/Unlocked
UNLOCKED
2
2
2
2
2
1
1
1
1
LOCKED
1
1
1
1
1
0
0
0
0
UNKNOWN
11/12/2023 22:20:41
11/12/2023 22:21:23
11/12/2023 22:21:26
12/12/2023 21:12:09
locked_unlocked.status

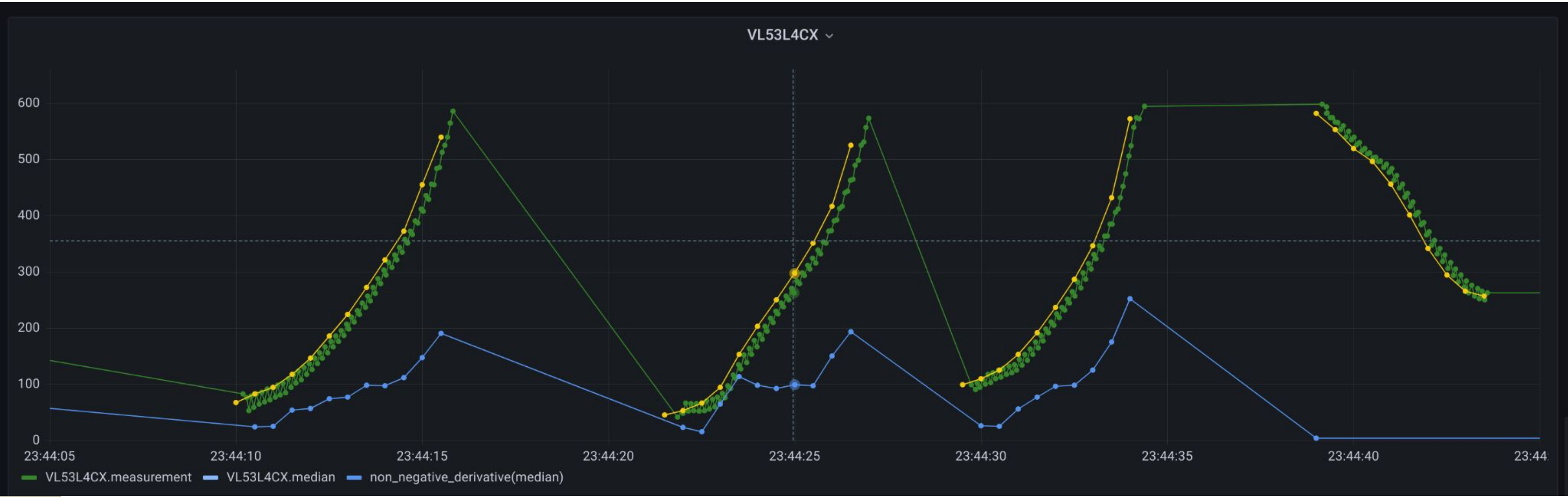

Open/Closed
CLOSED
2
2
2
2
2
1
1
1
1
OPEN
1
1
1
1
1
0
0
0
0
UNKNOWN
11/12/2023 22:21:34
12/12/2023 21:13:38
12/12/2023 21:28:38
13/12/2023 19:50:00
open_closed.status


Door Events
locked_unlocked.status
LOCKED
open_closed.status
OP
UNKWNON
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
LOCKED
UNLOCKED
CLOSED
OPEN
UNKWNON

Analysing the Data

- event = person entering/leaving
- define minimum duration of event
  - 1ms
- define minimum interval between two different events
  - 1ms
- create groups of measurements

Analysing the Data


VL53L4CX
23:44:05
23:44:10
23:44:15
23:44:20
23:44:25
23:44:30
23:44:35
23:44:40
23:44:
VL53L4CX.measurement
VL53L4CX.median
non_negative_derivative(median)