RUNTIME VERIFICATION FOR SPATIO-TEMPORAL PROPERTIES OVER IOT NETWORKS

Second partial release of the project

DEGREE IN COMPUTER ENGINEERING

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Index

Introduction

Development

Problems and solutions

Work done until now

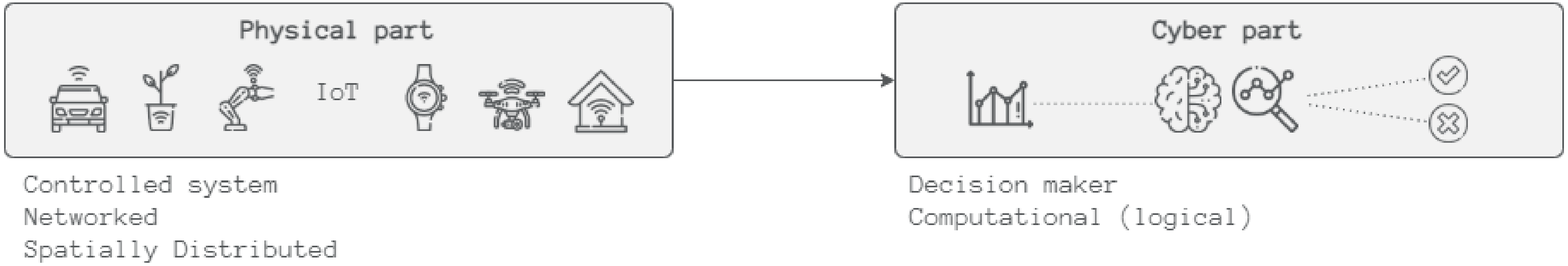
Conclusions

Introduction

- Description
- Objectives

Description

- CPS (Cyber Physical Systems) is one of the systems that can exploit an IoT infrastructure
  - IoT is a field that is growing fast (2030 → 25,44 billion worldwide connected devices)
  - In CPS physical systems are monitored and/or controlled by a computational core
    - Monitoring is an activity related to the wider category of Runtime Verification (RV)
  - The increasing numbers of IoT devices and intelligent systems made CPS influence society



Objectives

This project focuses precisely on the challenges when doing monitoring on CPS over IoT.

☑ Feed MoonLight monitor with live data

☑ Implement a middleware that offers different services

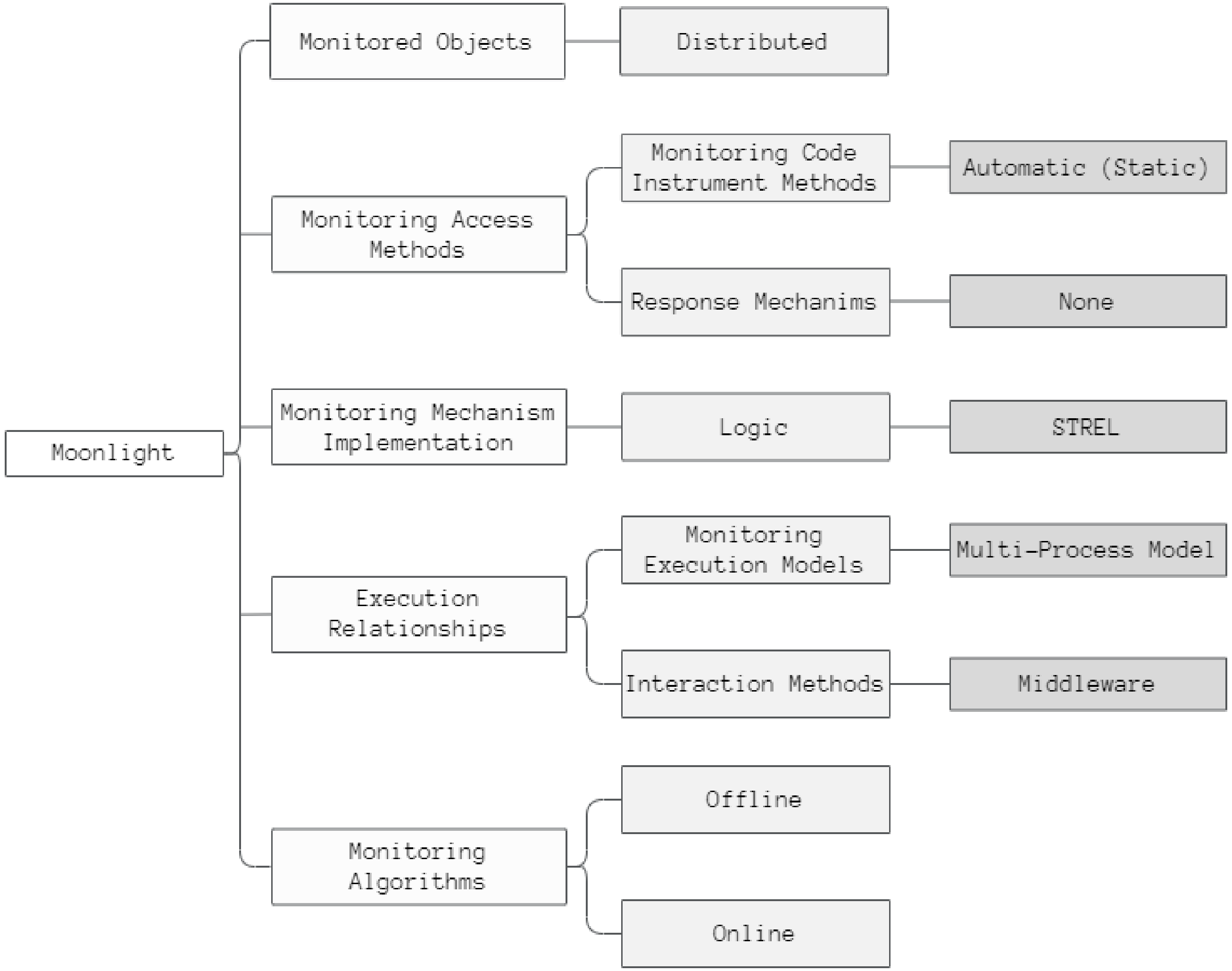
☑ Establish the communication between the sensors and the monitor

☑ Show the results to the user

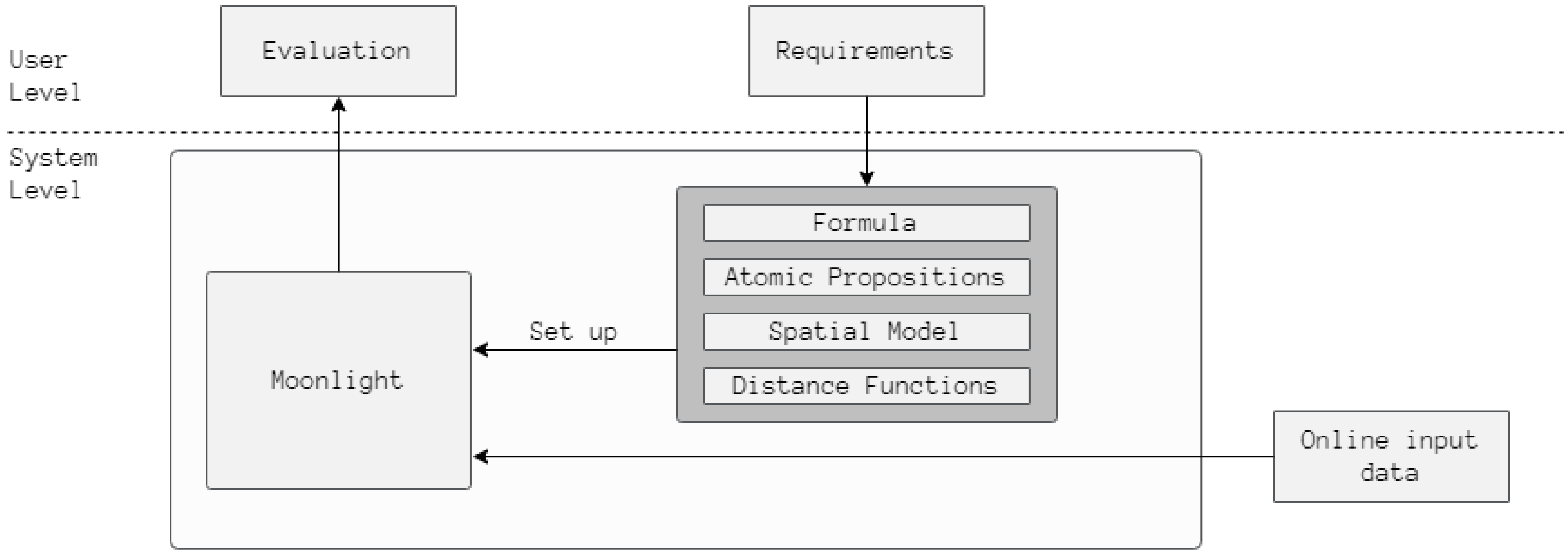
Development

- Moonlight features
- Moonlight online monitor
- Middleware
- Services
- Service Oriented Architecture
- Physical system
- Use case

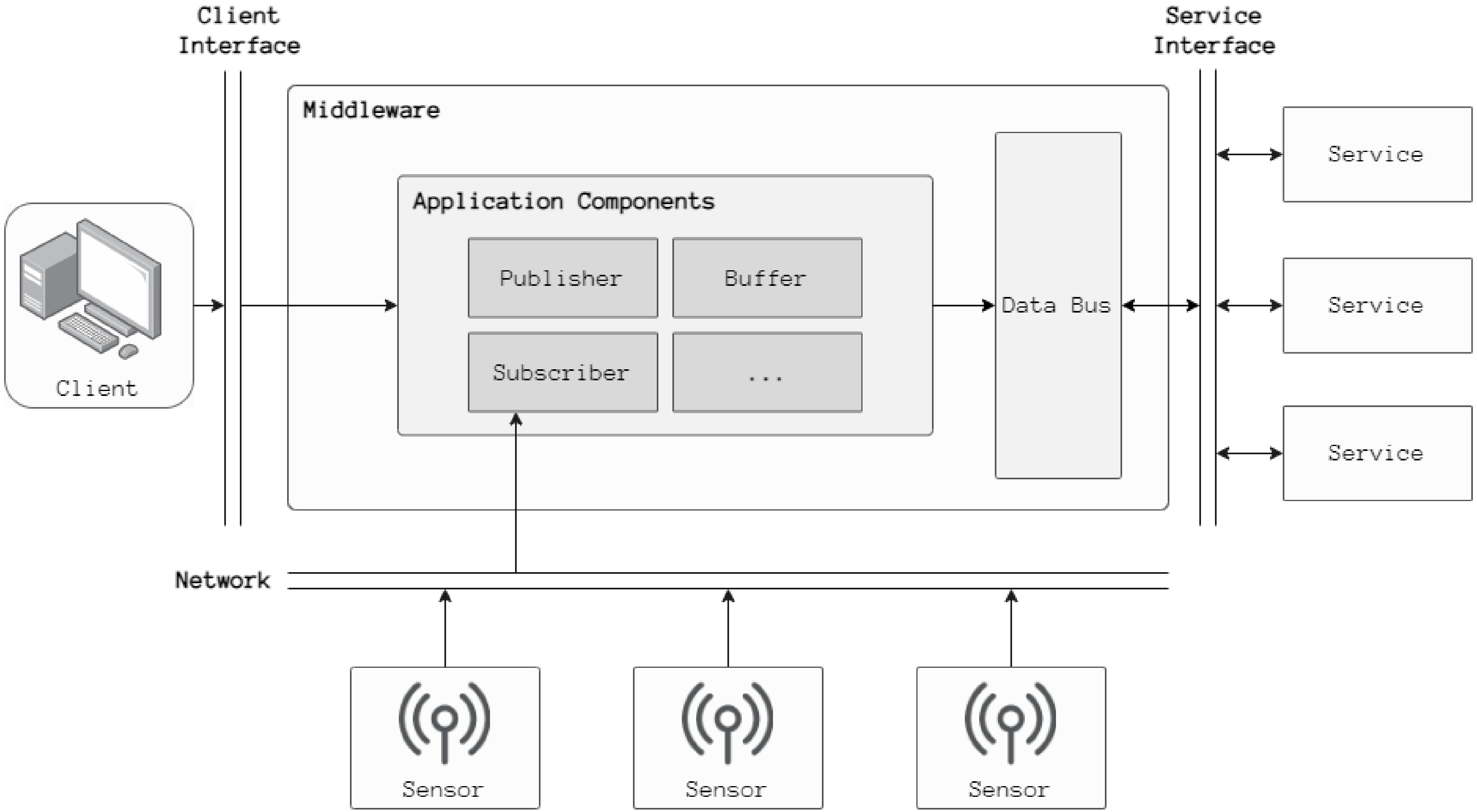
Moonlight features



Moonlight online monitor



Middleware


Client
Interface
Service
Interface
Middleware
Application Components
Publisher
Buffer
Subscriber
...
Data Bus
Service
Service
Service
Client
Network
Sensor
Sensor
Sensor

Services

- **Sensor service**

Receives the messages of the sensors.

Communication using MQTT

- **Moonlight service**

Converts the raw data to be adequate for the monitor

Save the values in a buffer

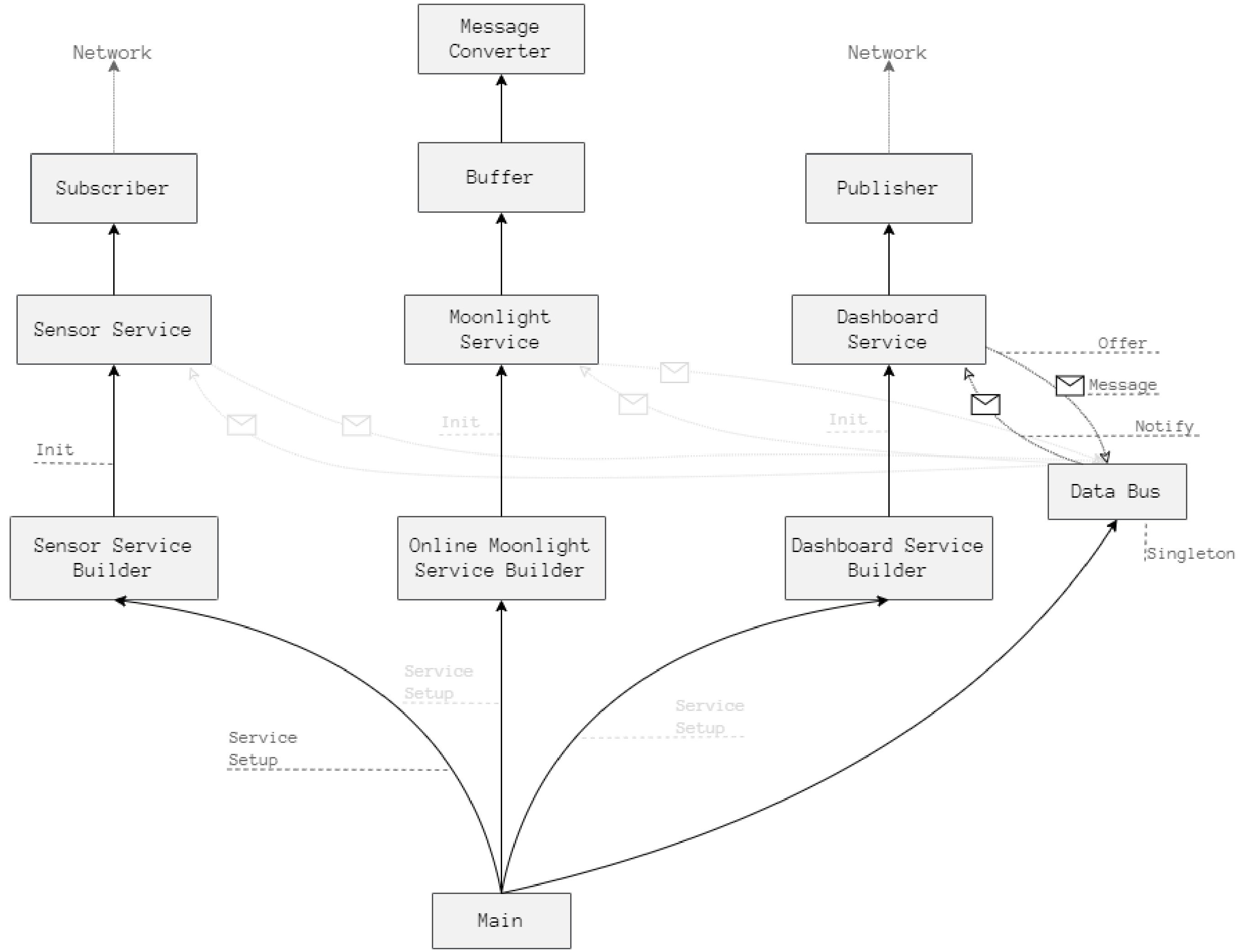
Monitor the input data

- **Thingsboard service**

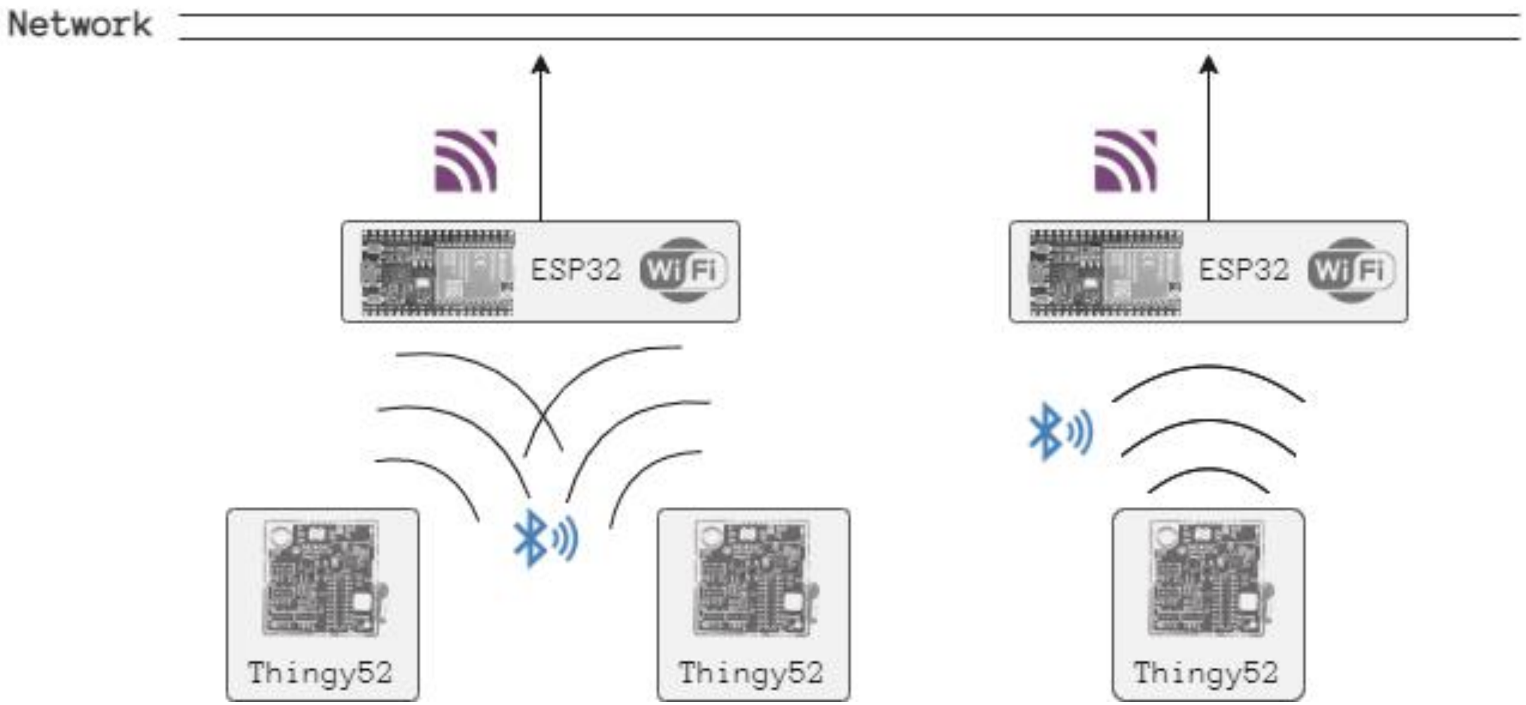
Sends the system’s information to the dashboard using MQTT

1. The sensors values
2. Monitor results

Service Oriented Architecture



Physical system



Use case

Office use case

The environmental conditions must be adequate:

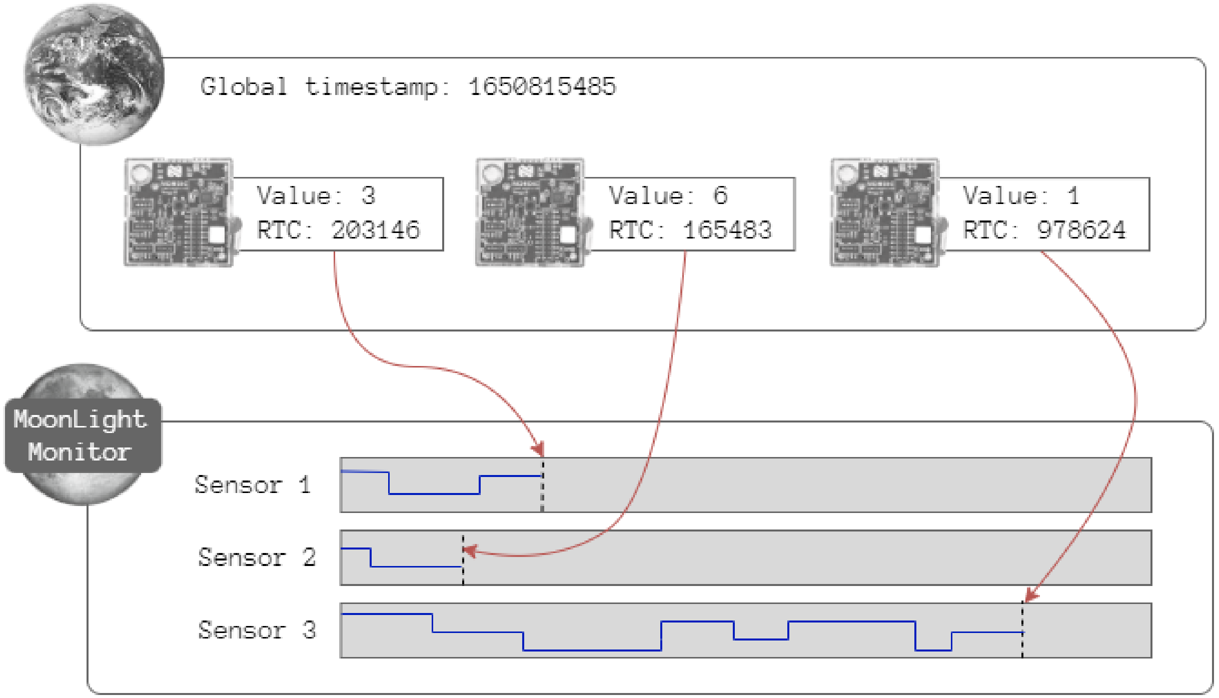
$$\text{Temperature} < 30\text{ºC}$$
$$\wedge$$
$$(\text{CO2} > 600) \rightarrow F_{[0,1500]}(\text{CO2} < 600)$$

Problems and solutions

- Sensors time synchronization
- Missing values and imprecise signals
- Other problems

Sensors time synchronization

PROBLEM



SOLUTION

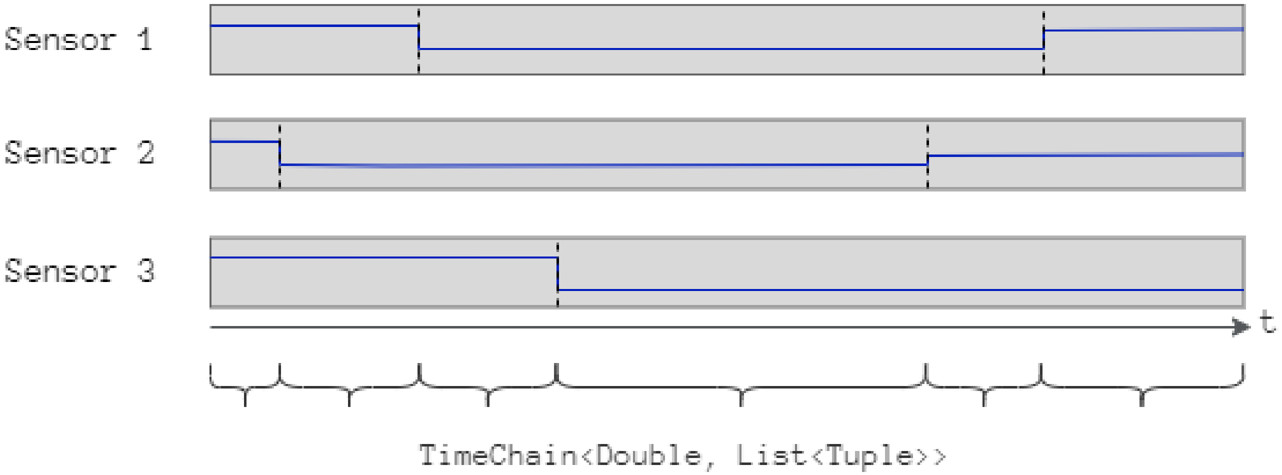
Time List
203146
165483
97624

Missing values and imprecise signals

PROBLEM

- Not all the sensors send the data at the same time
- There are gaps between each sensor's messages
- The time interval between messages can change

SOLUTION



ESP problems

PROBLEM

SOLUTION

- The ESP is not stable
  - Sometimes it doesn’t connect to the MQTT
  - Sometimes the connections are abruptly interrupted
- It does not have a long memory
  - Disconnecting and connecting multiple times to the Thingy52s consume a lot of memory and it crushes → Set permanent connections
  - It can’t handle more than 3 BLE connections at the same time → Program each ESP to connect to less than 4 Thingys

Other problems

- MoonlightRecord (a Moonlight java class) had some problems:

  Escape formula + online monitor + MoonlightRecord = infinite loop

  MoonlightRecord null values didn’t throw errors, wrong error handling

  Solution: Notify this error to Ennio → He created Tuple a class that works in the same way but without problems

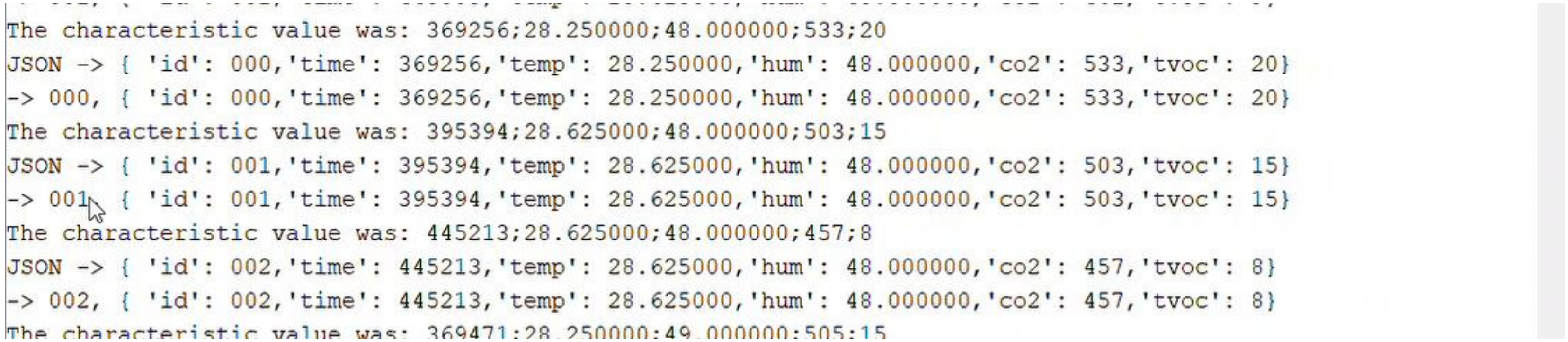
- I was having problems with Windows + Zephyr project

  Solution: Use ubuntu

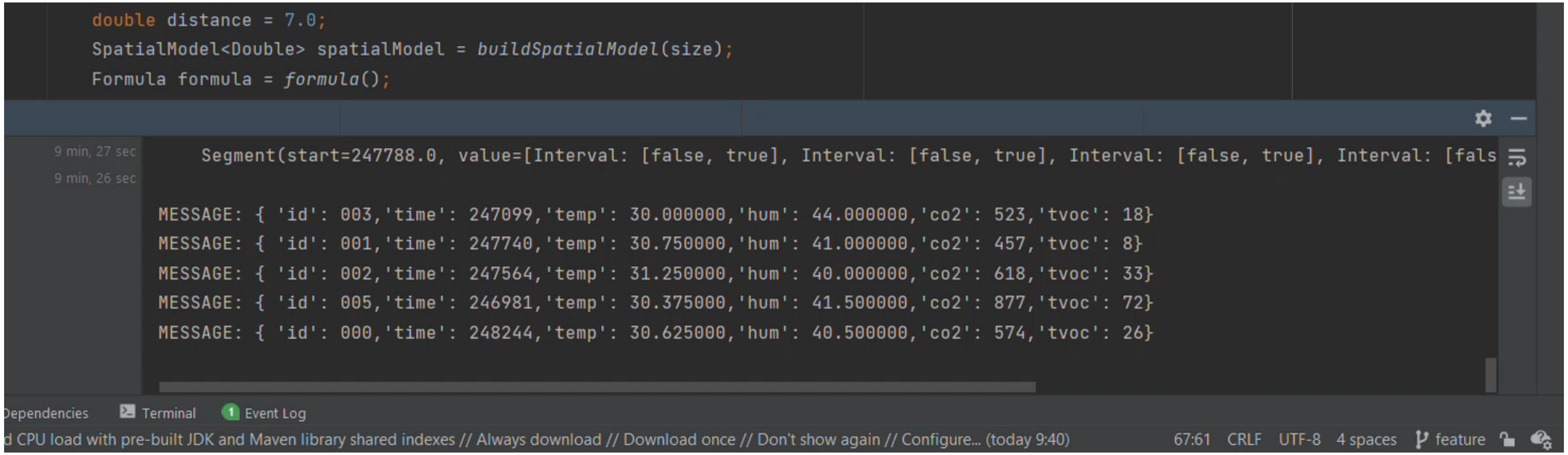
Work done until now

- Results
- June prospect

Results



```
The characteristic value was: 369256;28.250000;48.000000;533;20
JSON -> { 'id': 000,'time': 369256,'temp': 28.250000,'hum': 48.000000,'co2': 533,'tvoc': 20}
-> 000, { 'id': 000,'time': 369256,'temp': 28.250000,'hum': 48.000000,'co2': 533,'tvoc': 20}
The characteristic value was: 395394;28.625000;48.000000;503;15
JSON -> { 'id': 001,'time': 395394,'temp': 28.625000,'hum': 48.000000,'co2': 503,'tvoc': 15}
-> 001, { 'id': 001,'time': 395394,'temp': 28.625000,'hum': 48.000000,'co2': 503,'tvoc': 15}
The characteristic value was: 445213;28.625000;48.000000;457;8
JSON -> { 'id': 002,'time': 445213,'temp': 28.625000,'hum': 48.000000,'co2': 457,'tvoc': 8}
-> 002, { 'id': 002,'time': 445213,'temp': 28.625000,'hum': 48.000000,'co2': 457,'tvoc': 8}
The characteristic value was: 369471;28.250000;49.000000;505;15
```



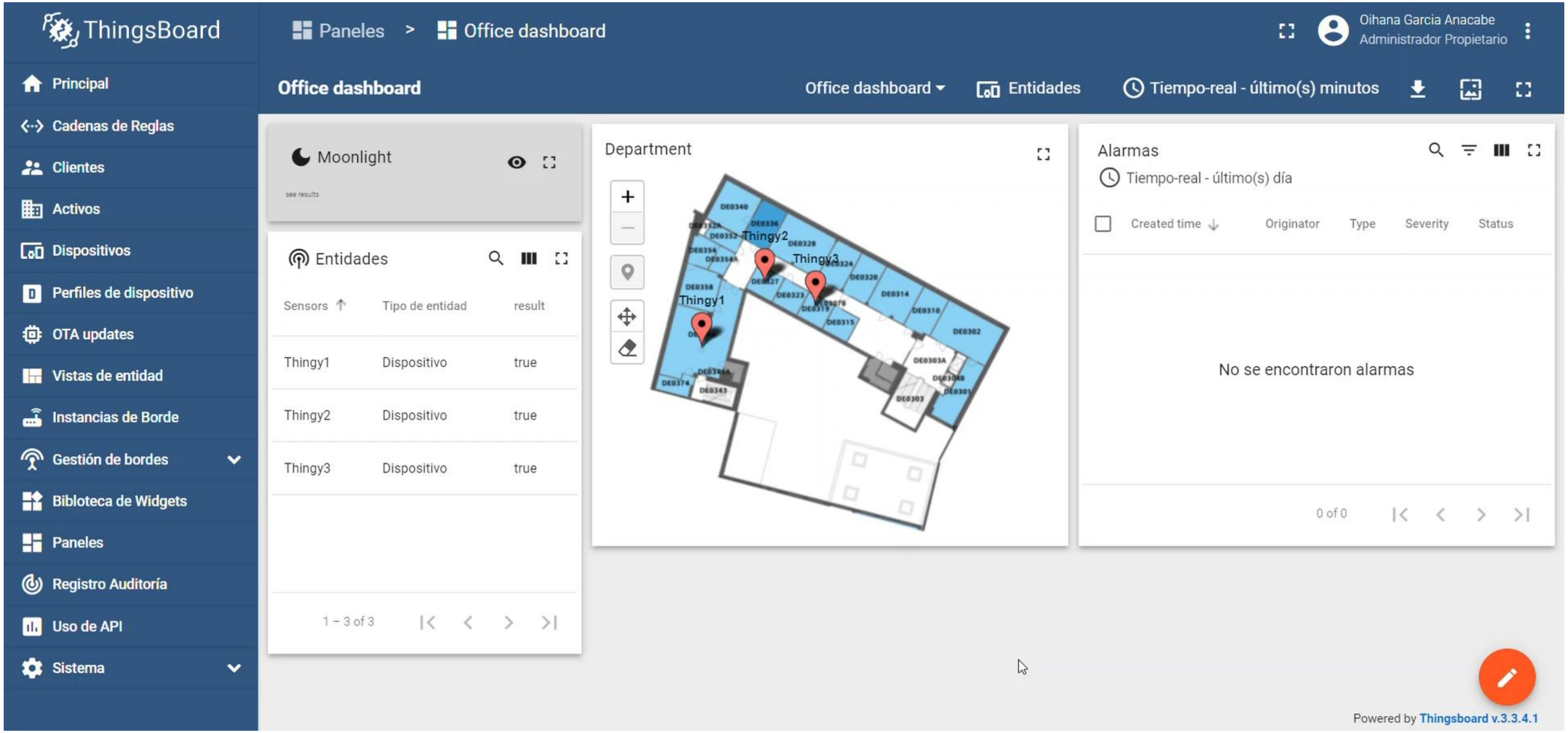
```
    double distance = 7.0;
    SpatialModel<Double> spatialModel = buildSpatialModel(size);
    Formula formula = formula();
```

```
    Segment(start=247788.0, value=[Interval: [false, true], Interval: [false, true], Interval: [false, true], Interval: [fals

MESSAGE: { 'id': 003,'time': 247099,'temp': 30.000000,'hum': 44.000000,'co2': 523,'tvoc': 18}
MESSAGE: { 'id': 001,'time': 247740,'temp': 30.750000,'hum': 41.000000,'co2': 457,'tvoc': 8}
MESSAGE: { 'id': 002,'time': 247564,'temp': 31.250000,'hum': 40.000000,'co2': 618,'tvoc': 33}
MESSAGE: { 'id': 005,'time': 246981,'temp': 30.375000,'hum': 41.500000,'co2': 877,'tvoc': 72}
MESSAGE: { 'id': 000,'time': 248244,'temp': 30.625000,'hum': 40.500000,'co2': 574,'tvoc': 26}
```

d CPU load with pre-built JDK and Maven library shared indexes // Always download // Download once // Don't show again // Configure... (today 9:40) http://thingsboard.stefanschupp.de/dashboard/5f30bde0-d68f-11ec-9ec4-a14ea361d371?publicId=0587e3b0-d750-11ec-9ec4-a14ea361d371

Results



Entidades

Sensors ↑	Tipo de entidad	result
Thingy1	Dispositivo	true
Thingy2	Dispositivo	true
Thingy3	Dispositivo	true

1 – 3 of 3

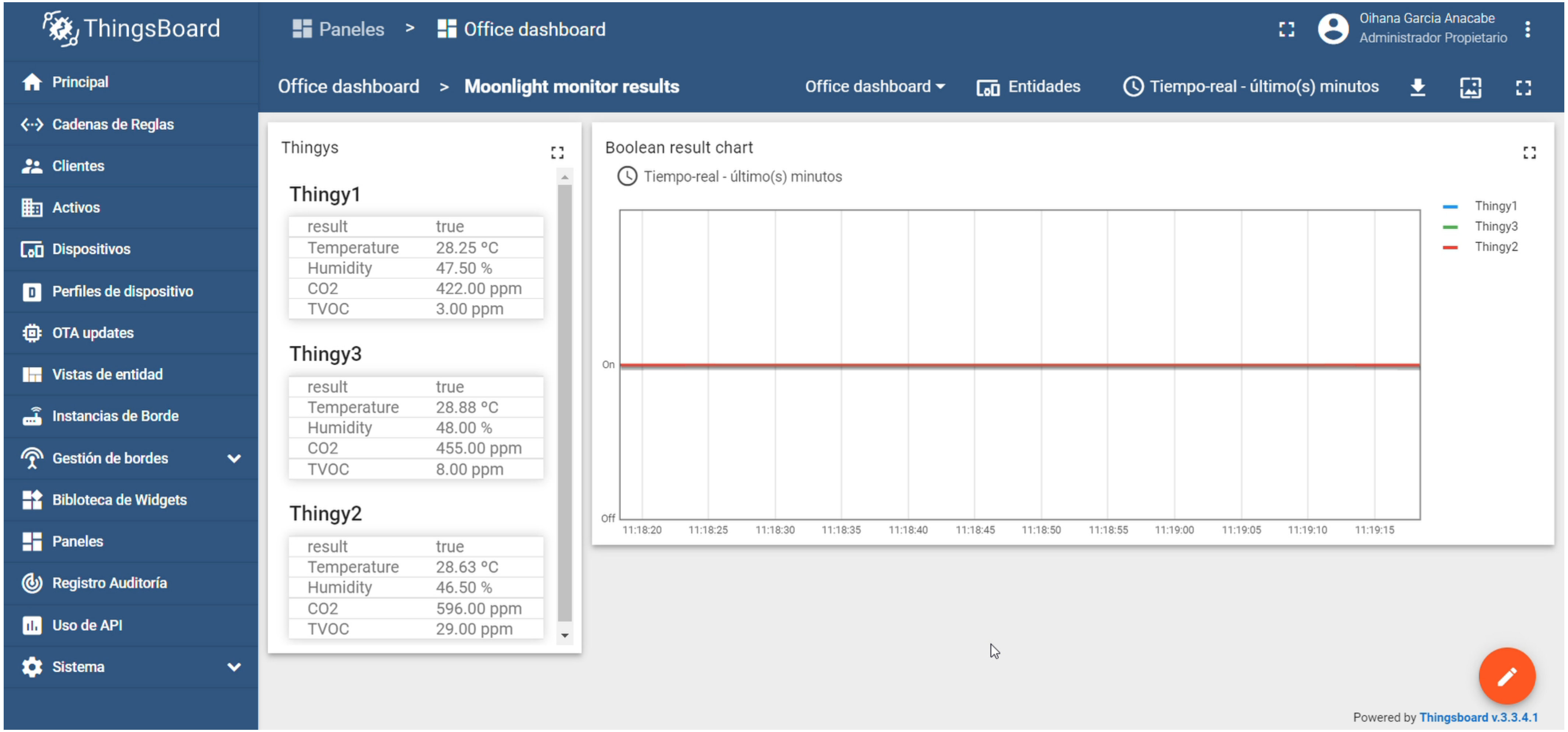
□	Created time ↓	Originator	Type	Severity	Status

No se encontraron alarmas

0 of 0

http://thingsboard.stefanschupp.de/dashboard/5f30bde0-d68f-11ec-9ec4-a14ea361d371?publicId=0587e3b0-d750-11ec-9ec4-a14ea361d371

Results



Thingy1

result	true
Temperature	28.25 °C
Humidity	47.50 %
CO2	422.00 ppm
TVOC	3.00 ppm

Thingy3

result	true
Temperature	28.88 °C
Humidity	48.00 %
CO2	455.00 ppm
TVOC	8.00 ppm

Thingy2

result	true
Temperature	28.63 °C
Humidity	46.50 %
CO2	596.00 ppm
TVOC	29.00 ppm

June prospect

- Client
  - Let the client customize the monitor’s features
- Add another use case
  - Wiener Linien use case

Conclusions

- Technical conclusions
- Methodological conclusions

Technical conclusions

The proposed objectives are reached:

Moonlight monitor is fed with live data

The middleware is implemented

The communication from the sensors, to the monitor and to the dashboard works

Methodological conclusions

Moonlight monitor has been implemented in real-life systems. Based on the use cases, Moonlight has been proven to be a suitable monitor for CPS.

- Currently the available tools for monitoring formal specifications are restricted to temporal properties
- It is a usable tool that can handle spatio-temporal properties in an online way

Thank you

Eskerrik asko