Mobility platform in Aveiro Tech City Living Lab Infrastructure

Milestone 4

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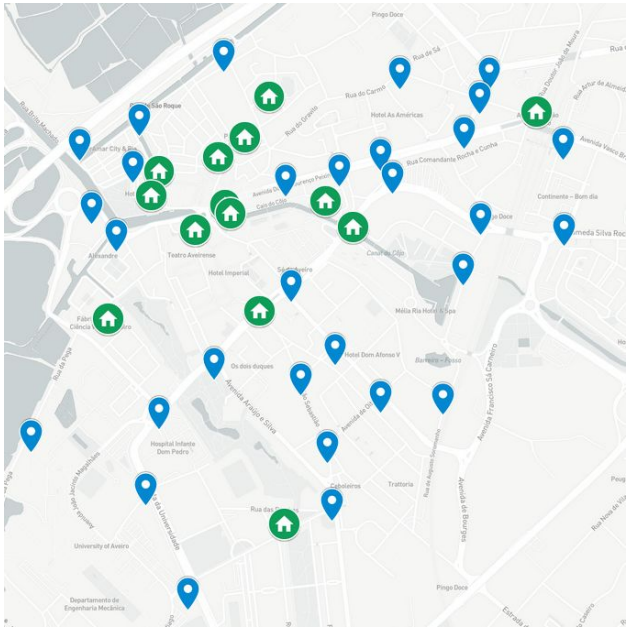
Introduction

Context

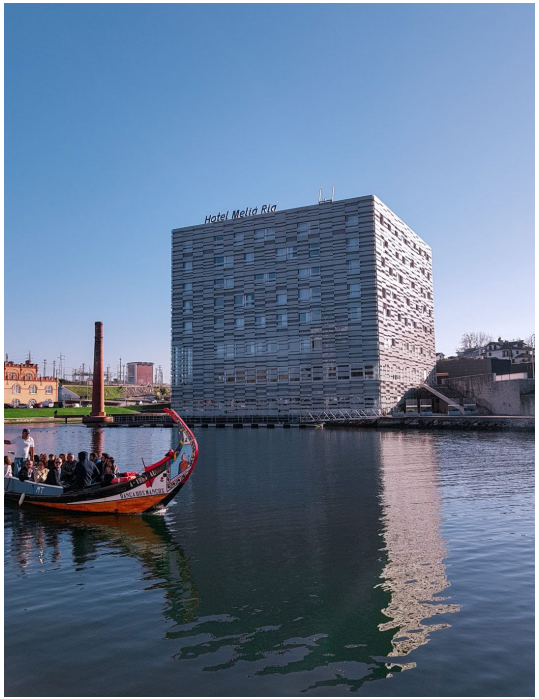
- In Aveiro there are 44 stations installed and interconnected with fibre
- The stations contain environmental sensors, radars, LIDARs, video cameras and computer edge units
- This infrastructure is connected to the data center in IT
- **Goal**: build a tech city living lab as a complete connected city to experiment future services and applications in a real environment



green home → buildings
blue pins → smart lamp posts

Problem

- Enrich the Aveiro Tech City Living Lab (ATCLL) infrastructure in order to improve the lifestyle of citizens and for research purposes
- The Aveiro's Town Hall proposed a task:
  - To monitor people in public spaces
  - To monitor the quantity and frequency of *moliceiros* in the *Ria de Aveiro*
  - To monitor people in the *moliceiros* in the *Ria de Aveiro*



Initial goals (I)

- Develop solutions to get values from the sensors and understand which type of sensors to use
- Develop mechanisms to detect people, *moliceiros*, movement, etc.
    - Use of different sensors
        - WiFi devices detection
        - Video AI for object detection
    - Sensor fusion and processing

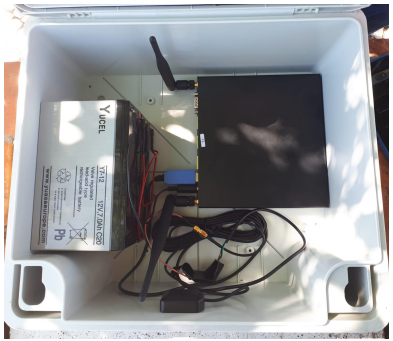
Initial goals (II)

- Develop a subscription broker to accumulate past and real time data
- Develop a web application to show the subscription broker’s data
- Overall data processing, persistence, analytics and visualization in the web application
- Improve team-working skills and learn how to work with new technologies and equipments
- Documentation writing

How to?

- Collect information regarding the number of people, cars, bicycles and moliceiros in certain areas of the city
- Use of object detection models to count the objects from the live video of cameras
- Use of Wi-Fi sniffing to count the number of devices near the smart lamp post
- Display of the data in a dashboard so that it may be observed by the public

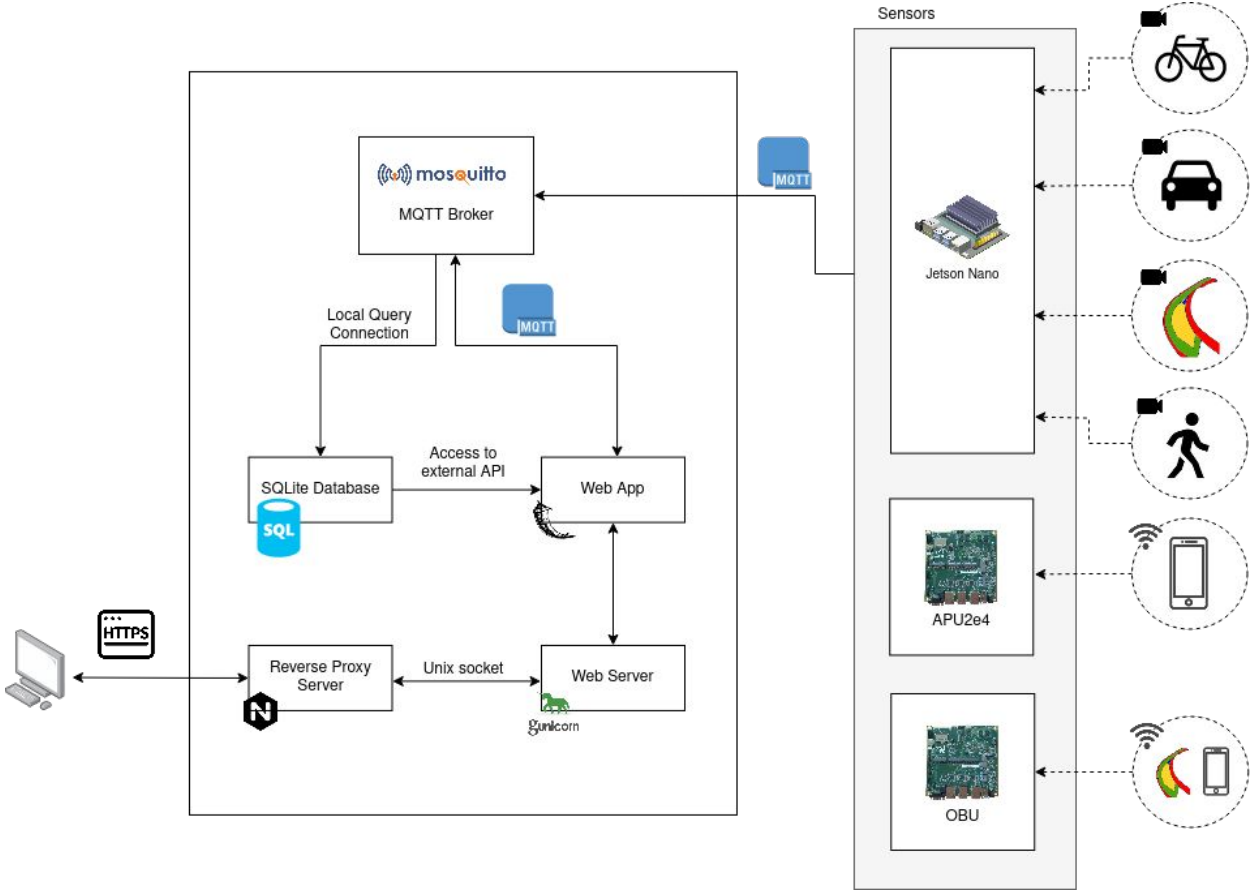
Our resources



Expected Results

- Detection mechanisms:
  - Vision and communication-based
  - Objects and movement
  - Aggregated detection
- A web application to present the results obtained in real-time as well as past results
  - Detection of people, *moliceiros* and vehicle movements
  - Analysis of the collected data
- Make use of the infrastructure to integrate people and *moliceiros*
- Expand the Aveiro Tech City Living Lab project

Architecture of the project



Data Acquisition

Detection Module (I)

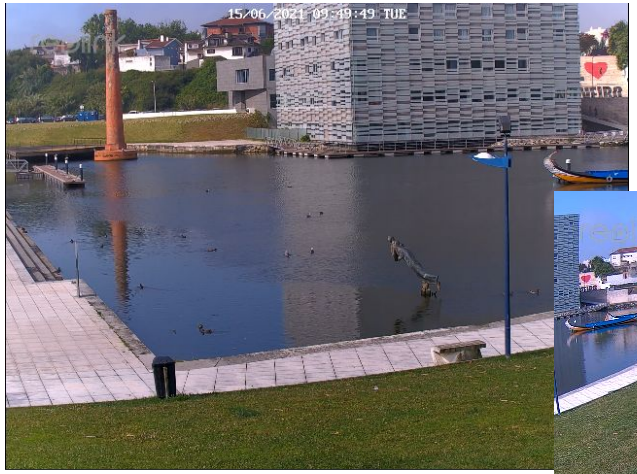
- Use of a Nvidia Software Development Kit, DeepStream, which was installed in two Jetson Nanos to allow video streaming analysis
- Detection of people, vehicles, two wheeler vehicles and moliceiros using python scripts
- Data sent to two topics of each local broker and then received by IT's central MQTT broker to be persisted
- The web application backend receives the data and displays it in the dashboard

Detection Module (II)

Problem	Solution
Loss of frames due to clock discrepancies	Script adjusted based on information found in Nvidia forums
Values very high due to noise in the image	Search of false detection patterns to filter of unwanted areas and adjustment of the threshold
No DeepStream model to perform *moliceiros* detection	Use of python library OpenCV
Impossibility of using OpenCV and DeepStream at the same time in the same Jetson Nano	To be solved in future work

Detection Module (III)

- Three different positions of the camera



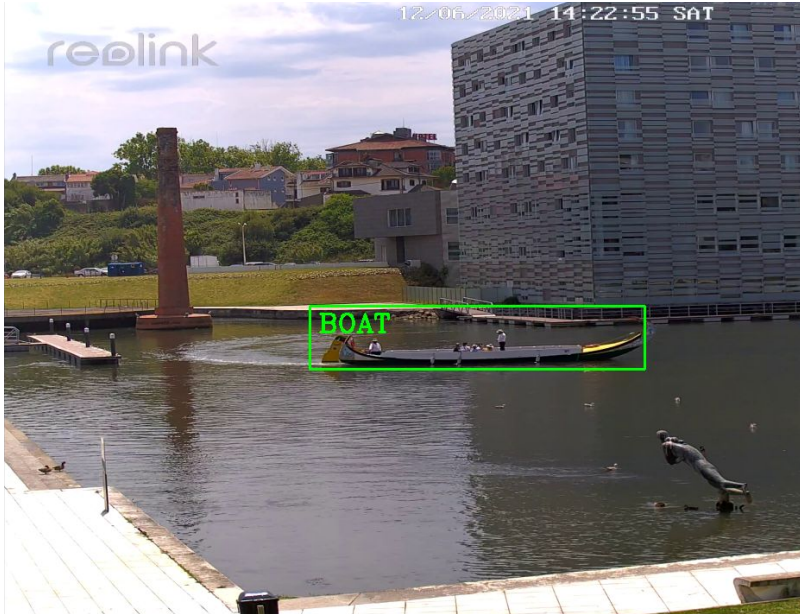
Moliceiros + People position

People position

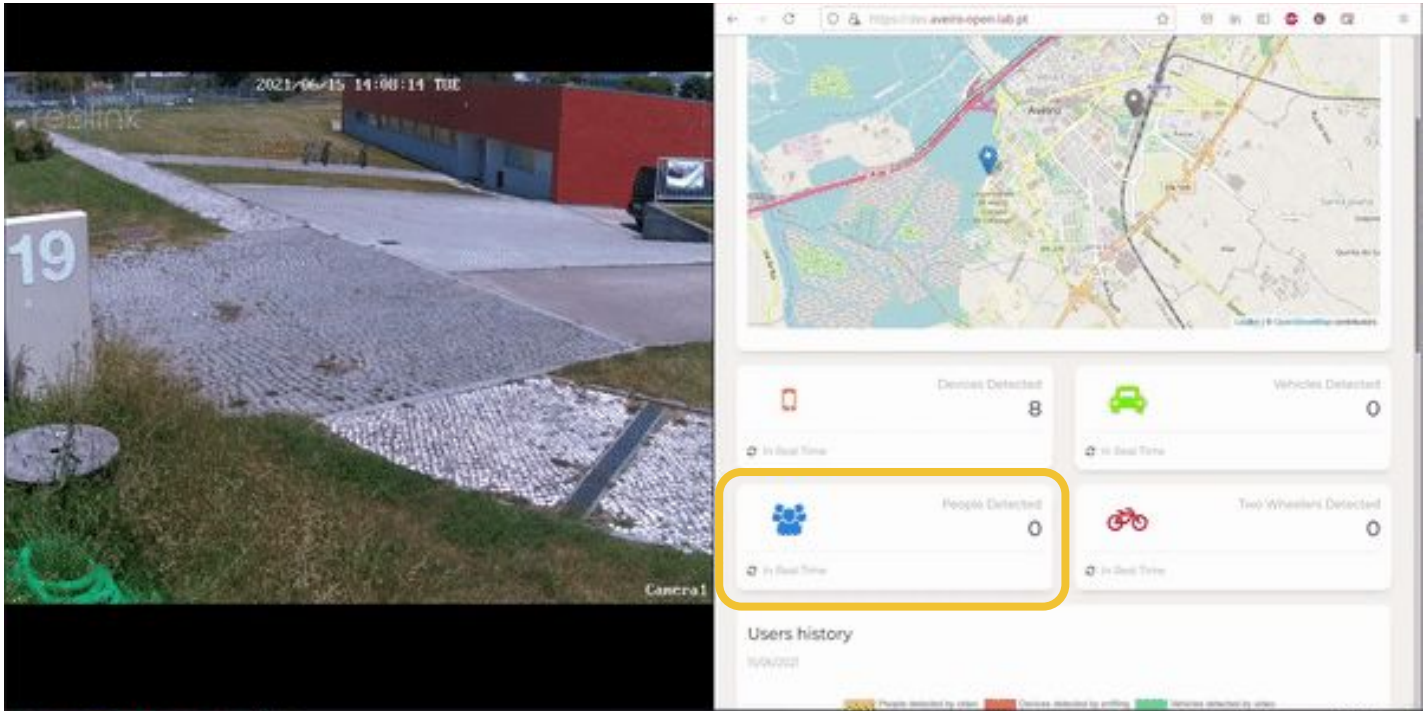
Cars + People position

Detection Module (IV)

- Detection of people, vehicles, two wheeler vehicles and moliceiros
- Frame processing of 30 FPS



Detection Module (V)



WiFi Detection Module (I)

- Detection of devices near the smart lamp posts through WiFi
- Estimation of the current number of devices in real time as well as the number of different people that pass near the Smart Lamp Posts
- Send data to the central broker in order to be persisted and shown in the web application

WiFi Detection Module (II)

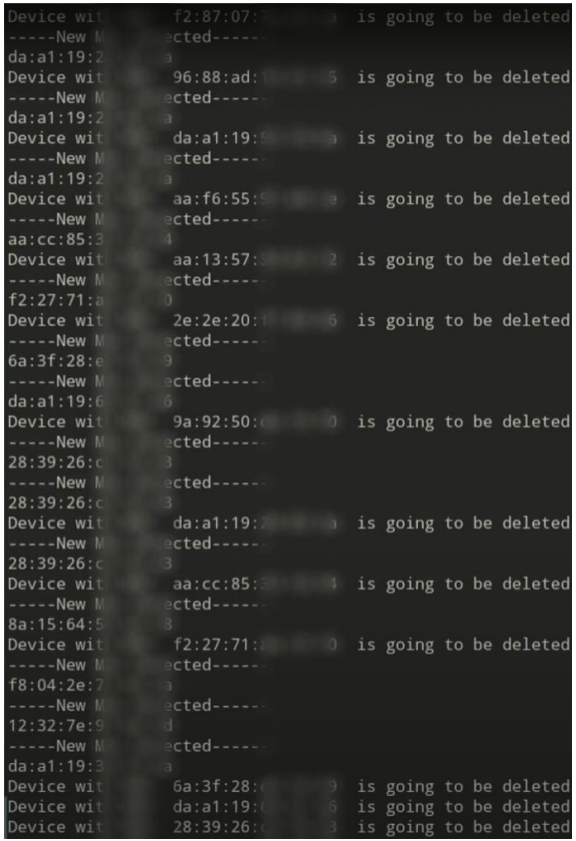
- The sniffing module captures WiFi probe request packets through the APU's/OBU's wireless network adapter set in monitor mode
- Every time a new packet is captured, the handler extracts the sender's mac address and stores it
- The current nearby MAC addresses are stored in a list and deleted after 5 seconds of not emitting probe requests
- The unique devices are stored in a set which is cleared in intervals of 10 minutes
- This data is sent to the 2 topics of each local broker and then is received by the IT's central MQTT Broker where data is persisted.

WiFi Detection Module (III)

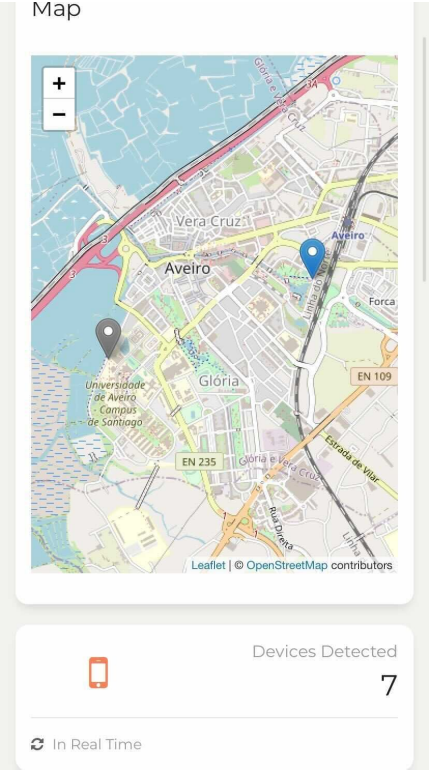
Problem	Solution
The sniffing module used 100% of the APU's CPU which led to a crash in the APU	Use of another program to capture and filter packets in order to diminish the CPU usage: *pyshark*
Routers probe requests were being counted as a device	Excluded packets that contained an SSID and that were not broadcasted
Very high number of devices detected	Adjusted the detected packages time to live to obtain more accurate results

WiFi Detection Module (IV)

- We are able to detect devices near the Smart Lamp Posts with a good level of confidence



WiFi Detection Module (V)



Sensor information BOT Hoje às 18:43

[Sniffing_p1] Avg: 20.9

[Sniffing_p22] Avg: 31.1

[Sniffing] More than 40 unique devices! Current Devices: 8

[Sniffing_p1] Avg: 37.5

[Sniffing_p22] Avg: 30.8

[P22 Object Detection] More than 25 people!2

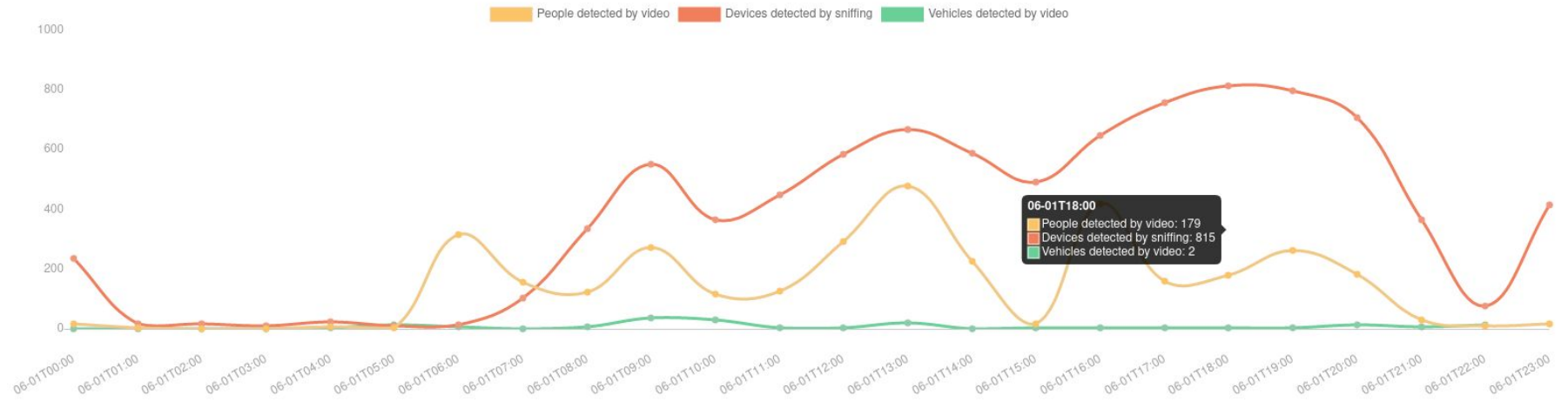
[Sniffing] More than 40 unique devices! Current Devices: 5

Users history

Into Detail

Start Date: 01/06/2021 Start Time: 00:00

End Date: 01/06/2021 End Time: 23:00 APPLY

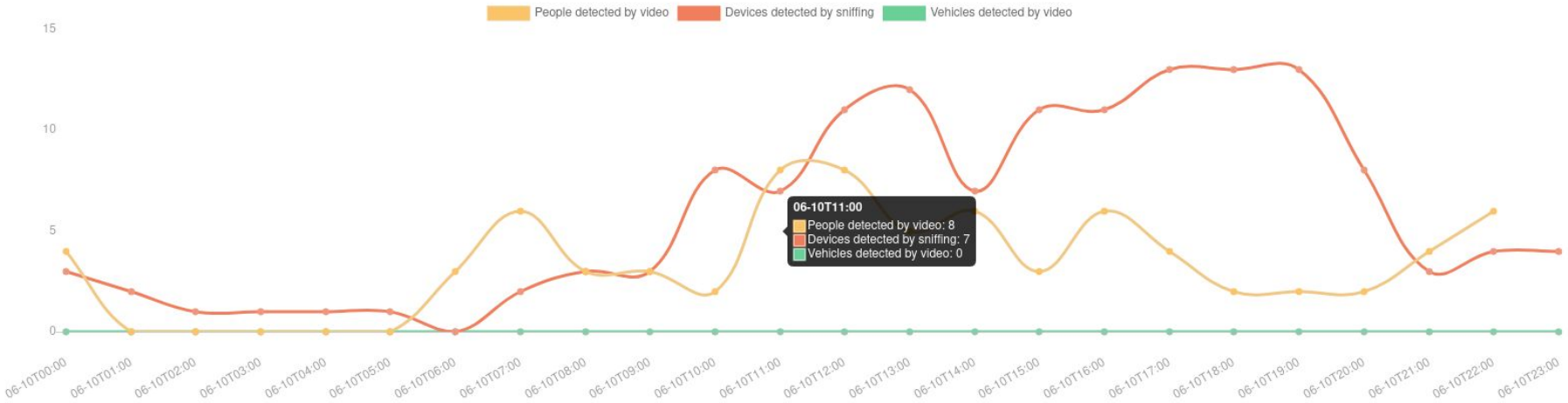


Users history

Into Detail

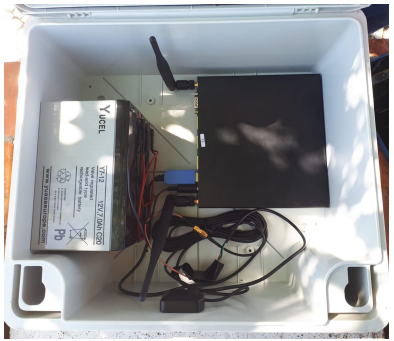
Start Date: 10 / 06 / 2021 Start Time: 00 : 00

End Date: 10 / 06 / 2021 End Time: 23 : 00 APPLY



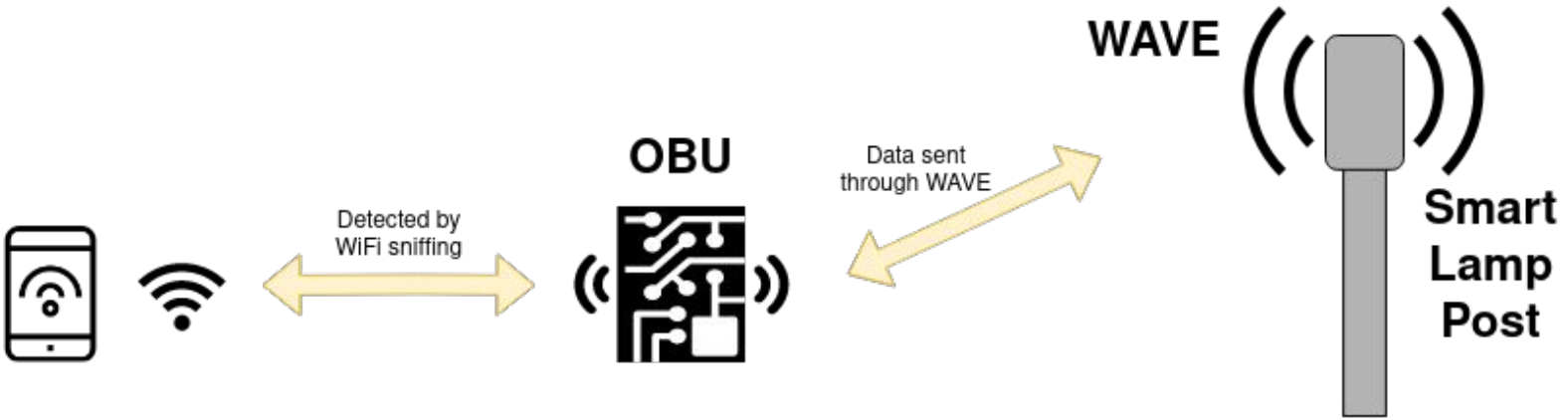
OBUs (On-Board Units) (I)

- Estimation of the number of people inside moliceiros using detection of devices through WiFi Detection
- 1 OBU includes 2 batteries, 1 APU and 1 GPS module
- Visualization of the location of the moliceiros via the GPS coordinates



OBUs (On-Board Units) (II)

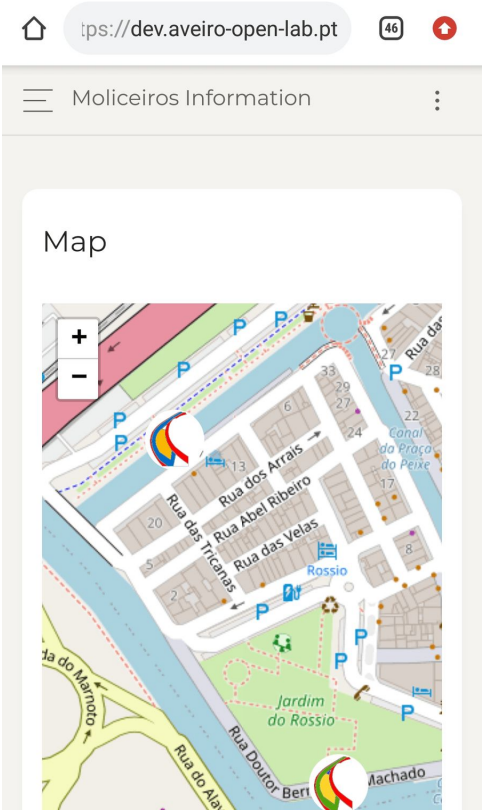
- OBUs in *moliceiros* do not have direct connection to the internet/ATCLL's network
- Using the smart lamp posts near the *Ria de Aveiro* (RSUs) the OBUs send data through WAVE to the central server



OBUs (On-Board Units) (III)

Problem	Solution
Low Signal Strength	Repositioned the OBU to a higher open place in the moliceiros
Higher than expected battery consumption	Placed two batteries in parallel per OBU
Very high number of devices detected	Adjusted the detected packages time to live to obtain more accurate results

OBUs (On-Board Units) (IV)



Web Application

Web Application - Goals

- Display the collected data from the sensors in real-time
  - Cars, People, Devices.
- Display *moliceiros* moving in a map based on the GPS location
- Show past-time data from the sensors
  - Based on user’s input
  - Last 24 hours

Web Application - Back End

Back End - Problems

Problem	Solution
Web Sockets didn’t send any data	Use of Server Sent Events (SSEs)
SSEs have a maximum of 6 events at a time	Optimization of the number of SSEs used
Access to the cameras API was limited because it was closed-sourced	Reverse engineering of the camera’s API to access its controls from the Back End

Back End - Results

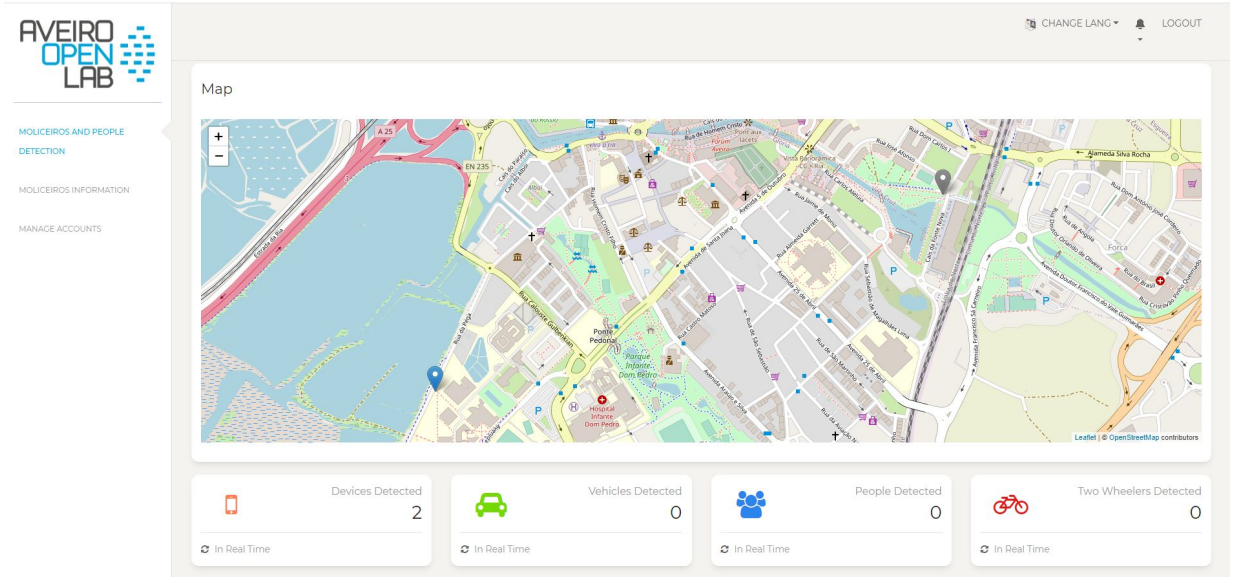
- Back End service : Flask
- Subscription to the central broker topics to obtain the real time data
- Access to an external API to obtain persisted data
- Use of Server Sent Events (SSE) to send the data to the dashboard
- Development of an API to simplify and facilitate the access to information
- Implementation of an account system, to manage access to certain information

Web Application - Front End

Front End - Results (I)

Moliceiros and People Detection

- Map that allows users to switch between Smart Lamp Posts



Front End - Results (II)

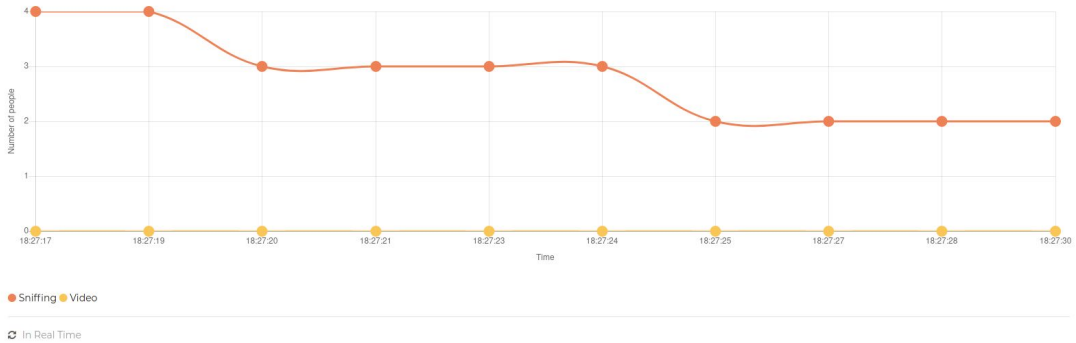
Moliceiros and People Detection

- Display data of real time sniffing, people, cars, two wheelers and moliceiros detection in cards, based on location

Front End - Results (III)

Moliceiros and People Detection

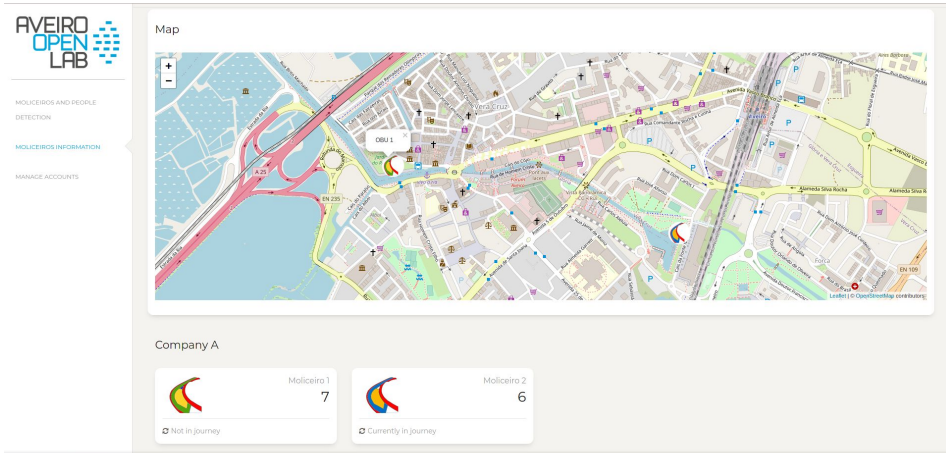
- Visualization of past values in a chart
  - According to a date and time filter
  - Last 24 hours
  - Last 10 real-time values



Front End - Results (IV)

Moliceiros information

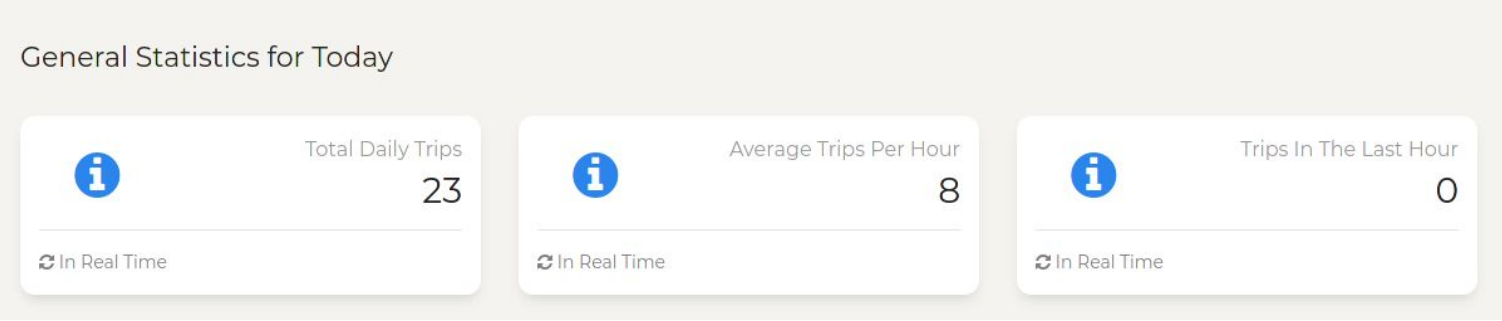
- Display data of real time sniffing in moliceiros in cards, for each moliceiro
- Display *moliceiro*'s locations in map



Front End - Results (V)

Moliceiros information

- Display general statistics of moliceiros in a day
  - Total daily trips
  - Average trips per hour
  - Trips in the last hour



Front End - Results (VI)

Moliceiros information

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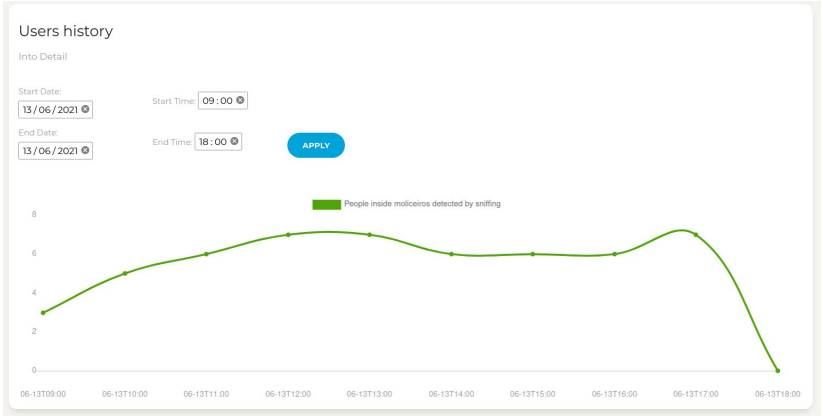
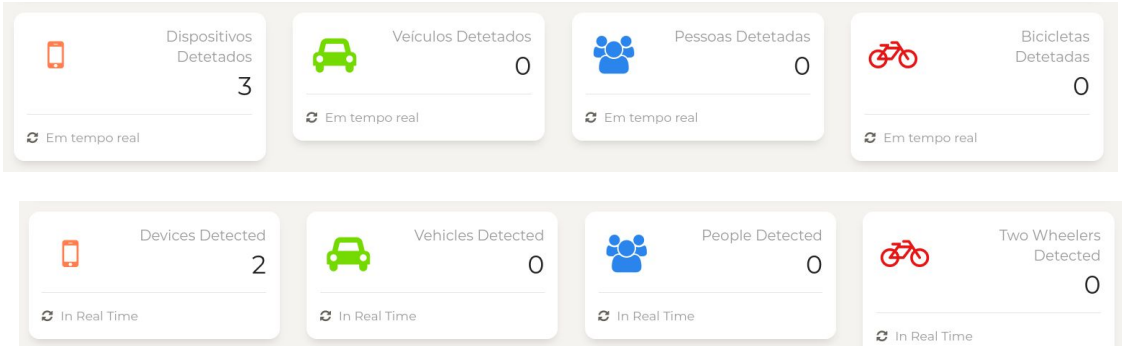


Front End - Results (VII)

General

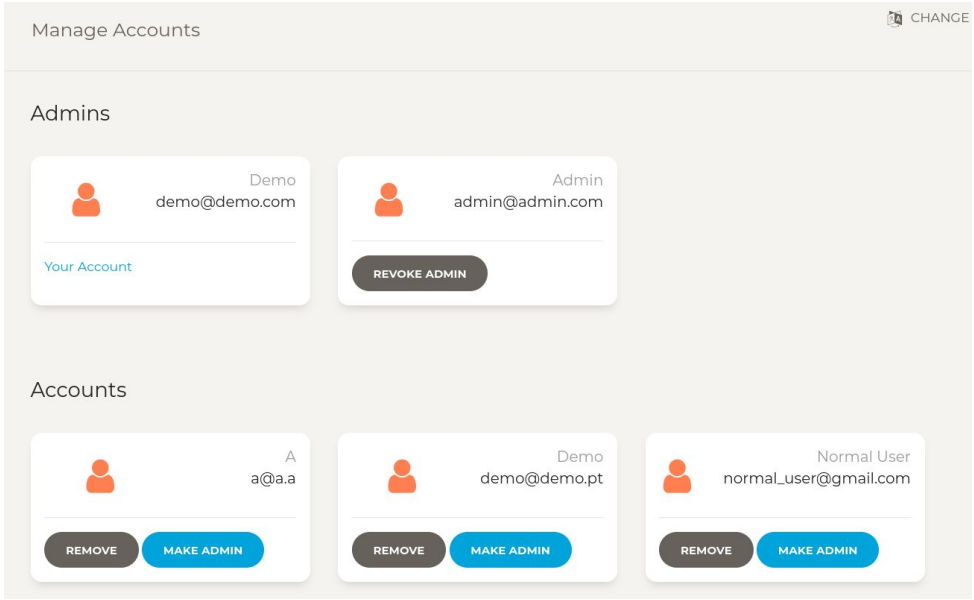
- Language translations



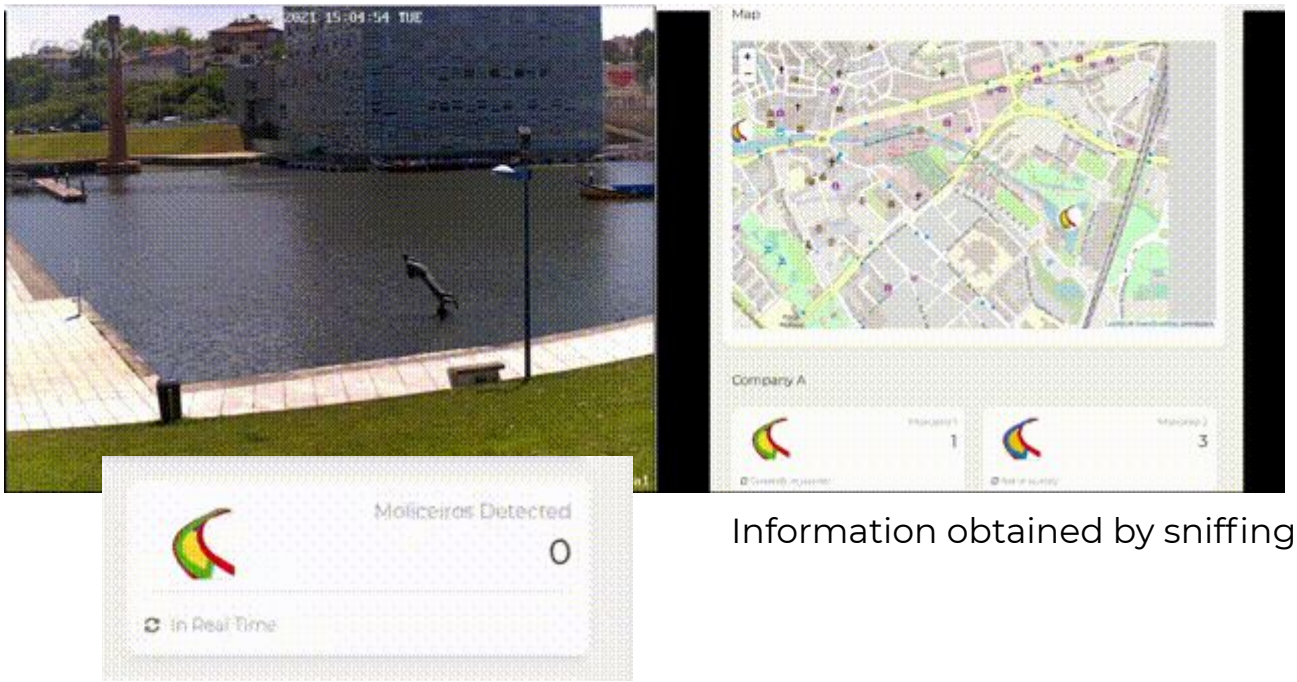
Front End - Results (VIII)

General

- Account system to protect *moliceiros* information



Front End - Results (IX)



Information obtained by sniffing

Moliceiros Detection using the camera

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- Documentation writing

Achieved goals

- All initial goals were achieved!

Extra goals achieved

- Use of OBUs (On-Board Units) in the middle step between the smartphones and the edge devices
- OBUs with Wi-Fi sniffing
- Estimation of the number of people inside a *moliceiro* by detecting how many devices are in proximity

Future Work

- Increase the accuracy of the number of devices detected through Wi-Fi Sniffing
- Implement the detection of *moliceiros*, people and vehicles using the same model and coordinating with the different positions of the camera
- Implement the data acquisition in other smart lamp posts in the city

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