About the infrastructure
The access infrastructure is supported on state-of-the-art fibre technology, reconfigurable radio units, 5G-NR radio and 5G network services, WiFi, LoRaWAN, Vehicular, and passive Radars, edge computing units, aggregating and interconnecting a panoply of sensors, such as environmental sensors, Lidars, Radars and mobility sensors, and remote information gathering units that extend throughout the urban area of the city of Aveiro.

The data gathering from all these elements provides the necessary conditions to support services and applications such as:

- Internet access for all citizens
- Internet of Things
- Mobility services and intermodal services
- Services for residents and tourists
- Environmental monitoring
- Distribution of info and multimedia content
- Emergency and health services
- New social responses
- Assisted driving, among others
The following figure represents the overall diagram of the infrastructure, architecture and services of the Aveiro Open Lab.

Fig. 1
Diagram of infrastructure, architecture and services of Aveiro Open Lab.
The access infrastructure is based on last generation fibre link technology (16km of length, depicted in Fig. 2), reconfigurable radio units and 5G network services, in 44 strategic places covering the urban area of Aveiro.

These points are deployed in a form of Smart Lamp Posts or wall boxes on building facades, and their location is depicted in Fig. 3.

**Fig. 2**
Map of the fiber deployment all over Aveiro. Red network is phase 1 (completed). Blue network is phase 2 (under completion).

**Fig. 3**
Map of the 44 points of the infrastructure deployed in Aveiro. Smart Lamp Posts are represented by blue points and wall boxes on building facades are represented by icons of green houses.
Examples of Smart Lamp Posts and wall boxes are depicted in Fig. 4 and 5, respectively.

For more examples, please visit the Aveiro Open Lab website and click on each point - the figure of the access infrastructure in that place will be shown.

**Fig. 5a**
Smart Lamp Post top structure drawing

**Fig. 5b**
Picture of Smart Lamp Post deployed in Aveiro.

**Fig. 6a**
SWall boxes for building facades drawing. Bigger box integrates all the equipment and the top box makes room for the antennas.

**Fig. 6b**
Wall boxes deployed in the Art Nouveau Museum of Aveiro.
Communication technologies, Computing units & Sensors

Acess Equipment
- 16km of fibre optic
- Wi-Fi access points
- Road Side Units
- Edge Computing Units
- LoRa Gateways
- LoRaWAN compatible Gateways
- 4G/5G Access Points (SDR based)
- Spectral probes

Central Equipment
- Datacenter
- Switches SDN with optical interfaces
- Servers
- Network monitoring and management system
- Data platform
- 4G/5G Core

Mobile Equipment
- Sensor units with LoRa communication (LoRaWAN compatible, if necessary)
- WiFi and vehicular communication units (WAVE), which can be upgraded to C-V2X, with the possibility of including 5G CPEs/5G terminals
The communications infrastructure integrates a communication network with radio terminals, multiprotocol, spread throughout the city, connected by fibre optics to a data processing centre (located at the Institute of Telecommunications - Fig. 7).

![Datacenter located in Instituto de Telecomunicações Aveiro.](image)

This network is complemented by mobile and fixed sensor equipment and mobile communication equipment installed in vehicles or carried by the STEAM City users.
Moreover, vehicular communication and sensors equipment are installed in buses and garbage collection vehicles, which currently record mobility and environmental data, making a complete live map of these parameters in the city, and providing the required data for traffic monitoring and safe driving systems.

The following equipment are some examples:
- Environmental sensors
- Mobility sensors (GPS, LiDARs and Radars)
- Wi-Fi Antennas

The mobile sensor equipment installed in public transport (10 buses) and 3 garbage collectors are composed of:

- **DCU** (Data Collection Unit, Fig. 8) which integrates Wi-Fi and LoRa communication to send the following information:
  - temperature
  - humidity
  - barometric pressure
  - UV radiation
  - ambient light
  - sonometer
  - GPS (latitude, longitude, altitude, speed);

- **OBU** (On-board Unit, Fig. 9) which integrates Wi-Fi, WAVE and cellular communication (ready to integrate 5G CPEs) to establish the connection with the RSUs (Road Side Units) and with the other vehicles.
Aveiro Open Lab makes use of mobile sensing devices and other geolocation sensors installed on vehicles (buses and municipality cars), bicycles and boats (“moliceiros”). The available mobile sensing information comprises GPS location, speed and heading, temperature and sound, which enables the complete mobility map of the city. In the future, it will also gather data from people’s smartphones through their connectivity in the city.

In addition to the physical communication infrastructure, Aveiro STEAM City’s team is deploying radars, LiDARs, video cameras and computing units. Information coming from these devices is aggregated and correlated to give insights on the people’s flow, providing concrete elements for new solutions on public transportation, bike sharing systems, safety-critical systems, and to identify problems and optimize the mobility in the city. This approach will be extended to the municipality vehicles, bicycles and boats in the city.
A set of Unmanned Aerial Vehicles (UAVs) are also considered as mobile sensing units to gather data from the city and give support to patrolling and traffic management.

Finally, a smart parking system is being installed in the train station new parking area in Aveiro, with sensors communicating to special gateways, providing real-time information of available parking spaces in the area, both to the Digital Urban Platform and the citizens.

**Examples of tests under development:**

Comprehensive statistics about driving profile (velocity, acceleration) in the city transportation system in space and time, analysing the most problematic areas and times and possible measures to improve safety.

**Fig. 10**

*Data of average speed of the buses represented in a map.*
Accurate measurement of the radio spectrum in points of interest in the city.

Figure 11 shows a real-time measurement of RF power in 4 frequency ranges and comparison to the maximum limit which is allowed to be transmitted.

Figure 12 is a record of the measurement of the spectrum in a number of frequencies over a duration of a week; it’s possible to identify the concentration of people during certain time intervals.

**Fig. 11**

*Measured power (blue) vs. maximum limit for the transmitting power (red) for different frequency ranges.*
Analysis of traffic flow in various points of the city (as well as entrances and exits), through LiDARs, radars and vehicles in communication.

Detection of people in dangerous situations (Vulnerable Road Users - VRUs - including crosswalks), with a real-time warning system to the vehicles approaching the crosswalk.

User app to enhance the citizen experience when searching for bus lines and destinations, which provides information about the bus location and expected time of arrival.

Determination of the level of exposure of citizens to potentially adverse environmental conditions in the city.

Traffic monitoring in intelligent transport systems, and/or safety such as autonomous coordination of priority vehicles to support emergency situations.

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*Fig. 12*

*Measured power in different frequencies of the spectrum during a week in the IT 2 entrance door.*
Third-party access to the infrastructure

Some partnerships are already ongoing with the Aveiro STEAM City project where they take advantage of the infrastructure of the Aveiro Open Lab.

- **Universidade de São Paulo / Universidade Federal do Rio Grande do Norte: Integration of the Helix platform in the Aveiro Open Lab infrastructure.**

The aim of this partnership is to evaluate and test the integration of the platform Helix Multi-layered (https://gethelix.org) with the Aveiro Open Lab infrastructure, in order to develop an architecture with support for IoT applications with low latency requirements or high density of devices. The diagram of the architecture aimed for the evaluation is depicted in Fig. 13.

![Diagram of the integration of Helix broker with Aveiro Open Lab infrastructure.](image-url)
• **Ubiwhere: smart parking system with real-time information of available parking spaces**

This use case was already demonstrated during the Aveiro Tech Week, in October 2020. This infrastructure helped to make the deployment of a video processing detection for free parking in real-time (Fig. 14).

**Fig. 14a**  
Wall box in P8 Mercado Manuel Firmino, used by this use case for communication and edge computing.

**Fig. 14b**  
Camera installed in the building for video capturing.

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**Availability to researchers**

**Aveiro Open Lab** is available for research all over IT and beyond. Researchers can test their own protocols, mechanisms, prototypes (anything that would be useful to have in a real lab), or explore collected data, by contacting steam@av.it.pt.

For the infrastructure map, the data being collected by the sensing network and for further information on the living lab, visit the **Aveiro Open Lab website**.