Interreg Sudoe
TR@NSENER
European Regional Development Fund

Report

Transferability of two project pilots developed in the frame of Tr@nsener project

Contents

Project Pilot 1: neOCampus – Toulouse III University Paul Sabatier Campus (France)

I. Description of the project pilot

The neOCampus scientific operation of the University of Toulouse III Paul Sabatier (www.neocampus.org) leads by Marie-Pierre Gleizes, brings together the potential of 11 laboratories of the university: CESBIO, CIRIMAT, CRCA, ECOLAB, IRIT, LA, LAAS, LAPLACE, LCC, LERASS, LMDC which aims to design the campus of the future to improve the comfort and quality of life on campus while reducing the ecological footprint and reducing operating costs (fluids, electricity, water, etc.), to make the campus a field for innovation experiments and to make users active in order to develop their campus.

A campus is a complex system similar to a small town, allowing innovative processes for the smart city to be tested. As a complex system, it has multiple dynamics, non-linearities that make it impossible to predict all the consequences of even the smallest change. The neOCampus approach is scalable and adaptive because such a complex system must be instrumented and regulated by multiple devices, therefore heterogeneous, spread over space and time. As technology evolves very quickly, neOCampus is incremental and open because no one can predict what the campus will look like in the 2030s. Incremental in the sense that a device (hardware or software) can be added without having to question the existing system. This equipment will integrate several generations of device types and software. neOCampus is open because it remains operational while integrating new digital products from the market and research products. It is a territory of permanent innovations added as they emerge. neOCampus is based on commercialized materials but enriched with the latest research from our laboratories, promoting a short circuit between research and potential applications, particularly for the renovation of buildings.

neOCampus aggregates a set of research projects, based on IoT (Internet of Things), with the objective of contributing to the construction of the campus of the future. The main areas of focus are: energy, water and air, the quality of life in and around buildings, the mobility (in particular the autonomous vehicle: autOCampus), and the interdisciplinarity for the design of innovative services and products.

neOCampus is simultaneously a field for innovative experimentations. To break through the siloed actions, it integrates innovations from different fields on the same site. This experimental site is open to companies under agreement in partnership with researchers. A company can innovate collaboratively on a brick of a project and benefit from the infrastructure of neOCampus. In this context, the research operation supported by neOCampus equipment aims to design products and services associated with ambient cyberphysical systems. Thus, this equipment consists of many interconnected software and hardware devices for the digital campus of tomorrow, sustainable and intelligent, combining innovative teaching materials, sensors, communication systems, storage, location, simulation and innovative materials within university buildings and the campus to increase the quality of life of users and reduce fluid consumption.

In the context of the Interreg Transener project, the part of neOCampus related to the energy project has been concerned. neOCampus has benefited from the purchase of equipment to implement projects related to energy saving, in particular a CUBE2020 competition and the consOCampus project.

II. Challenges

We participated in the CUBE202020 competition in 2018, which aims at saving energy in a public building without having to carry out major renovation work. In this context, we carried out small works and bought screens to complete the paper display for users. The posting consisted in giving good practices to users by changing every month. For example, turn off the lights when you leave a classroom, take the stairs instead of the elevator.... With the flow economist and the university's services, we conducted this experiment on the U4 building of the University Toulouse III Paul Sabatier and we won a silver medal thanks to the 19.17% cumulative energy savings over the year 2018. As a reminder, these savings are calculated by comparing your consumption in 2017 with a reference consumption defined on the basis of consumption and climatic conditions in 2014, 2015 and 2016).

We carried out the consOCampus project, which focuses on energy savings in lighting in classrooms. A classroom has a set of intelligent lights with adjustable brightness and automatic shutters. Light capture devices located outside and inside the building make it possible to measure in real time the brightness at several points in the room. The project consisted in developing with artificial intelligence technologies the management of brightness in a classroom by minimizing energy expenditure.

Thanks to the Interreg Transener project, in 2017, we set up and proposed a PermAnent Lifelong Adaptation of Intelligent IoT Systems with a non finalistic approach project as part of the ANR CHIST-ERA projects with Pr. Asuncion Santamaria of UPM/CEDIT, Spain met during the Interreg Transener project meetings and Pr. Giovanna Di Marzo Serugendo UniGe-ISS, Switzerland. Unfortunately this project was not selected.

III. Results

The equipment purchased collected data from several sensors installed in the classrooms of Building U4. The different displays obtained from these collected data are shown in the figures below.

Figure 1: An equipped classroom with remote-controlled lighting

Figure 2 : Different values of the installed sensors in the classrooms

Figure 3: Curves about the usage

Figure 4: Curves about the energy consumptions

IV. Lessons learned during the development of the project pilot

Marie-Pierre Gleizes, the neOCampus manager, proposed a platform project to the CNRS in order to obtain the budget to carry out some of the classroom instrumentation.
The difficulties in installing the platform are due to the fact that we have to equip real classrooms used for teaching. Thus, the work can only be done during the holidays.
The fact that we had to equip an existing and old building required more work and was more expensive than in a new building.

These devices provide data that are used in many research projects because they are made available to researchers free of charge. Several thesis have been initiated between different laboratories on energy themes. This ensures to begin to work in interdisciplinary way.

Moreover, this project is very attractive for researchers but also for industrialists who do not have the capacity to collect data on uses in the real world and thus contributes to increasing the visibility of the University Toulouse III Paul Sabatier.

Project Pilot 2: Open-IoT Smart Campus Pilot at Montegancedo (Spain)

I. Description of the project pilot

The main goal of this project is to improve the outdoor smart street lighting system installed at the University Campus of Montegancedo. The new system is able to control the dimming level of each streetlight by measuring the luminosity level reflected below the luminaire and detecting pedestrian's presence. Throughout the daylight, as there is enough luminosity, the streetlights remain turned off. At dusk, the streetlights turn on and establish a minimum luminosity level (dimming the luminaire to comply with outdoor illumination regulations). Whenever a streetlight detects that someone is approaching, it increases the dimming level to improve the safety and comfort levels of passersby. At the same time, this streetlight sends a notification to its neighbor streetlight to inform about the detection, so they can anticipate the dimming boost and improve user experience. After a certain time without more detections or notifications from neighbors, the streetlight reduces the dimming to the minimum level.

Communications rely on BatNET, a self designed and developed IoT connectivity solution. BatNET connectivity is based on a capillary network of nodes with mesh topology that communicates through Std.IEEE802.15.4 Physical Layer and 6LoWPAN over IPv6 to implement Link and Network Layers. The Transport Layer is UDP and the Application Layer is based on CoAP (Constrained Application Protocol). Information encryption is done accordingly to AES-128. For the communication and processing tasks, the nodes include an Atmel ATmega256RFR2 microprocessor with a Contiki OS. Network nodes (metering, sensing, dimming, etc.) from the mesh network, which access to internet through a border router

This system, which aims to reduce energy consumption by optimizing the outdoor lighting levels without compromising the security and comfort of end users, includes the following devices:

- 2 BatLinks., which act as IoT network router or gateway to the Internet,.
- 69 BatStreetLights. These IoT devices are designed specifically for the public lighting system and are installed in every streetlight which belongs to the project. They include a luminosity sensor, a presence sensor and a dimmer to manage the luminosity level.
- 2 BatMeters. These IoT devices monitors the energy consumption of the outdoor lighting system, by measuring voltage and current at the electric panel board.

Main goals:

- Improvement of lighting quality and reduction of light pollution.
- Reduction of energy consumption with respect to the previous installation.

- Optimization of management and remote maintenance of the system.
- Validation of the pilot project and its technology in the specific context of Campus lighting.
- Validation of the lighting management algorithms (dimming level, on/off strategies, time parameters, etc.).

II. Characterization of passers-by behavior. Challenges

Low luminosity on the sidewalks within the campus was the cause of insecurity at sunsets and nights. The previous lighting system was old, prone to breakdown and with a tedious maintenance. Therefore, its retrofitting was proposed as part of set of initiatives oriented to the campus modernisation.

In 2010, during the design phase, the first decision was to use light emitting diode (LED) luminaires, a more energy efficient illumination source than traditional ones such as high-pressure sodium (HPS) or mercury-vapor lamps. Besides, LED lamps allow an easy fine control or dimming. Among available commercial luminaries, it was selected a plain model that illuminates just the ground, avoiding light pollution. After weighing various alternatives, Philips Lighting Iberica was selected as the LED luminaire supplier. It was chosen the model STELA 36 LED 4000ºK, round-sized for the pedestrian paths and wide-sized for the parking area. Besides, Philips was in charge of the replacing the entire outdoor illumination infrastructure (posts, power wiring, etc.)

Taking into account that LED luminaires can be regulated continuously, it was decided to develop a smart management solution, which had to fulfil the following requirements:

- Reliable, simple, robust and economically affordable system.
- Compatible system with commercial luminaires with regulation through the interface 1-10V.
- Autonomous operation of the system, independent of the connection to the outside of the subnetwork formed by the set of streetlights.
- IP accessibility.
- System capable of reconfiguring network routes in case of failure of one or several nodes.
- Remotely reprogrammable system through the IPv6 network.
- Detection of presence / movement of people.
- Measurement of luminosity reflected on the surface below the streetlight.
- Different administrator and user configuration interfaces.
- Operation governed by an algorithm that uses user configuration, luminosity measurement and presence / movement detection to control the regulation of the luminaire.
- Waterproof system prepared for exteriors.
- System to fix it to conical trunk columns.

Taking into account those requirements, it was decided to take advantage of the IoT connectivity solution (BatNET) that was being developed at the time. Accordingly, a specific IoT device to control luminaire illumination level was designed and developed: BatStreetLight (BSL). Commercial presence motion sensors were used and water-proof ABS encapsulations were adapted to integrate the devices. Their installation was subcontracted to a specialized company.

Figure 5 shows the new BSL (and presence motion sensors) attached in the two types of Philips luminaries:

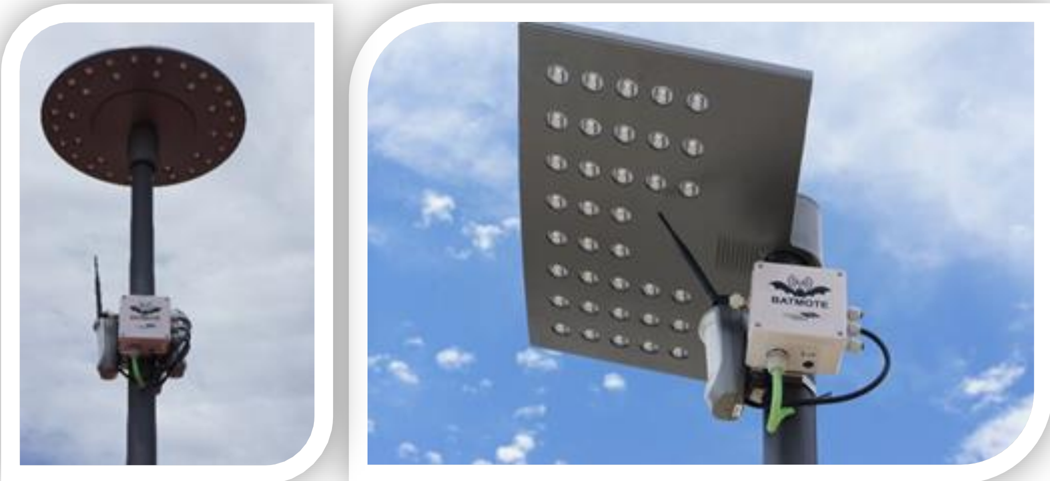

Figure 5: New streetlamps: Philips Luminaires, BSLs and motion sensors.

III. Results

Every streetlamp is configured to operate in an autonomous mode based on a finite states machine, where two stable states can be distinguished: STDALOME and IDLE. Other five meta-stable states complete the whole states machine: INIT, DETECTION, NEIGHBOR, CONTROLLED and ALARM (see Figure 2).
During the night, after a certain number of luminosity measures with a value lower than a minimum threshold (THMIN±HYST), the BSL switches from the IDLE to the STDALONE state. During the STDALONE state, the light will be regulated so that the minimum light level is guaranteed (ca. 20%). If the BSL detects motion or receives a message from a neighbor, the system changes to the DETECTION/NEIGBOR state, where the dimming is set to the max level (100%) during a certain time (dtout/ntout). When the luminosity level has been higher than the maximum threshold throughout a certain period of time, the BSL switches off.

Within the manual mode, which corresponds to the CONTROLLED state, the illumination level can be controlled remotely. In addition, the system will disable every autonomous action but will keep on monitoring luminosity levels and detecting presence on demand. This mode is especially intended for test operations and for the use of external management applications.

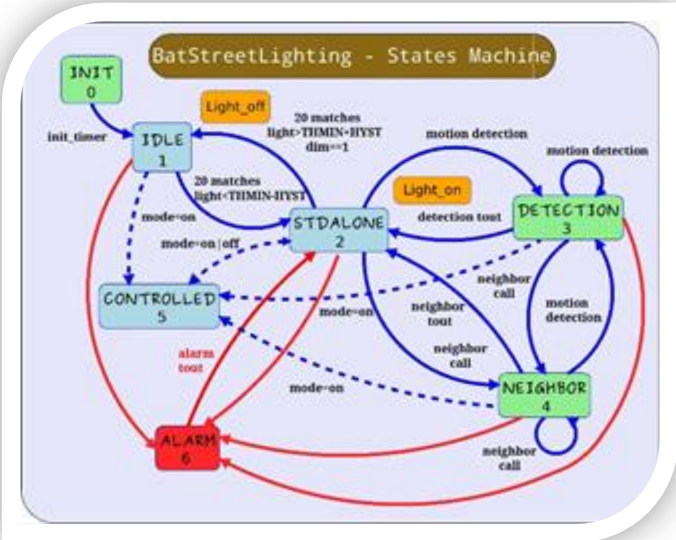

Figure 6: BSL states machine.

The UPM pilot has been working without major breakdowns since 2014, achieving a yearly energy consumption reduction of 84.7 %. The 40 % reduction is directly caused by the replacement of the HPS with LED lamps. The remaining 45 % is caused by the efficient illumination, which dynamically adapts to the campus users' needs.

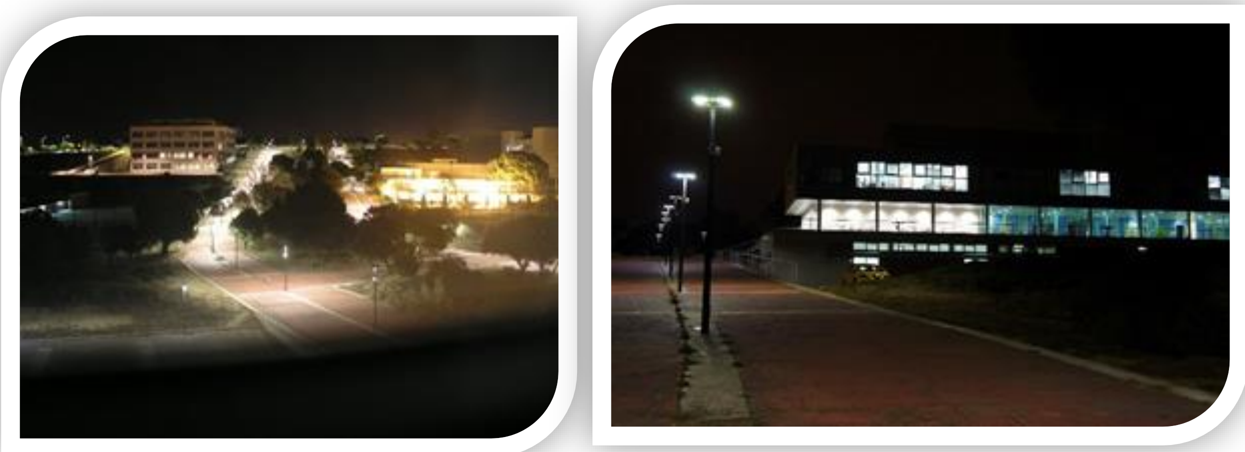

Figure 7: Outdoor illumination system: dimming at 100% (left) and 20% (right).

Figure 3 shows two different views of the system: dimming at 100% (left) and dimming at 20%.

The outdoor smart lighting system pilot is based on the presence detection carried out by presence sensors connected to the IoT devices installed in each streetlight post. There are two types of presence detection sensors: passive infrared sensors (PIR) and microwave sensor based on the Doppler's effect

Although during the design and development phases of the pilot, the use of commercial presence sensors was the best approach to shorten times and focus the effort in other components, there is room for improvement, mainly due to the following reasons:

1. Tedious and expensive maintenance: their encapsulation degrade over time due to weather effects (rain, sunlight, etc.), messing up the operation and requiring the replacement of the complete sensor.
2. False detections: the commercial sensors claim to detect just human movement, i.e. presences with a minimum volume and weight. However, it has been observed that the sensors are activated with small animal motion (e.g. rabbits) or even tree leaf swinging.
3. Limited functionalities: these sensors are binary, i.e. detect weather some is approaching or not, but they are not able to count passerby.

Therefore, in order to improve the system operation, the following actions have been planned:

1. To install cameras (at intersections or in the parking areas) to detect people/cars/bikes.
2. To replace degraded sensors by a new encapsulation integrating more precise presence sensors.

On the other hand, the system has served as an experimental platform for different IoT technologies, from the validation of the BatNET connectivity to the testing of different communication protocols and ML techniques. Examples are the connectivity of the IoT network using 3G and 4G communications, investigating the use of SDN (software defined network approaches) or the use of machine learning algorithms to detect and anticipate the most common paths followed by campus users. Figure 4 shows the IoT network map, where the lines represent the current links between nodes and the colour indicates the RSSI (received signal strength).

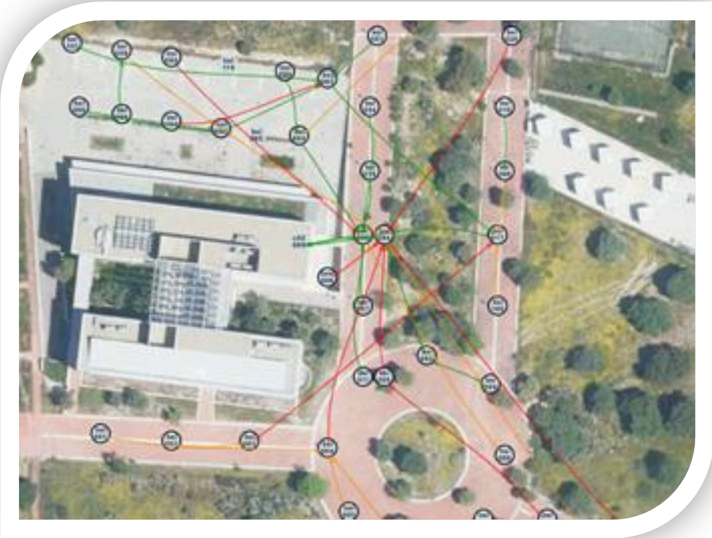

Figure 8: Outdoor lighting system IoT real-time network map

In order to monitor the status of each streetlamp, and the whole pilot, users have access to the devices through an user-interface located in a server (CeDInt IoT Platform), which is the software system that manages this pilot and monitors and stores its data. It consists of a central server where the installed apps run over the stored data and a set of gateways (BatPM). These gateways communicate directly with the end devices (BSL devices) associated to them and send the data obtained to the server. Figure 5 shows the visual interface for a specific streetlight.

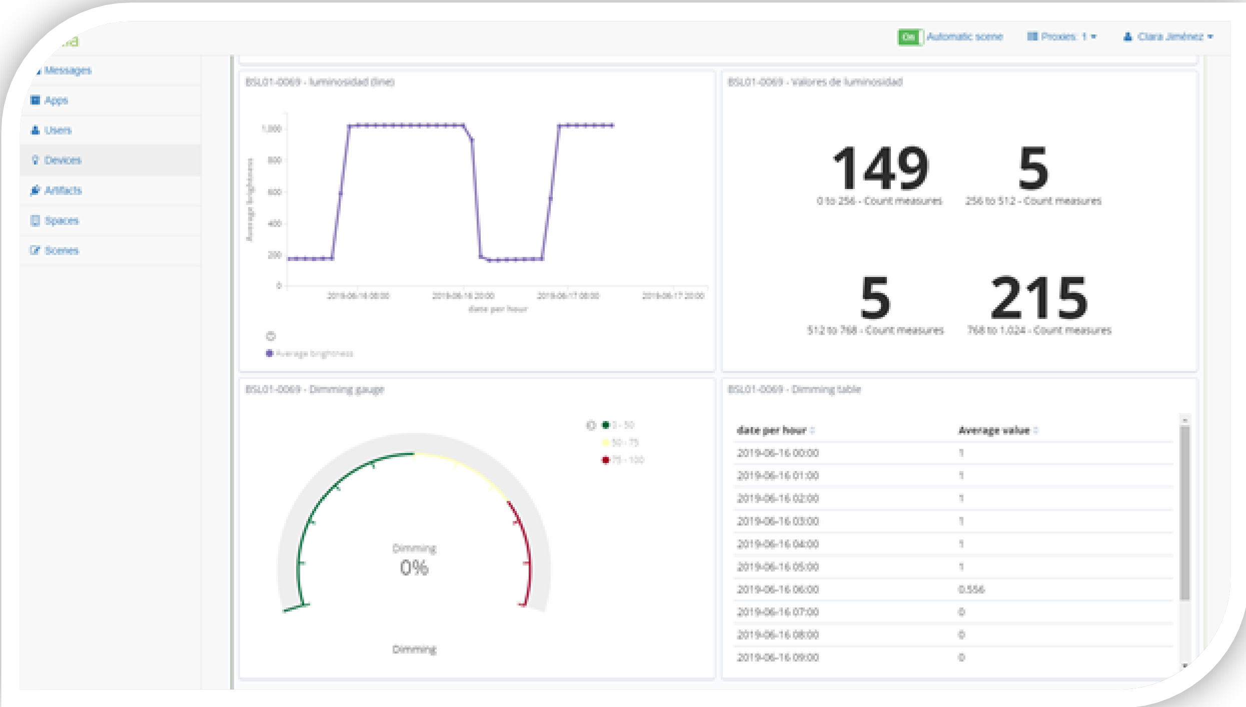

Figure 9: Spatia visual interface: Illumination and dimming level.

IV. Lessons learned during the development of the project pilot

The pilot has been funded mainly by the I2TECH CEI Montegancedo project, under the topic Enhancements to the Campus Environment (Lighting). However, the available budget had to include other deployments, such as the architectural illumination of other campus buildings. Therefore, it was co-funded by other Spanish National projects.
Regarding the administrative aspects, being a university campus scenario, the pilot deployment had to comply with softer regulations (in comparison with cities). Nevertheless, outdoor lighting requirements are met, especially those related with illumination levels to assure visual comfort and decrease light pollution. The main administrative difficulties were those related with bureaucracy processes related with public purchase.

The success of this pilot deployment and its performance have boost the participation of CeDInt-UPM in different EU and national research initiatives. Apart from Transener project, other EU projects awarded are Symbiote (H2020 OpenCall, 2018), ABIDI (Chist-ERA, 2019-2022), CPSE Labs (H2020 ICT-01-2014, 2015-2018); and awarded National Spanish projects are: ALLIPOP (MINECO, 2015-2017), PIELSEN (MICCIN, 2018-2020).

Besides, the pilot has been part of R&D collaborations with other UPM groups in the framework of the EIT Climate KIC, focused on Sustainable Lighting.
On the other hand, the pilot has helped to improve visibility of both CeDInt and UPM by its participation in different dissemination and communication activities, such the EIT Climathon, the Night of the Researchers or the Annual Science Week.

Results of the pilot deployment have been presented at different scientific forums (IoT Success Stories Magazine, Urb-IoT Conference).
Finally, the validation of BatNet technology in the Smart Street Lighting scenario has led to a technology transfer agreement with the company T6000 (a Spanish SME). T6000 is in negotiation with different stakeholders (city halls, energy service providers, etc.) to upscale the solution in Spain and other countries (LA and Europe).

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