

# Benefits of metering and intelligent control in energy savings of public street lighting - UA Smart Campus use case

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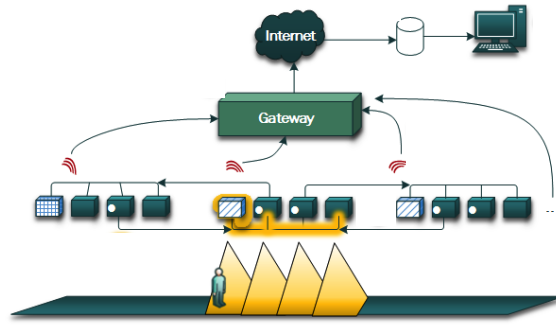
**Abstract:** We describe an intelligent lighting solution suitable for public spaces. The proposed design optimally combines sensor information, LED based lighting, and dynamic control. Departing from this set of starting objectives, project LITES (funded by the EC CIP-ICT-PSP framework) proposed the development of an intelligent lighting solution suitable for public street lighting. This solution was based on the usage of motion sensors as means to control the luminous flow. Following this approach, the lighting necessities are adapted to the actual necessities, thus enabling to reduce energy spent on lighting. The solution was designed to be compliant with enforced EU lighting regulations [1, 2] demanding a minimum lighting flux due to security reasons, and was tested under real live scenarios in three pilots spread on the European space (Municipality of Bordeaux, Riga Technical University and Universidade de Aveiro). This paper focus on the results achieved by the pilot installed in the Universidade de Aveiro (UAV), which highlighted after one year of continuous work that more than 65% energy savings are within reach of currently available technology.

## 1 Pilot Description

The LITES UAV pilot site was implemented inside the University of Aveiro Campus, on a 300m pedestrian bridge linking the main campus with the student's residences, university canteen, and main student's bar. The bridge is situated in a river basin, offering interesting conditions to test LITES proposed solution. The Aveiro region is subjected to strong winds and presence of dense fog events during the morning periods. Particularly relevant is the impact of rain drops on system performance, as it will be discussed during results analysis. Also, the users flow on the bridge has delicate characteristics. Under normal conditions the flow increases between 19h00 and 22h00. However, during student's festivities, it is possible to observe users crossing the bridge in late night hours.

The solution selected is based on currently available corridor function drivers. This solution is ideal for this pilot, given that the degrees of freedom for pedestrian motion are less than those found in normal city streets. Corridor function drivers are currently part of the portfolio of Tridonic, a brand related with ThornLighting, the industrial partner in LITES consortium [3]. Basically, corridor function drivers allow a simple control strategy, where luminaires (or groups of luminaires) are controlled by dedicat-

ed motion sensors. This allows the system to react to the presence of users on the bridge and adequately dim down the light for periods of reduced usage. Corridor function drivers allow progressive light dimming. This feature is particularly important as it allows to smooth transitions between lighting states, which are more pleasant for pedestrians passing by. This pilot took into consideration the safety and comfort of the pedestrian users on the bridge [4]. Safety is assured maintaining a minimum lighting level, under the absence of motion detection events. Comfort is assured employing some means of advance reaction. To achieve this goal, luminaire groups were connected in such a way that users crossing below a group of luminaires trigger reaction of neighboring groups, improving user comfort, as depicted in Figure 1. The advanced triggering action lights up the path ahead in advance so that users are able to recognize objects and other users crossing the bridge.



**Fig. 1.** – UAV pilot conceptual diagram.

This solution is based on wired interfacing between elements, thus no radio transmission means are used for lighting control. In this sense, the implemented solution operates in a standalone fashion. In order to retrieve valuable data from the pilot, it was also implemented a wireless mesh sensor network able to collect real time data from the pilot activity. This entails, power consumption, LED's temperature, infrastructure vibration and humidity inside the luminaire enclosures. Data is sent to a gateway that implements the ETSI GSCL component, then transmitting the information to a M2M platform. For the purpose of benchmarking, information is also transmitted using OASIS MQTT, and using JSON over a HTTP API.

The pilot site is operating since its starting date in January 2014. Data records are being stored since the pilot start data, reaching now to a collection of 16 months of data. This paper focus on the power consumption data acquired during the year 2014 [5]. Power consumption consisted of the daily-accumulated power consumed by the pilot. The retrieved power consumption data was recorded with an average sampling rate of 10s. The average term is used since different nodes may not reach directly the gateway, thus requiring passing information to neighbor nodes using mesh mechanisms.

Sampling time reduction is then a consequence of eventual packet loss due to medium access collision.

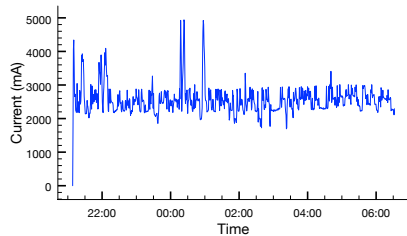
## 2 Achieved Results and Discussion

To have a basis of comparison, it was necessary to estimate the power consumption before the LITES solution. For this purpose the operating working hours were estimated using the circadian cycle tuned for the region of Aveiro (Portuguese central territory). The power consumption estimation used also the total number of luminaires and their power ratings, as summarized in Table 1.

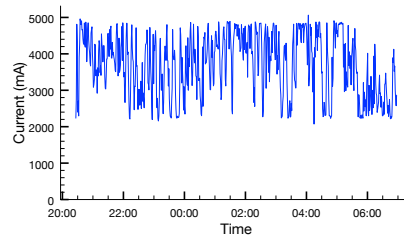
Installation	Device type	N° of Luminaires	Power Ratings	Control Type
Baseline	HID	55	35W	Fixed
LITES	LED	31	36,37W	Motion sensor

**Table 1.** – Lighting device specifications.

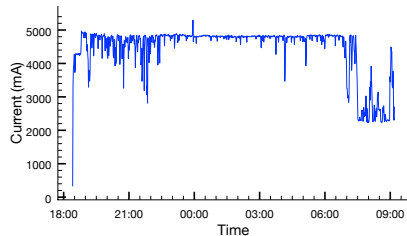
Concerning LITES solution, it was also measured the maximum and minimum power ratings, corresponding to maximum luminous output and the minimum assured luminous output under low dimming conditions (10% dimming). For the used Tridonic drivers, these power ratings were  $36,37W$  and  $16,55W$ . These values were measured at the input of the driver, thus entailing internal driver consumption and power delivered to the LEDs (the maximum power of the LED strings was  $26W$ , as specified by Tridonic). It is noticeable that, the consumed power under 10% dimming condition is



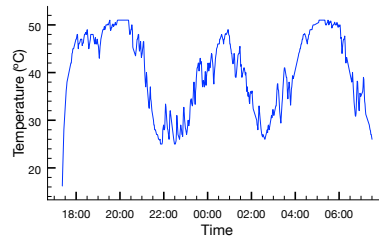
**Fig. 2.** - Clear Weather, low user flow.



**Fig. 3.** – Clear weather, high user flow.



**Fig. 4.** - Rainy days.



**Fig. 5.** – Clear day with festivity (temp).

not 10% of the power consumed under maximum luminous output. This is due to the driver internal power consumption and not the power required by the LEDs, which is  $2,43W$  (measured), close to the 10% dimming condition. As it will be explained, this internal power limits the power savings achieved by the pilot, thus raising the necessity of different driver design strategies optimized for public street lighting installations with variable luminous output.

Figures 2 and 3 show the record of the overall power consumption, and clearly demonstrate the dimming action of the pilot as function of the users flow. As it was intentionally aimed, the motion sensors action effectively reduces the energy consumption under low usage profiles. Figure 4 on the other hand show the effects of rain on the system performance. As it can be seen, the sensor is severely affected by rain. This is not a direct consequence, since the microwave motion sensors, used for this purpose, are not directly sensitive to rain. It comes rather due to raindrops accumulating on the luminaire case. A solution to this problem entails the usage of Passive Infra-Red (PIR) and microwave sensors combined in such a way to enable the reduction of false detection events. Not also that PIR sensors were considered, but given the environmental characteristics of this pilot, their action would be compromised due to the presence of fog and wide thermal amplitudes during the day. This highlights the importance of a thorough planning, and the role of each particular scenario, so that power savings can be maximized, and the overall system behavior is the correct.

Figure 5 demonstrates that public lighting infrastructures can be used as sources of information regarding several aspects related to urban dynamics. In this case, the chart shows the temperature variation, which is not instantaneous, but depends on the consumption and dissipation characteristics: higher number of persons consecutively crossing the bridge will lead to higher temperature, due to higher number of activations per time unit. This allows to potentially estimate volume of people, and the time that people arrive or leave the festivity. In the day depicted, temperature is higher from 20h to 21h, which relates to the dinnertime, and then at around 1h, 3h and 5h, which indicates the traffic of students to and from festivity.

Figure 6 shows the power savings estimated on a daily basis (blue line), considering the relative power variation from LITES installation against the baseline (old installation). The power measurements considered the total power required, which includes, the LEDs, the drivers and the sensors. The smooth red curve presents also the same relative perspective but taking the accumulated average power starting from January 1<sup>st</sup> 2014. As can be seen, the savings agree with the maximum (dashed line) and minimum (dash-dotted line) savings projections, taking again the 100% and 10% dimming conditions. The maximum power savings that could be achieved with UAV pilot site is limited to 73% (settled by the drivers efficiency as previously mentioned). The pilot site showed for the evaluation period of 12 months that the accumulated savings are on the range of 65%. This is a good result given the upper bound of 73%, and it demonstrates the effectiveness of LITES proposed solution, which effectively regulates the energy consumption for low consumption under reduced usage.

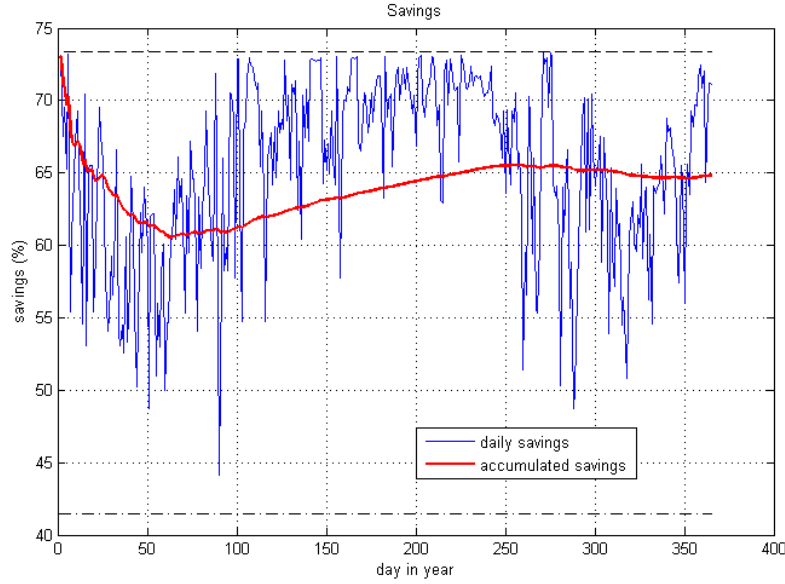


Fig. 6. – Power consumption and accumulated savings during 2014.

### 3 Conclusions

The presented results disclose important observations pertaining systems performance. The relevant conclusions can be summarized by the following remarks.

**LED driver's efficiency** – as discussed the LED driver efficient plays a key role in intelligent lighting systems able to react to the external factors (as for instance, road usage). Standard design approaches advocate the optimization of the driver efficiency for maximum load conditions. As the previous results demonstrate, this standard approach is not able to cope in full with the maximization of power savings similar to LITES approach. In fact, it was ascertain that the driver's efficiency under low dimming conditions compromises the achievement of higher savings.

**Better motion sensors** – motion detection is the basis of the proposed solution. Thus, high accuracy sensors able to filter out environmental factors such as ambient temperature variations (affecting PIR sensors), rain drop accumulation (affecting microwave sensors) are required. As the results demonstrate, a single sensing technology is not the best course of procedure. In particular, motion detection employing microwave sensors is severely affected by rain, thus compromising the envisage power savings. Possible solutions may include different types of sensors (for instance PIR and microwave), combined in such a way able to minimize false detection events.

**Data aggregation** – As disclosed by the results, correlation of measured power consumption or devices temperature with external factors such as environmental conditions or user habits may trigger different and powerful applications supported by lighting installations. Possible applications include the acquisition of street usage statistics (based on appropriate sensors), air quality monitoring inside cities, or even

exploitation of novel traffic control measures. Moreover, this results show that better control strategies may rely on environmental forecasts or even other usage profiles aggregated from other sources. These trends are well focused with current trends on big data and cloud computing and may pave the way for future improvements on public lighting systems [6]. Applied to a city-wide infrastructure, as an example, this same method could be used to facilitate the decision regarding the deployment of security forces, or to adjust the public transportation network.

## **4 References**

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- [5] LITES project deliverable D9.4, “Report on Energy Savings”, November 2014.
- [6] LITES project deliverable D9.5, “Report on scenarios for large urban lighting schemes”, November 2014.