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An Energy Management Platform for Public Buildings

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Abstract: This paper describes the development and implementation of an electronic platform for energy management in public buildings. The developed platform prototype is based on the installation of a network of wireless sensors using the emerging Long Range (LoRa) low power long-range wireless network technology. This network is used to collect sensor data, which is stored online and manipulated to extract knowledge and generate actions toward energy saving solutions. In this process, gamification approaches were used to motivate changes in the users' behavior towards more sustainable actions in public buildings. These actions and the associated processes can be implemented as public services, and they can be replicated to different public buildings, contributing to a more energy-sustainable world. The developed platform allows the monitoring and management of the heating/cooling, electric power consumption, and lighting levels. In order to validate the proposed electronic platform, sensor information was collected in the context of a university campus, which was used as an application scenario in public buildings.

Keywords: energy management; sustainability; Internet of Things (IoT); LoRa network; wireless sensor network

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1. Introduction

In the European Union, buildings are accountable for approximately 40% of final energy consumption and 36% of CO_2 emissions [1,2]. However, there does not exist a straightforward way to balance energy demand when addressing the building needs. Each building is different, and it needs to be adapted regarding two main factors: (1) Climate and local conditions—climate is a driver for space heating and cooling and also for supplying renewable energy resources; and (2) building type and use—the building type will dictate the rest of the energy demand [3]. There are also other factors that may affect the energy performance of a building, which are related to architectural, environmental or cost issues [3].

The evolution and convergence of several technologies, such as wireless communication, machine learning, online computer decision-making, sensors, cameras, and embedded computing are promoting the fast growth of the Internet of Things (IoT) [4]. These technologies, supported by a network of embedded sensors and applications, contribute to enhance the citizen's comfort and to simplify the work-life [5]. In this context, concerning a close interaction between citizens and applications, it is expected a considerable growth in the number of the embedded sensor devices connected to the Internet in the next years. Around the world, the potential market of the IoT is expected to reach US $724.2 billion by 2023 [6]. Several vendors are actively building out their IoT product and service portfolios; for example, General Electric invested more than $1.5 billion in this sphere in 2016, while Qualcomm has invested more than $50 billion over the past five years [6].

The IoT is part of a new paradigm, where it is possible to integrate every sensor to the Internet, allowing it to be even more immersive and pervasive. Most of the IoT sensor devices require sufficiently low-power consumption for their electronic circuits, given that these devices are expected to operate using a rechargeable battery for months or years without resorting to external power sources. In order to satisfy this expectation, suitable wireless sensor network technologies are required [7], including low power Wireless Personal Area Network (WPAN) standards such as Bluetooth Low Energy (BLE) [8,9], and ZigBee [10], as well as the emerging Low Power Wide Area Network (LP-WAN) [11,12] standards, such as the Long-Range (LoRa) network [13].

Taking into account the versatility of IoT sensors for different electronics applications, they can be applied in buildings in the context of monitoring and control processes such as: Energy and water consumption monitoring and optimization; user mobility monitoring; and temperature control. Besides, IoT systems may also provide alerts and help users to find desired services within the building. This network of IoT sensors generates a significant amount of new data that can be processed and used by building owners, managers and operators in the context of a new paradigm of facility management, with greater awareness and insight, to significantly reduce costs and improve performance.

From the resulting collected data, new challenges are emerging regarding knowledge extraction and data visualization. In this complex scenario, the development of an electronic platform based on an IoT approach, in the context of a university campus (consisting of a smart campus used as an application scenario in public buildings), is of particular interest:

- It creates significant opportunities for improving the managing quality of complex and multi-dimensional institutions as public buildings (e.g., universities);
- It responds to several initiatives pushed by many national governments to adopt Information and Communication Technology (ICT) solutions in the management of public buildings, putting in practice the so-called smart city concept [14];
- It has the potential to reduce the operational costs of the public administration;
- The data collected reveals an entirely different understanding of how buildings are working, with a new awareness of the origins of issues and problems, enabling new knowledge that leads to improved operational methods and design standards.

Managing a university campus has become a complex and challenging task, due to the large number of persons involved, the diversity of equipment and the demand for cost reductions. There is also the need to support the decision-making relating to the campus infrastructure. University buildings are aging, which, together with the need to comply with ever-evolving functional requirements, asks for improvements that will require structured information systems to be adequately designed. Organizations such as universities often use a lot of inefficient electrical equipment, resulting in high energy expenses. As an example, the ISCTE-IUL campus (located in Lisbon, Portugal), with 53,000 square meters gross built area, has an annual energy bill of 488,000 €, corresponding to 3.95 GWh/year of final energy (81% electricity, 19% natural gas), 8.74 GWh/year energy, and emissions of 1303 metric tons of CO_2/year [15]. Regarding users, around 10 thousand persons use the campus. There are considerable challenges, but also many opportunities, embedded in existing university campuses, where the data collected from the IoT sensors can be manipulated for valuable knowledge extraction and performance optimization.

Nowadays, people, buildings (public or private), and even entire cities can operate and interact in entirely new and different ways, with better and more productive outcomes. The key point is that data analytics, when harnessed, provide new methods for decision-making, enabling the future of process improvement and savings. A university campus is a good candidate for application of the IoT paradigm since its thousands of students are very active on social networks. In the case of ISCTE-IUL, from around 10,000 people on campus, 9200 are students.

In the context of this paper, the primary objective is to build IoT architectures and services that can be used to draw conclusions, regarding the campus operations, related to how the community interacts with the building infrastructure. The expected outcomes will result in significant savings in resource usage (energy). They also represent an opportunity to enhance sustainability-related communication, creating new channels to reach users by using appropriate analytics. The progressively and continuously improvement of institutional sustainability requires an active community willing to embrace behavioral changes. Therefore, accurate and fast communication is considered crucial for environmental and sustainability awareness, thus providing also beneficial feedback in the operation of the system.

The energy management platform proposed in this paper aggregates useful information from several sources, using a service-based approach. Such information includes both academic data (such as daily schedules, the various deadlines defined in the academic calendar, the opening hours for administrative services, etc.), and sustainability-related data (mainly related to climate, energy, water and building occupancy). Based on the data provided by the aggregator service, users can subscribe to events they are interested in. This service also provides a unique opportunity to collect information from users that are not available in any other way, such as how users get to campus or how waste is generated and disposed of. Being able to collect and relate all of this information will undoubtedly allow a better understanding of how the campus is used, and will also permit the building of a calibrated model that may be used as a preventive midterm managing tool towards energy management.

2. State of the Art

Buildings can be classified in two types: Service buildings (offices, educational buildings, restaurants, hotels, retail, and others) or residential buildings (single-family or multi-family) [3]. A simple way to distinguish them is that service buildings have, usually, a higher occupancy rate, more equipment and, as a consequence, higher internal heat gains.

Energy in buildings can be classified into two categories:

(1) Operating energy, or direct. The energy required to support the services and comforts in buildings, such as thermal comfort, refrigeration, illumination, sanitation, communication, and entertainment, among others. This energy cost is usually the one in the monthly bill for energy services [16].
(2) Embodied energy, or indirect. The energy needed for the provision of infrastructures services, the production, and transportation of the materials used in construction, or the production of furniture and appliances. This energy depends highly on the design and construction techniques used in the building [16].

To start solving energy problems in buildings, there is a need to improve the energy efficiency and increase the production/use of renewable energy. This creates a synergy, because, with higher efficiency, tasks can be done with a smaller amount of energy, which also favors the use of renewable energy [17].

There are three options to try to make the buildings more efficient:

(1) Investing in architecture solutions adjusted to energy efficiency needs, for example, through passive strategies to obtain comfort.
(2) Investing in construction solutions taking into account several factors, such as climate or the use of the specific materials.
(3) Investing in more efficient electrical appliances, in order to reduce the energy consumption required for the operation of the building, as, for example, only having green-star rated electrical appliances [3].

From these three options, there are a great deal of energy efficiency technologies and practices to be used [3].

In 2011, a policy was released to better manage energy systems, ISO 50001:2011, requiring companies to develop ways for a more efficient use of energy, to define objectives to meet, to measure the results after implementing actions, and to use this data to understand the use of energy and to make better decisions regarding its use [18]. Therefore, in order to provide solutions that address these issues, there is a need to implement electronic systems that allow the monitoring of the energy consumption. This monitoring presupposes the construction of a set of indicators, which will serve as the basis for the evaluation of implemented measures regarding the outlined objectives. The construction of these indicators allows not only the evaluation of results but also tracking the progress, as well as the verification of the effectiveness of these measures. The measurement of energy efficiency or energy performance can have different meanings, as there are many ways to measure it. Indicators can be costs, energy consumption or emissions. Some examples of indicators can be extracted from References [19,20].

Energy monitoring is an energy efficiency technique based on the standard management axiom stating that "you cannot improve what you cannot measure." It implies the necessity of measurements and data organization [21].

Energy use predictions, to calculate the energy balance, require two separate aspects of energy flows: Building operational energy and energy generated on the building [22].

Nowadays, the monitoring systems for buildings are rather basic, and the amounts of data available are small and incomplete [3]. Therefore, a significant improvement is needed to manage the relation between demand and supply of energy [22]. However, it is impossible to manage the energy demand and supply without information. Therefore, we need information (data) about what is currently happening to the energy and what will happen (predictive models). This way, better management of the energy system is possible.

On the other hand, several universities around the world are trying to make their campus more sustainable, and one of the aspects of sustainability is smart energy management. Energy wastage in several spaces, such as teaching auditoriums, laboratories, computer rooms, and others can be found. The energy and environmental impact of universities can be reduced if organizational, technological and energy optimization measures are applied.

In this context, the European Commission created a specific project for developing services and applications supported by a data-gathering platform that integrates online information systems and intelligent energy management systems. This platform drives a bi-directional learning process, such that the user learns how to interact with the building and the building learns how to interact with the user in a more energy efficient way [23]. This strategy was applied to chosen universities in cities such as Lisbon, Helsinki, and Milan. This project reached 30% in energy savings through the use of ICT and gamification to promote user behavior transformation on public building users.

This pilot project in Portugal was done in Instituto Superior Técnico, University of Lisbon, in the Taguspark campus, and it consisted of the installation of automation equipment that increased the control of energy usage. It was also created an Intelligent Energy Management System (IEMS) that allowed managing several automated types of equipment such as lighting, Heating, Ventilation, and Air Conditioning (HVAC) systems, and others, as well as to interact with the users through the web and mobile apps [24]. Additionally, a recent work, presented in Reference [25], proposes an IoT based system for intelligent energy management in buildings, including with data collection from different sources and weather data, in order to produce daily and weekly action reports towards savings in buildings.

Our proposal uses online measurements of temperature, humidity, luminosity and electrical power, associated with data analytics and the information of student presence in the classroom. We focus mainly on savings on classroom lighting expenses as a first prototype application. Our approach can be used in any building with LoRa communication available. The verification of the students' presence inside our campus is an easy process since we use card readers at each classroom. For other buildings without this facility, it is possible to implement a solution based on mobile devices and their wireless connection, see Reference [26], based on mobile device probe requests in Wi-Fi routers. The knowledge regarding the persons in a room allows the implementation of a gamified approach, which is introduced towards a collective sustainable behavior (see Section 3.4).

3. Proposed Approach

The purpose of any IoT device is to connect with other IoT devices and applications (cloud-based mostly) to relay information using Internet transfer protocols. In this context, an IoT platform is used to provide insights by means of backend applications, to make sense of the overabundance of data generated by hundreds of sensors [27]. Nowadays, several IoT platforms are available in the market to be used as an option to deploy IoT applications and to meet the requirements from different users and application groups, such as enterprise, government, healthcare, communication, transport, and manufacturing [27]. Aiming a sustainability program, the first steps were about the definition and identification of the system requirements according to the central administrative services and to the sustainability goal. High energy and water bills without any control over consumption were the main problems identified. As a contribution for reducing this consumption, the following three goals were defined taking into account the electricity consumption:

Goal 1—Electricity consumption reduction oriented for two main problems: Heating/cooling systems and lighting control with human presence. To achieve this goal, we intend to implement smart heating zones, where heating is based on room occupancy. These strategies contribute to avoiding wasting energy in unoccupied areas, which can dramatically reduce the energy bill.

Goal 2—Online information about the electricity consumption, where the collected data from smart meters contributes to future decisions and provides online data about consumption.

Goal 3—Changing the users' behavior through enhancing their perception of unnecessary consumption (alerting for conscious actions), allowing them to contribute to collective savings in public buildings or shared spaces.

3.1. Data Sensors for IoT

In the context of the proposed system, we decided to measure electricity consumption, temperature, and humidity. A key issue is the choice of suitable sensors since there is a high number of sensors available in the marketplace right now for each task. The main goal of this decision process was the smooth integration and data calibration. For the electricity measurement, we chose the YHDC SCT013-000 current sensor (YHDC, Beijing, China), which is a current transformer (100 A:50 mA). Its analog output is received and processed by an Arduino with a LoRa module for wireless communication. Temperature and relative humidity measurements were obtained with the Texas Instruments CC2650STK BLE SensorTag (Texas Instruments, Dallas, TX, USA). The collected data is transmitted through BLE to a Raspberry Pi gateway, and then to a LoRa shield board, which provides long-range wireless data communication. Detection of students' presence is based on a card reader system available at each classroom, and for external users it is achieved using small wireless devices from the manufacturer Estimote, which emit identification data (Bluetooth beacons) that are received by the users' smartphones if they have the Bluetooth interface activated. The mobile app was developed aiming to provide guidance to external people, as well as beacon signal processing and communication with a cloud server [28]. The smartphone's Bluetooth Medium Access Control (MAC) address provides personal identification and allows the calculation of the user's position, i.e., as he moves through the campus.

3.2. Communication Layer

In the scope of this project, we have chosen the LoRa technology to provide wireless data communication inside the university campus. In this sense, a Cisco LoRa network was installed to cover all campus. The choice of LoRa was based on its long-range coverage (up to 15 km) compared to other available low power wireless technologies, such as ZigBee and BLE. As shown in Figure 1, the sensor devices implemented in the proposed system use the low data rate LoRa technology to connect to the LoRa gateway. On the other hand, the LoRa gateway uses high data rate networks such as IEEE 8201.11/Wi-Fi, Ethernet or cellular networks, to connect to The Things Network. The Cisco

IR829 router provides PoE (Power over Ethernet) to the LoRa gateway and an encrypted connection. From the IR829, data is sent to the IoT platform used in this system, which provides storage and data analytics.

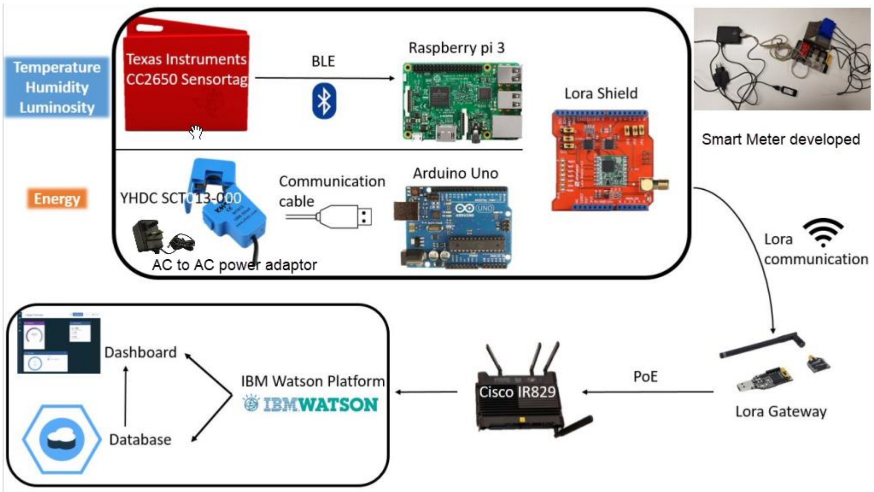

Figure 1. Implemented Long-Range (LoRa) network architecture based on Cisco equipment.

The infrastructure of the implemented ISCTE-IUL LoRa data communication network integrates two Cisco IR829 industrial integrated services router, installed indoor and outdoor, to accommodate both environments. The IR829 router allows redundancy with the support of both 4G LTE (Long-Term Evolution) for wireless Wide Area Network (WAN) backhaul and Cisco dual-radio WLAN on the same platform. With the advantage of dual WLAN radio, the integrated access point can serve both as an access point and as a client to a wireless mesh network. This provides another source for WAN diversity, along with Gigabit Ethernet, serial, and cellular. This infrastructure supports laboratory equipment, information technology equipment and other specific tools.

Figure 2 shows some components associated to the currently implemented solution, where the IMX-2 is a concentrator that performs tunneling of the LoRa MAC frames between an endpoint and an IR829 router. The ThingPark server enables connectivity with customers/devices to be used in multiple applications such as smart cities or building sustainable systems.

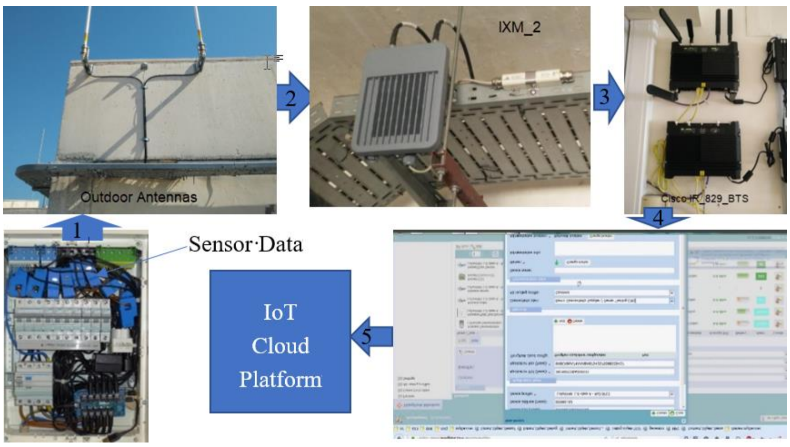

Figure 2. Components of the implemented Cisco LoRa communication solution: Local equipment performs sensor data acquisition and LoRa transmission. An outdoor antenna receives (1) the LoRa signal and directs it (2) to the IXM_2 (antenna and IXM_2 perform the function of the LoRa gateway identified on Figure 1). IP communication is performed (3) from the IXM_2 to Cisco IR829_BTS. The ThingPark software controls the process (4). Data is sent (5) to an Internet of Things (IoT) Cloud platform with encryption to ensure security.

3.3. IoT Platform

Based on a partnership with IBM, the Bluemix cloud platform was used in the development of the proposed smart campus system [29]. Bluemix is a Platform as a Service (PaaS) that allows users to register their devices and sensors in the cloud aiming to send the acquired data, as well as to monitor and control appliances, such as lights and heating/cooling systems. The Bluemix IoT service uses the Message Queue Telemetry Transport (MQTT) protocol [29], which is a machine-to-machine (M2M)/IoT connectivity protocol designed as an extremely lightweight publish/subscribe messaging transport protocol. It is used for connections with sensors where a small code footprint is required and/or network bandwidth is at a premium [30]. External actions to selected devices were developed using Node-RED, which provides a browser-based flow editor, making it easy to wire together flows using the wide range of nodes in the palette.

3.4. Gamification for a Sustainable Collective Behavior

Gamification is the use of game mechanics in non-game contexts. This allows users to work towards a pre-defined goal. Our implemented approach is based on public information about the student (users) presence in a room and the account of the energy consumed. The main idea is to create a collective behavior base on public information about user waste energy actions. One example is the problem of lights being left on after classroom use. There is a waste of energy until the beginning of a new lesson. For example, considering a class that finishes at 3 p.m. and the following one starts at 7 p.m., if lights were not turned off, we have 4 h of unnecessary energy consumption that can reach 4 kWh (considering our scenario of application). If we account for 40 students in the classroom, the system collected 100 Wh for each student, and 4 kWh for the teacher. With this approach, it is possible to account this metric (energy consumption) for week or month long periods and show them in university television circuits, with announcements of the top-ten most sustainable students (with the least energy accounted in the gamification platform) and the top-ten least sustainable (with more electricity consumption in their account). Additionally, when lights were turned off students win points related with the amount saved, consumption between two lessons in the same classroom divided by the number of presences. For example, in the previous example an amount of 100 Wh was saved, which was converted to points based on electricity price. Later, these savings (points) can be converted to save money on university services. With this approach, it is possible to enable and motivate consumers to change their consumption levels and to create more sustainable behaviors. The visualization board, in fact, creates a social comparison and serves to provide motivation towards reaching the pre-defined goal and the savings points can lead to a collective behavior changed.

Based on social change theory, it enables, accredits and awards university individuals, communities and departments for their sustainability efforts, while helping them to reduce costs. Based on the collected data, the platform identifies actions to generate economic savings, encouraging university staff to protect the environment. During the first implementation months (September and October 2018), it was noticed a reduction in energy consumption (related with lighting) of about 40% in the monitored classrooms, based on the proposed gamification approach. A transversal goal is to engage the whole ISCTE-IUL community (students, teaching staff, non-teaching staff, and researchers) towards ecological behaviours and sustainability. Focus groups and questionnaires will be used for gathering information on two levels: Individual and organizational. At the individual level, the project will measure environmental knowledge; attitudes towards engagement; intentions to behave more ecologically; acceptance of new and sustainable technologies; and perceived barriers and constrains. At this stage, we are involving sociologists and psychology professors to analyze and study: (1) Effects of this proposed gamification on collective behavior; and (2) perception of online measurement on individual consumption behavior on a project with Portuguese National Fundings.

4. Electricity Monitoring

Figure 3 shows the developed prototype for the measurement of the voltages and currents in the three phases of the electrical installation in a non-intrusive way. The current was measured using a current transformer (CT) based on sensor SCT-013-000 (YHDC, Beijing, China). These CTs were installed on the three phases of the electrical installation, each one on each phase. The voltage of each phase was measured using voltage transformers. Since the output signals are in ac, and the internal Analog-to-Digital Converters (ADCs) of the Arduino are prepared only for positive signals, an additional circuit was used to adjust the measurement of each signal, in terms of amplitude and average value, according to the requirements of the ADCs (i.e., a peak-to-peak amplitude of 5 V and an offset of 2.5 V).

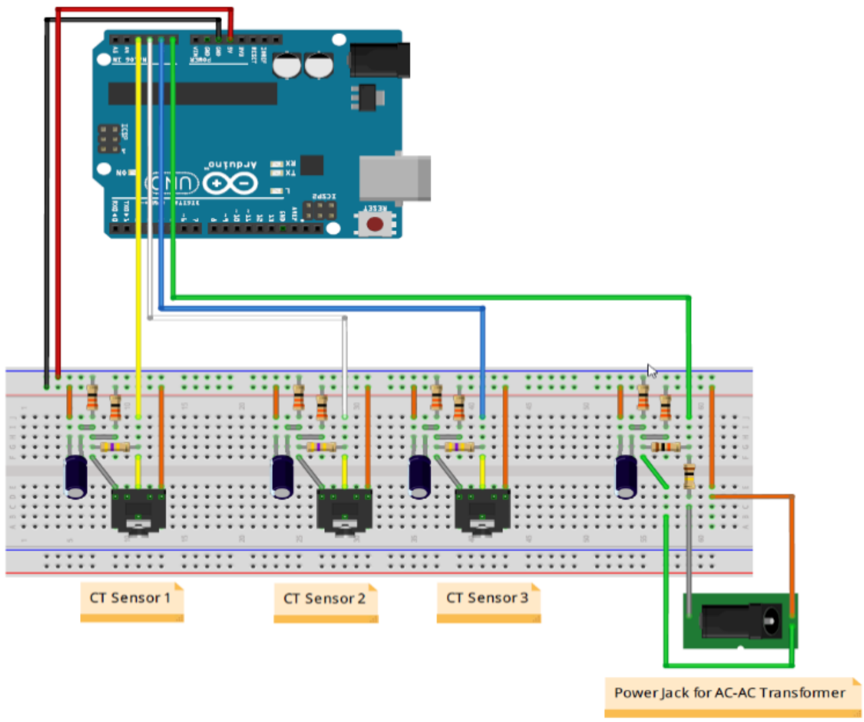

Figure 3. Prototype for measurement of currents and voltages in a three-phase electrical installation.

The sensor data is transferred through the LoRa network to the IBM platform, where it is stored for later analysis. Rules can be implemented in Node-RED to create automatic actions, such as: Sending an SMS or an email alert when consumption increases above a predefined value; provision of reports about month/week consumption; correlation of obtained information with external data, like weather conditions, among others.

The proposed system has to be scalable to the whole campus of the ISCTE-IUL university, which has 744 rooms. Since the data communication in the proposed system is supported by a LoRa network, the amount of data transferred through the network needs to be controlled, because LoRa presents low data rates, ranging from 0.3 kbps to 50 kbps. To reduce the amount of data, an algorithm has been implemented in the code, where only significant changes in the value of the current (user defined, default 50 mA) are sent. Sample data were collected from the three phases in a classroom between 17 and 19 March (2018) to estimate the data consumption with this algorithm, resulting in a total of 0.48 MB, or 0.16 MB per day. Another test was performed from March 20 to 21, in which the collected information was sent out every 10 s, instead of using the proposed algorithm to reduce the amount of data. In this case, the total data consumption was 3.87 MB (1.94 MB per day), which represents a significantly larger amount of data. Based on this comparison, it can be concluded that by sending data only when there are significant changes, the amount of data generated is significantly lower (about 12 times less in this case).

5. Sensor Data Collection

Using the proposed system, it was possible to collect data from rooms of the "Ala Autonoma" building of the ISCTE-IUL university campus in the period between 16 December 2017 and 20 March 2018.

5.1. Electric Power

Figure 4 shows the daily electric power consumption of a monitored classroom for three weekdays, where there is a sharp increase in consumption of around 5 a.m. This is a big classroom, where lights are automatically turned on at 5 a.m., although classes start only at 8 a.m. The proposed system allowed the identification of this situation, which arises from the fact that there are no independent light switches in the classrooms, and thus the only way to turn on the lights is through the central electrical panel. Therefore, this 3 h of wasted energy consumption can be eliminated through the installation of independent electrical switches in the classroom to control lighting. This example illustrates the potential of the proposed system, which can achieve more energy savings when extended to the whole university campus. Additionally, based on classroom occupancy, we verified that during 40% of the time the lights were on and nobody was in the classroom, which represents a cost of around 150 € per year in electricity consumption for this classroom alone. Taking into account that the number of classrooms in the campus is around 140, this results in an average waste of 21 k€ per year.

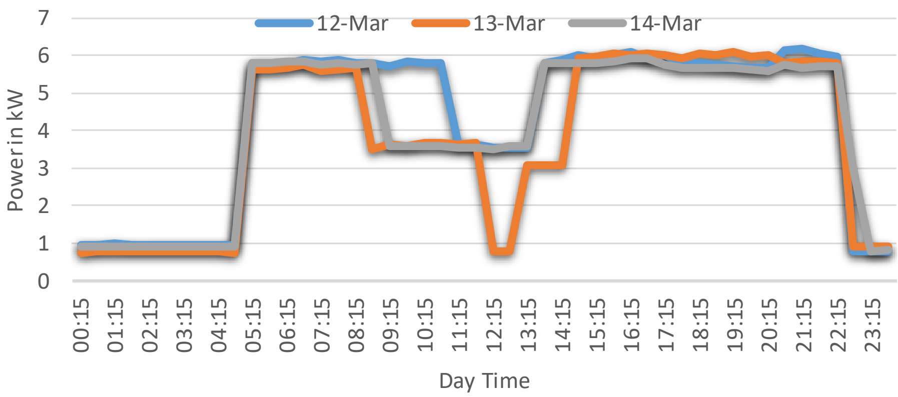

Figure 4. Daily power consumption in the monitored classroom.

Figure 5 shows statistics of power consumption for the data collected from the three phases of the electrical installation, and for the total power of the same monitored classroom. From the analysis of the charts, it can be verified that the power consumption values are higher in phase 1, which indicates that there is a more significant number of equipment connected to this phase. Concerning phase 2, it can be verified that the median is very close to zero, which shows that most of the time there is no consumption at this phase. Phase 1 and phase 3 always have values higher than zero. However, phase 1 presents greater variability in power consumption. Regarding the total power consumption, the median is close to 1000 W.

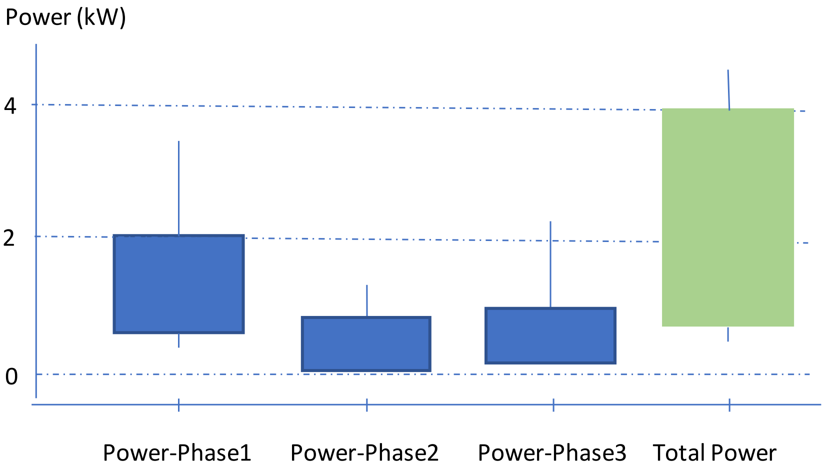

Figure 5. Power consumption for the three phases and for the total power in the monitored classroom, during the test period. Plot box represents all measurements performed.

5.2. Temperature

We have developed services oriented to the room comfort, with temperature control, because there is a connection between environmental temperature and cognitive performance [31]. Higher room temperature can increase the heartbeat to above 100 beats per minute. On a higher cardiac frequency, students end up consuming more calories and diminishing their cognitive performance. Our service uses as input a range of predefined temperatures and based on external weather conditions (exterior temperature), adapts the interior temperature to these predefined values. In winter, the comfort temperature should be between 22 degrees Celsius and 24 degrees Celsius, while during the summer it should be around 18 degrees Celsius [32].

The available information regarding external weather conditions can be used to predict near-future thermal comfort constraints. Correlating this set of data with data collected by sensors provides beneficial management information to predict future needs regarding heating and cooling. It is, therefore, possible to better manage the relationship between energy supply and demand, taking more advantage of renewable energy produced on-site. Figure 6 shows the temperature measurements performed on three weekdays. The higher temperature is correlated with increasing energy consumption. The classroom has a capacity of 80 students.

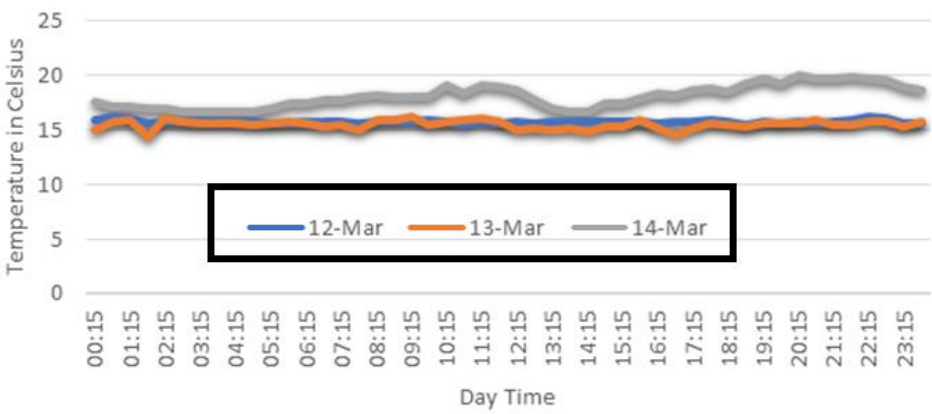

Figure 6. Daily temperature measurements in a classroom.

5.3. Lighting

Since the temperature sensor also provides lighting readings, this information was collected and used for light intensity control and window blinds up/down control. Figure 7 shows the measurements performed in a classroom. Light intensity can be controlled based on light sensor information and presence. Automatic actions, such as turn on/off lights, can be easily performed based on sensor input using the Node-RED platform.

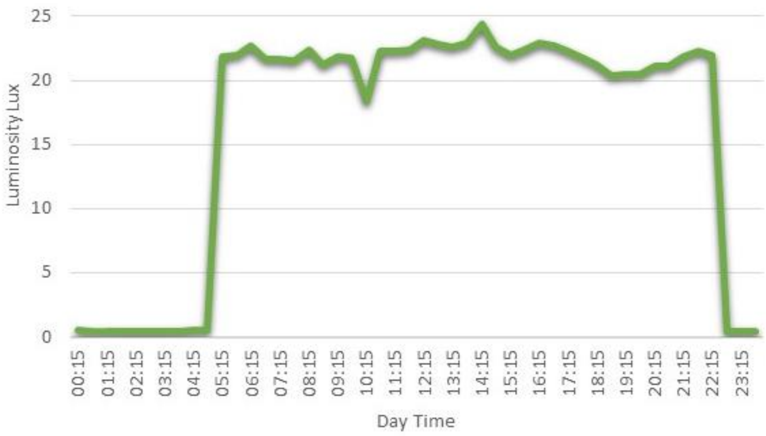

Figure 7. Light meter average measurements of the days 12 to 14 March in the monitored classroom.

6. Data Analytics and Functionalities

A mobile app was developed to visualize information online with an available dashboard to check historical data. Several templates were created: (1) Energy efficiency, performance against the predefined target; (2) electrical appliances efficiency; (3) lighting efficiency; (4) heating and cooling systems. Predefined actions can be performed using node-RED. For example, based on too low/high light measurement values, it is possible to turn on/off lights through interaction with the lighting system or to generate alerts through SMS or email. Moreover, this mobile app allows online user interaction and provides advice based on predefined criteria. For example, if a user is the last to leave a room and the lights are on, an alert is generated for the mobile user app. If a student is in a room with 20 persons (for example), the energy used in the room is divided by 20 and sent to the user. With this action, users will become more aware of their ecological footprint.

The heating or cooling system can also be interacted based on a number of persons in a room, external temperature and time to start an event. Consumption patterns allow previous actions to be set, like heating/cooling a room before a classroom event starts. This process can be based on the number of persons that usually attend the room and on the external temperature.

Based on the current approach, it is possible to identify data patterns and adapt the central system control with pre-defined actions based on a diversity of rules created and implemented in Node-RED.

We are using this study to involve other scientific areas, in interdisciplinary studies with architects and sociologists. This is being performed as a basis for future work, towards processing the collected data with respect to architectural and facilities descriptors, such as solar orientation, geometry, materials, and infrastructure equipment and devices. This approach will allow for a detailed understanding of how architectural features and types of equipment condition the use of energy and water, as well as waste production and disposal.

7. Conclusions

Academic infrastructure management is a task that faces several challenges in terms of controlling building consumption and services, requiring digital processes to assist in information management. In a data-fueled academic era, Internet of Things (IoT) systems enables detailed data collection and centralization, which is an essential approach for more efficient management.

In this paper, we presented a vision of our proposed IoT approach, which can monitor persons and processes, gathering data that can be manipulated to extract knowledge. The obtained knowledge may have a profound impact on the management of university buildings, streamlining campus operation. The main goal of this work consists of the creation of a prototype to obtain measurements about building environment variables, such as temperature, humidity, luminosity, and electrical consumption, and correlate the results with the presence of users. These measurements are important for supporting the department infrastructures and also for user perception of environment conditions and energy used. It is also a goal, in collaboration with the sociology and psychology departments, to explore the effects of this measured information towards the change in individual and collective behaviors. We have already presented some evidence of this approach in Section 3.4, where an initial case study in two monitored classrooms shows a change in behavior: Energy waste from lighting in a classroom decreases by 40% in the first testing period. Perception of user and community behavior, and the study of mechanisms to influence behavior toward sustainable goals are of vital importance for energy savings in shared spaces. Reward mechanisms, based on the proposed gamification approach, can contribute to guide individual and community behaviors towards changing actions and economic savings. As a consequence of the good results obtained so far, we are starting the second phase of this project, with an increase on the number of monitored classrooms, an expanded team with experts from other areas, and new financial aids.

As a future work perspective, focus groups and questionnaires will be used for gathering information on two levels: Individual and organizational. At the individual level, the project will measure environmental knowledge, attitudes towards engagement, intentions to behave more ecologically, acceptance of new and sustainable technologies, and perceived barriers and constraints. At the organizational level, we look for the improvement of management processes and savings with maintenance towards more sustainable use of the available resources.

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