Design and Implementation of a Platform for Smart Connected School Buildings

Dimitrios Amaxilatis[1], Ioannis Chatzigiannakis[1,2], and Georgios Mylonas[1]

[1] Computer Technology Institute & Press “Diophantus”, Patras, Greece
{amaxilat, mylonasg}@cti.gr
[2] Universitá degli Studi di Roma “La Sapienza”, Rome, Italy
ichatz@dis.uniroma1.it

Abstract. We have designed and implemented a platform that enables monitoring and actuation in multiple buildings, that has been utilised in the context of a research project in Greece, focusing on public school buildings. The Green Mindset project has installed IoT devices in 12 Greek public schools to monitor energy consumption, along with indoor and outdoor environmental parameters. We present the architecture and actual deployment of our system, along with a first set of findings.

1 Introduction

There are basically two routes towards cutting down on our carbon emissions: use more energy-efficient infrastructure/materials, or promote behavioral change on people living/working inside buildings, in order to consume less energy. The second approach is a solution to reach the envisioned environmental goals in reasonable time. In general, about 75% of buildings in Europe are residential [1]. Moreover, raising awareness among young people and changing their behavior and habits concerning energy usage is key to achieving sustained energy reductions. Specifically in the EU, people aged under 30 represent 33% of the total population [2]. Also, educational buildings constitute the 17% of the non-residential building stock (in m^2) in the EU [1]. By focusing on increased energy awareness and behavioral transformation within students and teaching staff we can envisage multiple benefits. Since energy costs are the second largest expenditure within school district budgets, significant savings can be had, if energy consumption can be reduced.

Our system provides real-time monitoring and actuation of multiple buildings over an IoT infrastructure. Our current implementation focuses more on energy consumption and environmental parameters monitoring, but can be tailored in order to support other applications and scenarios. In this context, it is currently being used as the basis for a Greek research project targeting energy efficiency in public school buildings. It is based on the installation of custom IoT infrastructure in a number of Greek public school buildings, monitoring energy consumption and environmental parameters, supplemented by a set of software tools aiming to help in educating students on energy and environmental matters and also achieve better energy efficiency in buildings.

2 Overview of the System

We wanted our system to be able to monitor and manage IoT infrastructure dispersed throughout several buildings in real-time and while using a single interface. The infrastructure is also spread out through several rooms inside the buildings. Moreover, we wanted our system to provide real-time update on what is happening in the real world, which on the one hand translates to storing vast quantities of data (since data are then produced by IoT nodes with a high rate), and on the other hand means efficient implementation practices throughout the whole stack of layers comprising the system.

Moving over to the implementation from an end-user point of view, the system aims to support different end-user groups. E.g., in the specific case of public school buildings, there are several such groups that can be identified: the students, the educators, the school building administrators and the Ministry of Education administrative staff. There is thus a need for the interface of the system to provide services and information in a way that suits all of these different categories of end-users. Lastly, we wanted our system to be expandable and easy to interface with other systems or components. There are numerous approaches and additional applications that can be implemented on top of the system.

Regarding the overall architecture of the system, at the lower layers we utilize multiple installations at school buildings. Each one of these installations consists of a multitude of IoT nodes (over 10) that communicate with the cloud infrastructure directly or via an IoT gateway device. The IoT gateways help to coordinate the IoT nodes and enable communication with the part of the system that is not capable of direct communication with the Internet, i.e., the IEEE 802.15.4 nodes that monitor the environment inside the buildings.

On the building level, the IoT nodes form an adaptive tree routing path to the gateway device over which they report their measurements to the gateway. On the Internet level, all information and control messages from and to the IoT nodes is passed on to a message bus system that is responsible for distributing the information gathered to the various subsystems responsible for storing the data, processing the data or generating notifications. On the data storage level, we use a distributed architecture with multiple services that offer us the ability to store data in multiple levels. With respect to interfacing the system with the end-users and the general public, we have implemented 2 web portals.

The overall design for the installation of IoT infrastructure in the school buildings participating in the project follows the same pattern inside each building: a) electricity consumption meters are installed to monitor the consumption of the building as a whole, or specific floors/sectors, b) a subset of the school's classrooms, or other rooms, have been fitted with IoT nodes, c) a set of gateway nodes provide bridging to the Internet, and, d) all IoT nodes communicate wirelessly with each other and the gateways. The system is complemented by the installation of IoT sensing and actuator infrastructure inside 2 office buildings, with devices also linked to the HVAC equipment., offering remote control of both air-conditioning/heating and lights. Apart from the indoor IoT infrastructure, there is a weather station and an air pollution monitoring station installed outdoors in each of the participating buildings.

Fig. 1. A close-up of a device installed inside an actual classroom (top of left image) and the weather station used at the Kastelorizo primary school (right image).

3 Implementation Aspects

As mentioned, we aimed for a system functioning over a heterogeneous IoT infrastructure. We utilised custom IoT nodes, built on open-source hardware and software. Additional hardware logic interconnects the sensors utilized for each class, i.e., humidity, temperature, luminosity, CH_4 and CO sensors, together with a noise level and PIR (motion) sensor. A custom plastic casing houses the hardware to enable easier installation in classrooms and offer additional safety to/from students and educators. The IoT nodes are AC powered, while they use an Xbee for communication. The weather station measurements are transmitted over Ethernet, also used to provide power. The radiation and environmental conditions monitors installed outside use WiFi to communicate with the Internet.

We implemented a web portal that enables a holistic view of the IoT infrastructure. End-users of the portal include educators and administrative staff from each school participating in the project, as well as administrative staff from the Greek Ministry of Educational Affairs.The first category of users have access only to data related to the respective school building, while the second ones have access to the entirety of the buildings. Visualization aspects also include some basic tools to add annotations to the produced data from the end-users, i.e., students, staff, parents, and also the ability to produce alerts from certain extraordinary events. In this way, end-users could provide annotations to the gathered data in order e.g., to classify certain events happening in the real-world and that could not be detected easily by software techniques, such as a spike in electricity consumption happening due to a school event.

4 Results so far - Conclusions

Table 1 summarizes the main figures so far. Regarding examples of preliminary results, we analysed the consumption of a school building housing a public secondary school and a private technical school, operating at different times of the day. It was impossible to distinguish between the consumption of the two entities, whereas now we have an overview of the energy consumed by each entity individually. At another building, located in an area with harsh conditions during wintertime, we noticed it required several days to reach comfortable conditions inside the building after the Christmas period, i.e., the temperature dropped to around 8° C and almost a week was needed to return to a more comfortable 20° C. Such data could be utilized in order to predict the average times that the building needs to be heated/cooled during the winter/summertime, saving time and resources and increasing overall comfort.

#schools	12	6 primary, 5 secondary, 1 high school
#sensing points	855	each node has ≥ 5 sensors
#students	2267	students in all levels
#teachers	294	teachers in all levels
#readings/sensor	960/day	classroom sensors (indoor)
sensing rate	90 sec	classroom sensors (indoor)

Concluding, our system follows a scalable architecture, built on open source technologies, that can be easily adapted and expanded. We have also developed several end-user interfaces that provide tools to both the educators and the administrators of such building facilities. Our first results are promising, showing that the current incarnation of the system is more than adequate for these tasks and it already helps in discovering trends in energy consumption, as well as findings in other cases. Regarding our future work, we intend to place an additional focus on the educational aspects.

References

1. Europe's buildings under the microscope: A country-by-country review of the energy performance of buildings. Tech. rep., Buildings Performance Institute Europe (BPIE) (2011), iSBN: 9789491143014
2. Key data on education in europe 2012. Tech. rep., Education, Audiovisual and Culture Executive Agency (EACEA P9 Eurydice, EUROSTAT) (2012), iSBN 978-92-9201-242-7