Teaching IoT Architectures and Technologies – An Application Project for the Monitoring and Control of Campus Lighting using LoraWAN

João Conceição[1*], Joel Gonçalves[1*], Frederico Santos[1,2], Carlos Coelho[1], Marco Silva[1] and Fernando Lopes[1,3]

[1]Polytechnic Institute of Coimbra, Coimbra Institute of Engineering
Rua Pedro Nunes, 3030 Coimbra, Portugal

[2] Instituto de Telecomunicações – Porto
Universidade do Porto, Rua Dr. Roberto Frias, Porto, Portugal

[3]Instituto de Telecomunicações - Coimbra
Pólo II da Universidade de Coimbra, Pinhal de Marrocos, 3030 Coimbra, Portugal

e-mail: {fred,ccoelho,msilva,flopes}@isec.pt

This paper describes an educational project aiming at teaching Internet of Things (IoT) network architectures and technologies to electrical engineering bachelor students. The project involves the monitoring and control of five Light Emitting Diode (LED) lights and associated electronics installed in the ISEC Campus. These objectives are achieved through the programming of a set of embedded systems that are integrated as network end devices in The Things Network (TTN).

The Internet of Things is a concept where Internet connectivity is extended into physical devices and everyday objects. It involves the convergence between communication technologies, embedded systems, wireless sensor networks, data analytics, machine learning, control and automation among many other fields. It has the potential to bring very high efficiency gains to most existing human activities involving technology, as well as creating new applications and business opportunities [1]. It is estimated that by 2020 it will interconnect about 24 billion devices [2].

Embedded systems are one of the key technologies supporting IoT and are especially important in the network end nodes or end devices that directly interface with the field sensors. In most architectures they are also a key component of the gateways that allow to bridge the sensor end devices wireless communication links to the Internet. In many IoT applications the end devices are based on a limited power, processing and memory embedded system, that features a very low data rate over a bandwidth–limited radio interface.

Applications are associated with the general concepts such as Smart Cities, Smart Grid, Smart Vehicles, Smart Homes, Smart Manufacturing, Smart Health, Smart Assisted Living and Smart Agriculture among others. These are fields where massive quantities of collected sensor information can be processed and used to control whole processes in a very intelligent way, leading to very high efficiency gains.

Many networks and technologies are being developed and used for the IoT. Among them, the LoRaWAN specification is developed and maintained by the LoRa Alliance, an open association of collaborating members [3]. The specification defines the device-to-infrastructure LoRa physical layer parameters and the LoRaWAN protocol, including AES encryption. The Things Network or TTN is a successful open IoT platform that follows the LoraWAN specification, with about 80500 members in 140 countries and with more than 8000 deployed gateways [4].

---

[*] Bachelor in Electrical Engineering – Electronics and Telecommunications Branch student
[*] Bachelor in Electrical Engineering – Automation Branch student

A specific field of application for the IoT is the reduction of the global energy consumption where optimizing street lighting is one very important component. In the context of the evolution to smart cities, it can be observed that lighting is a very significant fraction of cities spending, typically representing approximately 40% of a city's overall electricity costs, while an estimate staggering number of 4 billion outdoor lighting fixtures are in use globally [5,6]. Thus, among IoT applications, outdoor lighting applications have a very high potential for significant energy savings with the associated carbon footprint reductions.

Energy savings can be obtained through two main routes. Firstly, by gradually replacing old high-pressure sodium or mercury lamps (and other less representative technologies), by the much more efficient LED based lighting technologies. Secondly, large efficiency gains can be obtained from intelligent monitoring and control of light fixtures. The control system can be programmed to turn-off lights as per a predetermined schedule, to vary the intensity of lighting to suit ambient conditions such as sensed natural light and the presence of people and vehicles. Furthermore, the whole system can be designed to fully operate on solar energy with battery backup.

The project presented here addresses both above described energy saving components in an educational perspective. It is based on a IoT network that will allow to sense the required variables to monitor and control the light fixtures in order to maximize energy efficiency. Among sensed variables are internal state information from the electronic modules that control the light source such as current and voltages from led controller devices. This allows to use the communications infrastructure to both control in-service light fixtures and to simultaneously collect information aimed at improving the characteristics of light control electronic devices under development.

The project aims at developing hardware, software and the communications protocol that allow the monitoring and control of a set of five LED light fixtures integrated in the ISEC Campus. Two types of fixtures are used: 15W/12Vdc and 80W/34Vdc. The specified monitoring and control functions are as follows: instant and weekly scheduled on/off and dimming; ambient temperature and luminous intensity sensors; three voltage and there current sensors for electronic light controllers development and performance tests. The global architecture of the system is presented in Figure 1.

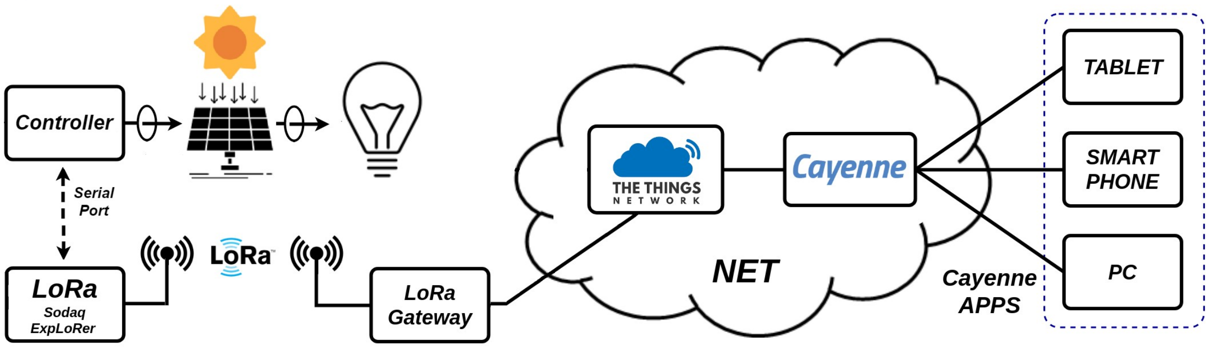

Figure 1: System architecture

The sensor end devices consist on a Sodaq ExpLoRer board featuring an Arduino compatible processor and a RN2483 radio module implementing the LoraWan PHY layer and the LoraWAN MAC protocol [7]. The end devices' software is written in *C*.

A Wirnet iFemtoCell LoRa nano gateway collects radio communication packets from end devices, one device per light fixture, and forwards them to the TTN network server through an IP connection using the Semtech IP/UDP Packet forwarder. The end devices and the gateway are configured to integrate the TTN network and are registered in the TTN infrastructure. Uplink data can be processed and is presented using an external integration through the Cayenne platform. The implemented Cayenne dashboard can be observed in Figure 2. Downlink information can be sent from the Cayenne dashboard or the TTN server back to the sensor devices through the deployed gateway.

Figure 2: Cayenne dashboard

Keywords— Embedded Systems, Internet of Things, Lighting Control, LoraWan, The Thighs Network

Acknowledgement: The authors would like to thank FikaLab for the use of a test Sodaq module and Gateway

References

[1] A. Zanella, N. Bui, A. Castellani, L. Vangelista and M. Zorzi. (2012). Internet of Things for Smart Cities. Internet of Things Journal, IEEE. 1. 10.1109/JIOT.2014.2306328.

[2] Business Insider Intelligence, “IoT 101: Your Essential Guide to the Internet of Things”, https://www.businessinsider.com/author/bi-intelligence

[3] Lora Alliance, https://lora-alliance.org/

[4] The Things Network, https://www.thethingsnetwork.org/

[5] Hannah Griffiths, IoT UK, “The Future of Street Lighting - The potential for new service development”.

[6] Smart Cities Council. Smart Street Lighting 101: How advanced street lighting systems can transform cities in remarkable ways. 2015.

[7] LoRa Alliance Technical Committee, “LoRaWAN™ 1.0.3 Specification”, July 2018.