ENSAM Rabat

National higher school of arts and crafts, Rabat

Internship report

Released In EMPEGEC company

Theme:

Street lighting's device registration and data publication in cloud

1st year, Engineering major EEIN

Electrical energy and Digital industry

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General Introduction

In Morocco, public lighting/street lighting, which represents a significant portion of the national energy consumption (public lighting alone accounts for between 30% and 40% of the energy consumption of a local community.[1]) is at the heart of energy challenges. The country is committed to an energy efficiency strategy aiming for a 20% improvement by 2030 [2]. The objectives include adopting more efficient lighting technologies and intelligent systems to reduce consumption, as primary energy and electricity demand are expected to double by then.

Due to the previously mentioned issue, street lighting will tend towards the use of solar energy, which involves the use of solar panels, batteries, sensors, and even controllers, that all together make a complete system that operates to convert solar energy during the day and use it for street lighting at night. This type of system requires monitoring to prevent any failure or to avoid reducing the lifespan of the equipment used.

Maintenance of street lighting in Morocco presents significant challenges. The lack of advanced monitoring methods can delay issue detection, thereby increasing costs. EMPEGEC, as a specialized in electrical work company, is engaged as a subcontractor of Marsa Maroc that is responsible for the infrastructure services at the port of Agadir. Its role includes managing various aspects such as electricity, plumbing, lighting, etc. This exposes the company directly to the challenges of street lighting, whether in terms of efficiency and energy independence or monitoring and preventive maintenance. That is why I chose to work on data registration from the central measurement unit of an intelligent and energy-autonomous street lighting system using solar energy, towards the cloud, to enable real-time monitoring and data analysis to prevent breakdowns.

This report will present the issue related to street lighting, the suggested solution, and other findings during the internship through the following chapters:

- The first chapter represents the company where the internship took place and its sector of activity.
- The second chapter addresses the challenges of street lighting and proposes technological solutions to deal with them.
- The third chapter represents the solution I worked on to allow optimized monitoring and preventive maintenance, which relies on recording data in the cloud to ensure real-time monitoring and data analysis to prevent breakdowns.

Acknowledgments

I want to express my sincere gratitude To EMPEGEC for welcoming me into The company during my internship.

I also wish to extend my warm appreciation to Professors Hossine El Ihssini and Fatima Ezzahra Nadir from the Higher School of Technology in Agadir for their valuable guidance and support throughout my internship. Their expertise and guidance were essential in achieving the solution I developed.

Through your company and under the mentorship of these dedicated professors, I have gained crucial skills and valuable experience that will have a significant impact on my academic and professional journey.I want to assure you that I will continue to apply the knowledge and skills I acquired during this internship.

Chapter 1: General presentation

Introduction:

This chapter is supposed to give general informations about the campany where the internship took place, and the mission that the internship aims to release.

1.1 Company Overview (EMPEGEC)

1.1.1 Creation

EMPEGEC is a young company established on November 8, 2006, by former senior executives of the former ODEP. They embarked on this venture after opting for voluntary retirement, having accumulated over two decades of experience in various leadership roles and in various ports throughout the kingdom.

EMPEGEC is a company specialized in electrical works. To assemble its teams, the company gathered professionals who had demonstrated competence, efficiency, and expertise in the field from various specialized enterprises and organizations.

The company EMPEGEC is officially recognized and accredited by both the Ministry of Equipment and the National Office of Electricity and Potable Water.

1.1.2 Headquarter

Mixed Company for Plumbing, Electricity, and Civil Engineering, 501, Tifaouine Building, Block E2, Oued Ziz Street, Q.I. 80020 Agadir – Morocco.

1.1.3 Activities

a) Audit:

- Ensure that the equipment and various electrical installations comply with ONEE (National Office of Electricity and Drinking Water) standards.
- Enhance the performance and functionality of the equipment, while ensuring cost control through the use of modern devices.
- Provide decision-making elements to carry out corrective interventions, anticipate and plan necessary work to prevent power interruptions.

b) Maintenance:

- Schedule preventive maintenance for medium and low-voltage electrical network and all electrical installations.
- Detect any anomalies and promptly replace faulty equipment.
- Analyze the dielectric oil sampled from transformer substations.

c) Corrective Maintenance and Repairs:

Offer the clients a nearby service for all repair interventions, with ready available teams, fast and cost-effective operations.

d) Engineering and Technical Assistance:

- Propose improvement solutions based on the resent electrical installations' potential and constraints.
- Evaluate cost savings associated with optimizing electrical installations.
- Cost control of installations through targeted solutions.

e) Installation and Equipment:

- Construct and install high-power transformer substations.
- Equip all electrical installations with suitable materials in compliance with safety, performance, and environmental standards.

1.1.4 Key Clients:

- ANP (National Ports Agency)
- MARSA MAROC
- ORMVA/SM (Regional Office for Agricultural Development Souss Massa)
- ONSSA (National Office for Food Safety) Souss-Massa Drâa Region
- ONP (National Fisheries Office)

1.1.5 Company datasheet

Address	immeuble Tifaouine 502 bloc E2 ouad ziz Q.I agadir
Phone number	05 28 84 72 48
RC :	12561
ICE :	001460260000085
Capital :	2 000 000.00 dhs
Revenue :	10,000,000 to 50,000,000 dh
Sector of activity :	Mixed Company for Plumbing, Electricity, and Civil Engineering
Creation date :	2006
CEO :	Mustapha Mouhtadi (Co-Gérant) Abderrahim Daouiri (Co-Gérant)
Workforce :	between 50 and 100

Figure 1.1: EMPEGEC datasheet

1.2 The mission

My mission was to guarantee the acquisition of the necessary parameters for keeping each street lighting pole under surveillance from Its controller, and then publishing it in cumolicity IOT cloud. First taking the acquisition data (Battery, voltage, current...) from the controller of every pole, spreading it throughout a mesh network that contains the street lighting poles in that area as its nodes, including the node with access to Internet, which is the pole that is connected to internet and could access to cumolicity IOT cloud to publish its data and the data of all the other poles in that cloud.

Conclusion:

Reading this chapter can give a brief impression of the internship, the company, and the mission, which is in fact monitoring street lighting poles, gather data via controllers, transmit it over a mesh network to a node with internet access, and publish data on an IoT cloud.

Chapter 2: Street lighting

Introduction

This chapter is going to introduce Moroccan street lighting alongside with its challenges as well as its opportunities and the technologies to implement in this field.

2.1 street lighting overview

Historically, street lighting in Morocco has been a primary element of urban infrastructure, since it contributed in safety, aesthetics, and functionality of the cities and towns. The focus was on providing adequate lighting in major spaces.

Recently, Morocco has made efforts to enhance its street lighting. This manifested in the adoption of more energy-efficient technologies such as LED lighting. LED lights offered many benefits, like lower energy consumption, longer lifespans, and reduced maintenance costs and also a reduction in gas emissions, which is suitable to Morocco's commitment to sustainable development. Efforts have also been made to expand street lighting to rural areas, improving safety and accessibility in these regions.

2.2 Chalenges

Despite the remarkable progress, Morocco's street lighting sector still faces several challenges :

- **Financial Constraints:** Upgrading and expanding street lighting infrastructure can require significant investment.So basically Budget constraints may limit the scale of improvements.
- **Maintenance:** Ensure a proper maintenance for lighting infrastructure is required for its effectiveness and long life span.And Adequate maintenance operations should be practiced regularly to prevent deterioration.
- **Energy Efficiency:** While LED technology offers energy savings, ensuring consistent energy-efficient operation requires monitoring and management. Poorly designed or maintained systems can still lead to energy wasting.
- **Smart Lighting and Automation:** By implementing smart lighting solutions that allow remote control and automation energy efficiency can be enhanced and operational costs can be reduced. However, the adoption of such technologies will require technical expertise and initial investments.

2.3 Technological development

2.3.1 Moroccan street lighting opportunities

There are several opportunities for the future of street lighting in Morocco thanks to the huge technological development the world has known with the fourth industrial revolution and the tendency into energy efficiently techniques, which will be shown as follows:

- **Renewable Energy Integration:** Morocco's commitment to renewable energy, basically solar power, presents an opportunity to integrate solar-powered lighting solutions into public infrastructure. This can free the street lighting from traditional energy sources and contribute to the sustainability goals.
- **Smart City Integration:** street lighting can be a foundational element of smart city initiatives.And ntegration with data analytics and IoT (Internet of Things) technologies can lead to more efficient lighting management.
- **Public-Private Partnerships:** The collaboration between government entities and private sector companies can lead speed up the upgrades in lighting infrastructure.
- **Tourism and Aesthetics:** Enhancing street lighting in historically and culturally significant areas can contribute in tourism development and highlight the beauty of Moroccan architecture and landscapes.
- **Environmental Impact:** The focus on energy-efficient technologies can contribute to Morocco's efforts to limit climate change and reduce its carbon footprint.

2.3.2 Technologies to involve in street lighting

Supervision

Supervision and the interest behind it The term supervision in industrial sectors refers to the act of continuously viewing/checking equipment and the different work forces to verify if they are working as planned, as well as controlling them. The main reason for doing supervision is to ensure the continuity and safety of industrial installations. Now after the huge advancement that the field of artificial intelligence has known, the used data in supervision can be collected to be exploited to predict future events or constraints in the future to avoid them or perfectly manage them. For example: predicting the right time to do the maintenance and machinery previewing...

Supervision's evolution through time

We may think that supervision has started under the forma we are seeing it nowadays, being done through multiple screens in specified rooms for that specific task; far from the worksite, but humans were always supervising their production, even before HMIs (human-machine interfaces) were invented, this task used to be done directly, humans must visualize the production evolution, and check if the working forces and machines are respecting the time schedules by themselves. After the industrial revolution, production kept getting bigger and bigger. Hence the supervision task started to be more complicated and challenging, and needed to be done in more effective ways, so after the third industrial revolution (also known as industry 3.0) in the late 1900s, which was characterized by the spread of automation and digitalization by using computers..., the supervision as well as other process has gotten automated. The manner to supervise machines has become representing actuators by LEDs (lighting up means that the actuator is ON and vice versa) and controlling them with actual physical buttons. Then it went to visualizing the working forces including machines through screens and controlling them from distant places. This turning point was due to evolution of protocols like Modbus (1979) which allow the read write of bit/ bits as well as word/words. With the evolution of automated systems, switching from hard-wired logic to programmed logic with microprocessors and programmable logic controllers, HMIs have also been developed to facilitate supervision tasks. They have gone from the control desk and screen printing (with buttons and indicator lights, etc.) to supervision screens and PCs, which is making the option range of human-machine interfaces wider, since graphic user interfaces are getting easy to develop, which is giving them a huge diversity. And recently with the emergence of IOT implementation it is getting even easier to supervise various installations in various remote places (like street lighting poles or farms...0) without the need to any physical support or constant transportation of workers to do checkups. This advancement cannot be anything other than profitable for diverse sectors, because the easier the supervision task gets, the less costing it becomes.

supervision in street lighting

Supervision in street lighting plays a pivotal role in ensuring the effective operation, maintenance, and management of lighting infrastructure. By implementing robust supervision systems, authorities can monitor lighting performance, promptly address malfunctions, and optimize energy usage. Real-time monitoring and data-driven analysis enable quick responses to technical issues, contributing to safer and well-lit public spaces. Additionally, supervision facilitates the implementation of smart lighting solutions, enabling remote control, dimming, and scheduling based on usage patterns. This approach not only enhances energy efficiency but also supports sustainable urban development by creating well-lit environments that promote security, aesthetics, and community well-being.

Figure 2.1: modern street lighting

Internet of Things

The Internet of Things (IoT) is a technological concept that refers to the interconnection of everyday's objects and devices through the internet,Making a network of interconnected devices that can communicate, share data, and perform actions without direct human intervention. Basically IoT technology in order to gather and transmit data, enabling real-time monitoring, analysis, and control systems, It relies on sensors, actuators, and communication protocols. Its potential applications are vast, from industrial processes and healthcare to smart homes and urban infrastructure/smart cities...

Figure 2.2: Internet of things

Use of IoT in street lighting

the way cities manage and optimize their lighting infrastructure could be revolutionized thanks to the integration of IoT technology into street lighting systems. IoT-enabled street lighting allows for remote monitoring and control of individual light fixtures or groups of lights. This may enable flexible adjustments in lighting levels based on various factors mostly external ones such as ambient light, and traffic patterns. Moreover, IoT sensors can detect faulty lights or malfunctions and automatically trigger maintenance alerts, accelerating timely repairs and minimizing downtime. The collected data from these systems can be analyzed to understand usage patterns, which helps city planners make informed decisions about energy consumption and urban planning. Overall, IoT can transform street lighting into a flexible, responsive, and efficient system that contributes to sustainable urban development and improved quality of life for residents and visitors alike.

Mesh network

A mesh network is a versatile and resilient communication topology that allows multiple devices (nodes) to interconnect with one another. Unlike traditional topologies like star or bus, where all communication goes through a central node, mesh networks allow nodes to communicate directly with each other. This creates a network architecture that can dynamically reroute data through various paths if one node becomes unavailable. Each node in a mesh network acts as a relay, amplifying the signal and extending the network's coverage. This self-healing and self-organizing characteristic makes from mesh networks well-suited architecture for scenarios where reliability, scalability, and adaptability are crucial.

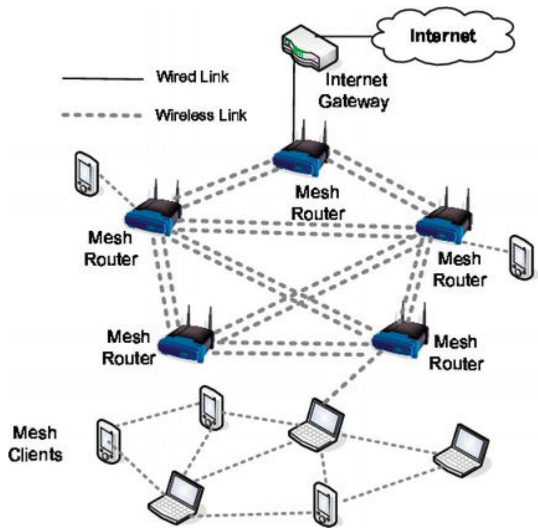


Figure 2.3: Mesh Network

Advantages of Mesh Network for street lighting Monitoring I found mesh networking is an ideal topology for street lighting monitoring/supervising for several reasons. One of the main advantages of mesh networks in this application is that they can work without the need to make every node connected to the internet, this is because mesh networks are designed to be self-organizing, meaning that each node can communicate with other nodes in the network, even if they are not directly connected to it or to the internet . This makes mesh networks more resilient to node failures and blackouts. Other benefits of mesh networks for street lighting monitoring include:

- **Scalability:** Mesh networks can easily scale to accommodate additional nodes, making them ideal for large-scale street lighting projects.
- **Range:** Mesh networks can cover large areas, which makes of them an ideal choice when it comes to street lighting monitoring/supervising in urban or rural areas.
- **Network topology:** Mesh networks can be designed to be adapted to different network typologies, making them flexible and adaptable to different street lighting monitoring needs.

Conclusion:

This Chapter represents a recap of the general information I had to gather in order to suggest a street lighting solution, which leaded to data registration to cumulocity iot cloud throughout a limited number of poles in each area that are connected to internet and that collect the data of the other poles in the same area via a mesh network.

Chapter 3: Mission development

introduction:

In the previous chapter, we concluded that the ultimate way to overcome the struggles that street lighting faces is the implementation of advanced technologies to manage energy consumption and supervision. This chapter will show the steps to prototype a system that guarantees the remote monitoring of a street lighting fixture that is based on solar energy and has a measurement Central that can share data like (current, battery, luminosity...) via serial communication.

3.1 Specifications

To overcome the problems of energy and Environmental impact, alongside with adopting renewable energy source like solar energy, several other procedures should have been followed to guarantee the efficiently and prevent breakdowns, most importantly permanently visualizing and diagnosing the public light fixtures' parameters. Therefore, this mission aims to manage the acquisition of the measurements From controllers associated to each street lighting pole and insure it is registration to cloud. Thus, the specification of this mission will be as follows:

- Data acquisition from the solar smart controller associated to each public light fixture with serial communication.
- Establishing a mesh network of the street lighting nodes and podcasting the collected data through it towards the final node that has internet access.
- Data reception using the final node and publishing it in cumulocity iot platform.

The following block diagram explains briefly what my mission is supposed to prototype:

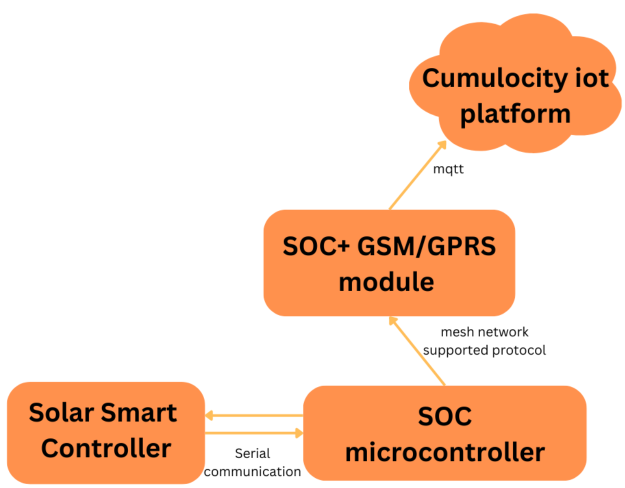


Figure 3.1: Bloc diagram of the mission's specifications

3.2 The used solar energy system

In general, our system consists of a street lighting pole powered by solar cylindrical PV panels and a solar smart controller as shone in the following figure:

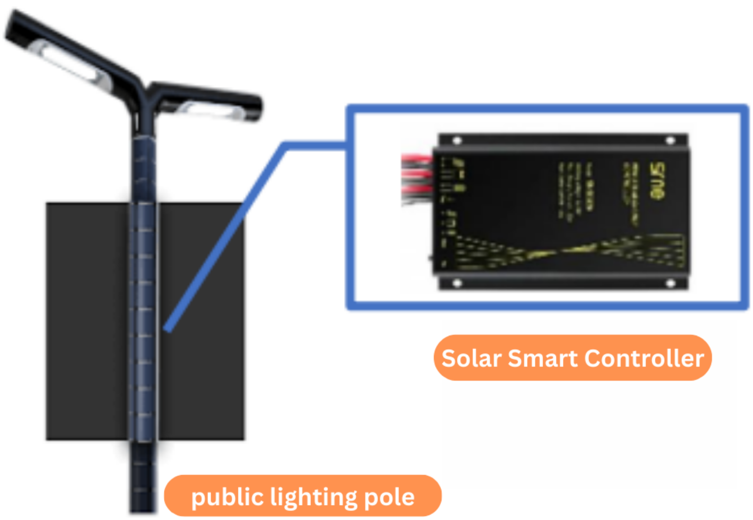


Figure 3.2: Agamin solar street lighting system

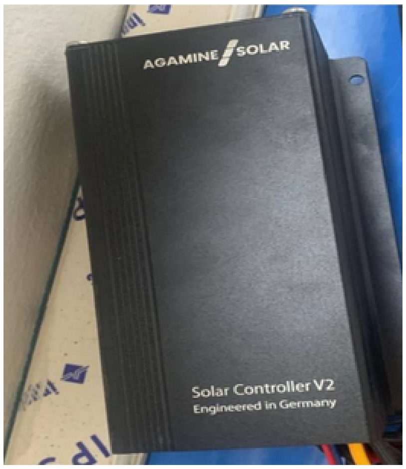


Figure 3.3: Agamin solar charge controller

In the pole, there are several sensors that collect informations about the system, such as temperature, voltage, and battery level... The values measured by the sensors are gathered in the Solar Controller. When the ASCII character "space" (SP,0x20) is sent to the charge controller, it will answer with a string of ASCII characters starting with echoing the space sent character followed with the measured values.

Example: (leftmost character before the first "0" is a space)

00005;00002;00488;01412;00000;009523;013095;00027;00003;002;000;00009;00000;032;13985;14000;100; +18;+17;+25;1;1;08194;00000;00000;00599;60994;

3.3 Tools to prototype the IOT solution

In order to do the necessary checks for both platform and the material then elaborate the prototype, I needed the following tools

3.3.1 Hardware

The charge controller

In the solar system, Agamin solar, the charge controller was the art with which I interacted since It is the one that provides the whole parameters it collects in a single frame ready to be transported or treated .

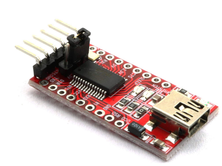
The system on a ship
This part is a necessary one in the IOT solution, because it is the one getting the collected data from the data charge controller and managing it. For this task's prototyping, I choose an ESP32, since it is very suitable for testing my prototype, what makes it a satisfying choice is a Wi-Fi module alredy integrated in it, its ability to communicate via 3 hardware serial canals for data transaction which will be very useful when integrating an GSM/GPRS module to get the access to internet network for data publication, moreover the price of it is very suitable comparing to other electronic cards that can handle the same applications, furthermore it is the easiest to use for testing this kind of prototypes.

And I used a raspberry pi 4; which is a low-cost, credit-card sized computer to get familiar with publishing data in cumulocity using a remote wireless device.

Modem

As said before, the frames transmitted through the mesh network must be published in complicity after being received by the node that has internet access, for this I used a sim808 gsm/gprs module to provide a node with internet connection.

Adapter
The USB to TTL converter kind of chips is usually used to interface microcontrollers with computer through USB cable. The one we used specifically is FTDI chip which allows the conversion of a USB signal to an UART signal that can be understood by devices like Arduino, ESP... This component was used to communicate with the GSM module via a serial port terminal through USB port.



Power supply

A 5V 2A power supply was needed to run the modem since it has a DC socket on the shield, which is for a 5V power supply: The power pins are 5V and GND, and the SIMCOM hardware manual for the module notes that it can draw up to 2A for short bursts.

3.3.2 Software

To elaborate the remote management irrigation system, the following software tools were used:

Integrated development environment

An integrated development environment (or an IDE) represents the programing software application that provides comprehensive facilities and tools to programmers and developers. The one I used is Arduino IDE since it is the proper one to program the electronic card used for data collection and management.

Cloud

To the IOT solution It was necessary to have a cloud-based service for remote data registration. I used Cumulocity IOT which is a self-service IoT platform that connects and manages any device and gateway over any network, in order to allow monitoring, controling, and analyzing devices in real-time.

Intermediate

Thin Edge is a data management and connectivity platform designed for the Internet of Things (IoT). It enables the collection, storage, and secure and efficient transfer of data between IoT devices and Cloud applications. I have employed Thin Edge to facilitate the transmission of collected data to the Cumulocity platform using the MQTT protocol whit a raspberry pi in the initial phase.

Emulator

Hercules emulator helped to preview the GSM module, modify the necessary configurations for it and even flash it before starting to use it. This serial port terminal could be also used to test the GSM module every now and then when facing any issues related to it,

IoT analytics platform service

ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud. I got advantage of this platforme to test my devces capability to publish data in cloud and test their reliability before using them with cumulocity IOT.

3.4 Phases of the mission

3.4.1 Tools' check

I first tried to get familiar with sending data to cumulocity, and tested my ability to publish in my environment using a remote device, for that I needed a raspberry pi where I set the thnedge using the following steps and used it as an intermediate to publish data in cumulocity. Seting thinedg using these commands:

1.sudo apt-get update && sudo apt-get upgrade

2.curl -fsSL
https://raw.githubusercontent.com/thin-edge/thin-edge.io/main/get-thin-edge_io.sh | sudo sh -s

3.sudo tedge config set c8y.url my cumulicity url

4.sudo tedge config set c8y.root.cert.path /etc/ssl/certs

5. sudo tedge cert create –device-id MY UNIQUE DEVICE ID mac adress

6.certificate upload steps: device management ==> management ==> trusted certificates ==> add certificate ==> brows ==> chose certificate in this path /etc/ssl/certs ==> enable

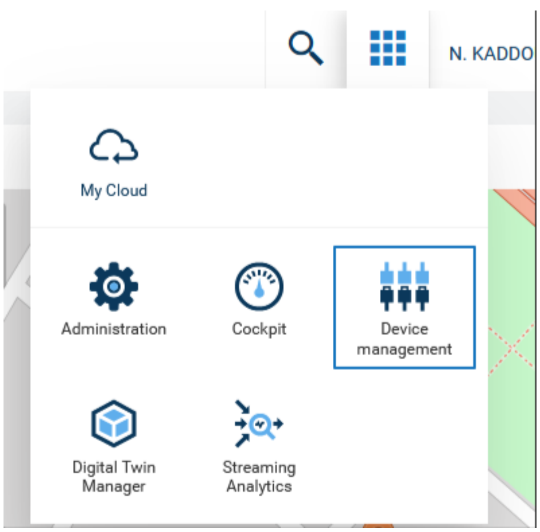


Figure 3.4: Cumulocity IOT's principal menu

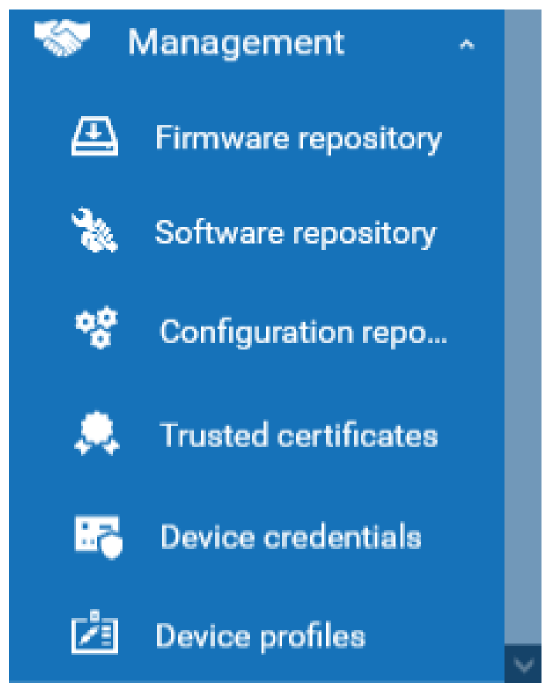


Figure 3.5: Device management options

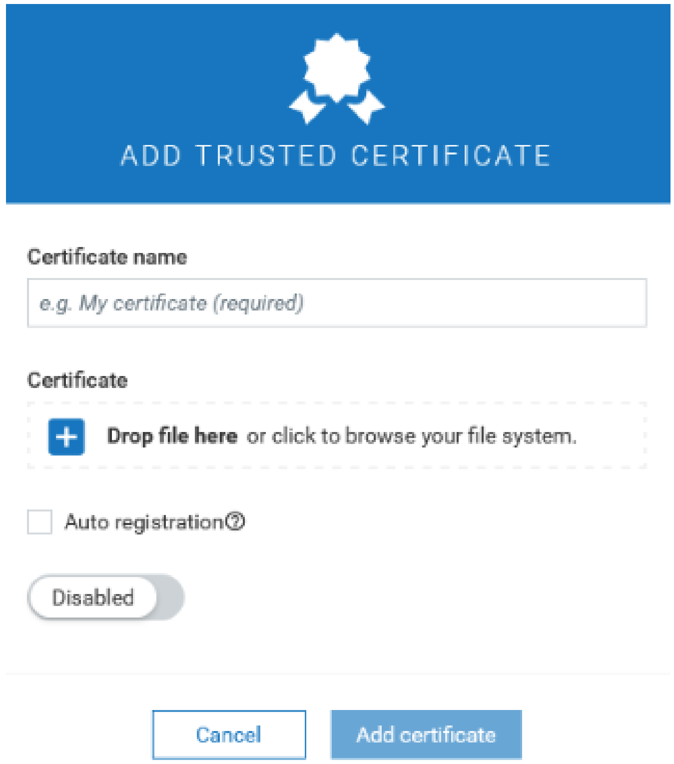


Figure 3.6: Certificate upload in Cumulocity IOT

To establish connection:

sudo tedge connect c8y
To publish a measurement (in mesearments section)

in main:

tedge mqtt pub tedge/measurements '

"temperature": 25 '

To publish a measurement (in mesearments section)

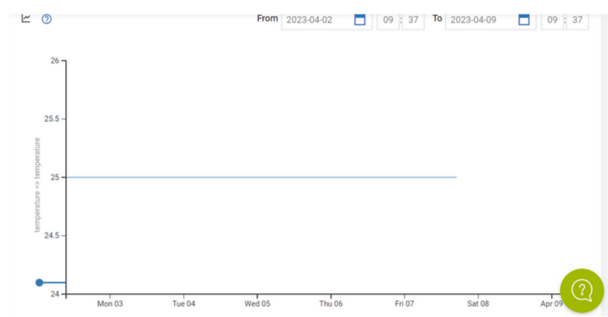
in main using a python code it is enough to import

os's standard library.

import os os.system("tedge mqtt pub

tedge/measurements/LDR3 "+"'

"+'"'+"temperature"+'"'+": 25 "+"'")



To publish event in event section of a child device (in this case it is door):

tedge mqtt pub tedge/events/door '"text": "A door was closed","time": "2022-06-10T05:30:45+00:00"'

Then the GSM module's simple check check, using The FTDI ship to interface it with the computer, in order to test the reliability of its response to AT commands(these commands will be later shown in the data publication part), especially the necessary ones for my mission.

And the last check was the esp32 check, to test its ability to connect to internet and publish data using a GSM module, in this step I tried to publish variant values in thing speak website using the sequence of at commands, and then see the evolution on the Thingspeak platform.

3.4.2 Esp device creation

steps to create esp device in cumulocity iot

In cumulocity IOT platform follow this path: Administration »> Users »> add user

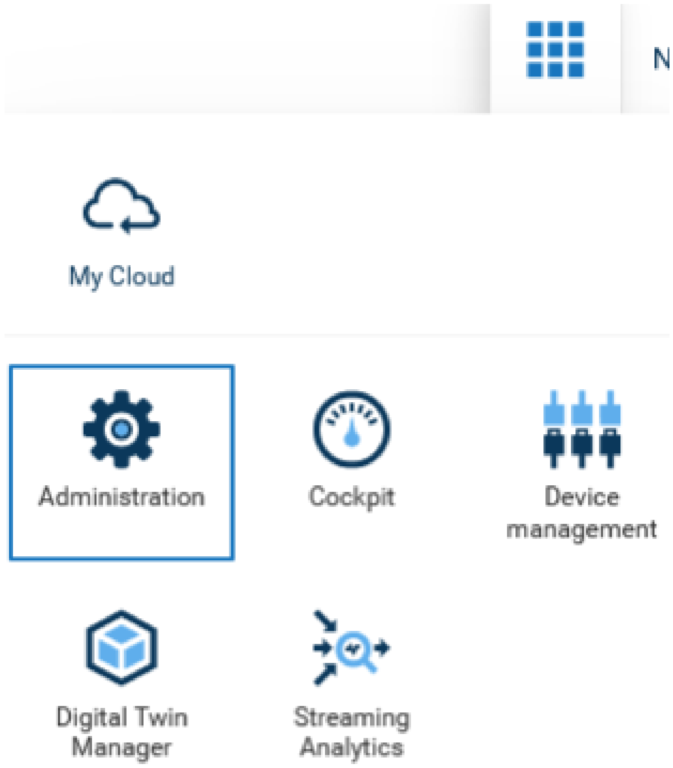


Figure 3.7: Cumulocity IOT's principal menu

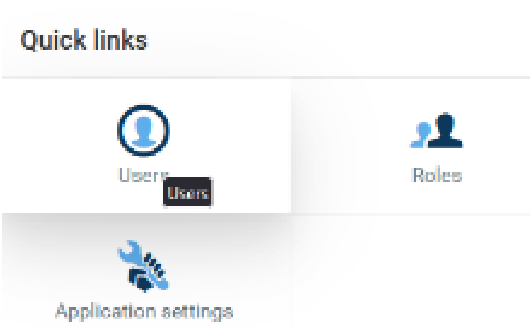


Figure 3.8: Users section

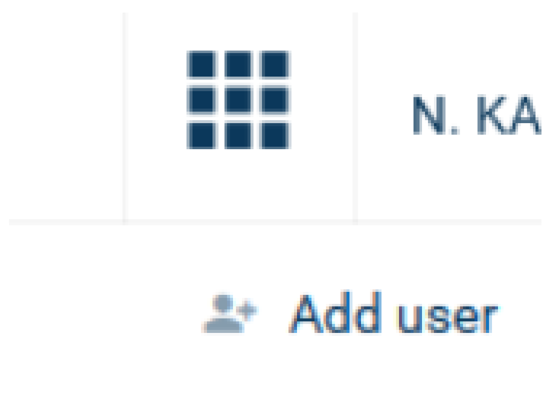


Figure 3.9: Add user

Once you click "Add user" a page like this will appear, fill it up and try to set the password using the link that will be sent via email (Note that when setting the password, you must enter the same new email with which you registered the user)

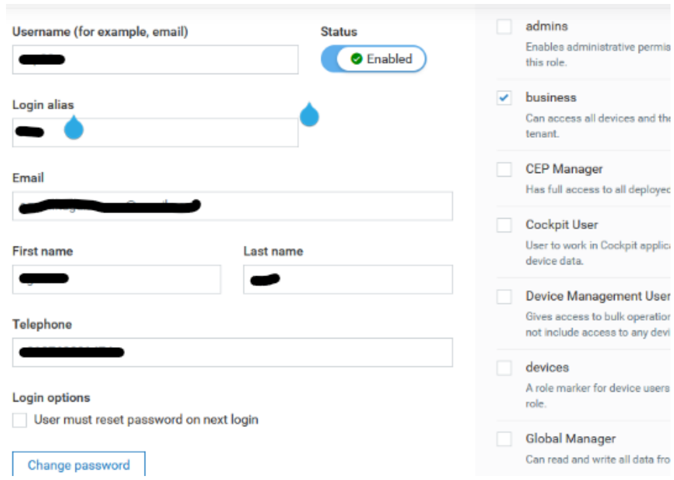


Figure 3.10: User creation and configuration

after changing the password successfully via the link select the following Roles:

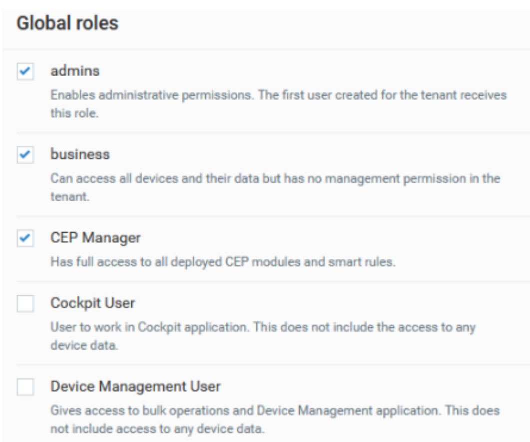


Figure 3.11: Global Roles configuration

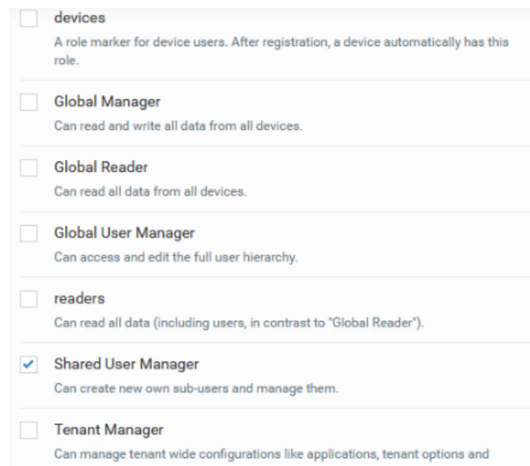


Figure 3.12: Global Roles configuration

3.4.3 Data collection

To get the measurements from the controller, I had to follow the protocol designed for it, which requires sending a space character to the controller in order to receive the values of all the measurements in a string of ASCII characters starting with echoing the previously sent space.

```
HEX:    20  30  30  30  30  35  B3 ... 3B  30  31  33  30  39  35  3B
ASCII: [SP] 0   0   0   0   5   ;  ... ;   0   1   3   0   9   5   ;
```

Figure 3.13: Smart controller response to space character

The following fragment of code could be used for data acquisition:

```
import serial
import time

ser = serial.Serial('/dev/ttyUSB0', baudrate=19200, parity=serial.PARITY_NONE, stopbits=serial.STOPBITS_ONE)
ser.write(b' ')
time.sleep(2)
l = b''
l = ser.read(143)
```

Figure 3.14: Lines of code to get data from the smart controller

3.4.4 Data transaction using mesh network

I have chosen a partially meshed network topology for the devices' connectivity to make it possible for all the wireless devices to send their measurements without the need for internet connection. To simply explain how I used the mesh network: each device sends its ID followed with the measurements of its pole after their acquisition as well as the data It received from other devices with smaller ID towards the pole with the greatest ID which is connected to internet. The following scheme can give an idea on how the established mesh network works: While in the hardware part I needed only the smart controller and the

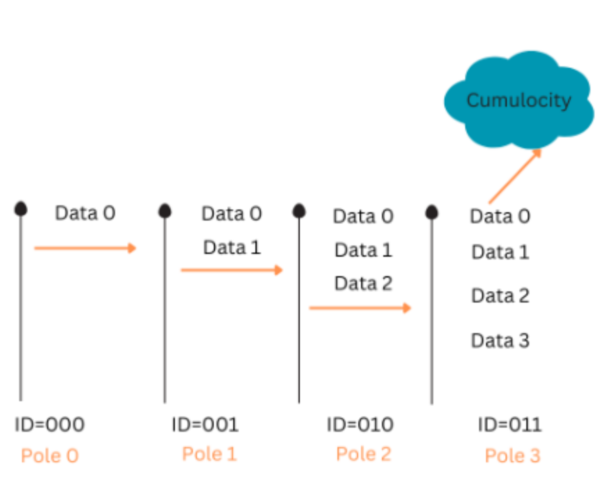


Figure 3.15: Simplified scheme of the established mesh network

electronic card, in the software part painlessmesh library was required to set the set the mesh network, integrate devices in it, and share data easily.

```
#include "painlessMesh.h"
```

In order to set the mesh network, It is a must to define the identification parameters and the port.

```
#define MESH_PREFIX "agamin"
#define MESH_PASSWORD "stage_mesh"
#define MESH_PORT 5555
```

Then I defined the receivedCallback function that is destined to be associated to the OnReceive Method of the mesh object that gets called when a message is received. In this function I store the received data and extract the sender's identifier from it, and finally convert it into integer to make it possible to compare it with the actual node's identifier.

```
void receivedCallback(uint32_t from, String &msg) {
  Serial.printf("Received from node %u: %s\n", from, msg.c_str());
  message =msg.c_str();
  String firstThreeChars = msg.substring(0, 3);
  SenderID = firstThreeChars.toInt();
}
```

Then setting up the configuration for a wireless mesh network in the setu function as follows

```
void setup() {
  Serial.begin(115200);

  mesh.setDebugMsgTypes(ERROR | STARTUP);
  mesh.init(MESH_PREFIX, MESH_PASSWORD, &userScheduler, MESH_PORT);
  mesh.onReceive(&receivedCallback);
 // mesh.begin();
}
```

- mesh.setDebugMsgTypes(ERROR | STARTUP);: This line configures the types of debug messages that should be displayed.
- mesh.init(MESH_PREFIX, MESH_PASSWORD, &userScheduler, MESH_PORT);: This line initializes the mesh network.
- mesh.onReceive(&receivedCallback);: This line sets up the callback function to handle incoming messages.

Then in the void loop I call the update function to check for received messages or errors. When a message is received, I check the previously extracted id's value, and add the received data to the measurements of the controller in case the sender's id is beneath the node's id to send them together, but if it is not, I send only the data received from the associated controller. To enssure that I do not send data back to its sender but to the poles with bigger identifiers instead.

```
void loop() {

  String msg;

  mesh.update();

  if (SenderID<nodeID)
  msg = String(nodeID)+";"+acquisition+"/"+message;
  else
  msg =  String(nodeID)+";"+acquisition;

  Serial.println("send : "+msg);
  mesh.sendBroadcast(msg);
  delay (500);

}
```

3.4.5 Data publish in cumulocity

The task of publishing data in cumulocity is released by the pole that has internet connection thanks to a GSM/GPRS module connected to the ESP32 with serial communication using the hardware serial of the ESP32. And the following steps are needed to set up the connection and send data to cumulocity platform.

I defined the following function to make it easy to read the data in the baffer received from the GSM module via serial communication and display it:

```
void ShowSerialData()
{
  while(Serial2.available()!=0)
  Serial.write(Serial2.read());
  delay(5000);

}
```

Note that Serial2 refers to the serial communication through the UART pins of ES32 GPIO 16 (RX) and GPIO 17 (TX).

First thing is checking the serial communication by sending the at command “AT”

```
Serial2.println("AT");
delay(1000);
ShowSerialData();
```

The response for this command must be “OK”. Then checking the sim cards operationality with the command “AT+CPIN?”

```
Serial2.println("AT+CPIN?");
```

The response for this command must be “+CPIN: READY” which means that the SIM card is ready and operational. Then I send the "AT+CREG?" command to the GSM module to inquire about the current registration status of the module on the cellular network.

```
Serial2.println("AT+CREG?");
```

The response must be +CREG: 0,1 , This response indicates that the module is registered on the network. It means that the module has successfully connected to a cellular network and is ready for communication. Then “AT+CGATT?” must be sent to check data attachment status of the module to the cellular network.

```
Serial2.println("AT+CGATT?");
```

There are two possible response:

- +CGATT: 0: This response indicates that the module is not attached to the GPRS service. In other words, the module is not currently connected to the cellular data network.
- +CGATT: 1: This response indicates that the module is attached to the GPRS service. It means that the module is currently connected to the cellular data network and is ready to send and receive data.

If the response is 0 then the module should be attached to GPRS with the at command “AT+CGATT=1”. After that I shut down or close any active network connections or sockets with the command "AT+CIPSHUT". After that, setting the APN, in my case it is the APN provided by the operator I use which is inwi by sending the following string:"AT+CSTT=ẅww.inwi.ma"̈. Then I send this command to bring up wireless connection :"AT+CIICR". The last thing before sending the data is to get local I address with the following at command: "AT+CIFSR". And this command is supposed to trigger a response that holds the token IP address by the device. After completing these steps successfully, the remaining task to do will be connecting to the mqtt broker and publishing the data using mqtt protocol. Cumulocity IoT supports MQTT both via TCP and WebSockets, and the following options are provided in the port choice.

	TCP	WebSockets
SSL	8883	443
no SSL	1883	80

Figure 3.16: Supported ports by Cumulocity

“8833” port which supports two-way SSL is enabled by default and it is the one I used. As URL I could use the domain of the instance in the format mqtt.<instance_domain> (for example mqtt.cumulocity.com) or my tenant domain (for example env443915.cumulocity.com/mqtt). In my implementation I used the first one. And the following AT command resumes the TCP communication initiation process:

```
Serial2.println("AT+CIPSTART=\"TCP\",\"mqtt.us.cumulocity.com\",\"1883\"");
delay(2000);
ShowSerialData();
```

When the initiation of TCP communication is done (response: CONNECT OK) It becomes possible to send data with the with the command AT+CIPSEND followed with the data to send in a frame that is compatible with mqtt (called mqtt packet). While using mqtt protocol it was mandatory to follow the standard mqtt packet structure, for example here is the standard structure for connect packet:

Byte	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Meaning	Header	Remaining Length	Length of prtocol name		Protocol Name +Version					Connect Flags	Keep Alive		Length								
Hex	0x10	0x13	0x0	0x4	0x4d	0x51	0x54	0x54	0x4	0x2	0x0	0x3c	0x0	0x7	0x70	0x79	0x74	0x68	0x6F	6E	0x31
Ascii		19		4	M	Q	T	T	4			60		7	P	Y	T	H	O	N	1

Figure 3.17: MQTT connect message structure

This packet had to be adapted to my needs by changing the remaining length, in this case it was “ex2C” which means 44 bytes, the connect flag also needed to be changed from 0x2 to 0xC2 by switching the value of the two msb bits of this byte from 0 to 1 to enable the username flag (bit 7) and the password flag (bit 6), the connect flags values are adapted according to this correspondence:

User name flag =	bit 7
Password Flag =	bit 6
Will Retain =	bit 5
Will QOS =	bit 5
Will QOS =	bit 4
Will Flag =	bit 2
Clean Session =	bit 1
Reserved =	bit 0

My payload holdes the following parameters;

00 05: Client ID Length (5 bytes)

37 33 31 33 35: Client ID (73135)

00 0F: username Length (15 bytes)

65 6E 76 32 33 35 31 33 38 2F 65 73 70 33 32: username (/env235138/esp32)

00 08: password Length (8 bytes)

45 73 70 33 32 40 30 30: password (Esp32@00)

And then the publish packet could be something like this:

Fixed Header:

30: MQTT Control Packet type (Publish)

11: Remaining Length (17 bytes)

Variable Header:

00 0D: Topic Name Length (8 bytes)

73 2F 75 73 2F 4C 44 45 31 : Topic Name (s/us/LED1)

Payload:

32 30 30 2C 32 35: Message (200,25) Sending this same packet in a loop may enable in the cumulo city iot platform the visualisation of the following graph: Since each node that has connection to internet

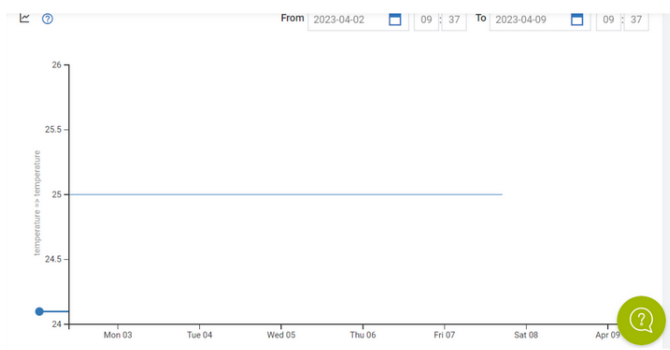


Figure 3.18: Displaying measurements in cumulocity cloud

ublishs its data and the data of all the other nodes in its erea, then the child device option could help to keep things organized in the platform, by including the child name in the publishing proccess, for example: s/us/LED1 in this case LED1 is the child device.

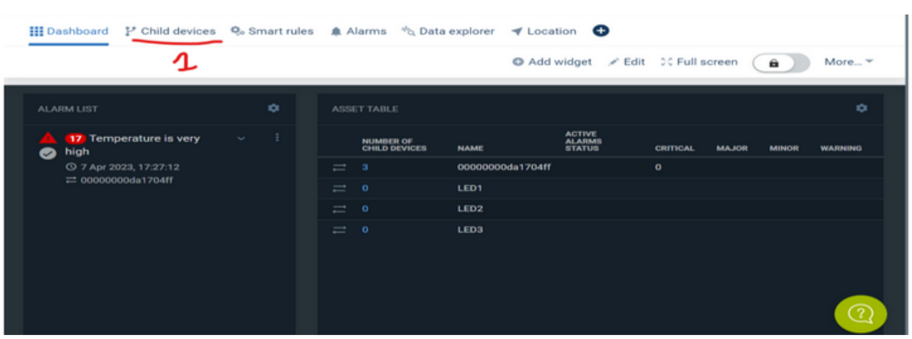


Figure 3.19: Device management in cumulocity platform

And then customizing the widgets to present the parameters inside each device, then the interface may look something like this:

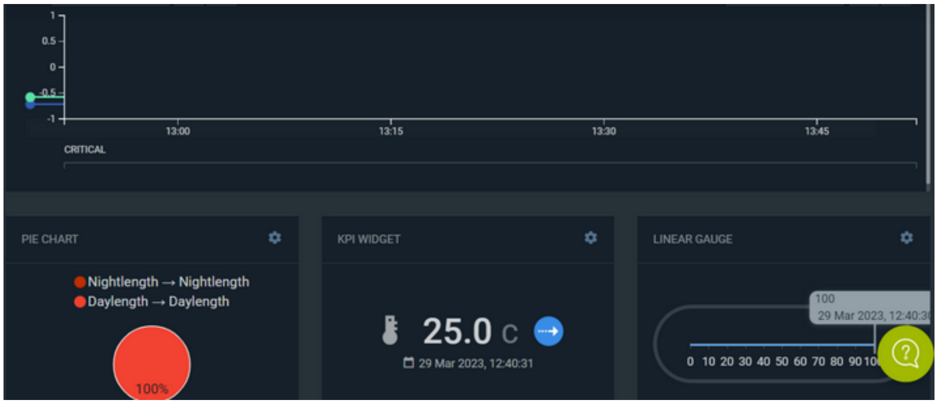


Figure 3.20: A customized item in cumulocity

conclusion:

This chapter highlighted the mission I had to release in my internship step by step, from collecting the data from the smart charge controllers using serial communication to data transmission in the mesh network and finally publishing it in cumulocity cloud using mqtt protocol. these phases accomplishment can pave the way to data analysis in cumulicity platform as a final phase in the global project.

General Conclusion

To resume, the report has highlighted the challenges of street lighting in Morocco, that represents a significant portion of commercial and public service energy consumption. Not to mention that the country is committed to an energy efficiency strategy, which basically imposes adopting more efficient lighting technologies to reduce consumption, so focusing on modernizing and optimizing street lighting is becoming a need. The report has proposed a technological solution to deal with the challenges of street lighting, which relies on recording data in the cloud to ensure monitoring and data analysis to analyse consumption behavior and prevent breakdowns. The solution is expected to enhance monitoring and preventive maintenance, which can help reduce costs and increase efficiency. Overall, the report has shed light on the importance of street lighting and the need for innovative solutions to address the challenges it poses. The mission that the report presents is the initial phase of the street lighting data registration and analyses in cloud roject, the accomplished steps still require data analysis in the cumulicity side in order to reach the goal of breakdown avoidance and remote maintenance when possible.