UNIVERSITY OF LIVERPOOL

Department of Electrical Engineering and Electronics

ELEC423

Assignment 2 – IoT Prototype Assignment

Module	ELEC423
Coursework name	Assessment 2
Component weight	25 %
Semester	1
Level	7
Lab location	PC lab 402 as timetabled, at other times for private study
Work	Individually
Timetabled time	9 hours
Suggested private study	28 hours (including report writing)
How much time did it take YOU?	Let us know anonymously via https://bit.ly/EEECARES
Assessment method	Summative
Submission format	Online via CANVAS
Submission deadline	Week 12 (17th of December at 23:59 UK time)
Late submission	Standard University penalty applies
Plagiarism / collusion	Standard University penalties and procedures apply for plagiarism and collusion.
Resit opportunity	Yes, a resit exam will replace Coursework Assessment (if total module failed)
Marking policy	Marked and moderated independently
Anonymous marking	Yes
Feedback	Via comments on Canvas
Learning outcome	M2: Demonstrate an ability to design and implement IoT based prototypes. M3: Demonstrate a knowledge of the IoT architecture and technologies used to design and implement it. M4: Demonstrate a knowledge of IoT embedded systems based on Linux.

Marking Criteria

Section	Marks available	Indicative characteristics	
		Adequate / pass (50%)	**Very good / Excellent**
Presentation and structure	15%	• The submission contains a document with a cover page (title, background, academic integrity declaration), the description contains focused screenshots, and an Appendix with full-screen screenshots (see below). • Submission contains original source code file(s). • Comprehensible language; punctuation, grammar and spelling are accurate. • Equations are legible, numbered and presented correctly where relevant.	• Appropriate use of technical, mathematic and academic terminology and conventions where relevant. • Word processed with consistent formatting. • Pages and equations are numbered; figures and tables are numbered/captioned. • Clear section headings and sub-headings where relevant • Correct cross-referencing (of figures, tables, equations) and citations where relevant.
Design and Method	50%	• Code is original and relates only to the assignment objectives. • Code is tidy, efficient and easy to follow / understand. • Code is clearly laid out and appropriately commented. • Code corresponds to design for each step. • Clear explanation of key procedures undertaken.	• Code is elegant, efficient and "DRY" (Don't Repeat Yourself). • Comments show excellent understanding of syntax and semantics. • Clear explanation of all aspects of your code. • Clear explanation of all the testing carried out. • Code is user-friendly where relevant.
Results	25%	• Execution results present for each block and well annotated. • Results presented for each step, including screenshots of the working solution. • Results for each step accompanied by a commentary. • Screenshots of program output, including the full desktop (date and time included) in the Appendix.	• Screenshots and code demonstrate successful, correct output for every task. • Tests indicating that there are no problems caused by wrong inputs. • The programs only satisfy the objectives of the Assignment, with no extra unnecessary functionality.
Introduction and Discussion	10%	• Problem background introduced clearly. • Discussion on what worked and what didn't. • Critical assessment of the design – strengths and weaknesses.	• Excellent understanding of the problem background is displayed. • Discussion on what could be improved or enhanced. • Discussion on how the program was fully tested.

IMPORTANT: Marking of all coursework is anonymous. Do not include your name, student ID number, email or any other personal information in your report or in the name of the file submitted via CANVAS.

DISCLAIMER: The IoT testbed is a testing environment, and you will be responsible for any activity carried out by using your account. Every activity is monitored, and you must comply with the IT Regulations and policies.

WARNING: You can use the IoT kit or the IoT testbed to attempt the assessment. Please keep in mind that the IoT testbed is a shared platform with only one LoRa hat, so multiple simultaneously LoRa transmissions may affect the behaviour of your solution.

WARNING: If you are going to use the IoT testbed, please make sure that you have changed your account password before starting to work! This can be done by using the **`passwd`** command, as underlined in the Lab 1 script.

WARNING: When marking the reports, I will be looking very closely for any signs of collusion, as this is unacceptable. I need to assess your own ability, not that of your friend or colleague. If I find any evidence of collusion, then the formal University rules will be followed, which normally results in all parties involved in the collusion being awarded 0 (i.e., if you do the original work and knowingly let somebody copy it, you may be awarded 0).

Instructions:

- Read this assessment script carefully before proceeding.
- Keep a record of everything you do.
- If you use data or work from other sources, be sure to reference them.
- Keep a record of all screenshots, results, answers and comments made for the report. When submitting your work, ensure all the results, screenshots, etc., are clear and readable; otherwise, you will lose marks.
- If you have any questions or feedback on this assessment, please send an email to V.Selis@liverpool.ac.uk.

Pre-requisites

You should have the IoT kit with the following:

- A Wi-Fi configured interface to connect the RPi4 to the eduroam Wi-Fi network.
- An SSH server accepting SSH connections from a PC.
- A working Bash and Python3 environment, the "nano" text editor, and the Thonny IDE.
- A working RPi4 equipped with the DHT11 sensor module and the Seeed Studio LoRa/GPS hat.
- A working MobaXterm or `ssh` application to SSH into the RPi4 with X11 forwarding enabled.

Otherwise, you should access the IoT testbed (IP: 138.253.76.230) via an MWS PC on Campus or the Remote Teaching Centre Service (RTCS) if not on Campus. Detailed information on how to use the RTCS is available on Canvas under "Supporting documents". You can access the IoT testbed using as a username your student ID by adding an "u" before it. For example, if your student ID is "123456789", your username will be "u123456789". By now, you should have changed your account password. If not, you need to use your student ID as a password by adding a "p" before it. For example, if your student ID is "123456789", your password will be "p123456789". **Change your password now!**

You should also have the following:

- Ability to use the terminal and the Thonny IDE and create and execute Python3 scripts (Lectures 11, 12, 13, 14, 16 and 17, and Laboratories 5, 6 and 7).
- Ability to use the DHT11 module (Lectures 12 and 13, and Laboratory 6).
- Understanding how to use the Seeed Studio LoRa/GPS hat (Lecture 16, and Laboratories 6 and 7).
- Understanding how LoRa, LoRaWAN and the TTN work (Lectures 15 and 16, and Laboratories 6 and 7).
- Understanding how to create a Cayenne LPP formatted message (Lectures 13 and 14, Laboratory 6).

If you are unsure of what to do, please contact me at V.Selis@liverpool.ac.uk before continuing.

Introduction

For this assessment, you will be using the IoT kit or the IoT testbed with a Debian-based embedded Linux (Raspberry Pi OS) to create an internet of things (IoT) solution based on long-range (LoRa), long-range wide area network (LoRaWAN) and the things network (TTN). This solution is based on using the LoRa physical layer protocol for long-distance communications developed by the Semtech company, the LoRaWAN protocol maintained by the LoRa Alliance, and implemented by the TTN. Moreover, it assesses your understanding of configuring an IoT device to use the activation by personalization (ABP) activation method, and how to format messages using cayenne low power payload (Cayenne LPP). During this assessment, you will be required to use a DHT11 temperature and humidity sensor module with the following connections:

- VCC is connected to 3.3 V (pin #1) of the RPi4 board.
- DATA is connected to GPIO26 (pin #37) of the RPi4 board.
- GND is connected to ground (pin #25) of the RPi4 board.

Assignment Preparation

Before starting this assignment, you are required to configure your IoT system by following these steps.

Step 1 – Configuration of The Things Network

To connect your device to the TTN, you are required to create an account, only if you haven't created an account before. You can do this by browsing https://www.thethingsnetwork.org/, and clicking "Sign Up". You are required to follow the instructions on the screen to create an account and then forward your account ID to V.Selis@liverpool.ac.uk. This will allow you to receive messages from the TTN.

Step 2 – Configuration of the Seeed Studio LoRa/GPS with Python 3

In this step, you are required to download the PyLoRa module to communicate with the TTN by managing the Seeed Studio LoRa/GPS hat. This can be downloaded on the end device (IoT kit or IoT testbed) using the "`wget`" command as follows:

```
wget https://www.dropbox.com/s/7q8etdq23b8k158/LoRaWAN_TTN.zip
```

After downloading it, you need to decompress the file using the "`unzip`" command as follows:

```
unzip LoRaWAN_TTN.zip
```

A "`LoRaWAN_TTN`" folder will be created, which will be your **working directory**.

Step 3 – Configuration of the DHT11 sensor module with Python 3

In this step, you are required to download the Python 3 module to manage the DHT11 sensor module inside your **working directory**. This can be downloaded using the "`wget`" command as follows:

```
wget https://www.dropbox.com/s/fvhizr8z9iyd14h/dht11.py
```

Step 4 – Installation of the Cayenne LPP module for Python 3 (IoT kit only)

In this step, you are required to install the Cayenne LPP module for Python 3 to work with the RPi4 to send formatted messages to the TTN via LoRa/LoRaWAN, if you haven't done it yet. The module can be installed using the "`pip3`" command as follows:

```
sudo pip3 install pycayennelpp
```

Assignment Outline

You are required to carry out the following tasks:

1. Create an IoT application on The Things Network. **(2)**
2. Register an end device to receive data from the IoT kit or IoT testbed via LoRa/LoRaWAN using the ABP activation method and Cayenne LPP as the payload formatter for uplink messages. **(7)**
3. Create a Python 3 script inside your **working directory**, which sends and receives data to/from the TTN via LoRa/LoRaWAN. This script needs to:
   i) Receive as input from the terminal at least the GPIO pin number (BCM numbering system) to be used to manage the DHT11 module. **(5)**
   ii) Manually calculate the digit sum of your student ID, e.g. using a calculator, and assign the result to a variable called "`DIGIT_SUM`"; avoid including your student ID in the code. For example, if your student ID is "123456789", the digit sum will be $1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 = 45$. **(1)**
   iii) Retrieve the current temperature and humidity sensor values from the DHT11 module. Please note that sensor values may not always be available. **(10)**
   iv) Create a Cayenne LPP formatted message containing the sensor values retrieved at step 3.iii). Include also the "`DIGIT_SUM`" using the digital output as data type. **(15)**
   v) You are required to configure the LoRa modulation so that the bit rate $R_b \approx 1760\ bits/s$ (DR3). **(10)**
   vi) Send five Cayenne LPP formatted messages created in step 3.iv) to the TTN application by randomly selecting a frequency from the G1 group with a bandwidth of 125 kHz. This must be achieved using the LoRaWAN ABP activation method. **(15)**
   vii) Handle received messages from the TTN, if any, by correctly setting the end device to listen to RX1. Stop waiting for downlink messages if nothing is received by two times the 'desired Rx1 delay' seconds specified in the advanced settings of the TTN application. **(3)**
4. Your solution must comply with the European Telecommunications Standards Institute (ETSI) EU regulations and TTN policies so that the maximum number of messages can be sent in a day. **(7)**

Summary

That's the end of the assessment. You should now have created an Internet of Things solution based on LoRa/LoRaWAN.

What to Hand In

You should submit a Word or PDF document including a 1-page cover sheet (with title and academic integrity declaration), a contents page, section headings and page numbers, etc. (see Marking Criteria.)
This document should also incorporate:

1. A note stating whether you have used the IoT testbed or the IoT kit.
2. Introduction/background (no more than 500 words).
3. Description of each task must be documented with the following information (no more than 10 A4 pages using 12-point Times font):
    a. Written explanation of the functionality of your program.
    b. Evidence of the working steps showing the correct operation (e.g., result code, screenshots, etc.).
    c. Examples of the log file(s) created, if any.
4. Conclusion/discussion (no more than 500 words).
5. Include in the Appendix (not included in the 10-page limit above):
    a. The source code of the program you created with appropriate comments. **Please note that the source code must be included as text, not as a figure!**
    b. All the full-screen versions of your focused screenshots with relevant windows and the taskbar with date and time visible as evidence of original work. These do not have to be numbered.

Please note that the marks distributions above in brackets are an approximate guide and are subject to reasonable, slight adjustments at the point of grading. The bracketed marks add up to 75 and cover 'Design and Method' and 'Results' in the appropriate proportions. 25 marks are left over for 'Presentation and Structure' and 'Introduction and Discussion' as described in the Marking Criteria. Note that the use of the English language will be taken into account when marking your report; this is worth 5% of the total mark, and part of the 'Presentation and Structure' criteria shown on Page 2.

Version History

Name	Date	Version
Dr V Selis	November 2023	Ver. 1.3
Dr V Selis	November 2022	Ver. 1.2
Dr V Selis	November 2021	Ver. 1.1
Dr V Selis	December 2020	Ver. 1.0