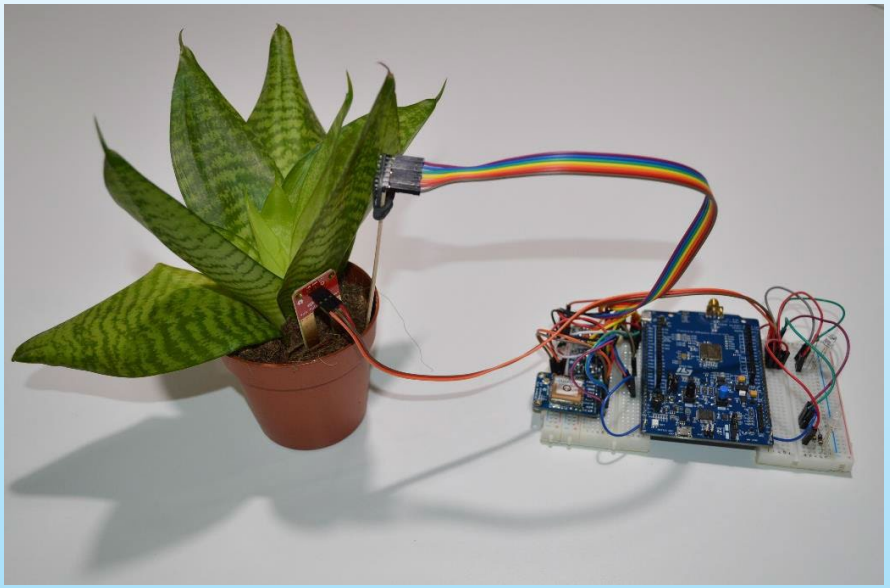
Master of Science in Internet of Things

Embedded Platforms and Communications for IoT (EPC4IoT)

Final Project



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Final Project

- Implementation of an embedded platform for plant monitoring IoT System using the B-L072Z-LRWAN1 ARM mbed-based platform
- Objectives:
  - To develop an IoT system for plant health monitoring.
  - The complete system must:
    - Measure physical parameters
    - Check plant status
    - Report alarms
    - Send data to central server
    - Manage/display information

HW + SW
This course

Communications
Sensor Networks (next bimester)

- Possible market for this system?

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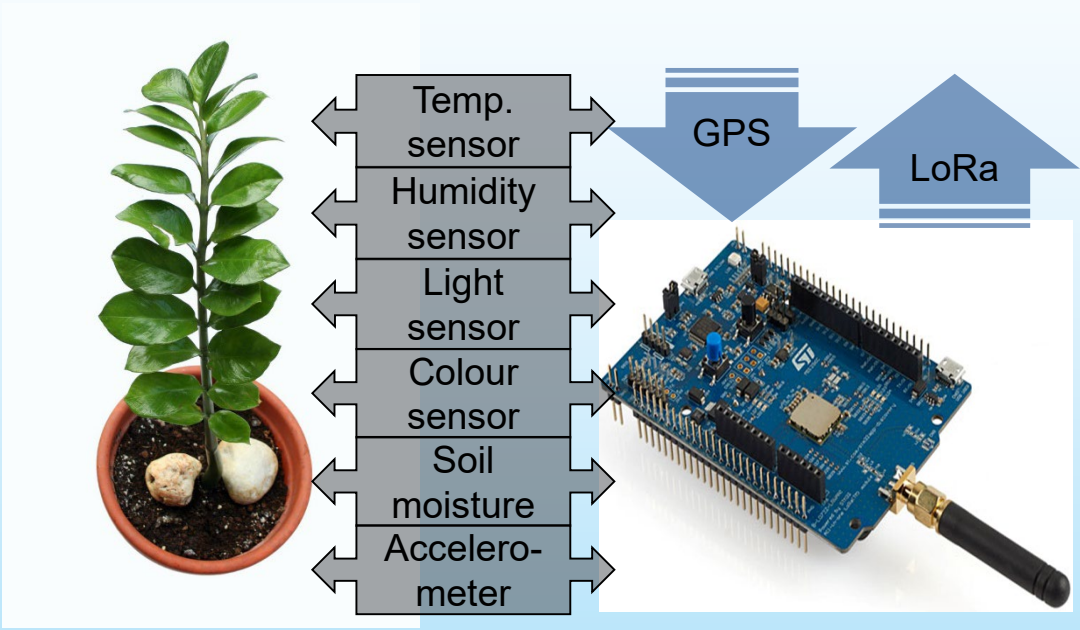
- Possible market for this system?
  - Smart greenhouse
  - Plant distributor

Project objectives

- The system must monitor **basic environmental parameters** that affect directly to plants' health:
  - Temperature
  - Relative Humidity
  - Ambient Light
  - Soil Moisture

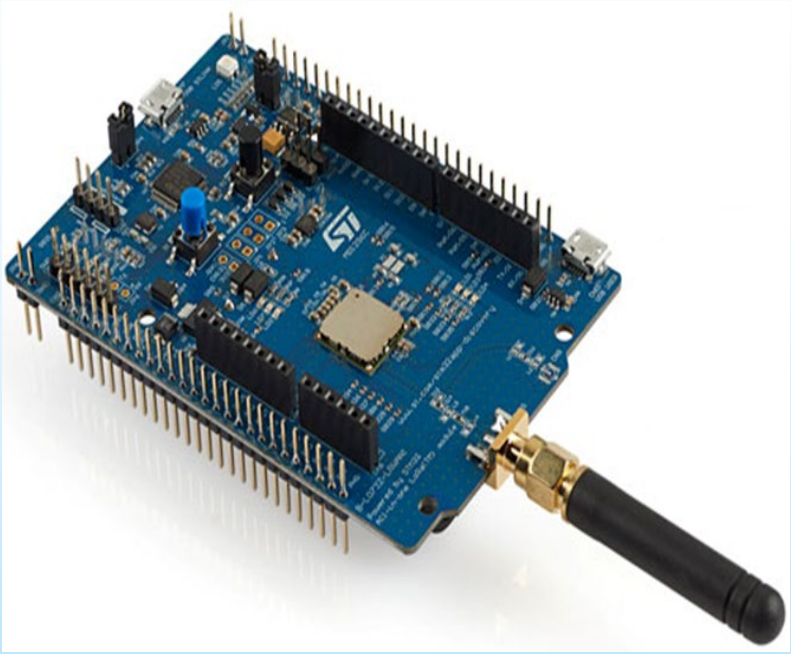


- …and some additional information:
  - Leaves Colour
  - Acceleration
  - Global position

Materials

The Platform

- B-L072Z-LRWAN1
  - ARM based platform
  - Mbed support
  - LoRaWAN connectivity
  - Multiple on-board peripherals
    - LEDs, Buttons
    - I2C, SPI, UART
    - ADCs, PWMs



[1] *ST Microelectronics, "B-L072Z-LRWAN1 LoRa®/Sigfox™ Discovery kit,"*

[2] *ST Microelectronics, "UM2115. User manual. Discovery kit for LoRaWAN™, Sigfox™, and LPWAN protocols with STM32L0,"*

The sensors

Parameter	Sensor/module	Connection	Approx. price (€)
	B-L072Z-LRWAN1 LoRa®/Sigfox™ Discovery kit		39.5
Temperature/Humidity	Si7021	I2C	5.9
Ambient light	HW5P-1	Analog	0.8
Soil moisture	SEN-13322	Analog	4.2
Leaf colour	TCS34725	I2C / digital	6.8
Storage and transport issues	MMA8451Q	I2C / digital	6.8
Global location	FGPMMOPA6H	Serial / digital	34.0
Status	RGB LED	Digital	0.1
TOTAL price (approx.)			98.1

Summary of suggested hardware for the IoT system

Sensor references

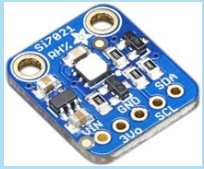
Analog


[1] Adafruit, “Photo Transistor Light Sensor,”

[2] SparkFun, “SparkFun Soil Moisture Sensor,”

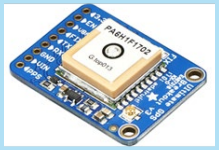
Digital

I2C



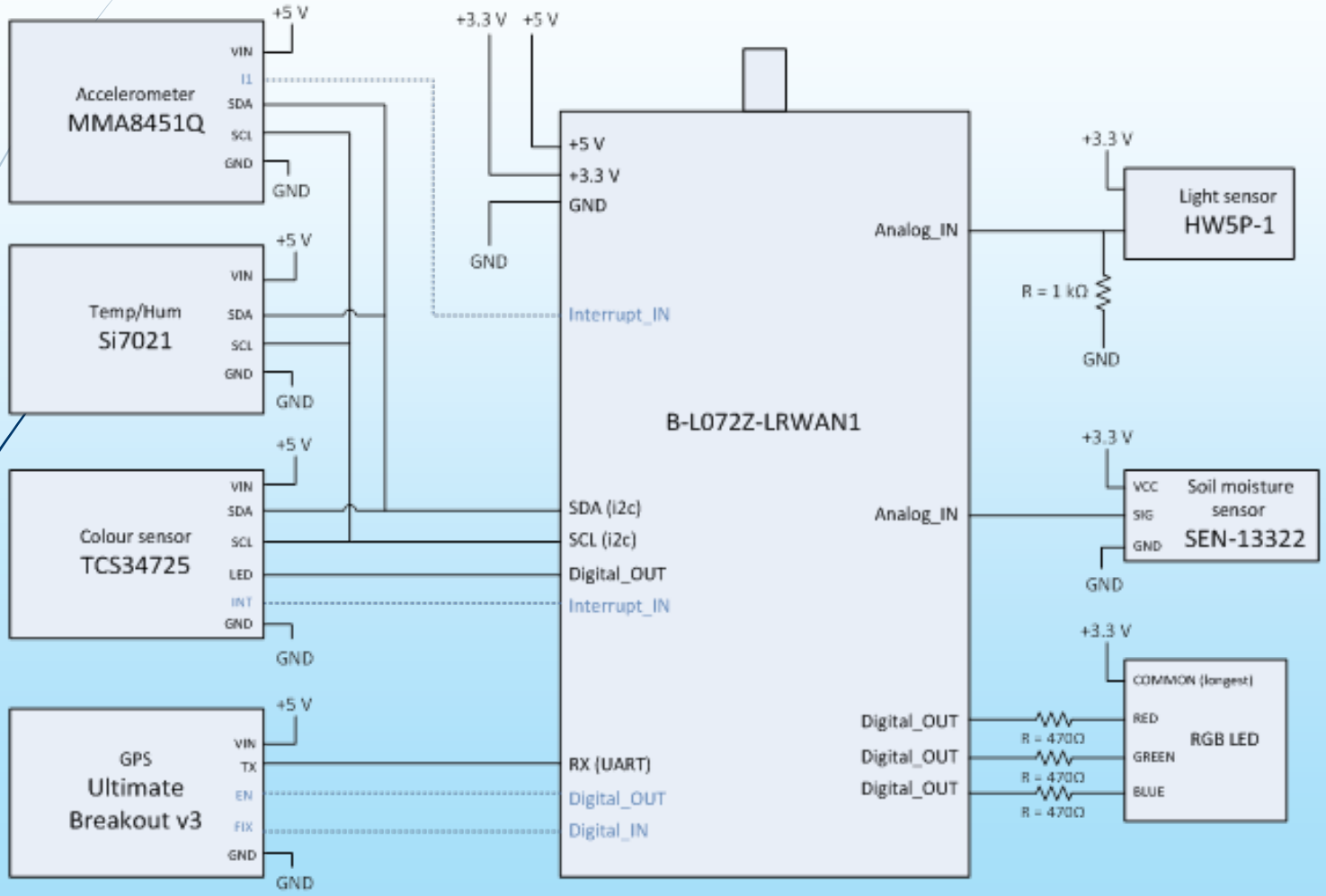
[4] Adafruit, “RGB Color Sensor with IR filter and White LED - TCS34725,”
[5] Texas Advanced Optoelectronic Solutions, “TCS3472 COLOR LIGHT-TO-DIGITAL
[6] NXP Semiconductors, “MMA8451Q, 3-axis, 14-bit/8-bit digital accelerometer,”
[7] Adafruit, “Adafruit Triple-Axis Accelerometer - ±2/4/8g @ 14-bit - MMA8451,”
[8] Adafruit, “Adafruit Si7021 Temperature & Humidity Sensor Breakout Board,”
[9] Silicon Labs, “Si7021-A20. I2C HUMIDITY AND TEMPERATURE SENSOR,”

Serial RS-232



[10] Adafruit, “Adafruit Ultimate GPS Breakout - 66 channel w/10 Hz updates - Version 3,”
[11] GlobalTop Technology Inc., “FGPMMOPA6H GPS Standalone Module Data Sheet,”

Block Diagram



Connections?

Connections between B-L072Z-LRWAN1 and sensors								
	Sensors			B-L072Z-LRWAN1			Software	
Parameter	Sensor	Pin description	Sensor PIN name	B-L072Z-LRWAN1 pin (connector and pin number)	B-L072Z-LRWAN1 Pin Name	Function	Keil name	Comment
Temperature/humidity	Si7021	Vin 3-5 V	Vin	CN2_20	+5V	5 V		5V
		Output 3.3 V reg.	3Vo					Not used
		GND						
		SCL i2c						
		SDA i2c						
Soil moisture	SEN-13322	Analog input			PA0	ADC_IN0	P_A0	Analog IN
		GND						
		Vcc (3.3V - 5V)	VCC					
Light	HW5P-1_2015 and resistor	VDD 3-15V	3.3V					
		Analog signal	Signal					
		GND	GND					
Color	TCS34725	LED on/off	LED					
		Interrupt out	INT					
		SDA i2c	SDA					
		SCL i2c	SCL					
		Output 3.3 V reg.	3V3					
		GND	GND					
		VIN 3.3 or 5 V	VIN					
GPS	Adafruit Ultimate GPS Breakout v3	Output 3.3 V reg.	3.3V					
		Enable	EN					
		Vbackup (batery)	UBAT					
		Fix output	FIX					
		Serial TX	TX					
		Serial RX	RX					
		GND	GND					
		Vin 3-5.5V	VIN					
		Pulse Per Second output	PPS					
Accelerometer	MMA8451Q	Vin	Vin					
		GND	GND					
		Output 3.3 V reg.	3Vo					
		Inertial interrupt 2, output pin	I2					
		Inertial interrupt 1, output pin	I1					
		SCL i2c	SCL					
		SDA i2c	SDA					
		I2C least significant bit of the device I2C address	A					
Led RGB	RGB LED and resistors	Common (longest)	C					
		Red + 470 Ω (one left)	R					
		Green + 470 Ω (first right)	G					
		Blue + 470 Ω (second right)	B					

Software

- ***(recommended) Mbed OS***. *Arm Mbed OS is a free, open-source embedded operating system designed specifically for the "things" in the Internet of Things. It includes all the features you need to develop a connected product based on an Arm Cortex-M microcontroller, including security, connectivity, an RTOS, and drivers for sensors and I/O devices. The mbed-os version used for the project implementation will be* ***above 6.***
- ***Mbed Studio*** *Mmbed studio us a free IDE for mbed OS based applications and library development. The framework allows users to tailor and install all the necessary tools and complementary packages.*
- ***(optional) Git*** *clients for Windows. Git is a free and open source distributed version control system designed to handle projects with speed and efficiency.*
- ***(integrated in Mbed OS) TeraTerm,*** *terminal emulator program, installed in the personal computers to manage the USB virtual COM port to communicate with the* B-L072Z-LRWAN1 board [20].

System requirements

- The system should measure some physical variables in the environment of the plant. The physical variables to be measured are the following

[SR1] Temperature in the range of -10ºC to 50ºC.

[SR2] Relative humidity in the range of 25%HR to 75%HR.

[SR3] Ambient light in %, corresponding 0% to total darkness and 100% to maximum light.

[SR4] Soil moisture in %, corresponding 0% to total dryness and 100% to maximum moisture.

[SR5] Colour of one leaf of the plant. The four associated parameters are clear, red, green, and blue values.

[SR6] Global location of the plant should be registered. The GPS module also offer the current time (only time, date is optional), that will be used to timestamp all the measurements taken by the system.

[SR7] The acceleration of the plant. At least the three axes (X, Y and Z) values should be monitored.

[GR1] The system must be robust and stable

[GR2] Task partitioning and threads management should be stablished according to the requirements

Operating modes

- TEST MODE

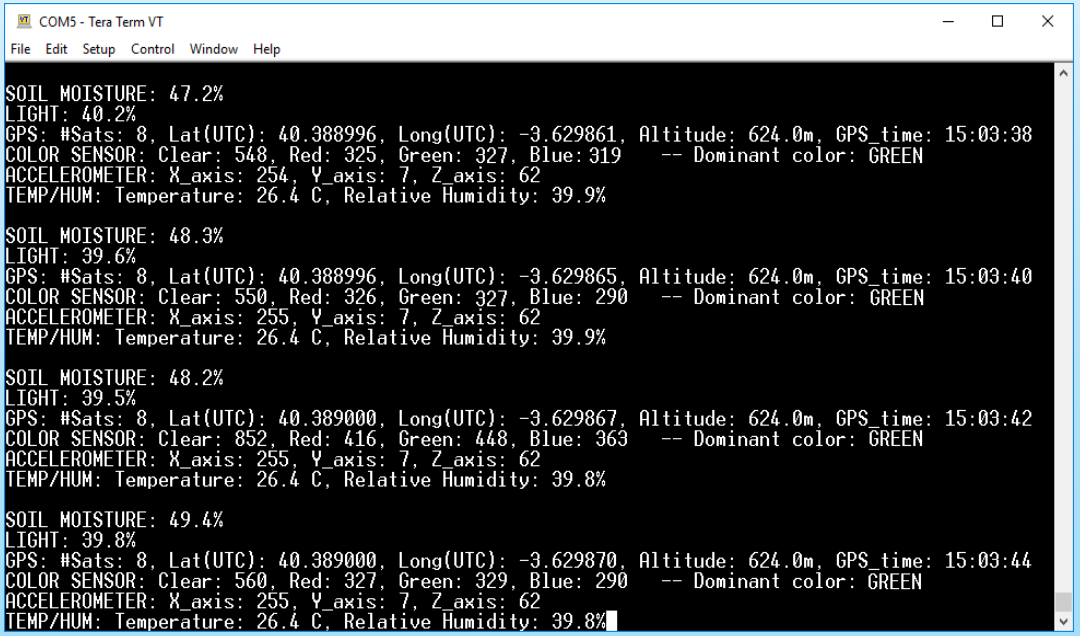
[TM1] First mode to develop: Check connections and sensor management

[TM2] All the required variables should be monitored every 2 seconds.

[TM3] The system sends every 2 seconds all the measured values to the computer (using the USB virtual COM port of the B-L072Z-LRWAN1 board).

[TM4] The RGB LED should be coloured in the dominant colour detected by the colour sensor.

[TM5] In this mode, the LED1 of the B-L072Z-LRWAN1 board should be ON.



Operating modes

- NORMAL MODE

[NM1] All the required variables should be monitored with a cadence of 30s.

[NM2] The system sends every 30 seconds all the measured values to the computer (using the USB virtual COM port of the B-L072Z-LRWAN1 board).

[NM3] The system calculates the mean, maximum and minimum values of temperature, relative humidity, ambient light and soil moisture every hour. These values are sent to the computer when calculated.

[NM4] The system calculates the dominant colour of the leave every hour. This means to calculate which colour has appeared as dominant more times during the last hour. This value is sent to the computer when calculated.

[NM5] The system calculates the maximum and minimum values of the three axes (X, y and Z) of the accelerometer every hour. These values are sent to the computer when calculated.

[NM6] The global location of the plant (coordinates) is sent to the computer every 30 seconds. This should include the GPS time converted to local time.

[NM7] Limits for every measured variable (temperature, humidity, ambient light, soil moisture, colour and acceleration) should be fixed. If current values of the measured parameters are outside the limits, the RGB LED should indicate this situation using different colour for every parameter.

[NM8] In this mode, the LED2 of the B-L072Z-LRWAN1 board should be ON

- ADVANCED MODE
  - This operating mode is optional.
  - The requirements for this mode will be different for each group of students and will be provided when the previous operating modes have been completely tested.
  - In this mode, the LED3 of the B-L072Z-LRWAN1 board should be On

Main project tasks

Task	Subtask	Comments
Analysis	Analysis of the final project specifications	This document
	Read of the technical documentation of the different sensors	See references (section 1.4) of this document
	Search in mbed repository for examples of C++ programming using the sensors	mbed website
Hardware	Identify the connections needed to interface the Si7021 with the B-L072Z-LRWAN1	I2C interface
	Identify the connections needed to interface the HW5P-1	Analog signal
	Identify the connections needed to interface the SEN-13322	Analog signal
	Identify the connections needed to interface the TCS34725	I2C interface
	Identify the connections needed to interface the MMA8451Q	I2C interface
	Identify the connections needed to interface the FGPMMOPA6H	Serial
	Identify the connections needed to interface the RGB LED	Digital
	Complete the block diagram of the Figure 13 with the connections of the sensor and actuators to the mbed B-L072Z-LRWAN1, identifying the B-L072Z-LRWAN1 pins	Complete the Excel file in the course website. Use reference [2] of this document
	Make the connections	Use the provided cables and the breadboard to connect all sensors to the B-L072Z-LRWAN1 board

Main project tasks

Task	Subtask	Comments
Software	**Download the Keil µvision project provided by the instructors**	**Course website**
	Decide the threads to be implemented	
	Implement simple test programs for the sensors with the objective of validating the physical connection and the basic functionality	Search for examples in mbed website
	Save your project software versions in your own GitHub repository	
Debugging	**Test the functionality of the different threads and the main application**	Verify that no memory stack corruption appears in the application. Debug always using the serial line connected to your computer (Teraterm will display messages with error if any)
	Test the functionality of every thread and every sensor using the debugger	
	Test all modes of the project	
	Ask for Advanced mode specifications to instructors	Depending on the intermediate validation
Documentation	Develop the technical documentation of the final project	Download the template from the course website

Group tasks

Group	Topic	Tasks	Number of students
Group 1	Accelerometers	Basis of accelerometers, functioning, technologies, comercial solutions, etc.	3
Group 2	Accelerometer MMA8451Q	Presentation of main sensor characteristics Software examples	4
Group 3	Positioning devices	Basis of positioning devices and services, functioning, technologies, GPS alternatives, Glonass, Galileo, etc.	3
Group 4	GPS module	Presentation of main sensor characteristics Software examples	4
Group 5	H&T sensors	Basis of H&T sensors, functioning, technologies, comercial solutions, etc.	3
Group 6	Humidity and temperature sensor Si7021	Presentation of main sensor characteristics Software examples	4
Group 7	Colour sensors	Basis of chromatic sensors, functioning, technologies, comercial solutions, etc.	3
Group 8	Colour sensor TCS34725	Presentation of main sensor characteristics Software examples	3

Final project schedule

	Monday	Friday
October 7th and October 11th	Release project specifications Distribution of work groups Control light exercise	**Control light assessment**
October 21th	Work	
October 28th	**Group presentations** (10 min. + 5 Q&A)	
November 4th and November 8th	Work	**Project functional validation** (not minimum requirements, but you can pass as much devices as possible) Applications for optional (at least 2 complex «RGB, GPS, Acc.» sensors validated)
November 11th	Work	
November 18th	**Project evaluation** (The system must be ready *at the begging* of the session). Individual assessment in 2 turns.	

Final project schedule

Units	Topics	Type of assessment	Weight	
1	General introduction Platform architecture			
2	MBED Classes & Keil MBED OS	Hands-on lab	15%	**October 11th**
3	HW description Serial interfaces			
4	Project design – use-case	Presentations	15%	**October 28th**
		Verification assessment	55 %	**Nov. 8th**
		Project assessment (min. 4,5/10)		**Nov. 18th**
		Final report	15%	**Dec. 1st**

Help?

- Important message: The hardware will be used in Sensor Networks course. Do not dismount it!
- Review documentation
  - Sensor/system datasheets
  - Project specifications
- Search for code at mbed.com
  - You will find examples for all sensors
  - **But the mbed version used in this project is new!! Adaptations to the examples may be required**
- Always analyze the code and adapt it to your project
- Test the examples before importing them to your project!
- Make an incremental development because B-L072Z-LRWAN has **reduced RAM memory**.
- Verify that mbed is updated!
- How to report problems:
  - Email to Guillermo Azuara <g.azuara@upm.es>, Miguel Chavarrias <miguel.chavarrias@upm.es> or Gonzalo Rosa <gonzalo.rosa.olmeda@upm.es>