TALLER DE COMUNICACIÓN Y OPTIMIZACIÓN ENERGÉTICA CON DISPOSITIVOS IOT CELULAR (NB-IOT, LTE-M)

TELECO RENTA

PLAN DE
PROMOCIÓN DE LOS ESTUDIOS
DE TELECOMUNICACIÓN

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1 Content

2 Instructor's guide

2.1 Contact information

The instructor can contact Dr. Marisa Catalan (marisa.catalan@i2cat.net) in case that some issues arise that cannot be adequately solved with the provided documentation and references.

2.2 Objectives

The goal of the workshop is to introduce the assistants to the cellular IoT low-power technologies (NB-IoT, LTE-M), which will for also part of the technologies for future 5G massive IoT communications. The main objectives are the following:

- Get familiar with hardware cellular IoT modules and be able to establish a connection and send/transmit data with TCP and UDP, emulating the actions that a real cellular IoT sensor device would perform.
- Understand the energy efficiency improvements of NB-IoT and LTE-M technologies and experiment with the available configuration parameters to learn how to optimize the consumption. This part can be done through real measurements (using the power consumption analyser if it is available) or with the analysis of the energy consumption examples that are provided.

The workshop is very extensive, but it has been planned in a step-by-step manner, so that assistants (depending on their prior knowledge) can progress and different rhythm and achieve intermediate goals in each of the steps. Thus, it is not strictly necessary to finish all the activities of the workshop to get some insights of the technology at its potential and characteristics.

2.3 Methodology and organization of the workshop

The workshop is very practical and is intended to let assistants test and interact with the hardware modules.

In this sense, it has been thought to cover four aspects:

- The AT communication between a host and a cellular IoT modem (in this case the host will be a PC; in a real case would be a microcontroller)
- Establishment of an end-to-end transmission with a remote server using UDP and TCP
- Configuration of energy efficiency (eDRX) modes in cellular IoT
- Analysis of the consumption of the device during the different stages of the communication and for different eDRX modes

These aspects are combined in the different Steps (6) that conform the workshop practice.

The practice have been conceived in a guided manner. It would be recommendable that the instructor performs the workshop together with the students; so that everyone can follow the explanation and progress at the same rhythm. However, the provided slides also would be sufficient to let students progress by their own if the guided workshop is not feasible.

As the workshop requires some hardware it has been conceived to provide some flexibility to instructors:

- Students can perform the practice in groups; so that they can share at least the OTII devices.
- Students can do the UDP/TCP connectivity practices without the power analyser. Some consumption example files are provided to help them understand the impact of commands on the overall consumption of the device.
- For the convenience of the instructors, some hardware alternatives are provided to run the workshop.
- Finally, other power analysis equipment could be used if it is available (as far as it allows to power the device at the required voltage).

2.4 Preparation of the workshop

The workshop requires the acquisition/use of different hardware components, the installation of some software in a local computer and the use of some public ECHO servers. For the hardware components, 2.1.1. presents some options, which are the ones that will be used in the material/slides provided for the practices. To give more flexibility, section 2.1.3. will give a list of alternative hardware that could be used and some hints/directives to adapt the workshop to this hardware.

2.4.1 Description of the components and material

The components, software and material needed for the workshop are the following:

1. **Global SIM Card with NB-IoT/LTE-M connectivity.**

There exist different SIM services providers that can be used. One option that fits well for the aim of the workshop is the 1NCE Sim card,

- Link: https://1nce.com/
- It has support for the three NB-IOT/LTE-M operators (Telefonica, Vodafone, Orange) in Spain.
- Flat rate: 10 € to be consumed during 10 years (max. 500 MB)
- Remark: The amount of data that can be transmitted is very few (500 MB), since the rate is meant for IoT devices. 500 MB are enough for running the workshop during several years (as few data will be sent); but the card should not be used to send/download big files, videos or similar content.

Figure 1. 1nce SIM card (Standard/Micro/Nano)[1]

2. **Dual NB-IoT/LTE-M modem. M5STAMP CAT-M MODULE(SIM7080G)**.
    - Description: https://docs.m5stack.com/en/stamp/stamp_catm
    - Target price: 36€
    - Provided by common distributors (e.g. Mouser, Digikey…). Reference link (Mouser):https://eu.mouser.com/ProductDetail/M5Stack/S003?qs=vvQtp7zwQdORdyJRVdnhEw%3D%3D
    - The hardware is based on the Simcom SIM7080G module. This module has been chosen due to the following reasons:
        - 3.3V and 5V supply
        - Dual module: Allows to communicate with NB-IoT or LTE-M.
        - There exist different providers that integrate this module (in case that the M5STAMP CAT-M is not available, other alternative hardware
        - could be acquired to perform the workshop with minor impact).
    - Remark: To be used in the workshop, some soldering is required (see next subsection).

Figure 2. M5STACK STAMP CAT-M module[2]

3. **Power consumption analyzer. Otii (Qoitech)**
    - Description : https://www.qoitech.com/
    - Available at different distributors (e.g. Digikey, RS-Online). Reference link from RS-Online: https://es.rs-online.com/web/p/analizadores-de-calidad-electrica/2564687
    - Cost: Aprox. 1000€
    - The Otii hardware has been chosen for the workshop because it allows to:
        - Supply and measure the consumption of devices up to 5V
        - Visualize and record NB-IoT/LTE-M consumption (from peaks of hundreds of mA to few µA)
        - Send commands through the UART (in this case, AT commands to control the NB-IoT/LTE-M module)
        - Easily understand the impact of each AT command in the consumption.
        - Portable unit

[1] https://1nce.com/es-es/
[2] https://docs.m5stack.com/en/stamp/stamp_catm

Figure 3. 3 Otii Arc Pro[3]

- Remarks:
  - The OTII does not include the banana cables to power up/measure the devices. They should be also acquired for the workshop.
  - To supply more than 3.7V, the OTII requires an external power adaptor (not included). This is not necessary for the workshop as the M5STAMP CAT-M module can be powered at 3.3V; but it is worth to consider it to use the unit to analyze devices powered at 5V. An external AC/DC adapter with 7-9VDC output would be necessary. The provider recommends this one: XP Power VER18US090-JA.
  - To be used in the workshop, some software is required in the computer connected to the Otii (see item 5.).

4. FTDI Converter (optional)

- The FTDI converter allows to connect directly to the NB-IoT/LTE-M module through a serial connection to send AT commands.
- It should have external output pints for 3.3V and 5V
- Target cost: 8€
- Can be acquired from various distributors.
  - Reference link 1 : https://www.amazon.es/hiletgo-CP2102-M%C3%B3dulo-Convertidor-Serie/dp/B00LODGRV8
  - Reference link 2: https://www.amazon.es/dp/B01N9RZK6I (reference used in the workshop slides)
- Alternative way to perform the communication practice of the workshop if the power consumption analyzer is not available for all the students.
- Remarks:
  - To be used in the workshop, some soldering might be required (see next subsection). It is advisable to acquire and option that has already a soldered connector.
  - To be used in the workshop, some software will be required in a computer to communicate with the module (see 5.)

[3] https://www.qoitech.com/products/

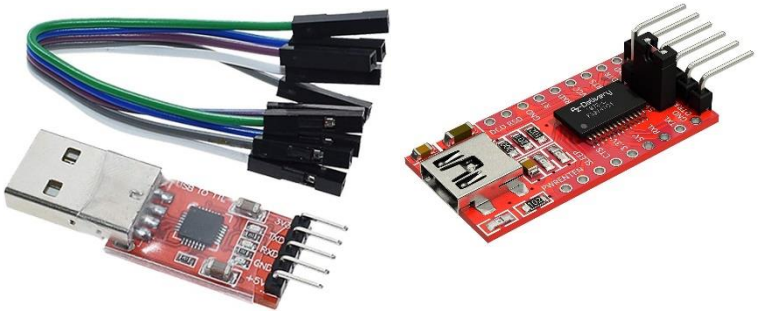

Figure 4. 3 Examples of FDTI converters

5. **Local Computer/Laptop**
    - The laptop is necessary to communicate to the NB-IoT/LTE-M module and also to measure the consumption of the module.
    - The following software needs to be installed in the computer:
        - Consumption analysis. OTII software:
            - The software can be downloaded from the Qotiech web page[4].
            - Before downloading the software, the page requires a previous registration.
            - OTII software version used for the workshop. Version 2.8.4 (download OTII 2 software)
        - Communication software (only if the OTII is not used):
            - Any serial terminal software (for example, putty) to send AT commands to the device.
            - YAT[5] (Yet another Terminal) is a freeware option recommended for the workshop.
                - Provides log features that allow to analyze the time to execute commands.
                - Has options to save commands and configurations (instructors can decide to create in advance and distribute a set of commands to make the workshop easier)
    - Remark: If students will bring their own laptops, it is advisable to tell them in advance to install the software.

6. **Remote/cloud server**
    - To perform the workshop, it is necessary to connect to TCP and UDP echo servers, accessible through a public IP. These servers will be the ones accessed by the students to test the NB-IoT/LTE-M communication. There exist some public UDP and TCP servers that might be used for the workshop to test UDP/TCP connectivity instead of building the custom services in a remote server [6]. The details of these servers are:
        - TCP Echo: IP: 52.43.121.77; PORT: 9001

[4] https://www.qoitech.com/download
[5] https://sourceforge.net/projects/y-a-terminal/
[6] https://www.digi.com/resources/documentation/digidocs/90002258/tasks/t_echo_server.htm

- UDP Echo: IP; 52.43.121.77; PORT: 10001

The workshop proposes to use these servers, as the amount of data that will be sent is very small. Note that these servers are active at the time of the preparation of the guide, but might be closed when the workshop is performed. In case that the servers are not available, the instructor should look for alternative servers that are publicly available. If no servers might be available, the recommended approach would be to implement some simple and custom ECHO servers and deploy them in an accessible cloud service. This possibility allows to do complementary test in the workshop (e.g. testing the impact of setting a delay for the ECHO response).

7. **Cables and connectors**
   - The following cables and connectors will be necessary to perform the workshop.
     - A pair of banana cables with a test hook clip on one of the sides (Example: https://www.amazon.es/Cleqee-unidades-conector-el%C3%A9ctricas-mult%C3%ADmetros/dp/B091KN4C3L)
     - Female-female and female-to mail jumpers (Example: https://www.amazon.es/Macho-Hembra-Macho-Macho-Hembra-Hembra-Prototipo-Protoboard/dp/B01NGTXASZ)
8. **Consumption examples**
   - To allow students to measure and understand the consumption of the different stages of a cellular IoT connection, some real examples of consumption captures are provided. The consumption file can be opened with the Otii software.
   - The file “example_workshopCIoT.otii” contains different examples, which are referred in the student’s guide. The structure of these examples is as follows:
     - Step 1 Verification. Corresponds to the consumption of the hardware verification commands.
     - Step 2. Debug config. Corresponds to the consumption of the configuration/debug commands.
     - Step 3. Check networks. Tracks the process of requesting and obtaining the list of available networks.
     - Step 3. Register LTE-M Example. Tracks the registration to an LTE-M network.
     - Step 4. EDRX impact. Shows the impact of the configuration of EDRX parameters in the consumption.
     - Step 5. UDP Echo Example. Tracks the complete process to connect to a UDP Echo server, send, receive information and close the socket.
     - Step 5. TCP Echo Example. Tracks the complete process to connect to a TCP Echo server, send, receive information and close the socket.
     - Step 6. UDP Echo delay 30s Example. Tracks the complete process to connect to a UDP Echo server with a delayed (30s) response, send, receive information and close the socket. This example cannot be executed with the available public servers; thus, students will not replicate it. Though, it is provided as an example to illustrate the impact of eDRX on asynchronous responses.
     - Step 5. TCP Echo delay 30 s Example. Tracks the complete process to connect to a TCP Echo server with a delayed (30s) response, send,

receive information and close the socket. This example cannot be executed with the available public servers; thus, students will not replicate it. Though, it is provided as an example to illustrate the impact of eDRX on asynchronous responses.

- Example eDRX in sleep. Complementary example configuring the sleep mode (is not described in the student slides).
- Example sleep and unregister. Complementary example configuring the sleep mode (is not described in the student slides)

2.4.2 Preparation of the hardware

Before the workshop:

- Take the encapsulation of the module (there is one screw).
- The antenna must be connected to the NB-IoT/LTE-M.
- Some connector pins need to be soldered in the NB-IoT/LTE-M module as shown in the image.
- Fix again the encapsulation.
- Put a SIM card, as shown in the image.
- Remark: It is advisable to verify that the hardware is working (see student's guide).

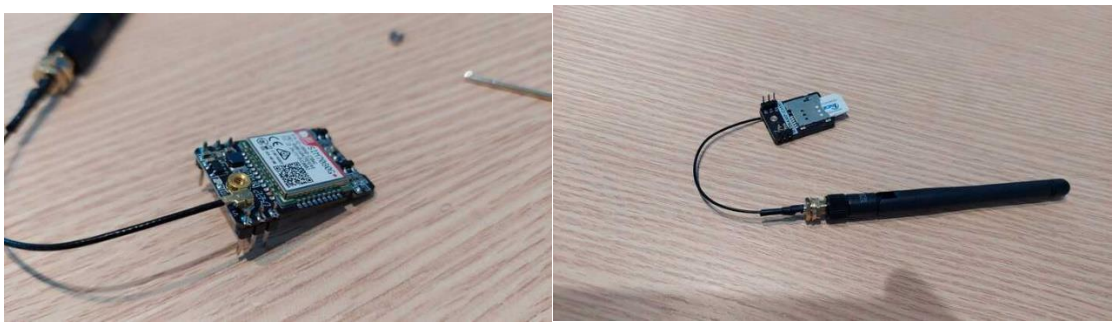

Figure 5. 3 Soldering of connectors and SIM collocation

- It might be necessary to solder a pin to the 5V output of the FTDI controller (if not already soldered). This is not necessary for the workshop but might be required if other NB-IoT/LTE-M modules are tested.

2.4.3 NB-IoT/LTE alternative modules

The following modules might be easily used as alternatives of proposed module (in case it's unavailable):

1. Waveshare SIM7080G (Pico shield)

- The Waveshare module integrates the SIM7080G transceiver.
- It can be powered at 3.3 Volts but the connectivity and initialization setup is more complex.
- AT commands are identical to the ones explained in the students guide.
- The module can be used in the workshop with few hardware modifications. The connection setup is shown in the following figure.
    - Solder a connector (included) in both sides of the board.

- Connect VSYS to 3.3V
- VSYS and 3.3V(out) pin in the board must be connected.
- To start the module, it's necessary to connect the PWR pin to 3.3V for few seconds (the OTII will show a consumption peak).
- Sleep mode can be tested as the DTR pin is accessible. DTR must be connected to 3.3V to wake-the module and to GND to allow entering sleep mode.

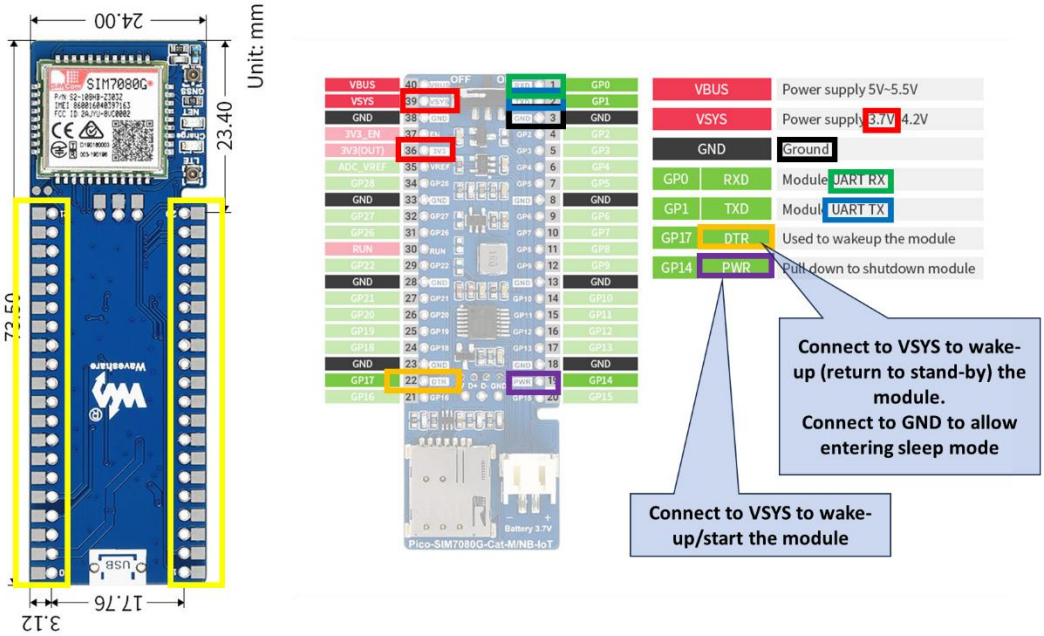

Figure 6. Pins to be soldered and connection setup [7]

2. Waveshare SIM7070G (Raspi HAT)

- The Waveshare module integrates the SIM7070G transceiver (GSM + NB-IoT/LTE-M).
- It can only be powered at 5 Volts. This requires an FTDI converter or the usage of an external 7.5 AC-DC adaptor to feed the OTII device.
- AT commands are identical to the ones explained for the SIM7080G module.
- The module can be used in the workshop with none or few hardware modifications. The connection setup is shown in the following figure.
    - Solder a connector to use the front pins. Alternatively, the Raspi connector can be used. All pins are accessible in both connectors.
    - To start the module, it's necessary to press the power button.
    - Sleep mode can be tested as the DTR pin is accessible; but it would require modifying first a hardware jumper (desolder a 0R SMD resistor).

[7] https://www.waveshare.com/pico-sim7080g-cat-m-nb-iot.htm

- Remark: The consumption (additional electronics to convert power levels) is higher than the one observed by the M5STAMP hardware.

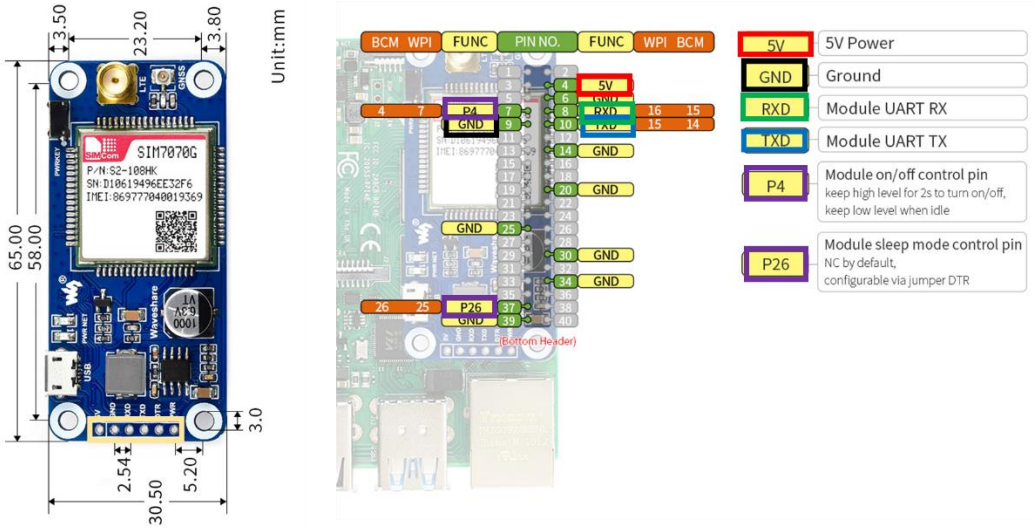

Figure 7. Pins to be soldered (optional) and connection setup (build-in connector)[8]

3. M5Stack NB-IoT/CAT-M module (SIM7080G)

- The module integrates the SIM7080G transceiver.
- It can only be powered at 5 Volts. This requires an FTDI converter or the usage of an external 7.5 AC-DC adaptor to feed the OTII device.
- AT commands are identical to the ones explained in the workshop.
- The encapsulation needs to be opened to put the SIM.
- Easy connection (only RX, TX, 5V and GND pins)
- Remarks:
    - It is not possible to wake-up from sleep mode and the consumption will be higher than the one of the M5STAMP module.
    - There is a similar form-factor hardware with NB-IoT only support (SIM7020G)[9]. The price is cheaper (around 20€) but the AT commands set differs from the ones of the SIM7080G[10]. The workshop slides would need a readaptation of most of the commands.

[8] https://www.waveshare.com/sim7070g-cat-m-nb-iot-gprs-hat.htm
[9] https://docs.m5stack.com/en/unit/nbiot_global
[10] https://m5stack.oss-cn-shenzhen.aliyuncs.com/resource/docs/datasheet/unit/nbiot/SIM7020%20Series_AT%20Command%20Manual_V1.05.pdf

Figure 8. M5Stack SIM7080G[11]

2.5 Indications for the workshop

It is recommended to read the introduction material provided in the student guide and to check the provided references to understand the NB-IoT/LTE-M functionalities to improve energy consumption and the interaction through AT commands.

It is also recommended to assist the students when they connect the module to the OTII or the FTDI controller. Crossing VCC and GND might have tragical consequences for the module.

It is recommended to connect to the Movistar LTE-M network if it is available (this will allow to follow the provided consumption examples).

For the workshop consider that:

- Not all the networks and operators might be available.
- Not all the networks might support the same configurations or perform in the same manner. For example:
    - Some networks might not support eDRX mechanisms.
    - Some networks might not accept eDRX configuration changes.
    - Some networks might experiment larger active times.
    - Some networks might not correctly return an echo response with TCP or UDP when eDRX is configured.

  Thus:
    - Check the availability of networks and their configuration in advance for the workshop and choose the best network for the aim of the workshop.
    - Ask all students to connect to the same network; so that they experiment the same issues.

[11] https://docs.m5stack.com/en/unit/cat_m

2.6 Troubleshooting

Some hints for common issues/problems that might appear in the workshop are listed below.

1. AT+CIMI returns an error → The SIM card is not correctly placed.
2. No consumption is observed → The module is not good connected, or the power supply is not enabled in the OTII.
3. Still no consumption is observed → Some hardware devices might require triggering the module with the PWR pin (this will not happen in the workshop)
4. AT+COPS=? returns no networks -> There is no coverage from any network (unlikely to happen).
5. At+COPS command does not register to the specified network -> The workshop will work for any network (thus, it's not necessary to try again or solve this). But try to force the technology as explained in the user guide.
6. AT+CAOPEN returns an error -> Try to close the connection (AT+CACLOSE=0). The context is not activated. Run AT+CNACT=0,1. Check that the "0" context has an IP with AT+CNACT?
7. AT+CASEND returns a time expiration error → The 10 seconds timer has expired. A message must be sent faster through the serial port.
8. AT+CEDRXS does not make any effect → Check that AT+CEDRXS=2,4,x is used for LTE-M networks and AT+CEDRXS=2,5,x is used for NB-IoT networks. The network might not support eDRX mechanisms (an OTII example is provided for this case).
9. The Simcom Serial port is not detected using the FTDI converter → It might be necessary to install a FTDI Driver (https://ftdichip.com/drivers/vcp-drivers/)
10. Students assess that the consumption is still very high for eDRX compared to the values of the datasheet → You can explain them that this is because the module is in stand-by mode and does not enter sleep mode. They can enter sleep mode with the command AT+CSCLK=1 to observe a lower consumption, but they will not be able to send more AT commands as the module is not prepared to wake-up from sleep mode. This requires to reset the power of the module and during the first seconds rapidly send AT+CSCLK=0 before the module goes to sleep again (might be complex to explain and execute). An OTII example of the consumption for eDRX in sleep mode is provided for illustration.

2.7 References

- Documentation M5STAMP CAT-M: https://docs.m5stack.com/en/stamp/stamp_catm
- SIM7080G AT Commands Manual: https://www.waveshare.com/w/upload/3/39/SIM7080_Series_AT_Command_Manual_V1.02.pdf
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