Waspmote

Technical Guide

libelium

wasp mote

Document version: v7.5 - 02/2018

INDEX

1. Introduction

This guide explains the features related to our product line Waspmote v15, released on October 2016.

If you are using previous versions of our products, please use the corresponding guides, available on our Development website.

You can get more information about the generation change on the document "New generation of Libelium product lines".

2. Waspmote Kit

Important:

- All documents and any examples they contain are provided as-is and are subject to change without notice. Except to the extent prohibited by law, Libelium makes no express or implied representation or warranty of any kind with regard to the documents, and specifically disclaims the implied warranties and conditions of merchantability and fitness for a particular purpose.
- The information on Libelium's websites has been included in good faith for general informational purposes only. It should not be relied upon for any specific purpose and no representation or warranty is given as to its accuracy or completeness.

2.1. General and safety information

- In this section, the term "Waspmote" encompasses both the Waspmote device itself and its modules and sensor boards.
- Please read carefully through the document "General Conditions of Libelium Sale and Use".
- Do not let the electronic parts come into contact with any steel elements, to avoid injuries and burns.
- NEVER submerge the device in any liquid.
- Keep the device in a dry place and away from any liquids that might spill.
- Waspmote contains electronic components that are highly sensitive and can be accessed from outside; handle the device with great care and avoid hitting or scratching any of the surfaces.
- Check the product specifications section for the maximum allowed power voltage and amperage range and always use current transformers and batteries that work within that range. Libelium will not be responsible for any malfunctions caused by using the device with any batteries, power supplies or chargers other than those supplied by Libelium.
- Keep the device within the range of temperatures stated in the specifications section.
- Do not connect or power the device with damaged cables or batteries.
- Place the device in a location that can only be accessed by maintenance operatives (restricted area).
- In any case, keep children away from the device at all times.
- If there is an electrical failure, disconnect the main switch immediately and disconnect the battery or any other power supply that is being used.
- If using a car lighter as a power supply, be sure to respect the voltage and current levels specified in the "Power Supplies" section.
- When using a battery as the power supply, whether in combination with a solar panel or not, be sure to use the voltage and current levels specified in the "Power supplies" section.
- If a software or hardware failure occurs, consult the Libelium Web Development section
- Check that the frequencies and power levels of the radio communication modules and the integrated antennas are appropriate for the location in which you intend to use the device.
- The Waspmote device should be mounted in a protective enclosure, to protect it from environmental conditions such as light, dust, humidity or sudden changes in temperature. The board should not be definitively installed "as is", because the electronic components would be left exposed to the open-air and could become damaged. For a ready-to-install product, we advise our Plug & Sense! line.

DO NOT TRY TO RECHARGE THE NON-RECHARGEABLE BATTERY, IT MAY EXPLODE AND CAUSE INJURIES AND DESTROY THE EQUIPMENT. USE NON-RECHARGEABLE BATTERIES ONLY WITH DEVICES PROPERLY PREPARED. PLEASE DOUBLE CHECK THIS CONDITION BEFORE CONNECTING THE USB OR THE SOLAR PANEL.

The document "General Conditions of Libelium Sale and Use" can be found at:
http://www.libelium.com/development/waspmote/technical_service

2.2. Conditions of use

General:

- Read the “General and Safety Information” section carefully and keep the manual for future reference.
- Read carefully the “General Conditions of Sale and Use of Libelium”. This document can be found at: http://www.libelium.com/development/waspmote/technical_service. As specified in the Warranty document, the client has **7 days** from the day the order is received to detect any failure and report that to Libelium. Any other failure reported after these 7 days may not be considered under warranty.
- Use Waspmote in accordance with the electrical specifications and in the environments described in the “Electrical Data” section of this manual.
- Waspmote and its components and modules are supplied as electronic boards to be integrated within a final product. This product must have an enclosure to protect it from dust, humidity and other environmental interactions. If the product is to be used outside, the enclosure must have an IP-65 rating, at the minimum. For a ready-to-install product, we advise our Plug & Sense! line.
- Do not place Waspmote in contact with metallic surfaces; they could cause short-circuits which will permanently damage it.

Specific:

- Buttons and switches: Handle with care, do not force activation or use tools (pliers, screwdrivers, etc) to handle it.
- Battery: Only use the original lithium battery provided with Waspmote. Connect with extreme care.
- Mini-USB connection: Only use mini-USB, mod. B, compatible cables.
- Solar panel connection: Only use the solar panels specified in the “Power supplies” section and always respect polarity.
- Lithium battery connection: Only use the connector specified in the “Battery” section and always respect polarity.
- Micro SD card connection: Only use 8GB maximum micro SD cards. HC cards are not compatible. There are many SD card models; any of them has defective blocks, which are ignored when using the Waspmote’s SD library. However, when using OTA, those SD blocks cannot be avoided, so that the execution could crash. Libelium implements a special process to ensure the SD cards we provide will work fine with OTA. The only SD cards that Libelium can assure that work correctly with Waspmote are the SD cards we distribute officially.
- Micro SD card: Make sure Waspmote is switched off before inserting or removing the SD card. Otherwise, the SD card could be damaged.
- Micro SD card: Waspmote must not be switched off or reseted while there are ongoing read or write operations in the SD card. Otherwise, the SD card could be damaged and data could be lost.
- XBee module connection: Waspmote allows the connection of any module from the XBee family, respect polarity when connecting (see print).
- Other modules connection: Only use the original modules created by Libelium.
- Antenna connections: Each of the antennas that can be connected to Waspmote (or to its boards) must be connected using the correct type of antenna and connector in each case, or using the correct adapters.
- USB voltage adapters: To power and charge the Waspmote battery, use only the original accessories distributed by Libelium.

Usage and storage recommendations for the batteries:

The rechargeable, ion-lithium batteries, like the ones provided by Libelium (capacity of 6600 mA·h), have certain characteristics which must be taken into account:

- Charge the batteries for 24 hours before a deployment. The aim is to have the charge of the batteries at 100% of their capacity before a long period in which they must supply current, but it is not necessary to improve the performance.
- It is not advised to let the charge of the batteries go below 20% of capacity, since they suffer stress. Thus, it is not advised to wait for the battery to be at 0% to charge it.
- Any battery self-discharges: connected to Waspmote or not, the battery loses charges by itself.
- Maximum capacity loss: as the charge and discharge cycles happen, the maximum charge capacity is reduced.
- Batteries work better in cool environments: their performance is better at 10 ºC than at 30 ºC.
- At temperatures below 0 ºC, batteries can supply current (discharge), but the charge process cannot be done. In particular:
  - discharge range = [-20, 60] ºC
  - charge range = [0, 45] ºC

Only use the non-rechargeable batteries with the Waspmote units specifically prepared for them (identified with a pink sticker on them). The reason is, a regular Waspmote will try to inject current in the non-rechargeable battery if the USB or the solar panel is connected. This is dangerous for the good working of a non-rechargeable battery. It could be damaged or even damage Waspmote.

Plug & Sense! line:

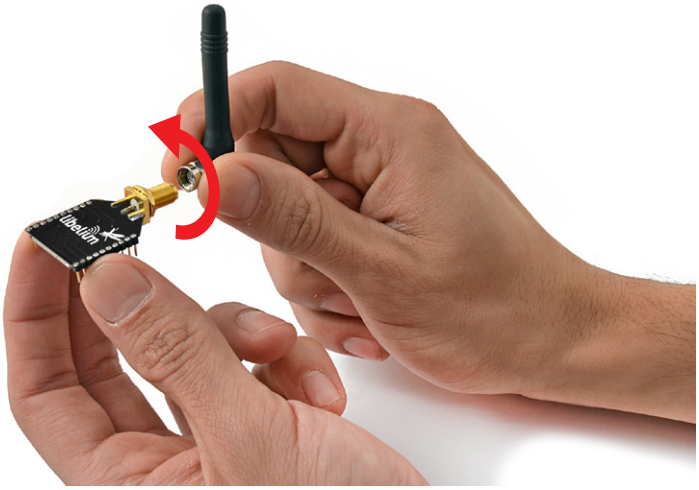
Libelium may provide the nodes with enclosures which are suitable to operate outdoors. The user, as final installer, must take great care when handling the product. We advise to read the Plug & Sense! Technical Guide to enlarge the life of your devices.

Remember that inappropriate use or handling of Waspmote will immediately invalidate the warranty.

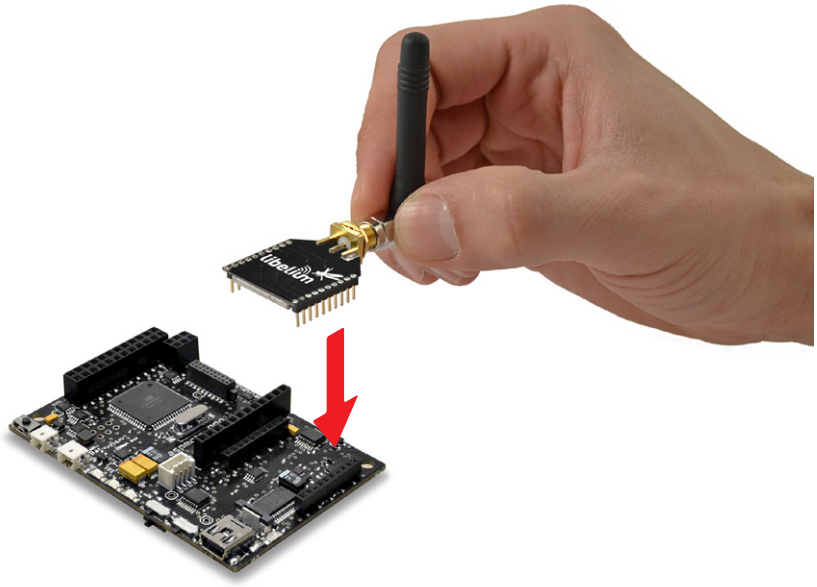
For further information, please visit http://www.libelium.com/development/waspmote

2.3. Assembly

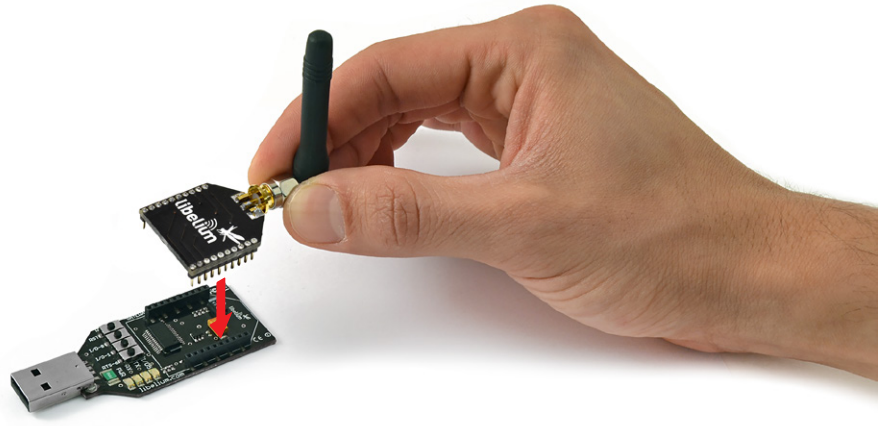
- **Connect the antenna to the wireless module**



- **Place the wireless module in Waspmote**

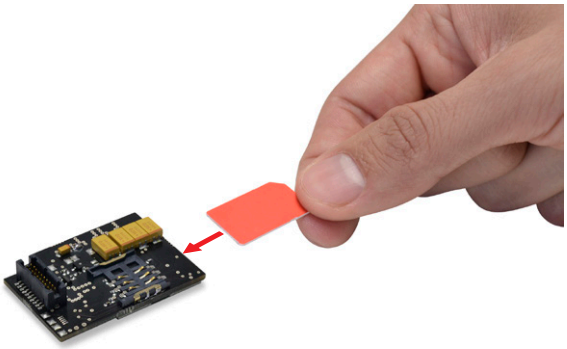


- **Place the wireless module in Waspmote Gateway**



- **Connect the antenna in the GPRS module**

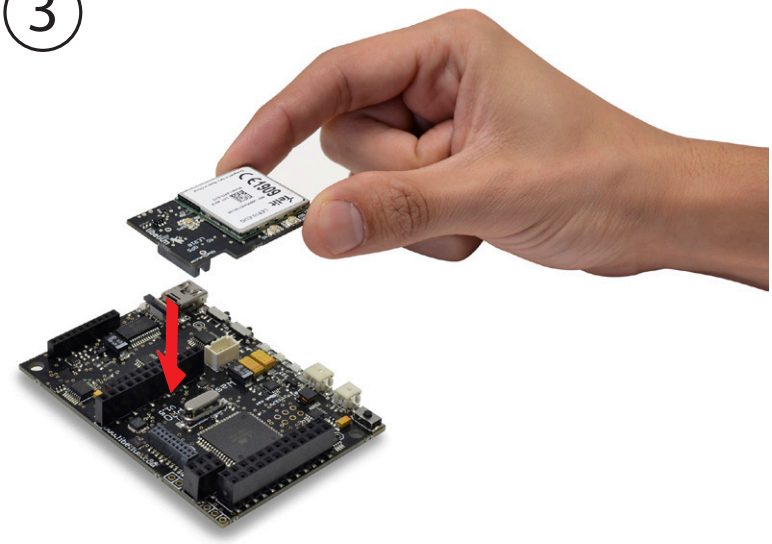
1



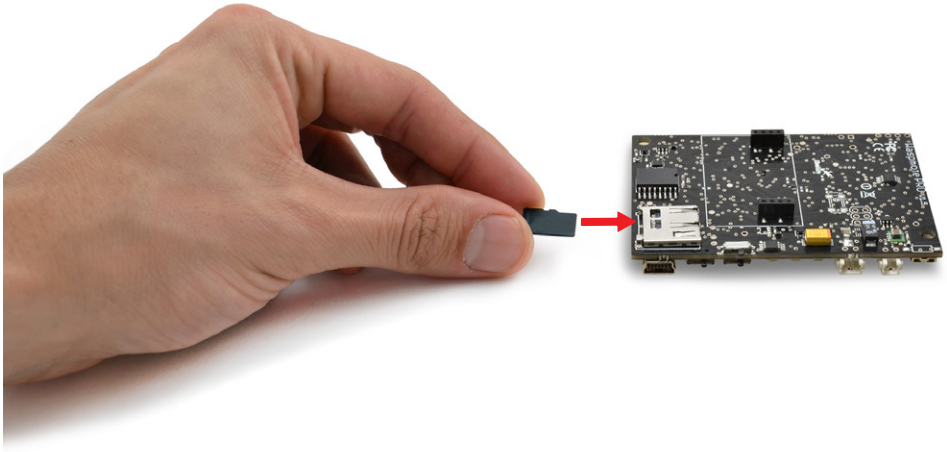
2

- **Place the GPRS module in Waspmote**

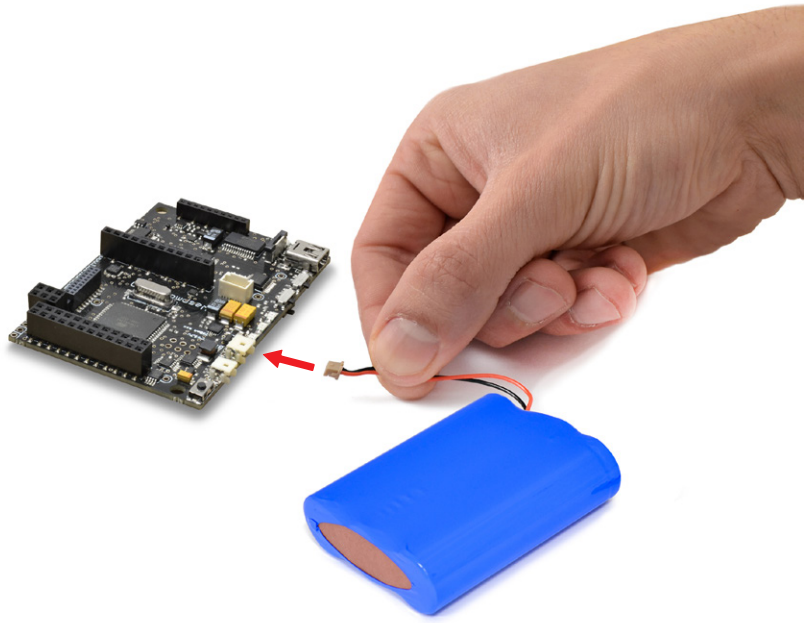
3



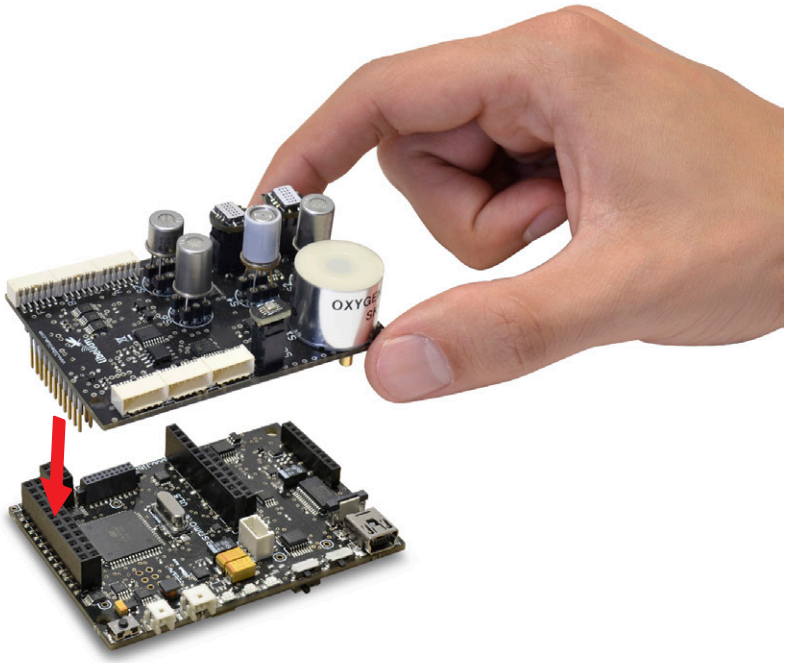
- **Place the SD card in Waspmote**



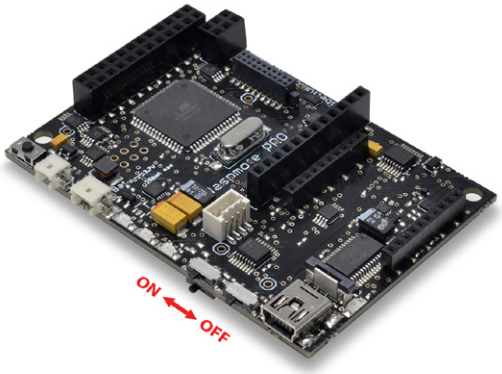
- **Connect the battery in Waspmote**



- **Connect the sensor board**

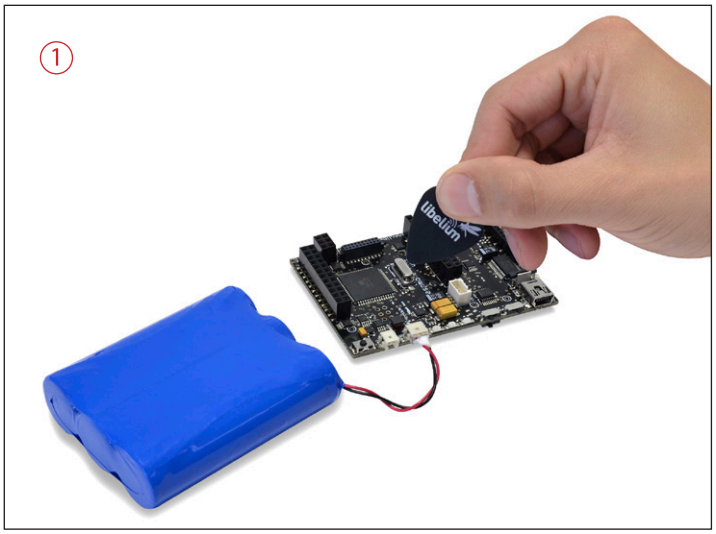


- **Switch it on**

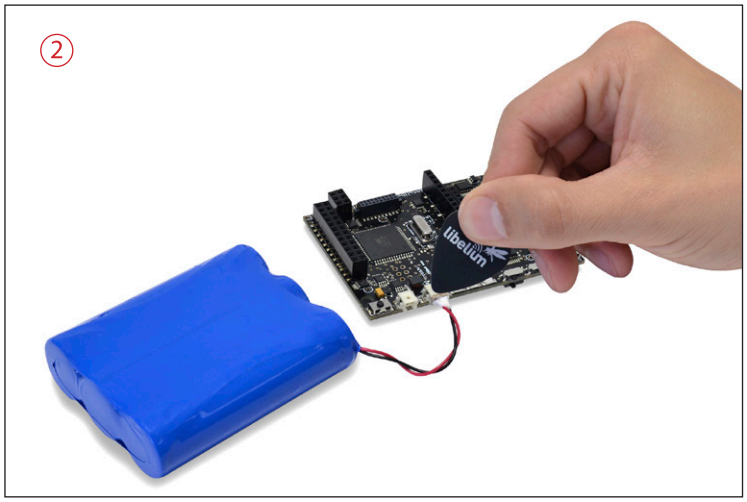


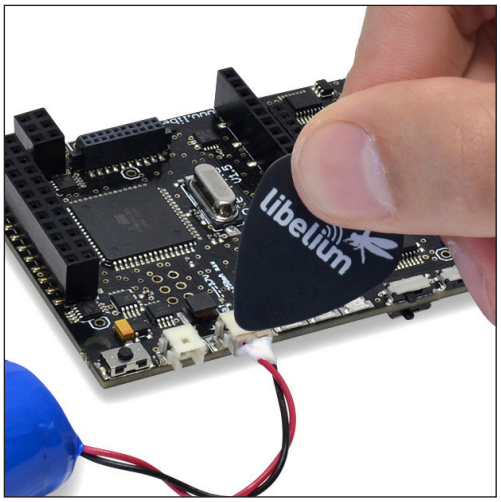
- **Waspmote battery disconnection**

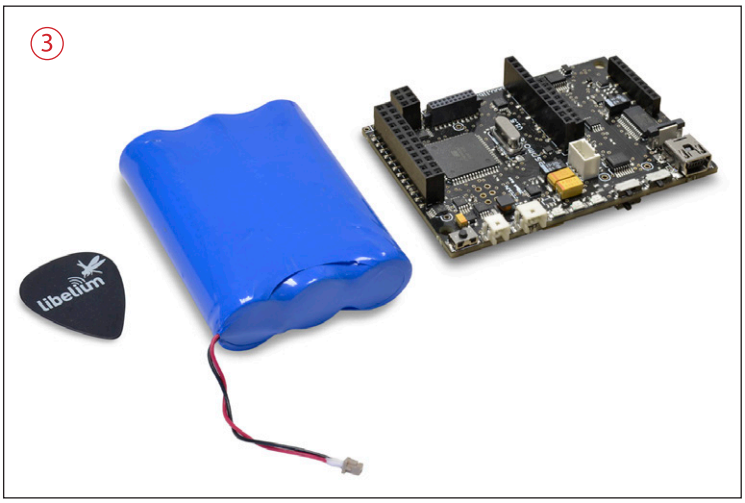
Use the pick supplied by Libelium in order to disconnect Waspmote battery.



Insert the pick on the slot of the battery connector and pull straight out.
Do not pull the battery cables.



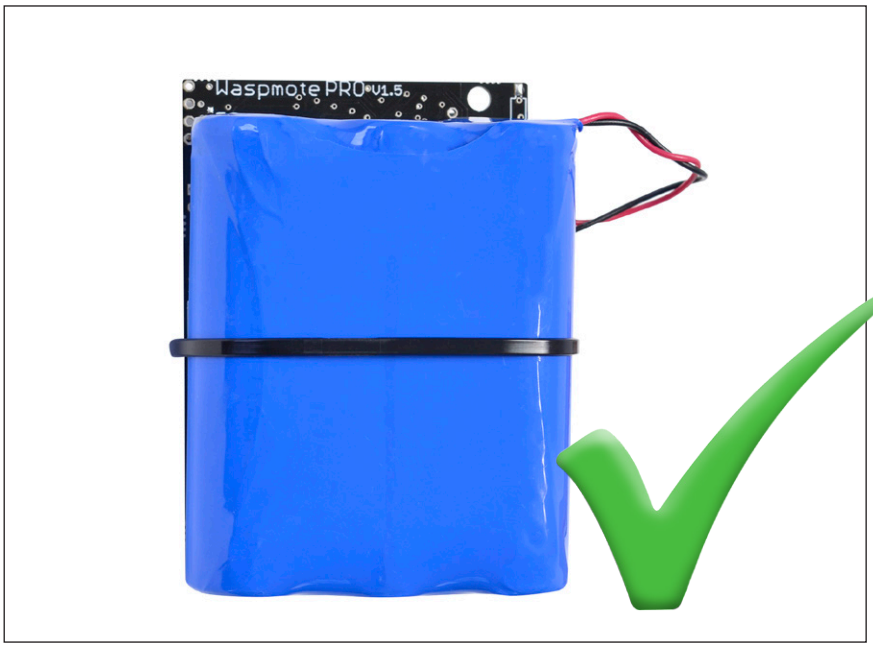




- **Battery handling instructions**

In order to prevent from cable breaking, avoid leaving battery freely suspended.

Use a nylon clamp in order to attach battery to Waspmote.



3. Waspmote Plug & Sense!

The Waspmote Plug & Sense! line allows you to easily deploy Internet of Things networks in an easy and scalable way, ensuring minimum maintenance costs. The platform consists of a robust waterproof enclosure with specific external sockets to connect the sensors, the solar panel, the antenna and even the USB cable in order to reprogram the node. It has been specially designed to be scalable, easy to deploy and maintain.

Note: *For a complete reference guide download the "Waspmote Plug & Sense! Technical Guide" in the Development section of the Libelium website.*

3.1. Features

- Robust waterproof IP65 enclosure
- Add or change a sensor probe in seconds
- Solar powered external panel option
- Radios available: 802.15.4, 868 MHz, 900 MHz, WiFi, 4G, Sigfox and LoRaWAN
- Over the air programming (OTAP) of multiple nodes at once (via WiFi or 4G radios)
- Special holders and brackets ready for installation in street lights and building fronts
- Graphical and intuitive interface Programming Cloud Service
- Built-in, 3-axes accelerometer
- External, contactless reset with magnet
- Optional industrial protocols: RS-232, RS-485, Modbus, CAN Bus
- Optional GPS receiver
- Optional External Battery Module
- External SIM connector for the 4G models
- Fully certified: CE (Europe), FCC (USA), IC (Canada), ANATEL (Brazil), RCM (Australia), PTCRB (USA, cellular connectivity), AT&T (USA, cellular connectivity)

Figure: Waspmote Plug & Sense!

3.2. General view

This section shows main parts of Waspmote Plug & Sense! and a brief description of each one. In later sections all parts will be described deeply.

3.3. Specifications

- **Material:** polycarbonate
- **Sealing:** polyurethane
- **Cover screws:** stainless steel
- **Ingress protection:** IP65
- **Impact resistance:** IK08
- **Rated insulation voltage AC:** 690 V
- **Rated insulation voltage DC:** 1000 V
- **Heavy metals-free:** Yes
- **Weatherproof:** true - nach UL 746 C
- **Ambient temperature (min.):** -30 °C*
- **Ambient temperature (max.):** 70 °C*
- **Approximated weight:** 800 g

* *Temporary extreme temperatures are supported. Regular recommended usage: -20, +60 ºC.*

In the pictures included below it is shown a general view of Waspmote Plug & Sense! main parts. Some elements are dedicated to node control, others are designated to sensor connection and other parts are just identification elements. All of them will be described along this guide.

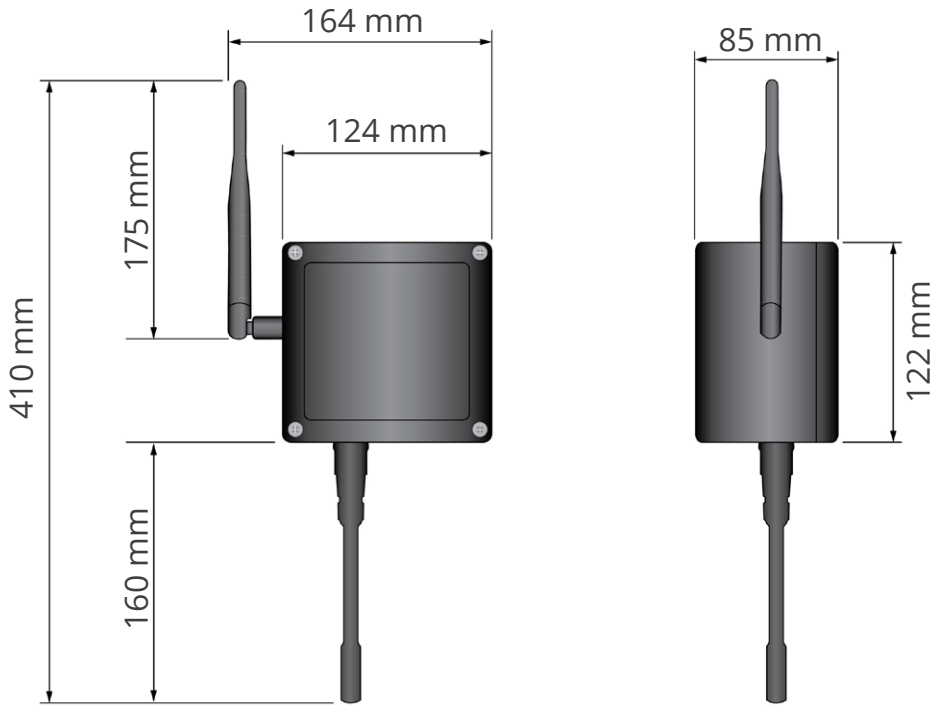


Figure: Main view of Waspmote Plug & Sense!

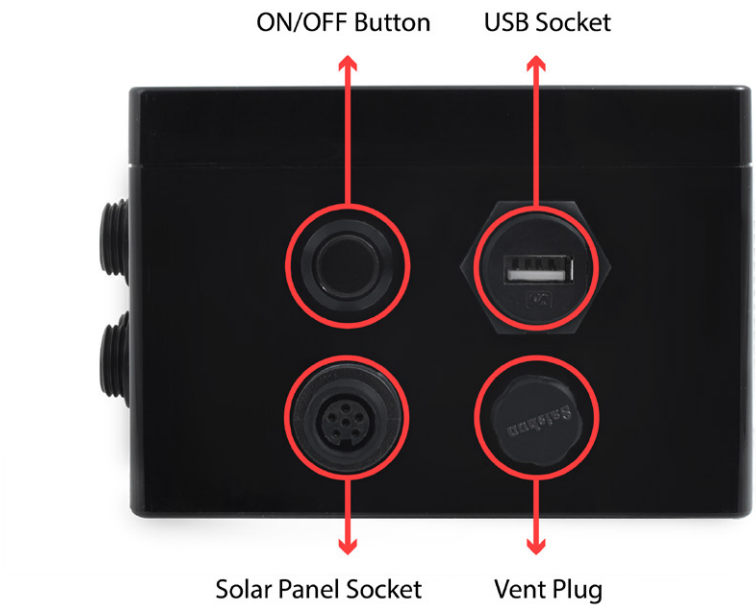


Figure: Control side of the enclosure

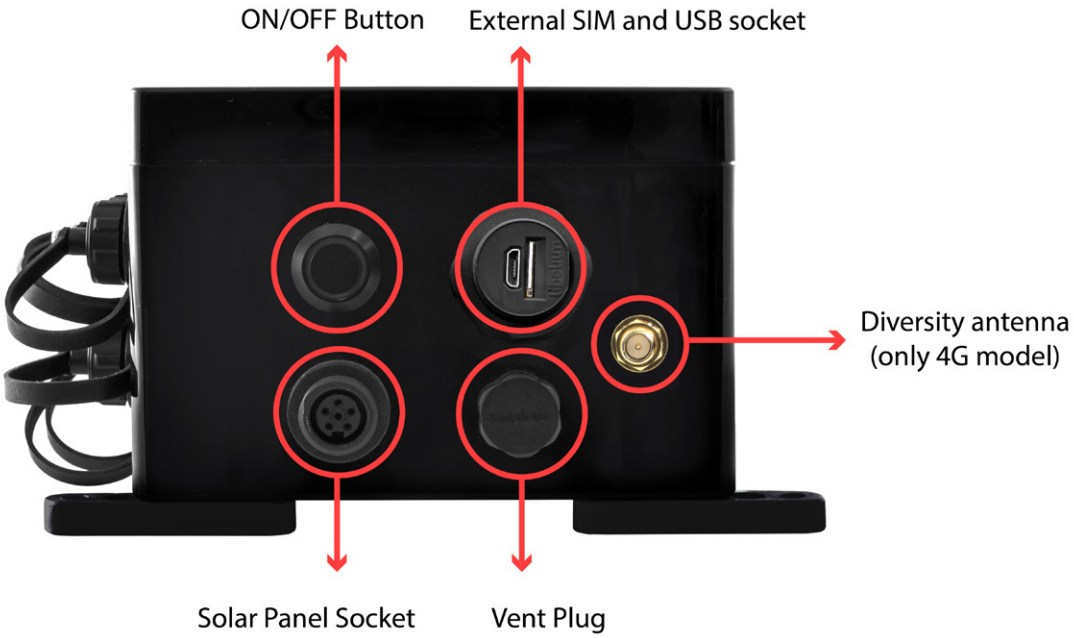


Figure: Control side of the enclosure for 4G model

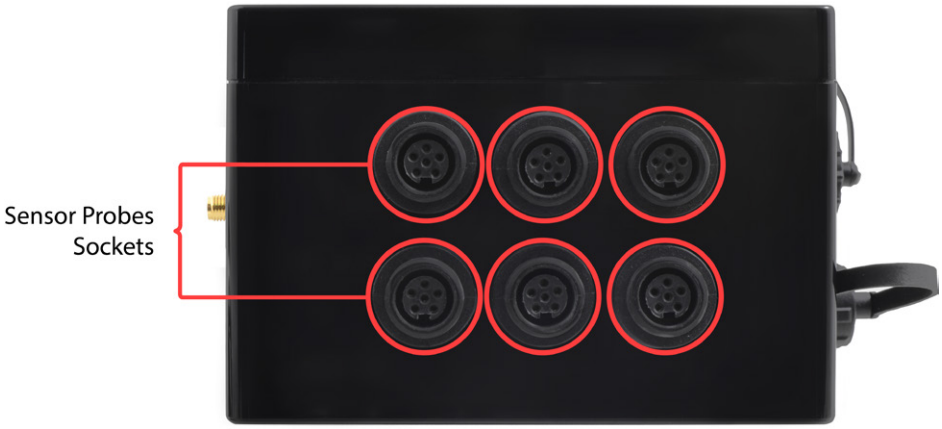


Figure: Sensor side of the enclosure

Figure: Antenna side of the enclosure

Figure: Front view of the enclosure

Figure: Back view of the enclosure

Figure: Warranty stickers of the enclosure

***Important note:** Do not handle black stickers seals of the enclosure (Warranty stickers). Their integrity is the proof that Waspmote Plug & Sense! has not been opened. If they have been handled, damaged or broken, the warranty is automatically void.*

3.4. Parts included

Next picture shows Waspmote Plug & Sense! and all of its elements. Some of them are optional accessories that may not be included.

Figure: Waspmote Plug & Sense! accessories: 1 enclosure, 2 sensor probes, 3 external solar panel, 4 USB cable, 5 antenna, 6 cable ties, 7 mounting feet (screwed to the enclosure), 8 extension cord, 9 solar panel cable, 10 wall plugs & screws

3.5. Identification

Each Waspmote model is identified by stickers. Next figure shows front sticker.

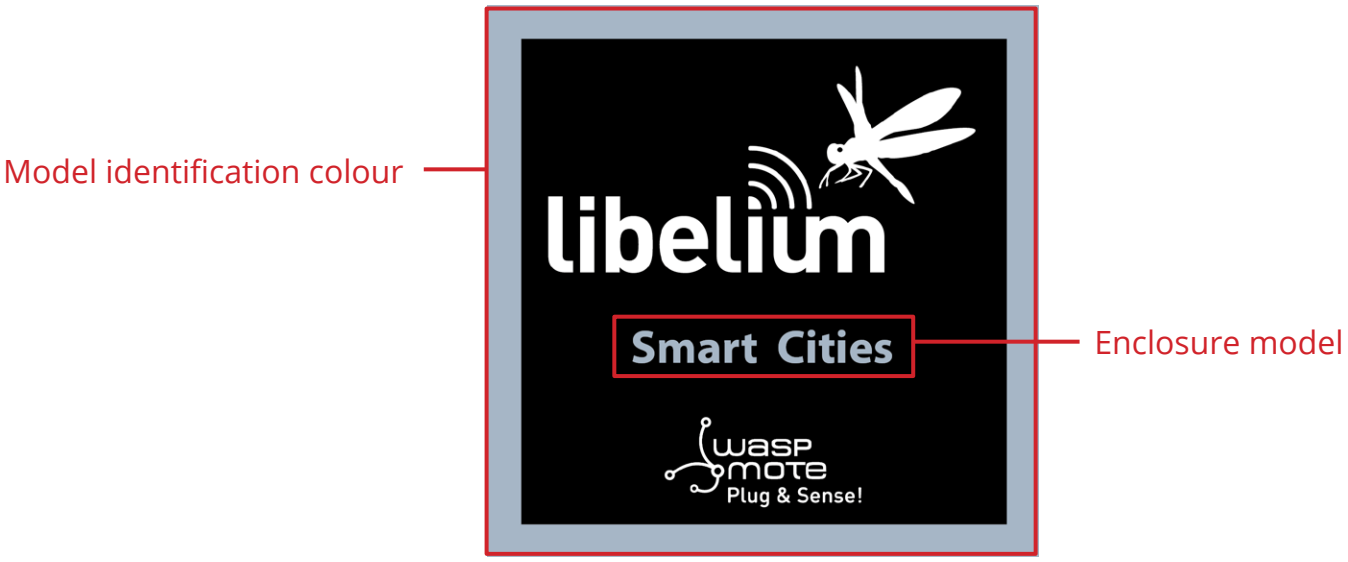


Figure: Front sticker of the enclosure

There are many configurations of Waspmote Plug & Sense! line, all of them identified by one unique sticker. Next image shows all possibilities.

Figure: Different front stickers

Moreover, Waspmote Plug & Sense! includes a back sticker where it is shown identification numbers, radio MAC addresses, etc. It is highly recommended to annotate this information and save it for future maintenance. Next figure shows it in detail.

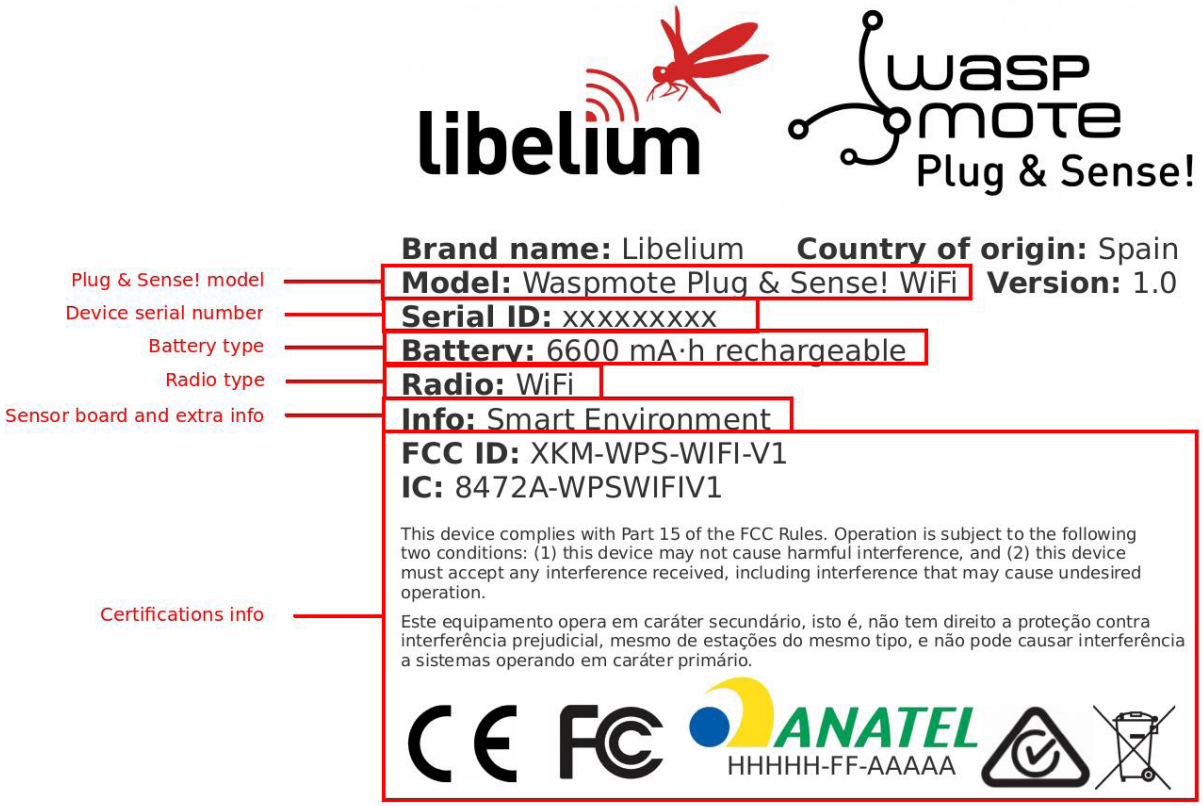


Figure: Back sticker

Sensor probes are identified too by a sticker showing the measured parameter and the sensor manufacturer reference.

Figure: Sensor probe identification sticker

3.6. Sensor probes

Sensor probes can be easily attached by just screwing them into the bottom sockets. This allows you to add new sensing capabilities to existing networks just in minutes. In the same way, sensor probes may be easily replaced in order to ensure the lowest maintenance cost of the sensor network.

Figure: Connecting a sensor probe to Waspmote Plug & Sense!

Go to the Plug & Sense! Sensor Guide to know more about our sensor probes.

3.7. Solar powered

The battery can be recharged using the waterproof USB cable but also the external solar panel option.

The external solar panel is mounted on a 45º holder which ensures the maximum performance of each outdoor installation.

Figure: Waspmote Plug & Sense! powered by an external solar panel

3.8. External Battery Module

The External Battery Module (EBM) is an accessory to extend the battery life of Plug & Sense!. The extension period may be from months to years depending on the sleep cycle and radio activity. The daily charging period is selectable among 5, 15 and 30 minutes with a selector switch and it can be combined with a solar panel to extend even more the node's battery lifetime.

Note: Nodes using solar panel can keep using it through the External Battery Module (EBM). The EBM is connected to the solar panel connector of Plug & Sense! and the solar panel unit is connected to the solar panel connector of the EBM.

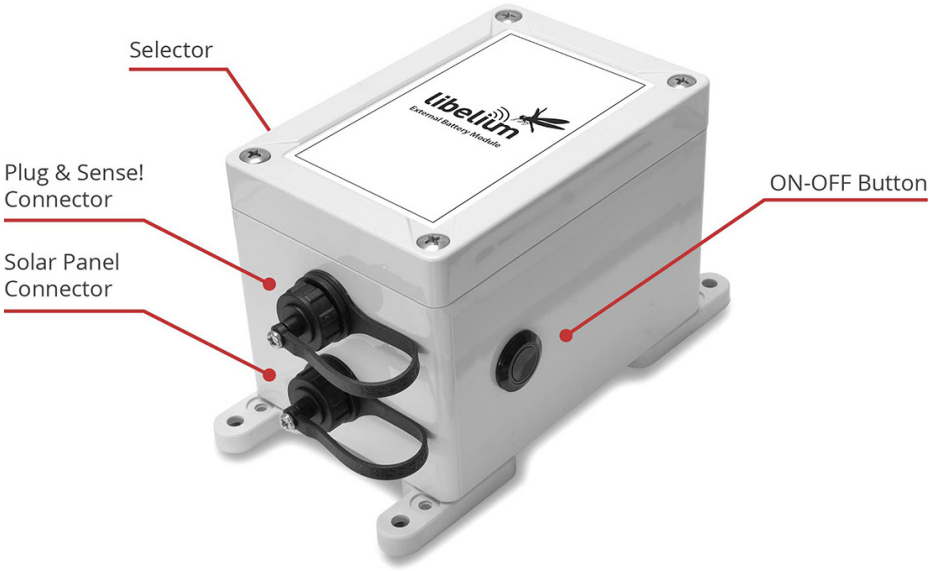


Figure: Plug & Sense! with External Battery Module

Figure: Plug & Sense! with External Battery Module and solar panel

3.9. Programming the Nodes

Waspmote Plug & Sense! can be reprogrammed in two ways:

The basic programming is done from the USB port. Just connect the USB to the specific external socket and then to the computer to upload the new firmware.

Figure: Programming a node

Over the Air Programming (OTAP) is also possible once the node has been installed (via WiFi or 4G radios). With this technique you can reprogram, wireless, one or more Waspmote sensor nodes at the same time by using a laptop and Meshlium.

Figure: Typical OTAP process

3.10. Program in minutes

The Programming Cloud Service is an intuitive graphic interface which creates code automatically. The user just needs to to fill a web form to obtain binaries for Plug & Sense!. Advanced programming options are available, depending on the license selected.

Check how easy it is to handle the Programming Cloud Service at:

https://cloud.libelium.com/

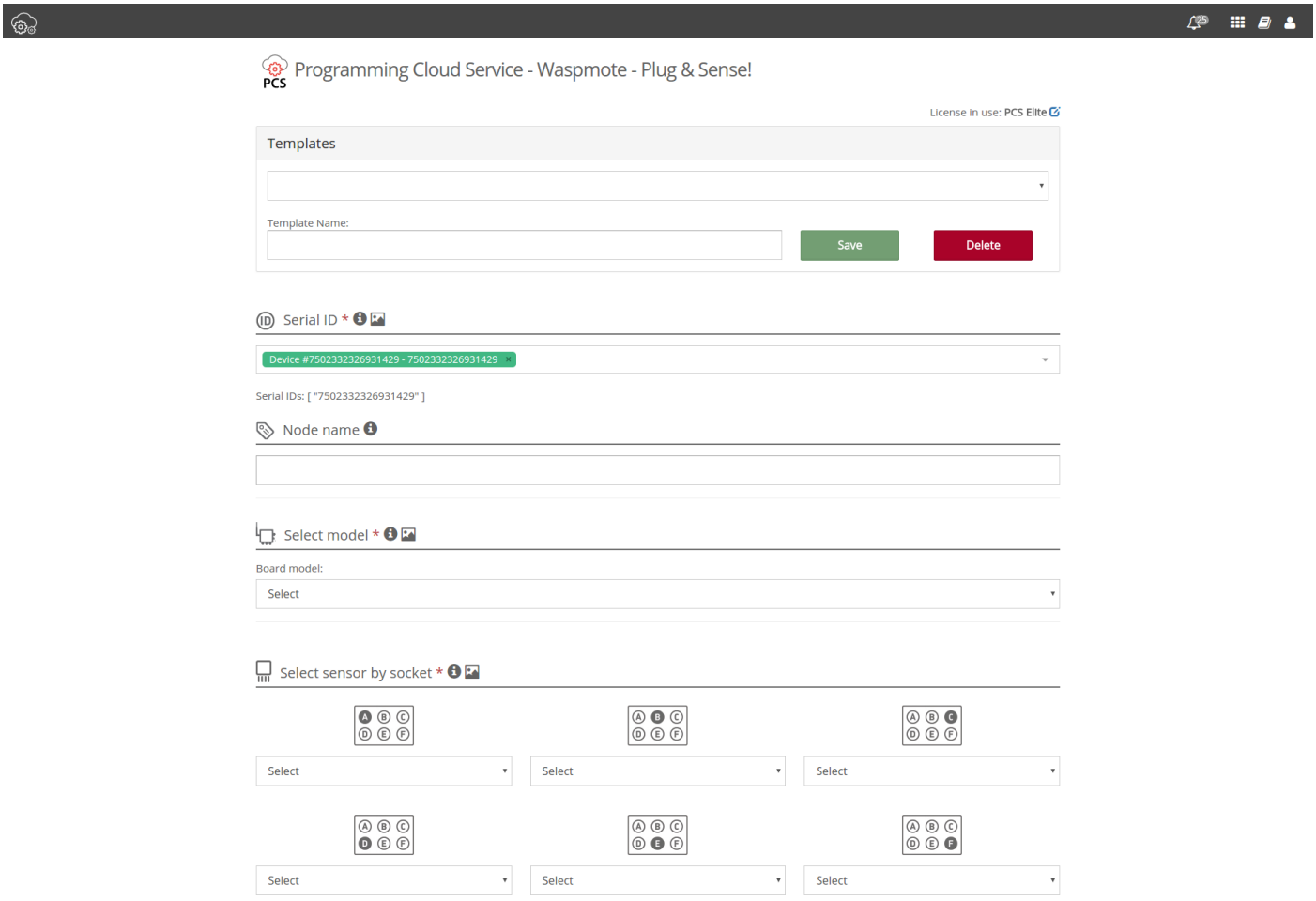


Figure: Programming Cloud Service

3.11. Radio interfaces

Radio	Protocol	Frequency bands	Transmission power	Sensitivity	Range*	Certification
XBee-PRO 802.15.4 EU	802.15.4	2.4 GHz	10 dBm	-100 dBm	750 m	CE
XBee-PRO 802.15.4	802.15.4	2.4 GHz	18 dBm	-100 dBm	1600 m	FCC, IC, ANATEL, RCM
XBee 868LP	RF	868 MHz	14 dBm	-106 dBm	8.4 km	CE
XBee 900HP US	RF	900 MHz	24 dBm	-110 dBm	15.5 km	FCC, IC
XBee 900HP BR	RF	900 MHz	24 dBm	-110 dBm	15.5 km	ANATEL
XBee 900HP AU	RF	900 MHz	24 dBm	-110 dBm	15.5 km	RCM
WiFi	WiFi (HTTP(S), FTP, TCP, UDP)	2.4 GHz	17 dBm	-94 dBm	500 m	CE, FCC, IC, ANATEL, RCM
4G EU/BR	4G/3G/2G (HTTP, FTP, TCP, UDP) GPS	800, 850, 900, 1800, 2100, 2600 MHz	4G: class 3 (0.2 W, 23 dBm)	4G: -102 dBm	- km - Typical base station range	CE, ANATEL
4G US	4G/3G/2G (HTTP, FTP, TCP, UDP) GPS	700, 850, 1700, 1900 MHz	4G: class 3 (0.2 W, 23 dBm)	4G: -103 dBm	- km - Typical base station range	FCC, IC, PTCRB, AT&T
4G AU	4G (HTTP, FTP, TCP, UDP)	700, 1800, 2600 MHz	4G: class 3 (0.2 W, 23 dBm)	4G: -102 dBm	- km - Typical base station range	RCM
Sigfox EU	Sigfox	868 MHz	16 dBm	-126 dBm	- km - Typical base station range	CE
Sigfox US	Sigfox	900 MHz	24 dBm	-127 dBm	- km - Typical base station range	FCC, IC
LoRaWAN EU	LoRaWAN	868 MHz	14 dBm	-136 dBm	> 15 km	CE
LoRaWAN US	LoRaWAN	900 MHz	18.5 dBm	-136 dBm	> 15 km	FCC, IC

* *Line of sight and Fresnel zone clearance with 5dBi dipole antenna.*

3.12. Industrial Protocols

Besides the main radio of Waspmote Plug & Sense!, it is possible to have an Industrial Protocol module as a secondary communication option. This is offered as an accessory feature.

The available Industrial Protocols are RS-232, RS-485, Modbus (software layer over RS-232 or RS-485) and CAN Bus. This optional feature is accessible through an additional, dedicated socket on the antenna side of the enclosure.

Figure: Industrial Protocols available on Plug & Sense!

Finally, the user can choose between 2 probes to connect the desired Industrial Protocol: A standard DB9 connector and a waterproof terminal block junction box. These options make the connections on industrial environments or outdoor applications easier.

Figure: DB9 probe

Figure: Terminal box probe

3.13. GPS

Any Plug & Sense! node can incorporate a GPS receiver in order to implement real-time asset tracking applications. The user can also take advantage of this accessory to geolocate data on a map. An external, waterproof antenna is provided; its long cable enables better installation for maximum satellite visibility.

Figure: Plug & Sense! node with GPS receiver

Chipset: JN3 (Telit)
Sensitivity:

- Acquisition: -147 dBm
- Navigation: -160 dBm
- Tracking: -163 dBm

Hot start time: <1 s
Cold start time: <35 s

Positional accuracy error < 2.5 m
Speed accuracy < 0.01 m/s
EGNOS, WAAS, GAGAN and MSAS capability

Antenna:

- Cable length: 2 m
- Connector: SMA
- Gain: 26 dBi (active)

Available information: latitude, longitude, altitude, speed, direction, date&time and ephemeris management

3.14. Models

There are some defined configurations of Waspmote Plug & Sense! depending on which sensors are going to be used. Waspmote Plug & Sense! configurations allow to connect up to six sensor probes at the same time.

Each model takes a different conditioning circuit to enable the sensor integration. For this reason each model allows to connect just its specific sensors.

This section describes each model configuration in detail, showing the sensors which can be used in each case and how to connect them to Waspmote. In many cases, the sensor sockets accept the connection of more than one sensor probe. See the compatibility table for each model configuration to choose the best probe combination for the application.

It is very important to remark that each socket is designed only for one specific sensor, so **they are not interchangeable**. Always be sure you connected probes in the right socket, otherwise they can be damaged.

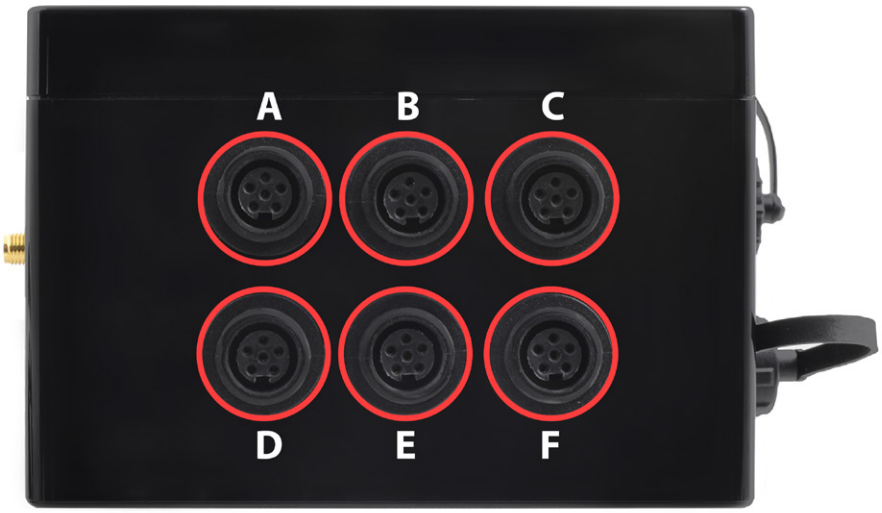


Figure: Identification of sensor sockets

3.14.1. Smart Environment PRO

The Smart Environment PRO model has been created as an evolution of Smart Environment. It enables the user to implement pollution, air quality, industrial, environmental or farming projects with high requirements in terms of high accuracy, reliability and measurement range as the sensors come calibrated from factory.

Figure: Smart Environment PRO Waspmote Plug & Sense! model

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A, B, C or F	Carbon Monoxide (CO) for high concentrations [Calibrated]	9371-P
	Carbon Monoxide (CO) for low concentrations [Calibrated]	9371-LC-P
	Carbon Dioxide (CO_2) [Calibrated]	9372-P
	Oxygen (O_2) [Calibrated]	9373-P
	Ozone (O_3) [Calibrated]	9374-P
	Nitric Oxide (NO) for low concentrations [Calibrated]	9375-LC-P
	Nitric Dioxide (NO_2) high accuracy [Calibrated]	9376-HA-P
	Sulfur Dioxide (SO_2) high accuracy [Calibrated]	9377-HA-P
	Ammonia (NH_3) for low concentrations [Calibrated]	9378-LC-P
	Ammonia (NH_3) for high concentrations [Calibrated]	9378-HC-P
	Methane (CH_4) and Combustible Gas [Calibrated]	9379-P
	Hydrogen (H_2) [Calibrated]	9380-P
	Hydrogen Sulfide (H_2S) [Calibrated]	9381-P
	Hydrogen Chloride (HCl) [Calibrated]	9382-P
	Hydrogen Cyanide (HCN) [Calibrated]	9383-P
	Phosphine (PH_3) [Calibrated]	9384-P
	Ethylene (ETO) [Calibrated]	9385-P
	Chlorine (Cl_2) [Calibrated]	9386-P
D	Particle Matter (PM1 / PM2.5 / PM10) - Dust	9387-P
E	Temperature, humidity and pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P

Figure: Sensor sockets configuration for Smart Environment PRO model

Note: *For more technical information about each sensor probe go to the Development section on the Libelium website.*

Calibrated gas sensors are manufactured once the order has been placed to ensure maximum durability of the calibration feature. The manufacturing process and delivery may take from 4 to 6 weeks. The lifetime of calibrated gas sensors is 6 months working at maximum accuracy. We strongly encourage our customers to buy extra gas sensors to replace the original ones after that time to ensure maximum accuracy and performance.

Note: *In March 2017, Smart Environment (which is the Plug & Sense! version for the Gases sensor board) was discontinued. The Gases sensor board is now only available in the Waspmote OEM product line. Libelium currently offers Gases PRO (Smart Environment PRO) and Smart Cities PRO for accurate measuring of gases.*

3.14.2. Smart Security

The main applications for this Waspmote Plug & Sense! configuration are perimeter access control, liquid presence detection and doors and windows openings. Besides, a relay system allows this model to interact with external electrical machines.

Figure: Smart Security Waspmote Plug & Sense! model

Note: *The probes attached in this photo could not match the final location. See next table for the correct configuration.*

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A, C, D or E	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
	Presence - PIR	9212-P
	Liquid Level (combustible, water)	9239-P, 9240-P
	Liquid Presence (Point, Line)	9243-P, 9295-P
	Hall Effect	9207-P
B	Liquid Flow (small, medium, large)	9296-P, 9297-P, 9298-P
F	Relay Input-Output	9270-P

Figure: Sensor sockets configuration for Smart Security model

As we see in the figure below, thanks to the directional probe, the presence sensor probe (PIR) may be placed in different positions. The sensor can be focused directly to the point we want.

Figure: Configurations of the Presence sensor probe (PIR)

Note: *For more technical information about each sensor probe go to the Development section on the Libelium website.*

3.14.3. Smart Water

The Smart Water model has been conceived to facilitate the remote monitoring of the most relevant parameters related to water quality. With this platform you can measure more than 6 parameters, including the most relevant for water control such as dissolved oxygen, oxidation-reduction potential, pH, conductivity and temperature. An extremely accurate turbidity sensor has been integrated as well.

The Smart Water Ions line is complementary for these kinds of projects, enabling the control of concentration of ions like Ammonium (NH_4^+), Bromide (Br^-), Calcium (Ca^{2+}), Chloride (Cl^-), Cupric (Cu^{2+}), Fluoride (F^-), Iodide (I^-), Lithium (Li^+), Magnesium (Mg^{2+}), Nitrate (NO_3^-), Nitrite (NO_2^-), Perchlorate (ClO_4^-), Potassium (K^+), Silver (Ag^+), Sodium (Na^+) and pH. Take a look to the Smart Water Ions line in the next section.

Refer to Libelium website for more information.

Figure: Smart Water Plug&Sense! model

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	pH	9328
B	Dissolved Oxygen (DO)	9327
C	Conductivity	9326
E	Oxidation-Reduction Potential (ORP)	9329
F	Soil/Water Temperature	9255-P (included by default)
	Turbidity	9353-P

Figure: Sensor sockets configuration for Smart Water model

Note: *For more technical information about each sensor probe go to the* Development section *on the Libelium website.*

3.14.4. Smart Water Ions

The Smart Water Ions models specialize in the measurement of ions concentration for drinking water quality control, agriculture water monitoring, swimming pools or waste water treatment.

The Smart Water line is complementary for these kinds of projects, enabling the control of parameters like turbidity, conductivity, oxidation-reduction potential and dissolved oxygen. Take a look to the Smart Water line in the previous section. Refer to Libelium website for more information.

There are 3 variants for Smart Water Ions: Single, Double and PRO. This is related to the type of ion sensor that each variant can integrate. Next section describes each configuration in detail.

Figure: Smart Water Ions Waspmote Plug & Sense! model

Single

This variant includes a Single Junction Reference Probe, so it can read all the single type ion sensors. Sensor sockets are configured as shown in the table below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A, B, C and D	Calcium Ion (Ca^{2+})	9352
	Fluoride Ion (F^-)	9353
	Fluoroborate Ion ($BF4^-$)	9354
	Nitrate Ion (NO_3^-)	9355
	pH (for Smart Water Ions)	9363
E	Single Junction Reference	9350 (included by default)
F	Soil/Water Temperature	9255-P (included by default)

Figure: Sensor sockets configuration for Smart Water Ions model, single variant

Note: *For more technical information about each sensor probe go to the Development section on the Libelium website.*

Double

This variant includes a Double Junction Reference Probe, so it can read all the double type ion sensors. Sensor sockets are configured as shown in the table below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A, B, C and D	Bromide Ion (Br^-)	9356
	Chloride Ion (Cl^-)	9357
	Cupric Ion (Cu^{2+})	9358
	Iodide Ion (I^-)	9360
	Silver Ion (Ag^+)	9362
	pH (for Smart Water Ions)	9363
E	Double Junction Reference	9351 (included by default)
F	Soil/Water Temperature	9255-P (included by default)

Figure: Sensor sockets configuration for Smart Water Ions model, double variant

Note: *For more technical information about each sensor probe go to the Development section on the Libelium website.*

Pro

This special variant integrates extreme quality sensors, with better performance than the Single or Double lines. In this case, there is only one type of reference probe and up to 16 different ion parameters can be analyzed in 4 sockets.

Sensor sockets are configured as shown in the table below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A, B, C or D	Ammonium Ion (NH_4^+) [PRO]	9412
	Bromide Ion (Br^-) [PRO]	9413
	Calcium Ion (Ca^{2+}) [PRO]	9414
	Chloride Ion (Cl^-) [PRO]	9415
	Cupric Ion (Cu^{2+}) [PRO]	9416
	Fluoride Ion (F^-) [PRO]	9417
	Iodide Ion (I^-) [PRO]	9418
	Lithium Ion (Li^+) [PRO]	9419
	Magnesium Ion (Mg^{2+}) [PRO]	9420
	Nitrate Ion (NO_3^-) [PRO]	9421
	Nitrite Ion (NO_2^-) [PRO]	9422
	Perchlorate Ion (ClO_4^-) [PRO]	9423
	Potassium Ion (K^+) [PRO]	9424
	Silver Ion (Ag^+) [PRO]	9425
	Sodium Ion (Na^+) [PRO]	9426
	pH [PRO]	9411
E	Reference Sensor Probe [PRO]	9410 (included by default)
F	Soil/Water Temperature	9255-P (included by default)

Figure: Sensor sockets configuration for Smart Water Ions model, PRO variant

Note: *For more technical information about each sensor probe go to the Development section on the Libelium website.*

3.14.5. Smart Parking

The Smart Parking node allows to detect available parking spots by placing the node on the pavement. It works with a magnetic sensor which detects when a vehicle is present or not.

The node benefits from Sigfox and LoRaWAN technologies (868 and 900 MHz bands), getting ubiquitous coverage with few base stations. The device is very optimized in terms of power consumption, resulting in a long battery life. Its small size and the robust and surface-mount enclosure enables a fast installation, without the need of digging a hole in the ground. Finally, the developer does not need to program the node, but just configure some key parameters. Remote management and bidirectional communication allow to change parameters from the Cloud.

Figure: Smart Parking node

> ***Note:*** *There are specific documents for parking applications on the Libelium website. Refer to the Smart Parking Technical Guide to see typical applications for this model and how to make a good installation.*

Figure: Smart Parking application diagram

3.14.6. Smart Agriculture

The Smart Agriculture models allow to monitor multiple environmental parameters involving a wide range of applications. It has been provided with sensors for air and soil temperature and humidity, solar visible radiation, wind speed and direction, rainfall, atmospheric pressure, etc.

The main applications for this Waspmote Plug & Sense! model are precision agriculture, irrigation systems, greenhouses, weather stations, etc. Refer to Libelium website for more information.

Two variants are possible for this model, normal and PRO. Next section describes each configuration in detail.

Figure: Smart Agriculture Waspmote Plug & Sense! model

Normal

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	Weather Station WS-3000 (anemometer + wind vane + pluviometer)	9256-P
B	Soil Moisture 1	9248-P, 9324-P, 9323-P
C	Soil Moisture 3	9248-P, 9324-P, 9323-P
D	Soil Temperature	86949-P
	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
E	Leaf Wetness	9249-P
	Soil Moisture 2	9248-P, 9324-P, 9323-P
F (digital bus)	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P

Figure: Sensor sockets configuration for Smart Agriculture model

Note: *For more technical information about each sensor probe go to the Development section on the Libelium website.*

PRO

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	Weather Station WS-3000 (anemometer + wind vane + pluviometer)	9256-P
B	Soil Moisture 1	9248-P, 9324-P, 9323-P
	Solar Radiation (PAR)	9251-P
	Ultraviolet Radiation	9257-P
C	Soil Moisture 3	9248-P, 9324-P, 9323-P
	Dendrometers	9252-P, 9253-P, 9254-P
D (digital bus)	Soil Temperature (Pt-1000)	9255-P
	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
E	Leaf Wetness	9249-P
	Soil Moisture 2	9248-P, 9324-P, 9323-P
F (digital bus)	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P

Figure: Sensor sockets configuration for Smart Agriculture PRO model

* Ask Libelium Sales Department for more information.

Note: *For more technical information about each sensor probe go to the Development section on the Libelium website.*

3.14.7. Ambient Control

This model is designed to monitor the main environment parameters easily. Only three sensor probes are allowed for this model, as shown in next table.

Figure: Ambient Control Waspmote Plug & Sense! model

Sensor sockets are configured as it is shown in figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	**Reference**
A	Temperature + Humidity + Pressure	9370-P
B	Luminosity (LDR)	9205-P
C	Luminosity (Luxes accuracy)	9325-P
D, E and F	Not used	-

Figure: Sensor sockets configuration for Ambient Control model

As we see in the figure below, thanks to the directional probe, the Luminosity (Luxes accuracy) sensor probe may be placed in different positions. The sensor can be focused directly to the light source we want to measure.

Figure: Configurations of the Luminosity sensor probe (luxes accuracy)

Note: *For more technical information about each sensor probe go to the Development section on the Libelium website.*

3.14.8. Smart Cities PRO

The main applications for this Waspmote Plug & Sense! model are noise maps (monitor in real time the acoustic levels in the streets of a city), air quality, waste management, smart lighting, etc. Refer to Libelium website for more information.

Figure: Smart Cities PRO Waspmote Plug & Sense! model

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Parameter	Reference
A	Noise level sensor	NLS
	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
B, C and F	Carbon Monoxide (CO) for high concentrations [Calibrated]	9371-P
	Carbon Monoxide (CO) for low concentrations [Calibrated]	9371-LC-P
	Carbon Dioxide (CO_2) [Calibrated]	9372-P
	Oxygen (O_2) [Calibrated]	9373-P
	Ozone (O_3) [Calibrated]	9374-P
	Nitric Oxide (NO) for low concentrations [Calibrated]	9375-LC-P
	Nitric Dioxide (NO_2) high accuracy [Calibrated]	9376-HA-P
	Sulfur Dioxide (SO_2) high accuracy [Calibrated]	9377-HA-P
	Ammonia (NH_3) for low concentrations [Calibrated]	9378-LC-P
	Ammonia (NH_3) for high concentrations [Calibrated]	9378-HC-P
	Methane (CH_4) and Combustible Gas [Calibrated]	9379-P
	Hydrogen (H_2) [Calibrated]	9380-P
	Hydrogen Sulfide (H_2S) [Calibrated]	9381-P
	Hydrogen Chloride (HCl) [Calibrated]	9382-P
	Hydrogen Cyanide (HCN) [Calibrated]	9383-P
	Phosphine (PH_3) [Calibrated]	9384-P
	Ethylene (ETO) [Calibrated]	9385-P
	Chlorine (Cl_2) [Calibrated]	9386-P
	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P
D	Particle Matter (PM1 / PM2.5 / PM10) - Dust	9387-P
E	Temperature + Humidity + Pressure	9370-P
	Luminosity (Luxes accuracy)	9325-P
	Ultrasound (distance measurement)	9246-P

Figure: Sensor sockets configuration for Smart Cities PRO model

Note: *For more technical information about each sensor probe go to the Development section in Libelium website.*

Calibrated gas sensors are manufactured once the order has been placed to ensure maximum durability of the calibration feature. The manufacturing process and delivery may take from 4 to 6 weeks. The lifetime of calibrated gas sensors is 6 months working at maximum accuracy. We strongly encourage our customers to buy extra gas sensors to replace the original ones after that time to ensure maximum accuracy and performance.

3.14.9. Radiation Control

The main application for this Waspmote Plug & Sense! configuration is to measure radiation levels using a Geiger sensor. For this model, the Geiger tube is already included inside Waspmote, so the user does not have to connect any sensor probe to the enclosure. The rest of the other sensor sockets are not used.

Figure: Radiation Control Waspmote Plug & Sense! model

Sensor sockets are not used for this model.

> ***Note:*** *For more technical information about each sensor probe go to the Development section on the Libelium website.*

3.14.10. 4-20 mA Current Loop

The applications for this Plug & Sense! model are focused on adding wireless connectivity to 4-20 mA devices and connecting them to the Cloud.

Figure: 4-20 mA Current Loop Waspmote Plug & Sense! model

Sensor sockets are configured as shown in the figure below.

Sensor Socket	Sensor probes allowed for each sensor socket	
	Board channel	**Reference**
A	Channel 1 (type 2 and type 3)	9270-P, DB9-P
B	Channel 2 (type 2 and type 3)	9270-P, DB9-P
C	Channel 3 (type 2 and type 3)	9270-P, DB9-P
D	Channel 4 (type 4)	9270-P, DB9-P

Figure: Sensor sockets configuration for 4-20 mA Current Loop model

Note: *For more technical information about each sensor probe go to the Development section on the Libelium website.*

4. Hardware

4.1. Modular architecture

Waspmote is based on a modular architecture. The idea is to integrate only the modules needed in each device. These modules can be changed and expanded according to needs.

The modules available for integration in Waspmote are categorized in:

- ZigBee/802.15.4 XBee modules (2.4 GHz, 868 MHz, 900 MHz)
- LoRaWAN module (433/868/900 MHz)
- LoRa module (868/900 MHz)
- Sigfox module (868/900 MHz)
- GPRS module (Quadband: 850/900/1800/1900 MHz)
- 3G module (Dual-Band WCDMA/UMTS 900/2100 MHz and Tri-Band GSM/GPRS/EDGE 850/900/1800 MHz)
- 4G Module (Europe/Brazil, America and Australia versions)
- WiFi module
- Bluetooth modules: Bluetooth Low Energy and Bluetooth Pro
- NFC/RFID module
- GPS module
- Sensor modules (Sensor boards)
- Storage module: SD Memory Card

4.2. Specifications

- **Microcontroller:** ATmega1281
- **Frequency:** 14.7456 MHz
- **SRAM:** 8 kB
- **EEPROM:** 4 kB
- **FLASH:** 128 kB
- **SD Card:** 8 GB
- **Weight:** 20 g
- **Dimensions:** 73.5 x 51 x 13 mm
- **Temperature range:** [-30 ºC, +70 ºC]*

** Temporary extreme temperatures are supported. Regular recommended usage: -20, +60 ºC.*

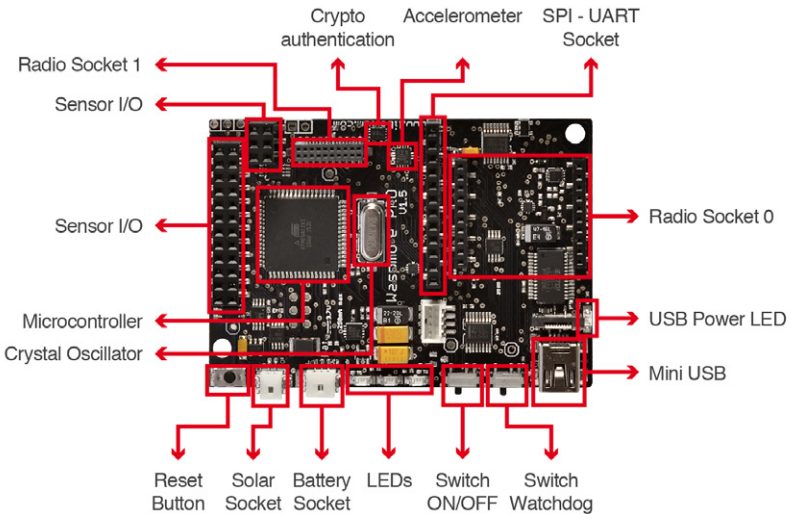
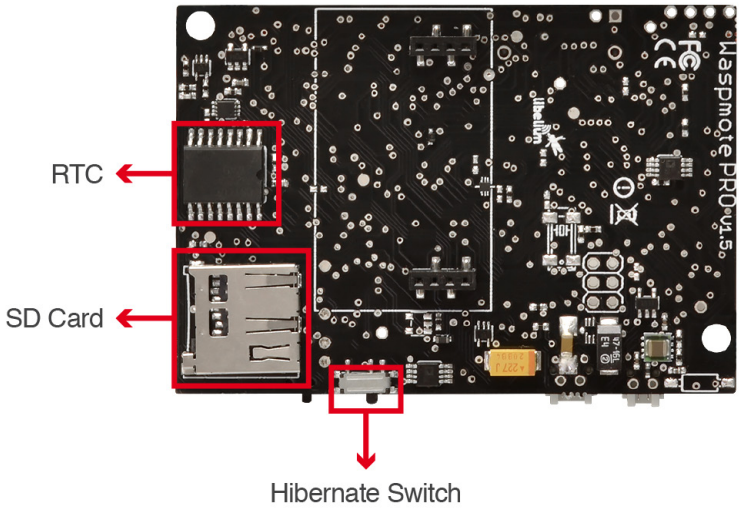


Figure: Main Waspmote components – Top side



Main Waspmote components – Bottom side

4.3. Block diagram

Data signals:

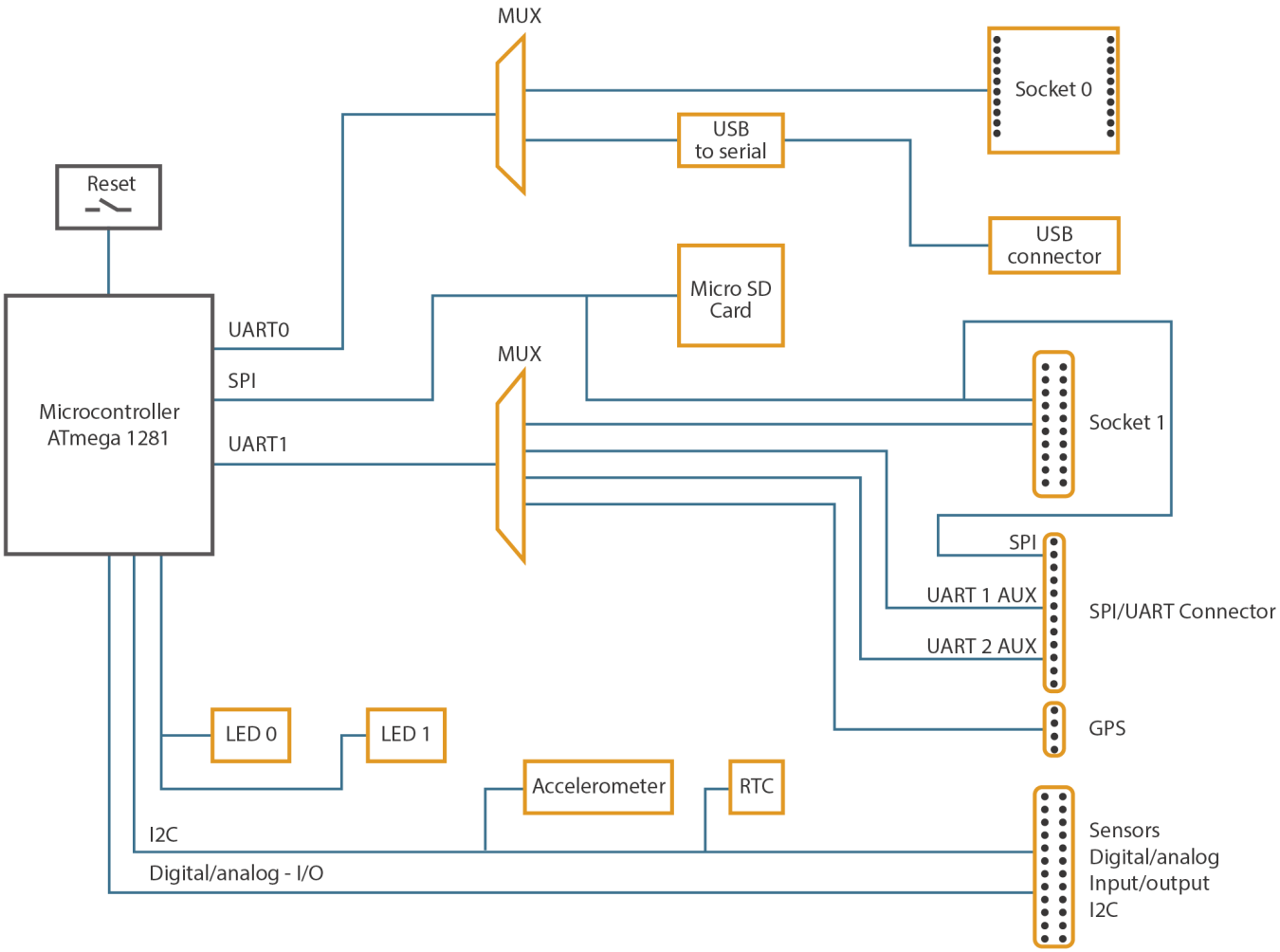


Figure: Waspmote block diagrams – Data signals

Power signals:

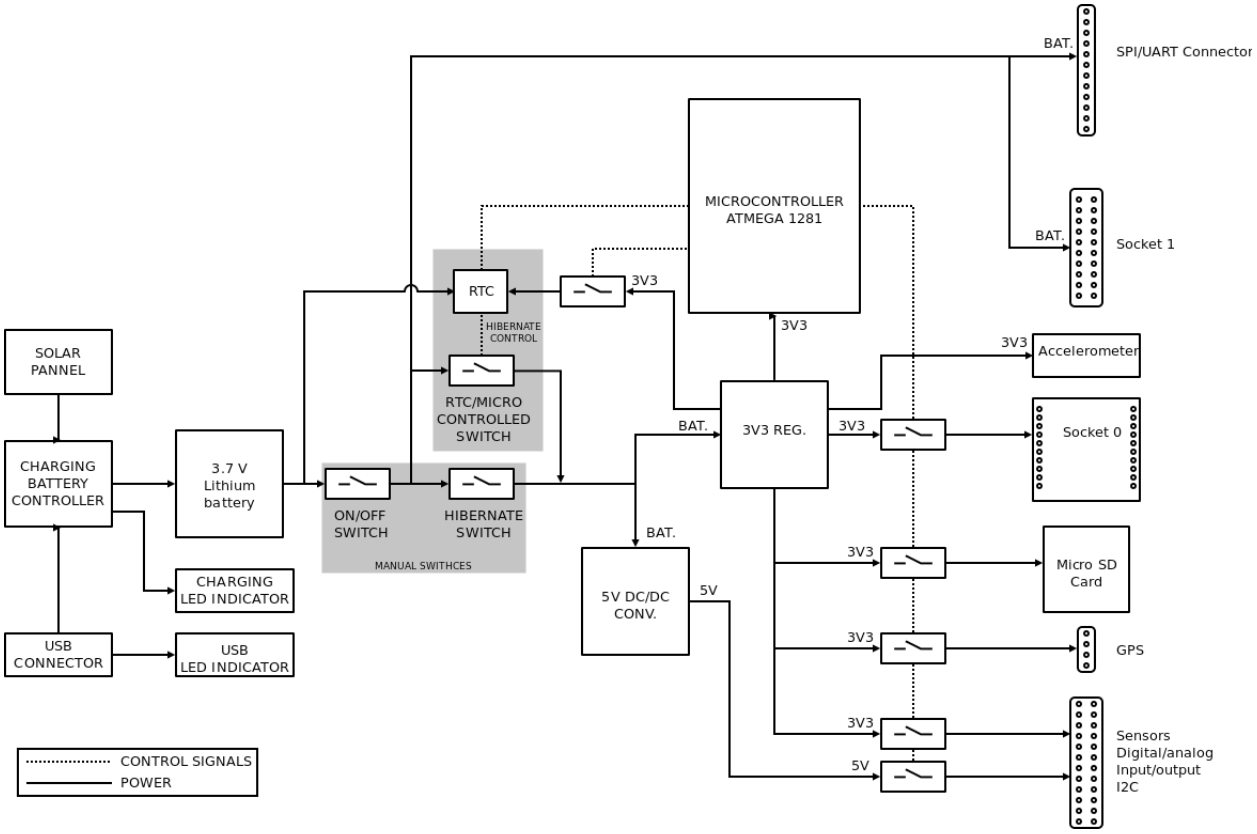


Figure: Waspmote block diagrams – Power signals

4.4. Electrical data

Operational values:

• Minimum operational battery voltage	3.3 V
• Maximum operational battery voltage	4.2 V
• USB charging voltage	5 V
• Solar panel charging voltage	6 - 12 V
• Battery charging current from USB	480 mA (max current input)
• Battery charging current from solar panel	300 mA (max current input)

Absolute maximum values:

• Voltage in any pin	[-0.5 V, +3.8 V]
• Maximum current from any digital I/O pin	40 mA
• USB power voltage	7 V
• Solar panel power voltage	18 V
• Charged battery voltage	4.2 V

4.5. I/O

Waspmote can communicate with other external devices through the using different **input/output** ports.

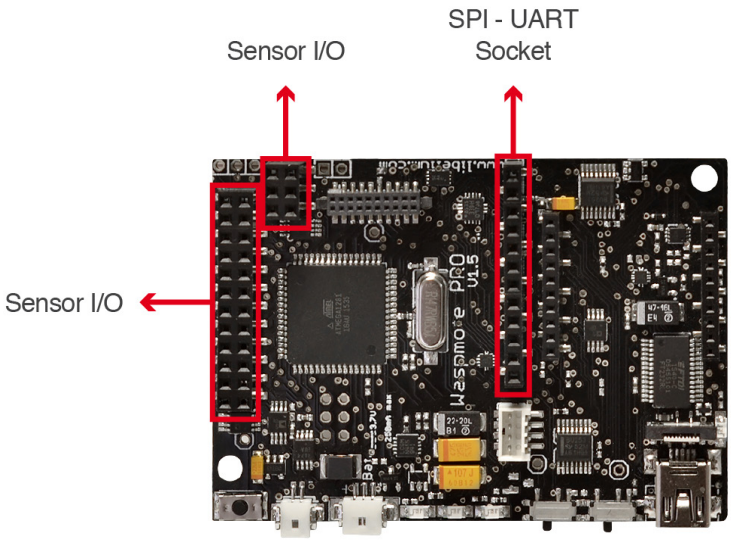


Figure: I/O connectors in Waspmote

Sensor connector:

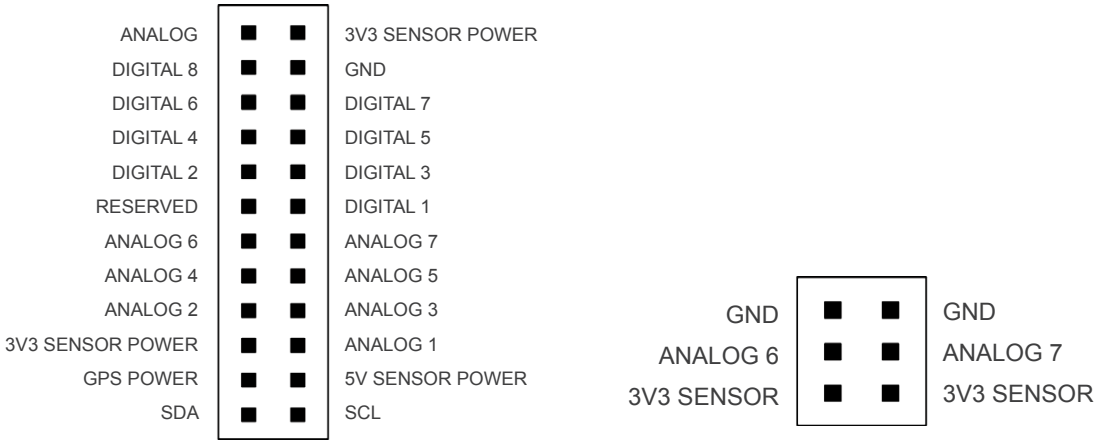


Figure: Description of sensor connector pins

Auxiliary SPI-UART connector:

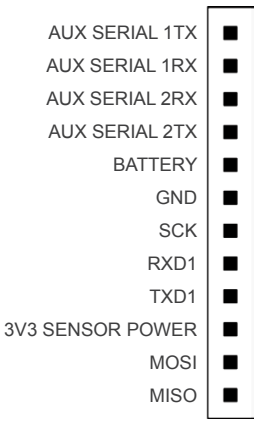


Figure: Description of auxiliary SPI-UART connector pins

4.5.1. Analog pins

Waspmote has **7** accessible analog inputs in the sensor connector. Each input is directly connected to the microcontroller. The microcontroller uses a **10-bit** successive approximation analog to digital converter (**ADC**). The reference voltage value for the inputs is **0 V** (GND). The maximum value of input voltage is **3.3 V** which corresponds with the microcontroller's general power voltage.

To obtain input values, the function `analogRead(analog input)` is used, the function's input parameter will be the name of the input to be read "ANALOG1, ANALOG2..." (see sensor connector figure). The value obtained from this function will be an integer number between **0 and 1023**, 0 corresponds to 0 V and 1023 to 3.3 V.

The analog input pins can also be used as digital input/output pins. If these pins are going to be used as digital ones, the following correspondence list for pin names must be taken into account:

Analog pin		Digital pin
ANALOG1	=>	14
ANALOG2	=>	15
ANALOG3	=>	16
ANALOG4	=>	17
ANALOG5	=>	18
ANALOG6	=>	19
ANALOG7	=>	20

```
{
  val = analogRead(ANALOG1);
}
```

4.5.2. Digital pins

Waspmote has digital pins which can be configured as **input** or **output** depending on the needs of the application. The voltage values corresponding to the different digital values would be:

- `LOW:` 0 V for logic 0
- `HIGH:` 3.3 V for logic 1

The instructions for control of digital pins are:

```
{
  // set DIGITAL3 pin as input and read its value
  pinMode(DIGITAL3, INPUT);
  val = digitalRead(DIGITAL3);

  // set DIGITAL3 pin as output and set it LOW
  pinMode(DIGITAL3 ,OUTPUT);
  digitalWrite(DIGITAL3, LOW);
}
```

4.5.3. PWM

DIGITAL1 pin can also be used as output **PWM (Pulse Width Modulation)** with which an analog signal can be "simulated". It is actually a square wave between 0 V and 3.3 V for which the proportion of time when the signal is high can be changed (its working cycle) from 0% to 100%, simulating a voltage of 0 V (0%) to 3.3 V (100%).The resolution is **8 bit**, so up to 255 values between 0-100% can be configured. The instruction to control the PWM output is `analogWrite(DIGITAL1, value);` where value is the analog value (0-255).

```
{
  analogWrite(DIGITAL1, 127);
}
```

4.5.4. UART

There are 2 UARTs in Waspmote: UART0 and UART1. Besides, there are several ports which might be connected to these UARTs through 2 different multiplexers, one for each UART.

- **UART0** is shared by the USB port and the Socket0. This socket is used for XBee modules, LoRaWAN module, LoRa module, Sigfox module, RFID/NFC module, Bluetooth modules, WiFi module, RS-485 module, etc. The multiplexer in this UART controls the data signal which by default is always switched to Socket0. When the USB needs to send info through the UART0, the multiplexer is momentarily switched to the USB port and set back again to Socket0 after printing.
- **UART1** is shared by 4 ports: Socket1, GPS socket, Auxiliar1 and Auxiliar2 sockets. It is possible to select in the same program which of the 4 ports is connected to UART1 in the microcontroller. UART1 multiplexer configuration is carried out using the following instructions:

```
{
  Utils.setMuxAux1(); // set Auxiliar1 socket
  Utils.setMuxAux2(); // set Auxiliar2 socket
  Utils.setMuxGPS();  // set GPS socket
  Utils.setMuxSocket1(); // set Socket1
}
```

4.5.5. I2C

The I2C communication bus is also used in Waspmote where several devices are connected in parallel: the accelerometer, a crypto-authentication memory and the RTC. In all cases, the microcontroller acts as master while the other devices connected to the bus are slaves.

4.5.6. SPI

The SPI port on the microcontroller is used for communication with the micro SD card. All operations using the bus are performed clearly by the specific library. The SPI port is also available in the SPI/UART connector and Socket0.

4.5.7. USB

USB is used in Waspmote for communication with a computer or compatible USB devices. This communication allows the microcontroller's program to be loaded.

For USB communication, microcontroller's UART0 is used. The **FT232RL** chip carries out the conversion to USB standard.

4.6. Real Time Clock - RTC

Waspmote has a built in Real Time Clock – RTC, which keeps it informed of the time. This allows Waspmote to be programmed to perform time-related actions such as:

"Sleep for 1h 20 min and 15sec, then wake up and perform the following action.."

Or even programs to perform actions at absolute intervals, e.g.:

"Wake on the 5th of next month at 00:20 and perform the following action.."

All RTC programming and control is done through the I2C bus.

Alarms:

Alarms can be programmed in the RTC specifying day/hour/minute/second. That allows total control about when the mote wakes up to capture sensor values and perform actions programmed on it. This allows Waspmote to be in the saving energy modes (**Deep Sleep** and **Hibernate**) and makes it wake up just at the required moment.

As well as relative alarms, periodic alarms can be programmed by giving a time measurement, so that Waspmote reprograms its alarm automatically each time one event is triggered.

The RTC chosen is the Maxim **DS1337C**, which operates at a frequency of **32.768 kHz** (a second divisor value which allows it to quantify and calculate time variations with high precision).

The RTC is powered by the battery. When the battery is connected, the RTC is powered on. However, the user must keep in mind that if the battery is removed or out of load, then time data will be not maintained. This is the reason we suggest to use RTC time as 'relative' and not 'absolute' (see Programming Guide for more info).

A coin or button battery is not needed. They have a limited life and therefore Waspmote can have a much longer power life expectancy. This is so because the RTC is powered from the "main" battery which has a much bigger charge.

The RTC is responsible for waking Waspmote up from sleep modes like **Deep Sleep** and **Hibernate**. This makes possible to use its battery to just power the RTC in sleep modes. The RTC controls when the device has to wake up and perform a particular action. This permits a consumption of **7 uA** in the Hibernate mode. Please refer to "Energy System" section for more information.

Related API libraries: **WaspRTC.h**, **WaspRTC.cpp**

All information about their programming and operation can be found in the RTC Programming Guide.

All the documentation is located in the Development section in the Libelium website.

4.7. LEDs

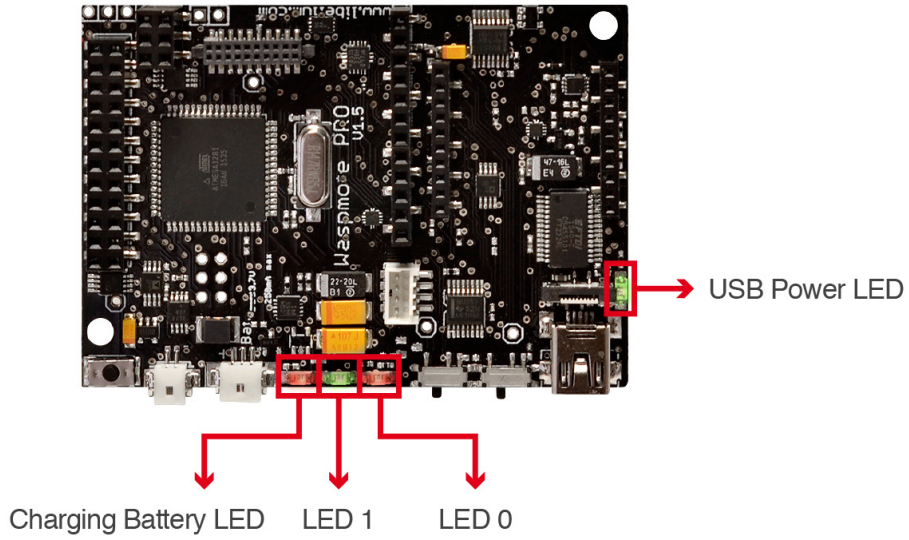


Figure: Visual indicator LEDs

The Waspmote LEDs are:

- **Charging battery LED indicator:** A red LED indicating that there is a battery connected in Waspmote which is being charged. The charging can be done through a mini-USB cable or through a solar panel connected to Waspmote. Once the battery is completely charged, the LED switches off automatically.
- **LED0 (programmable LED):** A green LED is connected to the microcontroller. It is totally programmable by the user from the program code. In addition, the LED0 indicates when Waspmote resets, blinking each time a reset on the board is carried out.
- **LED1 (programmable LED):** A red LED is connected to the microcontroller. It is totally programmable by the user from the program code.
- **USB Power LED indicator:** A green LED which indicates when Waspmote is connected to a compatible USB port either for battery charging or programming. When the LED is on, it indicates that the USB cable is connected correctly. When the USB cable is removed, this LED will switch off automatically.

Please refer to Waspmote Utilities guide for more information.

5. Architecture and system

5.1. Concepts

The Waspmote's architecture is based on the **Atmel ATmega1281** microcontroller.

When Waspmote is connected and starts the **bootloader**, there is a waiting time (62.5 ms) before beginning the first instruction, this time is used to start loading new compiled programs updates. If a new program is received from the USB during this time, it will be loaded into the FLASH memory (128 kB) substituting already existing programs. Otherwise, if a new program is not received, the last program stored in the memory will start running.

The structure of the codes is divided into 2 basic parts: **setup** and **loop**. Both parts of the code have sequential behaviour, executing instructions in the set order.

The **setup** is the first part of the code, which is only run once when the code is initialized. In this part it is recommended to include the initialization of the modules which are going to be used, as well as the part of the code which is only important when Waspmote is started.

The part named **loop** runs continuously, forming an infinite loop. Because of the behavior of this part of the code, the use of interruptions is recommended to perform actions with Waspmote.

A common programming technique to save energy would be based on blocking the program (either keeping the micro awake or asleep in particular cases) until any of the interruptions available in Waspmote show that an event has occurred. This way, when an interruption is detected the associated function, which was previously stored in an interruption vector, is executed.

To be able to detect the capture of interruptions during the execution of the code, a series of flags have been created and will be activated to indicate the event which has generated the interruption (see chapters "Interruptions" and "Energy system").

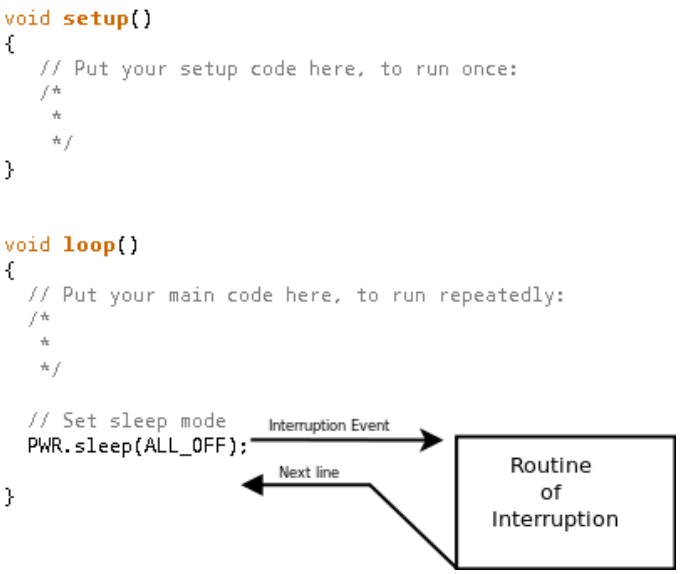


Figure: Blocking loop, interruption appears and is dealt with

When Waspmote is reset or switched on, the code starts again from the setup function and then the loop function.

By default, variable values declared in the code and modified in execution will be lost when a reset occurs or there is no battery. To store values permanently, it is necessary to use the microcontroller's **EEPROM (4 kB)** non-volatile memory. EEPROM addresses from 0 to 1023 are used by Waspmote to save important data, so they must not be over-written. Thus, the available storage addresses go from 1024 to 4095. Another option is to use of the high capacity **8 GB SD card**.

5.2. Timers

Waspmote uses a quartz oscillator which works at a frequency of **14.7456 MHz** as a system clock. In this way, every **125ns** the microcontroller runs a low level (machine language) instruction. It must be taken into account that each line of **C++** code of a program compiled by Waspmote includes several instructions in machine language.

Waspmote is a device prepared for operation in adverse conditions with regards to noise and electromagnetic contamination, for this reason, to ensure stable communication at all times with the different modules connected through a serial line to the UARTs (communication modules and USB) a maximum transmission speed of 115200 bps has been set for the communication modules and the USB port, and 4800 for the GPS, so that the success rate in received bits is 100%.

5.2.1. Watchdog

The ATmega1281 microcontroller has an internal Enhanced Watchdog Time – WDT. The WDT **precisely** counts the clock cycles generated by a **128 kHz oscillator**. The WDT generates an interruption signal when the counter reaches the set value. This interruption signal can be used to wake the microcontroller from the **Sleep** mode or to generate an internal alarm when it is running in on mode, which is very useful when developing programs with timed interruptions.

The WDT allows the microcontroller to wake up from a low consumption Sleep mode by generating an interruption. For this reason, this clock is used as a time-based alarm associated with the microcontroller's Sleep mode. This allows very precise control of small time intervals: **16 ms, 32 ms, 64 ms, 128 ms, 256 ms, 500 ms, 1 s, 2 s, 4 s, 8 s**. For intervals over 8 s (Deep Sleep mode), the RTC is used and not the microcontroller.

More information about the interruptions generated by the Watchdog can be found in the "Energy system" chapter.

Related API libraries: **WaspPWR.h**, **WaspPWR.cpp**

All information about their programming and operation can be found in the Interrupt Programming Guide.

All the documentation is located in the Development section in the Libelium website.

5.2.2. RTC Watchdog for reseting Waspmote

One of the alarms of the RTC (Alarm 2) is connected to a Watchdog reset circuit that is able to reset the microcontroller of Waspmote when the alarm is generated. This Watchdog has been implemented for reseting Waspmote if it gets stuck. That periodical reset avoids erratic behaviour. This is highly recommended for applications that need to be very robust and can never stop working. The use of the Watchdog feature enssures us that our Waspmote will never stop working.

The Watchdog feature requires the physical watchdog switch to be put in "enable" position.

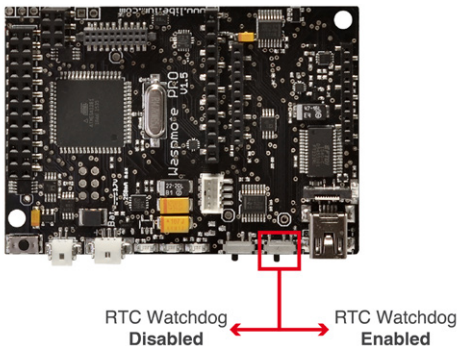


Figure: RTC Watchdog switch

Related API libraries: **WaspRTC.h, WaspRTC.cpp**

All information about the RTC programming and operation can be found in the RTC Programming Guide.

All the documentation is located in the Development section in the Libelium website.

5.2.3. RTC

As shown in the “Hardware” chapter, Waspmote has a real time clock (RTC) running a 32.786 kHz which allows to set an absolute time.

Alarms can be programmed in the RTC specifying day/hour/minute/second. This allows total control when the mote wakes up to capture values and perform actions programmed on it. Also, the RTC allows Waspmote to function in the maximum energy saving modes (**Deep Sleep** and **Hibernate**) and to wake up just at the required moment.

The RTC allows the microcontroller to be woken from a low consumption state by generating an interruption. For this reason, it has been associated to the microcontroller’s Deep Sleep and Hibernate modes, making it possible to put the microcontroller to sleep, and wake it up by activating an alarm in the RTC. Sleeping intervals can go from 1 s to minutes, hours or even days.

More information about the interruptions generated by the RTC and Deep Sleep and Hibernate modes can be found in the “Energy system” chapter.

Related API libraries: **WaspRTC.h, WaspRTC.cpp**

All information about the RTC programming and operation can be found in the RTC Programming Guide.

All the documentation is located in the Development section in the Libelium website.

6. Interruptions

Interruptions are signals received by the microcontroller which indicate it must stop the task it is doing to handle an event that has just happened. Interruption control frees the microcontroller from having to control sensors all the time. It also makes the sensors warn Waspmote when a determined value (threshold) is reached.

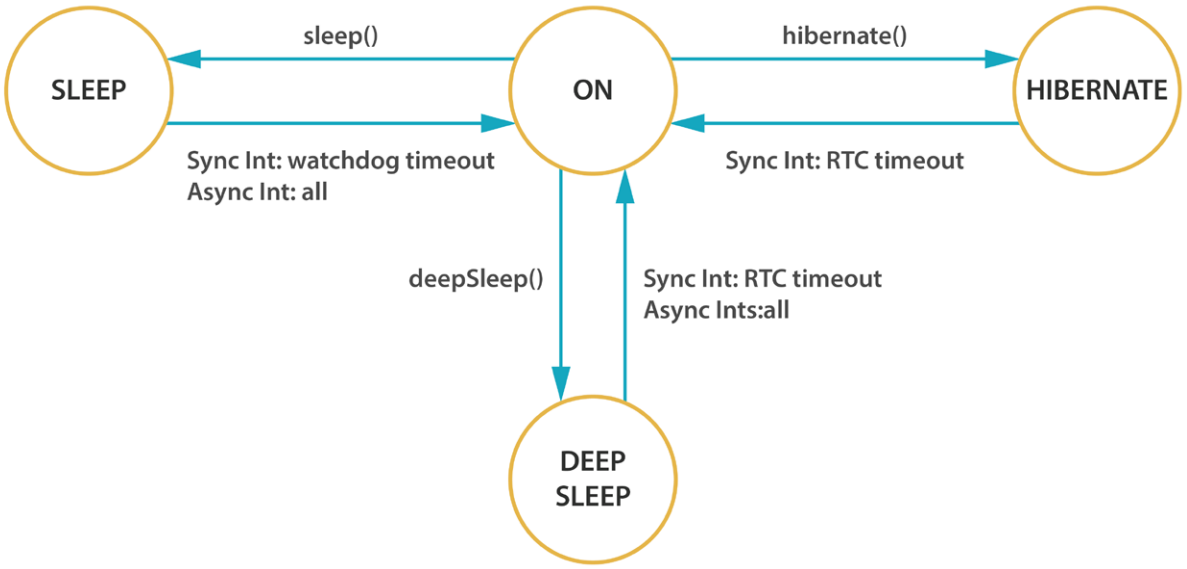


Figure: Diagram of mode in Waspmote

Waspmote is designed to work with 2 types of interruptions: Synchronous and asynchronous:

- **Synchronous interruptions:** They are scheduled by timers. They allow to program when we want them to be triggered. There are 2 types of timer alarms: periodic and relative.
  - **Periodic alarms** are those to which we specify a particular moment in the future, for example: "Alarm programmed for every 4th day of the month at 00:01 and 11 seconds". They are controlled by the RTC.
  - **Relative alarms** are programmed taking into account the current moment, eg: "Alarm programmed for 5 minutes and 10 seconds". They are controlled through the RTC and the microcontroller's internal Watchdog.
- **Asynchronous Interruptions:** These are not scheduled, so it is not known when they will be triggered. Types:
  - **Sensors:** The sensor boards can be programmed so that an alarm is triggered when a sensor reaches a certain threshold.
  - **Accelerometer:** Waspmote's accelerometer can be programmed so that certain events such (as a fall or change of direction) generate an interruption.

All interruptions, both synchronous and asynchronous can **wake** Waspmote up from the **Sleep** and the **Deep Sleep** modes. However, only the synchronous interruption by the RTC is able to wake it up from the **Hibernate** mode.

The **Hibernate** mode totally disconnects the Waspmote power, leaving only the battery powering the RTC to wake Waspmote up when the time alarm is reached. Because of this disconnection, when the RTC generates the corresponding alarm, the power in Waspmote is reconnected and the code starts again from the setup.

The way of detecting whether a reboot from the **Hibernate** mode has happened is to check whether the corresponding flag has been activated. The activation of this flag happens when the `ifHibernate()` function is called, which must be done at the beginning of the **setup** part of the code. This way, when Waspmote starts, it tests if it is a normal start or if it is a start from the **Hibernate** mode.

All information about the programming and operation of interruptions can be found in the Interruption Programming Guide.

7. Energy system

7.1. Concepts

Waspmote has 4 operational modes:

- **On:** Normal operation mode. Consumption in this state is **17 mA**.
- **Sleep:** The main program is paused, the microcontroller passes to a latent state, from which it can be woken up by all asynchronous interruptions and by the synchronous interruption generated by the Watchdog. The duration interval of this state is from **32 ms to 8 s**. Consumption in this state is **30 µA**.
- **Deep Sleep:** The main program pauses, the microcontroller passes to a latent state from which it can be woken up by all asynchronous interruptions and by the synchronous interruption triggered by the RTC. The interval of this cycle can be **from seconds to minutes, hours, days**. Consumption in this state is **33 µA**.
- **Hibernate:** The main program stops, the microcontroller and all the Waspmote modules are completely disconnected. The only way to reactivate the device is through the previously programmed alarm in the RTC (synchronous interrupt). The interval of this cycle can be **from seconds to minutes, hours, days**. Almost all devices are totally disconnected from the battery: only the RTC is powered through the battery, from which it consumes **7 µA**.

	Consumption	Microcontroller	Cycle	Accepted interruptions
On	17 mA	On	-	All interruption sources
Sleep	30 µA	On	Depends on INT source	All interruption sources
Deep Sleep	33 µA	On	1 s – 31 days	All interruption sources (RTC always used)
Hibernate	7 µA	Off	1 s – 31 days	Only RTC

On the other hand, each **module** (radio, sensor board, etc) might have up to several operation modes.

- **On:** Normal operation mode.
- **Sleep:** Some communication modules permit to set up sleep modes so as to save energy (depends on each module).
- **Off:** By using Waspmote's digital switches (controlled by the microcontroller), the module is switched off completely. This mode has been implemented by **Libelium** as an **independent layer of energy control**, so that it can reduce consumption to a minimum (**~7 µA**) without relegating to techniques implemented by the manufacturer.

For complete information about interruption types and their handling, see the "Interruption" chapter.

Related API libraries: **WaspPWR.h**, **WaspPWR.cpp**

All information about the programming and operation of interruptions can be found in the Interrupt Programming Guide.

All the documentation is located in the Development section in the Libelium website.

Note: *Before setting Waspmote to a low-power consumption mode, it is always recommended to switch any communication module off.*

7.2. Sleep mode

In this mode, the main program is paused, the microcontroller passes to a latent state, from which it can be woken by all asynchronous interruptions and by the synchronous interruption generated by the Watchdog. When the Watchdog Timer is set up, the duration interval can be programmed from **16 ms** to **8 s**. Consumption in this state is **30 µA**.

In this mode the microcontroller stops executing the main program. The program stack where all the variables and log values are stored keep their value, so when Waspmote returns to on mode, the next instruction is executed and the variable values are maintained.

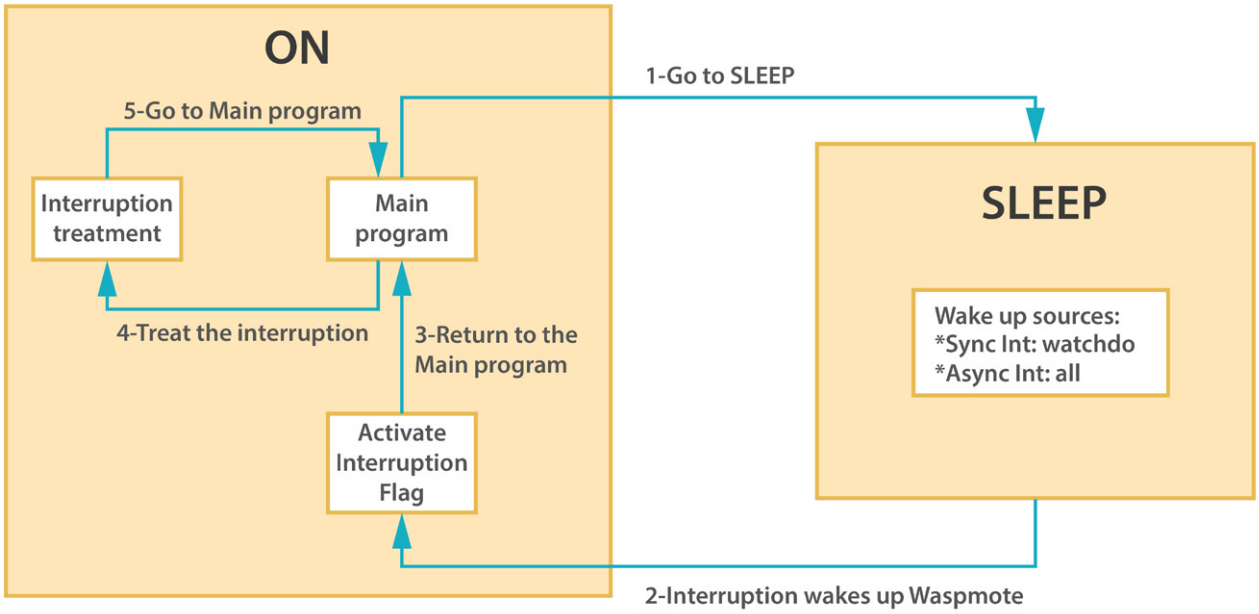


Figure: From on to Sleep mode

The following example would set Waspmote in the Sleep mode for 32 ms. The microcontroller would be in a state of minimum consumption waiting for the synchronous interruption from the Watchdog:

```
{
  PWR.sleep(WTD_32MS, ALL_OFF);
}
```

7.3. Deep Sleep mode

In this mode, the main program is paused, the microcontroller passes to a latent state from which it can be woken by all the asynchronous interruptions and by the synchronous interruption launched by the RTC. The interval of this cycle can go **from seconds to minutes, hours, days**. Consumption in this state is **33 µA**.

In this mode the microcontroller stops executing the main program. The program stack where all the variables and log values are stored keep their value, so when Waspmote returns to on mode, the next instruction is executed and the variable values are maintained.

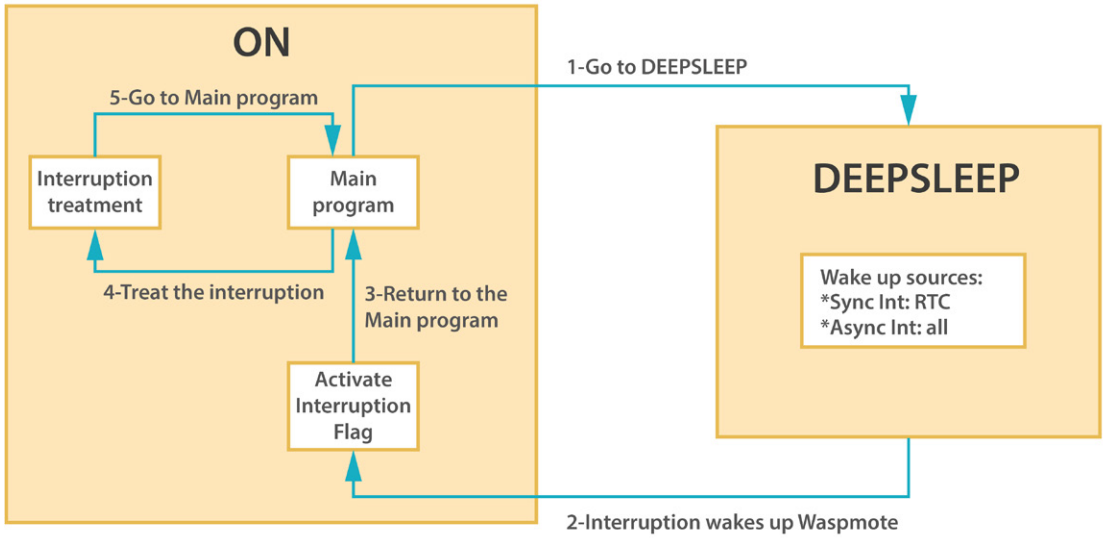


Figure: From on to Deep Sleep mode

7.4. Hibernate mode

In this mode, the main program stops, the microcontroller and all the modules are completely disconnected. The only way to reactivate the device is through the previously programmed alarm in the **RTC** (synchronous interrupt). The interval for this cycle can go **from seconds to minutes, hours or days**. Almost all devices are totally disconnected from the battery: only the RTC is powered through the battery, from which it consumes **7µA**.

In this mode the microcontroller does not store any values from variables or from the program stack. When leaving the Hibernate state the microcontroller is reset, so the **setup** and **loop** routines are run as if the main switch were activated.

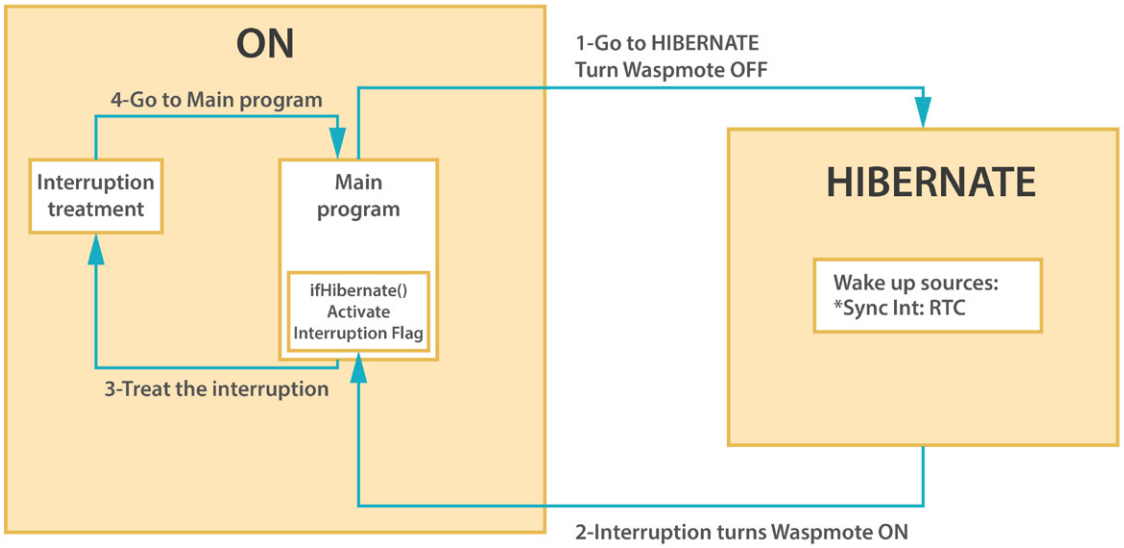


Figure: From on to Hibernate mode

The Hibernate mode requires the physical Waspmote's hibernate switch to be put in "enable" position. It is necessary to follow the next steps when executing the program for the first time after uploading it to Waspmote:

1. Connect the battery.
2. Switch Waspmote on.
3. Wait for the red LED to light on and turn the hibernate switch to the "enable" position while the red LED is on.
4. Once the hibernate switch is in the "enable" position, the green LED must blink to indicate that the program is running.

The following example would set Waspmote in the Hibernate mode for 2 days, 1 hour and 30 minutes. The microcontroller would be switched off waiting for the RTC to switch the device on again with a synchronous interruption.

```
{
  PWR.hibernate("02:01:30:00", RTC_OFFSET, RTC_ALM1_MODE2);
}
```

Related API libraries: **WaspPWR.h**, **WaspPWR.cpp**

All information about the programming and operation of sleep modes can be found in the Interruption Programming Guide.

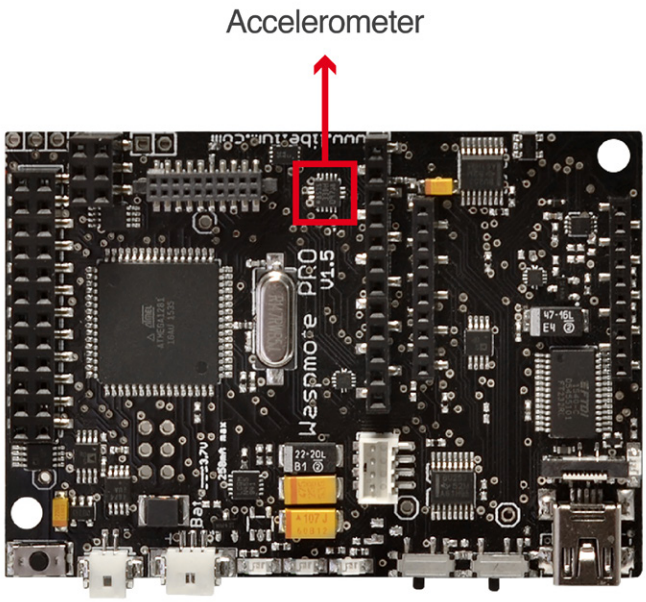
All the documentation is located in the Development section in the Libelium website.

8. Sensors

8.1. Accelerometer

Waspmote has a built-in acceleration sensor LIS3331LDH, by STMicroelectronics, which informs the mote of acceleration variations experienced on each one of the 3 axes (X,Y, Z).

The integration of this sensor allows the measurement of acceleration on the 3 axes (X, Y, Z), establishing 4 kinds of events: Free Fall, inertial wake up, 6D movement and 6D position which are explained in the **Interruption Programming Guide**.



The LIS331DLH has dynamically user-selectable full scales of **±2g/±4g/±8g** and it is capable of measuring accelerations with output data rates from **0.5 Hz to 1 kHz**.

The device features ultra low-power operational modes that allow advanced power saving and smart sleep to wake-up functions.

The accelerometer has several power modes, the output data rate (ODR) will depend on the power mode selected. The power modes and output data rates are shown in this table:

Power mode	Output data rate (Hz)
Power down	--
Normal mode	1000
Low-power 1	0.5
Low-power 2	1
Low-power 3	2
Low-power 4	5
Low-power 5	10

This accelerometer has an auto-test capability that allows the user to check the functioning of the sensor in the final application. Its operational temperature range is between -40 ºC and +85 ºC.

The accelerometer communicates with the microcontroller through the I2C interface. The pins that are used for this task are the SCL pin and the SDA pin, as well as another interruption pin to generate the interruptions.

The accelerometer has 4 types of event which can generate an interrupt: free fall, inertial wake up, 6D movement and 6D position.

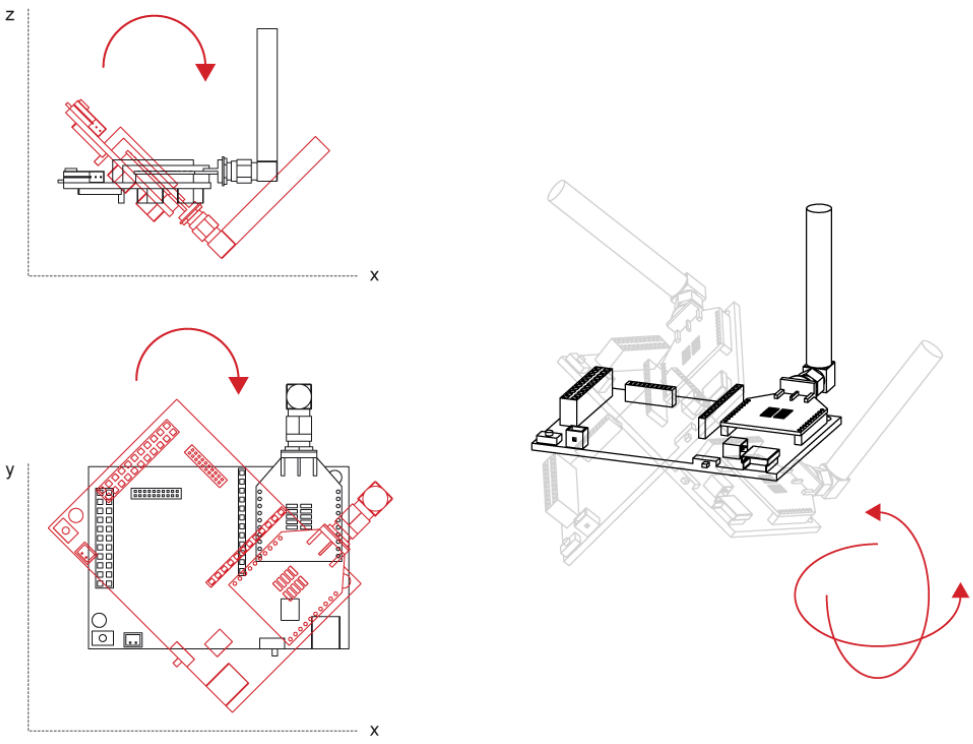
These thresholds and times are set in the WaspACC.h file.

To show the ease of programming, an extract of code about how to get the accelerometer values is included below:

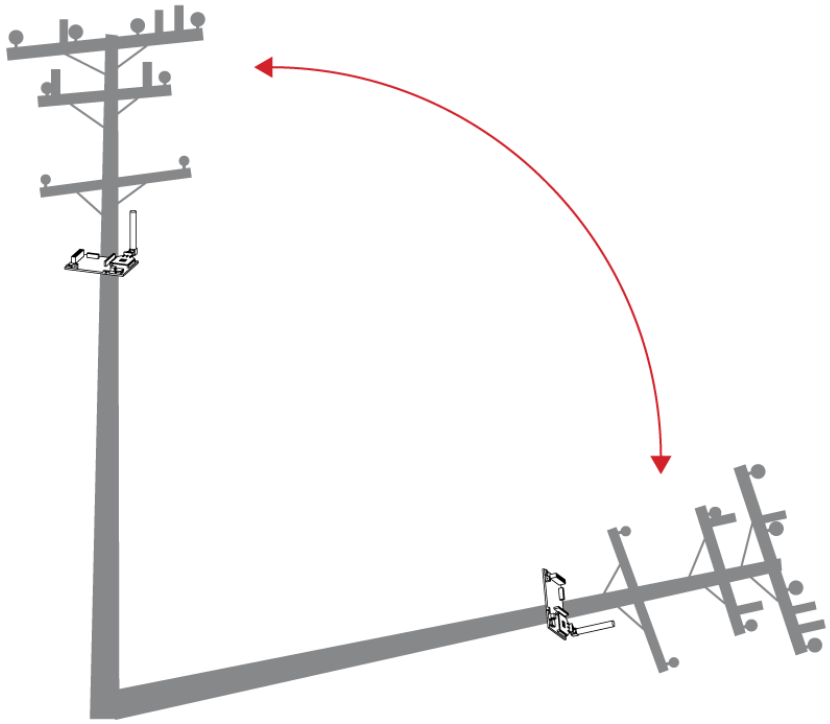
```
{
  ACC.ON();
  ACC.getX();
  ACC.getY();
  ACC.getZ();
}
```

Some figures with possible uses of the accelerometer are shown below:

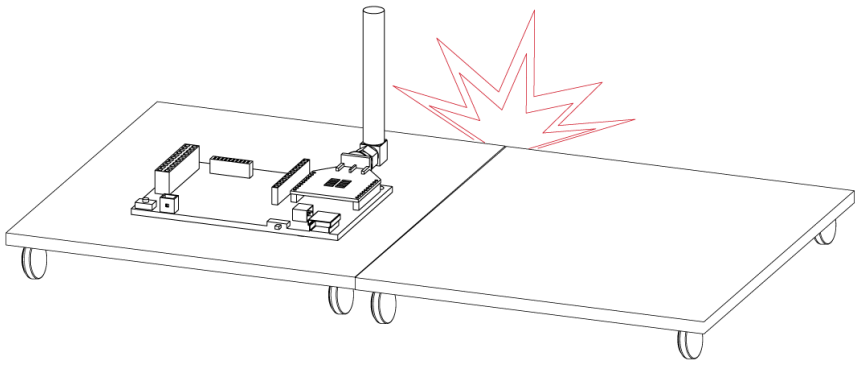
Rotation and twist:



Free fall of objects in which it is installed:



Crash:



More information about interruptions generated by the accelerometer can be found in the chapter “Interruptions” and in the **Interruption Programming Guide**.

Related API libraries: **WaspACC.h, WaspACC.cpp**

All information about their programming and operation can be found in the Accelerometer Programming Guide.

All the documentation is located in the Development section in the Libelium website.

8.2. Integration of new sensors

The Waspmote design is prepared for the integration of both **input (sensors)** and **output (actuators)** which allows to grow the wide range of existing Waspmote sensor boards. The new sensors can be connected to Waspmote's **2x12** and **1x12** pin connectors, which permit to use 16 input and output signals, 7 of which can be used as analog inputs and 1 as a **PWM** (Pulse Width Modulation) output signal. Besides, there is a line to ground, 3.3 V and 5 V power feeds, 2 selectable connections to the serial communication (UART) inputs and outputs, connection to the 2 lines of the (I2C) SCL and SDA Inter-Integrated Circuit bus, and connection to inputs for high level and low level interrupt. An image of the Waspmote output connectors can be seen in the "I/O" section.

The management the 2 power lines (3.3 and 5 V) for the sensor boards (described in more depth in section "Sensors" → Power) is carried out through 2 solid state switches which allow the continuous flow of a current of up to **200 mA** and whose control can be programmed using the functions included in the WaspPWR library, described in the files WaspPWR.h and **WaspPWR.cpp**.

The input and output voltage values for both digital and analog pins will be between 0 V and 3.3 V, logic zero (**'0'**) being found in values less than **0.5 V** and logic one (**'1'**) in values higher than **2.30 V**. To read analog signals, the microcontroller has a 10-bit analog-to-digital converter which allows a resolution of 3 mV. Waspmote also has one 8-bit resolution PWM output pin for the generation of analog signals. Information on the libraries and instructions used for reading and writing on these pins can be found in the API manual.

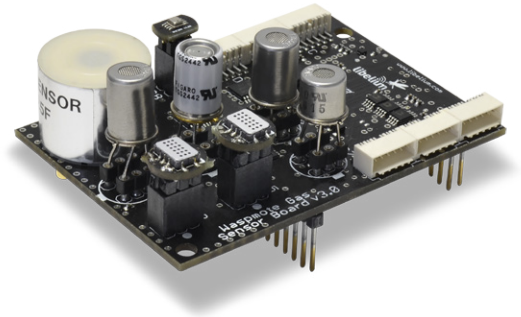
Waspmote includes 2 interruption pins, a low level (**TXD1**) one and a high level (**RXD1**) one, which offer an alternative to reading the sensors by survey, allowing the microcontroller to be woken up when an **event** occurs (such as exceeding a certain threshold in a comparator) which generates a change in a digital signal connected to one of the above pins, facilitating the sensor reading only at the moments when a remarkable event occurs.

This option is especially recommended for low consumption sensors that may remain active for long periods of time. Reading by survey (switched on and cyclical sensor reading after a set time) is more appropriate for those that, in addition to showing greater consumption, do not require monitoring that generates an alarm signal. The interruptions can be managed using the warning functions and vectors (flags) defined in the Winterruptions library, file Winterruptions.c. More can be learnt about their use in the **Interruption Programming Guide**.

Sensors reading can generate 3 types of response: storage of collected data (on the SD card), wireless transmission of data (via wireless module) or automatic activation through an actuator directly controlled by the microcontroller's output signals or through a switch or relay.

8.3. Sensor boards

The integration of sensors requiring some type of electronic adaptation stage or signal processing prior to reading by the microcontroller is carried out by the various microcontroller sensor boards. Connection between these and the mote takes place pin to pin using the two 2x12 and 1x12 connectors mentioned in the section “Hardware” → I/O. Currently, Waspmote has the following integration sensor boards:

GASES	APPLICATIONS	SENSORS
	• **City pollution** CO, CO_2, NO_2, O_3 • **Emissions from farms and hatcheries** CH_4, H_2S, NH_3 • **Control of chemical and industrial processeS** C_4H_{10} ,H_2, VOC • **Forest fires** CO, CO_2	• Carbon Monoxide – CO • Carbon Dioxide – CO_2 • Oxygen – O_2 • Methane – CH_4 • Hydrogen – H_2 • Ammonia – NH_3 • Isobutane – C_4H_{10} • Ethanol – CH_3CH_2OH • Toluene – $C_6H_5CH_3$ • Hydrogen Sulfide – H_2S • Nitrogen Dioxide – NO_2 • Ozone – O_3 • Hydrocarbons – VOC • Temperature, Humidity and Pressure • Luminosity (Luxes) • Ultrasound (distance measurement)

Note: *Calibrated sensors are available for more accurate measurement.*

GASES PRO v3*

(*) Calibrated gas sensors are manufactured once the order has been placed to ensure maximum durability of the calibration feature. Manufacturing process and delivery may take from 4 to 6 weeks. Lifetime of calibrated gas sensors is 6 months working at its maximum accuracy. We strongly encourage our customers to buy extra gas sensor probes to replace the originals after that time to ensure maximum accuracy and performance.

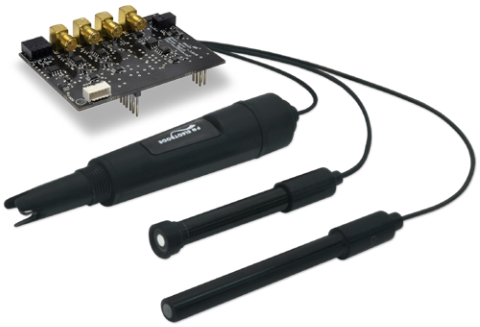
APPLICATIONS

- **City pollution**
  CO, NO, NO_2, O_3, SO_2, Particle Matter - Dust
- **Air Quality Index calculation**
  SO_2, NO_2, Particle Matter - Dust, CO, O_3, NH_3
- **Emissions from farms and hatcheries**
  CH_4, H_2S, NH_3
- **Greenhouse management**
  CO_2, CH_4, Humidity
- **Control of chemical and industrial processes**
  H_2, HCl, CH_4, SO_2, CO_2
- **Indoor air quality**
  CO_2, CO, Particle Matter - Dust, O_3
- **Forest fires**
  CO, CO_2

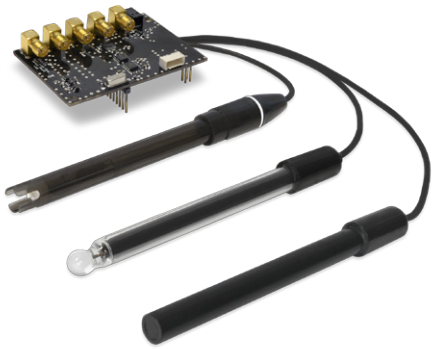
SENSORS

- Carbon Monoxide – CO
- Carbon Dioxide – CO_2
- Molecular Oxygen – O_2
- Ozone – O_3
- Nitric Oxide – NO
- Nitric Dioxide – NO_2
- Sulfur Dioxide – SO_2
- Ammonia – NH_3
- Methane – CH_4 – and other combustible gases
- Molecular Hydrogen – H_2
- Hydrogen Sulfide – H_2S
- Hydrogen Chloride – HCl
- Hydrogen Cyanide - HCN
- Phosphine – PH_3
- Ethylene Oxide – ETO
- Chlorine – Cl_2
- Particle Matter (PM1 / PM2.5 / PM10) – Dust Sensor [only for Plug & Sense!]
- Temperature, Humidity and Pressure

EVENTS v3	APPLICATIONS	SENSORS
	• **Security** Hall effect (doors and windows), person detection PIR • **Emergencies** Presence detection and water level sensors, temperature • **Control of goods in logistics**	• Pressure/Weight • Hall Effect • Temperature, Humidity and Pressure • Liquid Presence • Liquid Level • Liquid flow • Luminosity (Luxes) • Presence (PIR) • Ultrasound (distance measurement)

SMART WATER v3	APPLICATIONS	SENSORS
	• **Potable water monitoring** pH, ORP, Dissolved Oxygen (DO), Nitrates, Phosphates • **Chemical leakage detection in rivers** Extreme pH values signal chemical spills, Dissolved Oxygen (DO) • **Swimming pool remote measurement** pH, Oxidation-Reduction Potential (ORP) • **Pollution levels in the sea** Temperature, Conductivity (Salinity), pH, Dissolved Oxygen (DO) and Nitrates	• pH • Oxidation-Reduction Potential (ORP) • Dissolved Oxygen (DO) • Conductivity • Temperature • Turbidity

SMART WATER IONS



APPLICATIONS

- **Drinking water quality control**
  Calcium (Ca^{2+}), Iodide (I^-), Chloride (Cl^-), Nitrate (NO_3^-), Magnesium (Mg^{2+}), Sodium (Na^+), pH
- **Agriculture water monitoring**
  Calcium (Ca^{2+}), Nitrate (NO_3^-), Magnesium (Mg^{2+}), Sodium (Na^+), Potassium (K^+), Ammonium (NH_4^+), pH
- **Swimming pools**
  Bromide (Br^-), Chloride (Cl^-), Fluoride (F^-), pH
- **Waste water treatment**
  Cupric (Cu^{2+}), Silver (Ag^+), Fluoroborate (BF_4^-), Lithium (Li^+), Nitrite (NO_2^-), Perchlorate (ClO_4^-), pH

SENSORS

- Ammonium (NH_4^+)
- Bromide (Br^-)
- Calcium (Ca^{2+})
- Chloride (Cl^-)
- Cupric (Cu^{2+})
- Fluoride (F^-)
- Iodide (I-)
- Fluoroborate (BF_4^-)
- Lithium (Li^+)
- Nitrate (NO_3^-)
- Nitrite (NO_2^-)
- Magnesium (Mg^{2+})
- Perchlorate (ClO_4^-)
- Potassium (K^+)
- Silver (Ag^+)
- Sodium (Na^+)
- pH
- Temperature

SMART CITIES PRO*

(*) Calibrated gas sensors are manufactured once the order has been placed to ensure maximum durability of the calibration feature. Manufacturing process and delivery may take from 4 to 6 weeks. Lifetime of calibrated gas sensors is 6 months working at its maximum accuracy. We strongly encourage our customers to buy extra gas sensor probes to replace the originals after that time to ensure maximum accuracy and performance.

APPLICATIONS

- **Noise maps**
  Monitor in real time the acoustic levels in the streets of a city
- **Air quality**
  Detect the level of gases and particulates in the air
- **Waste management**
  Measure the garbage levels in bins to optimize the trash collection routes

SENSORS

- Carbon Monoxide – CO
- Carbon Dioxide – CO_2
- Molecular Oxygen – O_2
- Ozone – O_3
- Nitric Oxide – NO
- Nitric Dioxide – NO_2
- Sulfur Dioxide – SO_2
- Ammonia – NH_3
- Methane – CH_4 – and other combustible gases
- Molecular Hydrogen – H_2
- Hydrogen Sulfide – H_2S
- Hydrogen Chloride – HCl
- Hydrogen Cyanide - HCN
- Phosphine – PH_3
- Ethylene Oxide – ETO
- Chlorine – Cl_2
- Particle Matter (PM1 / PM2.5 / PM10) – Dust Sensor [only for Plug & Sense!]
- Temperature, Humidity and Pressure
- Noise level (dBA) [only for Plug & Sense!]
- Ultrasound (distance measurement)
- Luminosity (Luxes)

SMART PARKING

Figure: Plug & Sense! Smart Parking node

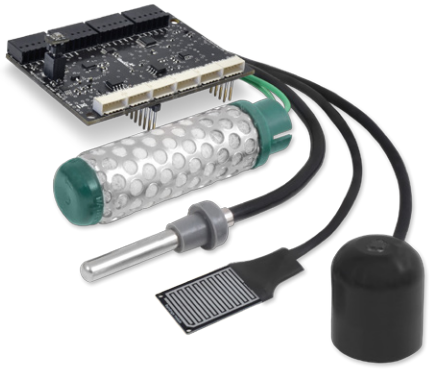
APPLICATIONS

- Car detection for available parking information
- Detection of free parking lots outdoors
- Parallel and perpendicular parking lots control
- Sigfox and LoRaWAN connectivity (EU and US)
- Extreme battery life
- Surface-mount enclosure, fast installation
- Easy configuration, remote management from the cloud

SENSORS

- Magnetic field
- Temperature

AGRICULTURE v30



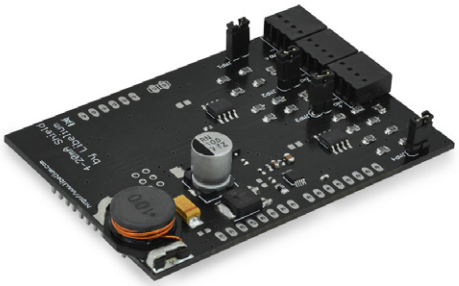
APPLICATIONS

- **Precision Agriculture**
  Leaf temperature, fruit diameter
- **Irrigation Systems**
  Soil moisture, leaf wetness
- **Greenhouses**
  Solar radiation, humidity, temperature
- **Weather Stations**
  Anemometer, wind vane, pluviometer

SENSORS

- Air Temperature, Humidity and Pressure
- Soil Temperature / Moisture
- Leaf Wetness
- Atmospheric Pressure
- Solar Radiation - PAR
- Ultraviolet Radiation - UV
- Trunk Diameter
- Stem Diameter
- Fruit Diameter
- Anemometer
- Wind Vane
- Pluviometer
- Luminosity (Luxes)
- Ultrasound (distance measurement)

4-20 mA CURRENT LOOP



APPLICATIONS

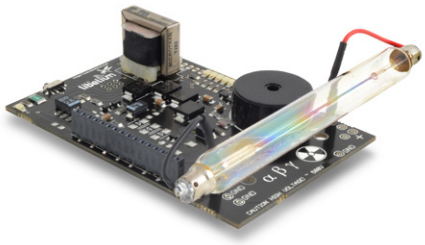
- Sensors and instruments
- Remote transducers
- Monitoring processes
- Data transmission in industrial ambients

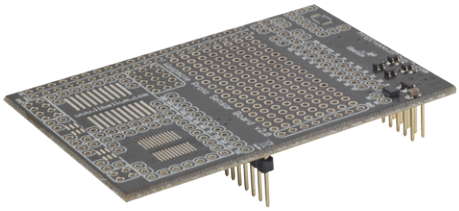
FEATURES

- Type: Analog
- Media: Twisted Pair
- No. of devices: 4
- Distance: 900m
- Supply: 12 V

The user can choose among a wide variety of standard sensors

VIDEO CAMERA	APPLICATIONS	SENSORS
	• Security and surveillance • Take photos (640 x 380) • Record video (320 x 240) • Realtime Videocall using 3G network • Night Vision mode available	• Image sensor • Luminosity • Infrared • Presence (PIR)

RADIATION	APPLICATIONS	SENSORS
	• Monitor the radiation levels wirelessly without compromising the life of the security forces • Create prevention and control radiation networks in the surroundings of a nuclear plant • Measure the amount of Beta and Gamma radiation in specific areas autonomously	• Geiger tube [β, γ] (Beta and Gamma)

PROTOTYPING SENSOR	APPLICATIONS	
	• Prepared for the **integration of any kind of sensor**.	• Pad Area • Integrated Circuit Area • Analog-to-Digital Converter (16b)

It is possible to find more detailed information in the manual for each board at:

http://www.libelium.com/development/waspmote/documentation

8.4. Power

In the sensor connector there are also several power pins, specifically GND, 3.3 V and 5 V.

- **3V3 SENSOR POWER**: 3.3 V power voltage (200 mA maximum) which is controlled from the Waspmote execution code.
- **5V SENSOR POWER**: 5 V power voltage (200 mA maximum) which is controlled from the Waspmote execution code.

9. 802.15.4/ZigBee/RF modules

Waspmote integrates the Digi's XBee modules for communication in **the ISM** (Industrial Scientific Medical) bands.

These modules communicate with the microcontroller using the UART0 or UART1 at 115200 bps.

There are several possible XBee modules distributed by Libelium for integration in Waspmote.

Radio version	Frequency	Transmission power	Sensitivity	Range*
XBee-PRO 802.15.4 EU	2.4 GHz	10 dBm	-100 dBm	750 m
XBee-PRO 802.15.4	2.4 GHz	18 dBm	-100 dBm	1600 m
XBee-PRO DigiMesh	2.4 GHz	18 dBm	-100 dBm	1500 m
XBee-PRO ZigBee	2.4 GHz	17 dBm	-102 dBm	3200 m
XBee 868LP	863 - 870 MHz	14 dBm	-106 dBm	8.4 km
XBee 900HP US	902 - 928 MHz	24 dBm	-110 dBm	15.5 km
XBee 900HP BR	902 - 906.8 MHz 915.6 - 928 MHz	24 dBm	-110 dBm	15.5 km
XBee 900HP AU	915.6 - 928 MHz	24 dBm	-110 dBm	15.5 km

** To determine your range, perform a range test under your operating conditions*

9.1. XBee-PRO 802.15.4

Radio version	Frequency	Transmission power	Sensitivity	Range*
XBee-PRO 802.15.4 EU	2.4 GHz	10 dBm	-100 dBm	750 m
XBee-PRO 802.15.4		18 dBm		1600 m

** To determine your range, perform a range test under your operating conditions*

Figure: XBee-PRO 802.15.4

The frequency used is the free band of 2.4 GHz, using 12 channels with a bandwidth of 5 MHz per channel.

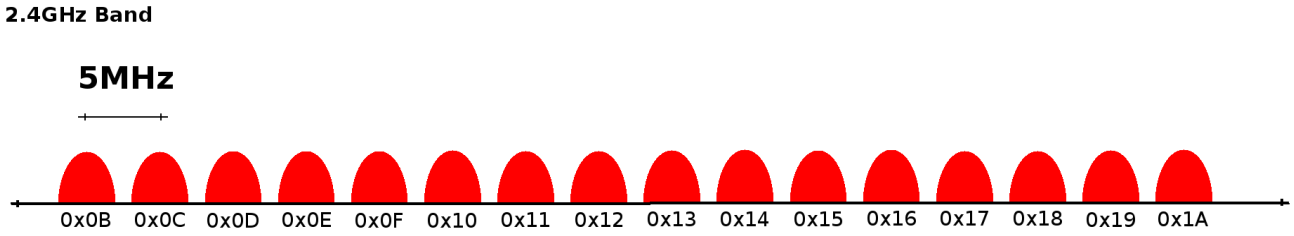


Figure: Frequency channels in the 2.4 GHz band

Channel Number	Frequency
0x0C – Channel 12	2.405 – 2.410 GHz
0x0D – Channel 13	2.410 – 2.415 GHz
0x0E – Channel 14	2.415 – 2.420 GHz
0x0F – Channel 15	2.420 – 2.425 GHz
0x10 – Channel 16	2.425 – 2.430 GHz
0x11 – Channel 17	2.430 – 2.435 GHz
0x12 – Channel 18	2.435 – 2.440 GHz
0x13 – Channel 19	2.440 – 2.445 GHz
0x14 – Channel 20	2.445 – 2.450 GHz
0x15 – Channel 21	2.450 – 2.455 GHz
0x16 – Channel 22	2.455 – 2.460 GHz
0x17 – Channel 23	2.460 – 2.465 GHz

Figure: Channels used by the XBee modules in 2.4GHz

The XBee-PRO 802.15.4 modules comply with the standard **IEEE 802.15.4** which defines the physical level and the link level (MAC layer). The XBee modules add certain functionalities to those contributed by the standard, such as:

- **Node discovery:** certain information has been added to the packet headers so that they can discover other nodes on the same network. It allows a node discovery message to be sent, so that the rest of the network nodes respond indicating their data (Node Identifier, @MAC, @16 bits, RSSI).
- **Duplicated packet detection:** This functionality is not set out in the standard and is added by the XBee modules.

The classic topology of this type of network is a star topology, as the nodes establish point to point connections with brother nodes through the use of parameters such as the MAC or network address.

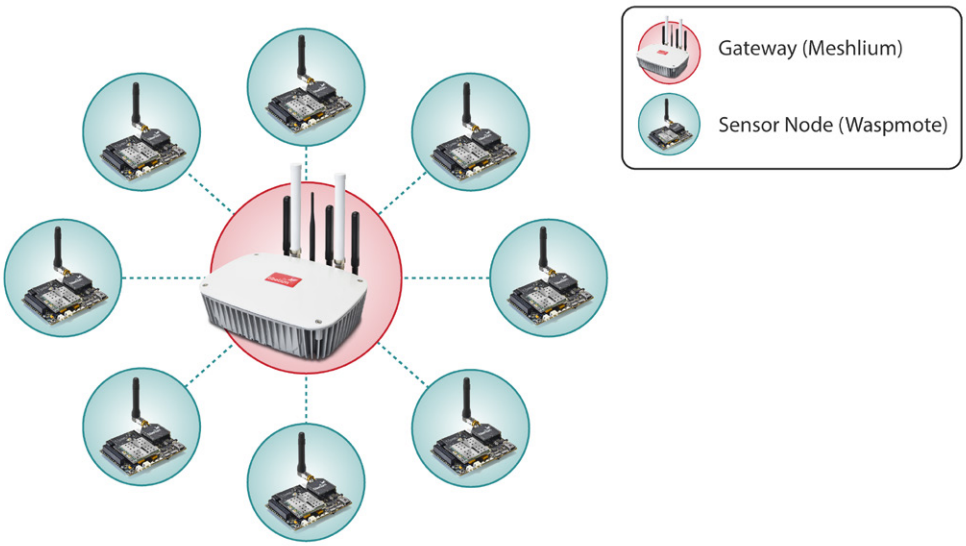


Figure: Star topology

Regarding the transmission power, it can be adjusted to several values depending on the radio version:

Parameter	XBee-PRO 802.15.4	XBee-PRO 802.15.4 EU
0	10 dBm	-3 dBm
1	12 dBm	-3 dBm
2	14 dBm	2 dBm
3	16 dBm	8 dBm
4	18 dBm	10 dBm

Figure: Transmission power values

Related API libraries: **WaspXBeeCore.h, WaspXBeeCore.cpp, WaspXBee802.h, WaspXBee802.cpp**

All information about their programming and operation can be found in the 802.15.4 Networking Guide.

All the documentation is located in the Development section in the Libelium website.

9.2. XBee-PRO ZigBee

Radio version	Frequency	Transmission power	Sensitivity	Range*
XBee-PRO ZigBee	2.4 GHz	17 dBm	-102 dBm	3200 m

** To determine your range, perform a range test under your operating conditions*

Figure: XBee-PRO ZigBee

As the ZigBee standard is supported in the IEEE 802.15.5 link layer, it uses the same channels as described in the previous section, with the peculiarity that the XBee-PRO ZigBee model limits the number of channels to 13.

The XBee-PRO ZigBee modules comply with the **ZigBee-PRO v2007** standard. These modules add certain functionalities to those contributed by ZigBee, such as:

- **Node discovery:** some headings are added so that other nodes within the same network can be discovered. It allows a node discovery message to be sent, so that the rest of the network nodes respond indicating their specific information (Node Identifier, @MAC, @16 bits, RSSI).
- **Duplicated packet detection:** This functionality is not set out in the standard and is added by the XBee modules.

The topologies in which these modules can be used are: star and tree.

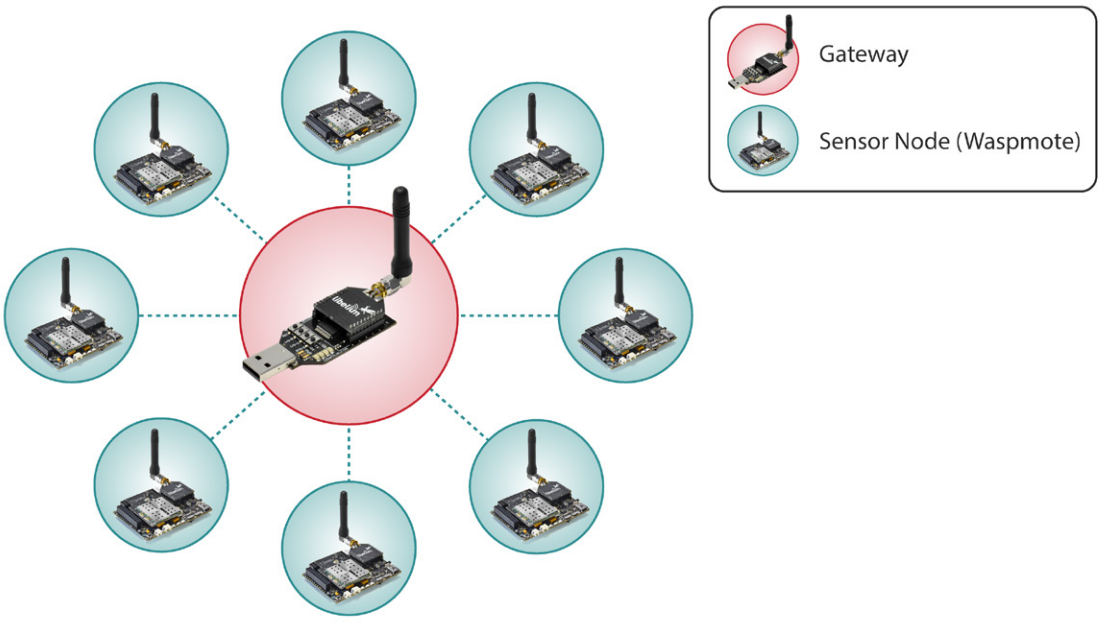


Figure: Star topology

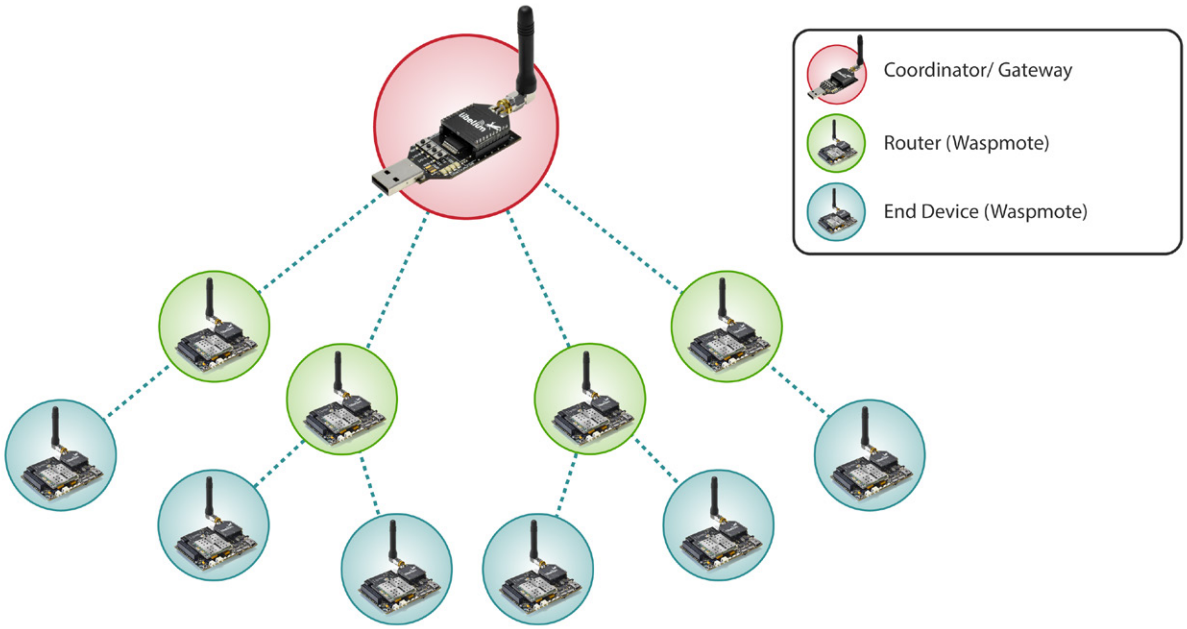


Figure: Tree topology

Regarding the transmission power, it cannot be adjusted because it is always set to 17 dBm.

Related API libraries: **WaspXBeeCore.h, WaspXBeeCore.cpp, WaspXBeeZB.h, WaspXBeeZB.cpp**
All information about their programming and operation can be found in the ZigBee Networking Guide.
All the documentation is located in the Development section in the Libelium website.

9.3. XBee 868LP

Radio version	Frequency	Transmission power	Sensitivity	Range*
XBee 868LP	863 - 870 MHz	14 dBm	-106 dBm	8.4 km

** To determine your range, perform a range test under your operating conditions*

Figure: XBee 868LP

***Note:** The XBee 868 MHz module is provided with 4.5dBi antenna, which enables maximum range.*

The frequency used is the 868 MHz band, using 30 software selectable channels. Channels are spaced 100 kHz apart. The transmission rate is 10 kbps.

The classic **topology** for this type of network is a star topology, as the nodes can establish point-to-point connections with brother nodes through the use of the MAC address.

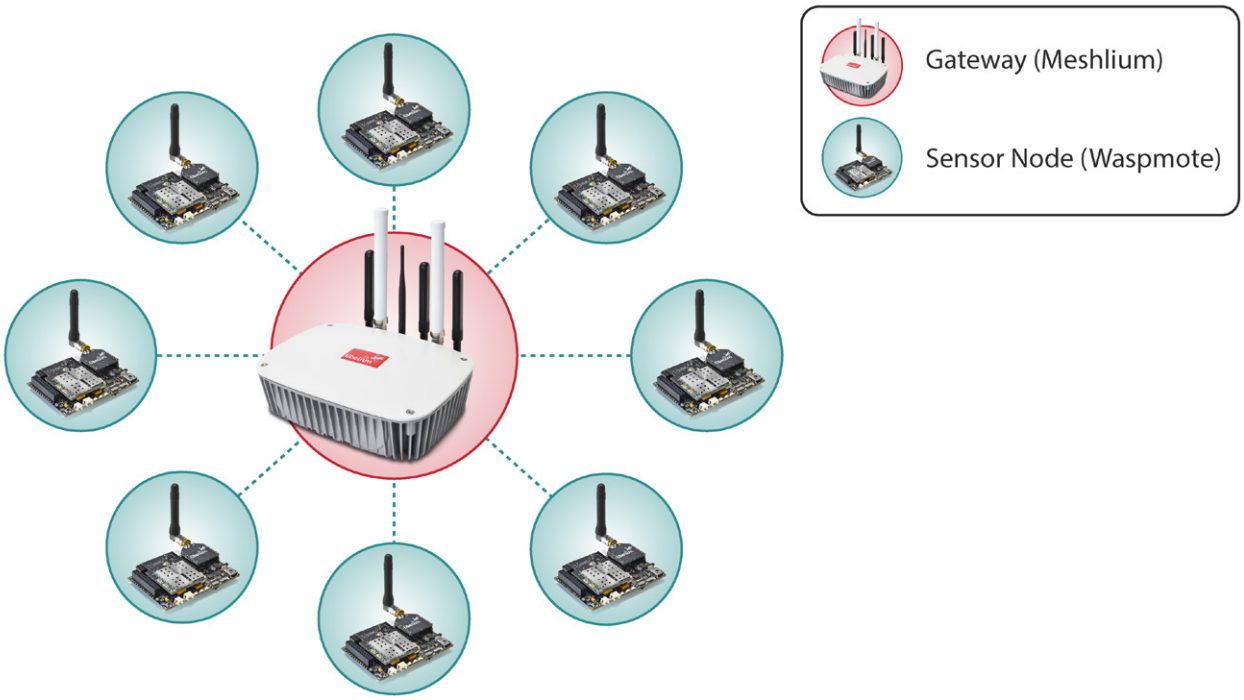


Figure: Star topology

Regarding the transmission power, it can be adjusted to several values:

Parameter	XBee 868LP
0	3 dBm
1	7 dBm
2	10 dBm
3	12 dBm
4	14 dBm

Figure: Transmission power values

Related API libraries: **WaspXBeeCore.h, WaspXBeeCore.cpp, WaspXBee868LP.h, WaspXBee868LP.cpp**

All information about their programming and operation can be found in the 868 Networking Guide.

All the documentation is located in the Development section in the Libelium website.

9.4. XBee-PRO 900HP

Radio version	Frequency	Transmission power	Sensitivity	Range*
XBee-PRO 900HP US	902 - 928 MHz	24 dBm	-110 dBm	15.5 km
XBee-PRO 900HP BR	902 - 906.8 MHz 915.6 - 928 MHz			
XBee-PRO 900HP AU	915.6 - 928 MHz			

** To determine your range, perform a range test under your operating conditions*

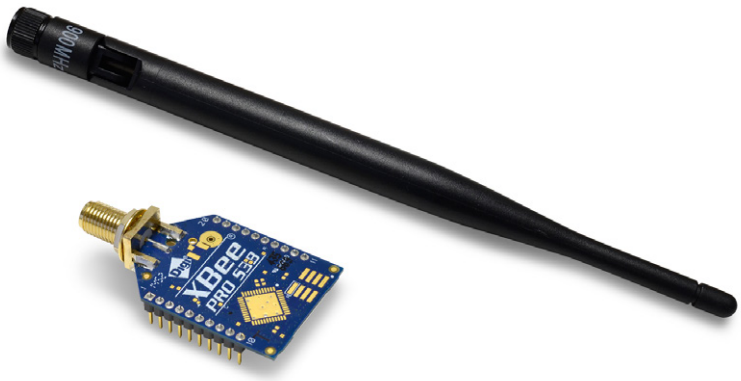


Figure: XBee-PRO 900HP

The frequency used is the 900 MHz band, using 64 software selectable channels. Channels are spaced 400 kHz apart. The transmission rate is 10 kbps. There are different versions of the XBee 900HP: USA & Canada, Brazil and Australia.

The different versions differ mainly in the available channels, which are hard-coded in the XBee. Be aware that it is not possible to change from one version to other with just a firmware change. **According to the country where the user is located, a different version must be chosen.**

The classic topology for this type of network is a star topology, as the nodes can establish point-to-point connections with brother nodes through the use of parameters such as the MAC address or that of the network.

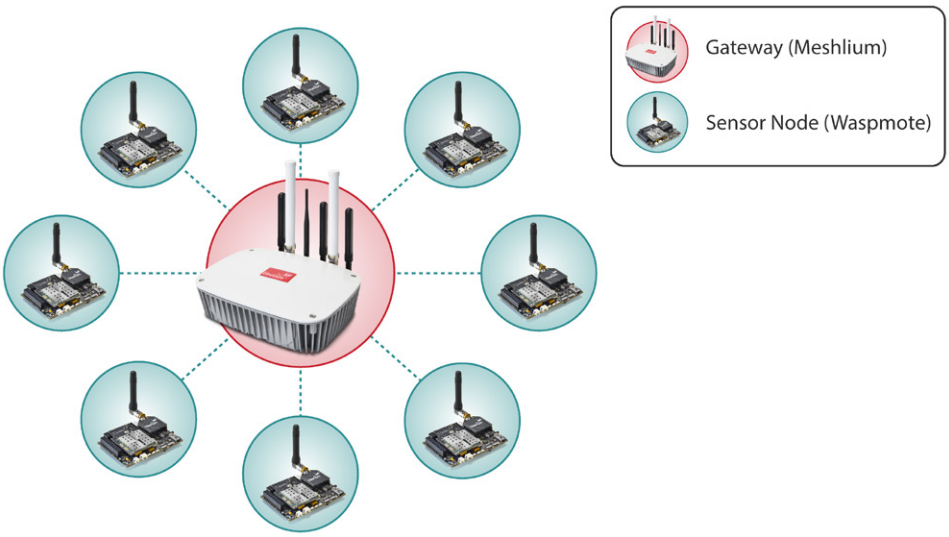


Figure: Star topology

API libraries: **WaspXBeeCore.h, WaspXBeeCore.cpp, WaspXBee900HP.h, WaspXBee900HP.cpp**
All information about their programming and operation can be found in the 900 Networking Guide.
All the documentation is located in the Development section in the Libelium website.

9.5. XBee-PRO DigiMesh

Radio version	Frequency	Transmission power	Sensitivity	Range*
XBee-PRO DigiMesh	2.4 GHz	18 dBm	-100 dBm	1500 m

** To determine your range, perform a range test under your operating conditions*

The XBee-PRO 802.15.4 modules can use an optional firmware called **DigiMesh**. So the modules can create **mesh networks** instead of the usual point-to-point topology. This firmware has been developed by Digi in order to allow the modules to sleep, synchronize themselves and work on equal terms, avoiding the use of node routers or coordinators that have to be permanently powered on. Characteristics of the implemented protocol:

- **Self healing:** any node can join or leave the network at any moment.
- **All nodes are equal:** there are no father-son relationships.
- **Silent protocol:** reduced routing heading due to using a reactive protocol similar to AODV (Ad hoc On-Demand Vector Routing).
- **Route discovery:** instead of keeping a route map, routes are discovered when they are needed.
- **Selective ACKs:** only the recipient responds to route messages.
- **Reliability:** the use of ACKs ensures data transmission reliability.
- **Sleep modes:** low energy consumption modes with synchronization to wake at the same time.

The classic topology of this type of network is mesh, as the nodes can establish point-to-point connections with brother nodes through the use the MAC address doing **multi-hop connections** when it is necessary.

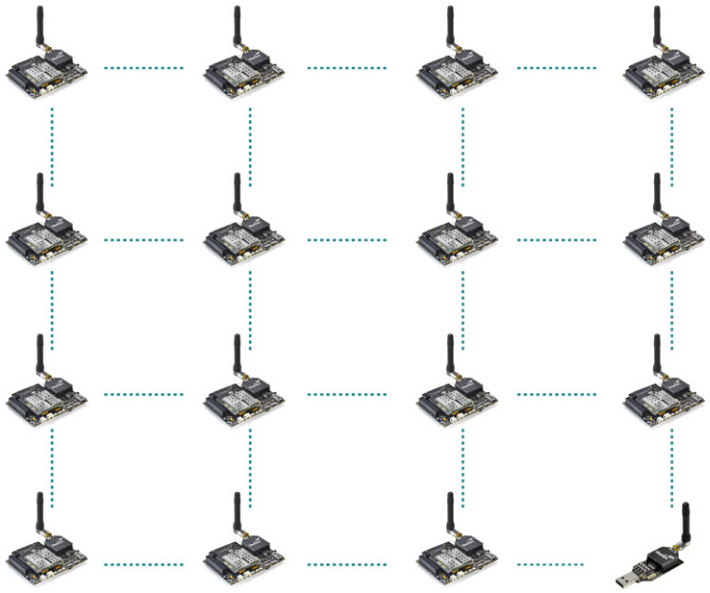


Figure: Mesh topology

The XBee DigiMesh modules share the hardware module with the XBee-PRO 802.15.4. So it is possible to change the firmware of this kind of modules from one to another and vice versa (this can be done with a Gateway). For this reason, the characteristics related to the hardware are the same.

The XBee DigiMesh modules are based on the standard **IEEE 802.15.4** that supports functionalities enabling mesh topology use.

Related API libraries: **WaspXBeeCore.h, WaspXBeeCore.cpp, WaspXBeeDM.h, WaspXBeeDM.cpp**
All information about their programming and operation can be found in the DigiMesh Networking Guide.
All the documentation is located in the Development section in the Libelium website.

10. LoRaWAN modules

LoRaWAN is a Low Power Wide Area Network (LPWAN) specification intended for wireless battery-operated devices in regional, national or global network. LoRaWAN target key requirements of Internet of things such as secure bi-directional communication, mobility and localization services. This standard will provide seamless interoperability among smart Things without the need of complex local installations and gives back the freedom to the user, developer, businesses enabling the role out of Internet of Things.

LoRaWAN network architecture is typically laid out in a star-of-stars topology in which gateways is a transparent bridge relaying messages between end-devices and a central network server in the back-end. Gateways are connected to the network server via standard IP connections while end-devices use single-hop wireless communication to one or many gateways.

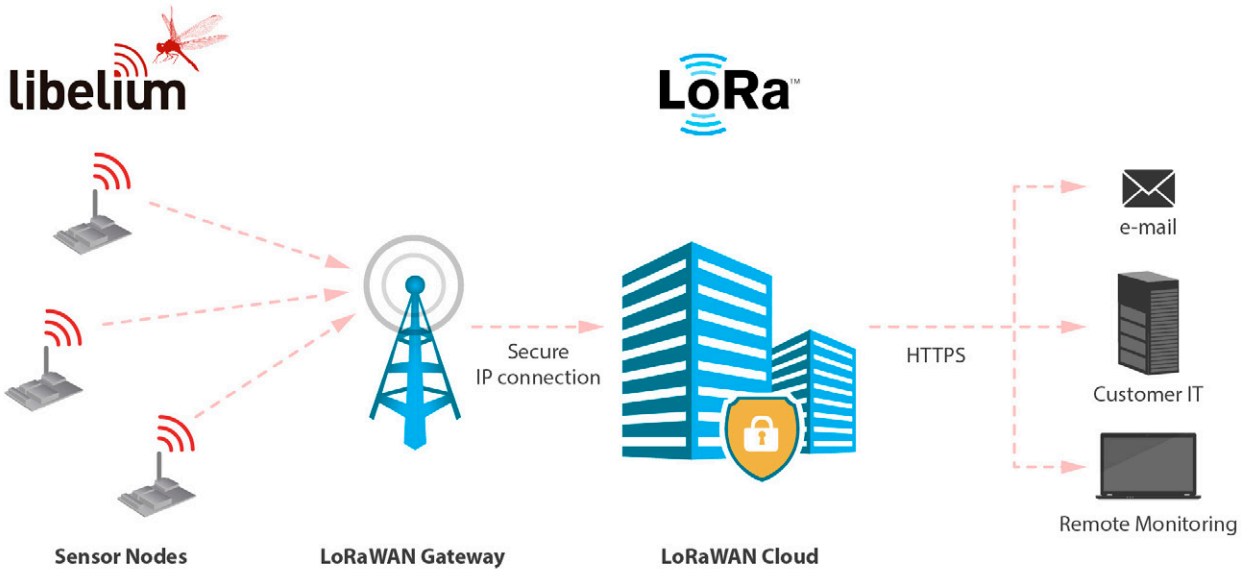


Figure: LoRaWAN network

Communication between end-devices and gateways is spread out on different frequency channels and data rates. The selection of the data rate is a trade-off between communication range and message duration. Due to the spread spectrum technology, communications with different data rates do not interfere with each other and create a set of “virtual” channels increasing the capacity of the gateway. To maximize both battery life of the end-devices and overall network capacity, the LoRaWAN network server is managing the data rate and RF output for each end-device individually by means of an adaptive data rate (ADR) scheme.

National wide networks targeting Internet of Things such as critical infrastructure, confidential personal data or critical functions for the society has a special need for secure communication. This has been solved by several layer of encryption.

Protocol: LoRaWAN 1.0, Class A
LoRaWAN-ready
Frequency:

- LoRaWAN 868/433 modules (EU): 868 MHz and 433 MHz ISM bands
- LoRaWAN 900 module (US): 900-930 MHz ISM band

TX power:

- LoRaWAN 868/433 modules (EU): up to 14 dBm
- LoRaWAN 900 module (US): up to 18.5 dBm

Sensitivity: down to -136 dBm
Range: >15 km at suburban and >5 km at urban area. Typically, each base station covers some km. Check the LoRaWAN Network in your area.
Chipset consumption:

- LoRaWAN 868/433 modules (EU): 38.9 mA
- LoRaWAN 900 module (US): 124.4 mA

Radio data rate:

- LoRaWAN 868/433 modules (EU): from 250 to 5470 bps
- LoRaWAN 900 module (US): from 250 to 12500 bps

Receiver: purchase your own base station or use networks from LoRaWAN operators

Figure: LoRaWAN EU module

Related API libraries: **WaspLoRaWAN.h, WaspLoRaWAN.cpp**
All the information about their programming and operation can be found in the LoRaWAN Networking Guide available at Development section of Libelium website.

11. LoRa module

- **Protocol:** LoRa “raw”. P2P links (node to node).
- **Model:** Semtech SX1272
- **Frequencies available:** 860-1000 MHz, fits both 868 (Europe) and 900 MHz (USA) ISM bands
- **Max TX power:** 14 dBm
- **Sensitivity:** -137 dBm
- **Range:**
  - Line of Sight: 21+ km / 13.4+ miles (LoS and Fresnel zone clearance)
  - Non Line of Sight: 2+ km / 1.2+ miles (nLoS going through buildings, urban environment)
- **Antenna:**
  - 868 / 900 MHz: 4.5 dBi
  - Connector: RPSMA
- **Encryption:** AES 128/192/256b (performed by Waspmote API)
- **Control Signal:** RSSI
- **Topology:** Star
- **Receiver/Central node:** Special Gateway LoRa (SPI) or another Waspmote unit

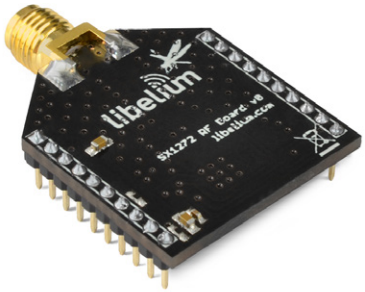


Figure: LoRa module

Note: *The LoRa module is provided with a 4.5 dBi antenna, which enables maximum range.*

This radio module provides an optimum range performance, thanks to the excellent receiver sensitivity that the LoRa™ technology offers. Besides, Libelium developed a library which enables addressable, reliable and robust communications with ACK, re-tries or time-outs strategies.

The user can set any **frequency** in the 868 and 900 MHz bands, with pre-defined channels. The use of this module is allowed in virtually any country.

Encryption is implemented in the application level, thanks to the Waspmote’s AES library. The payload inside the wireless packet is encrypted so only nodes knowing the key can read the content. The encryption activation is as simple as running one of our LoRa with AES encryption examples.

The **topology** for this type of network is a star topology, as the nodes can establish point-to-point connections with brother nodes, normally with the central one.

Related API libraries: **WaspSX1272.h, WaspSX1272.cpp**

All information about programming the LoRa module can be found in the **SX1272 LoRa Networking Guide**.

All the documentation is located in the Development section in the Libelium website.

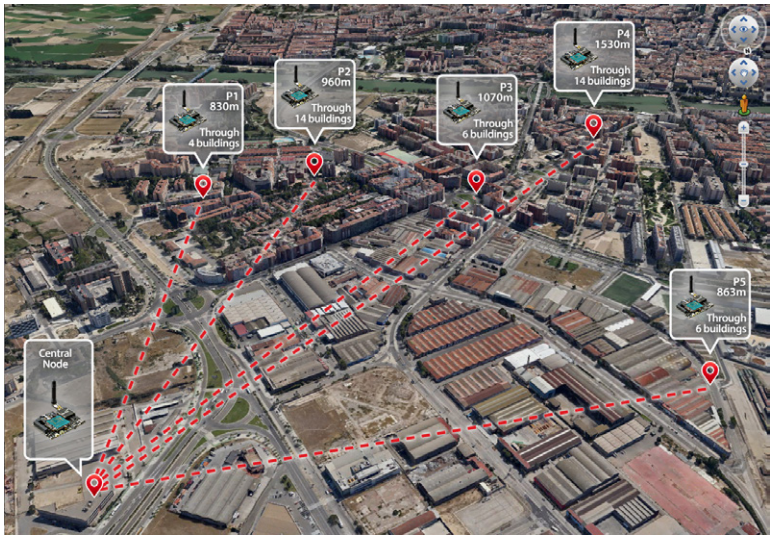


Figure: Star topology

12. Sigfox modules

Sigfox is a private company that aims to build a worldwide network especially designed for IoT devices. The network is cellular, with thousands of base stations deployed in each country. Sigfox technology offers very long ranges for low-power, battery-constrained nodes. Sigfox is great for very simple and autonomous devices which need to send small amounts of data to this ubiquitous network, taking advantage on the Sigfox infrastructure.

So Sigfox is similar to cellular (GSM-GPRS-3G-4G) but is more energy-efficient, and the annual fees are lower.

Sigfox uses a UNB (Ultra Narrow Band) based radio technology to connect devices to its global network. The use of UNB is key to providing a scalable, high-capacity network, with very low energy consumption, while maintaining a simple and easy to rollout star-based cell infrastructure.

- **Frequency**
  - Sigfox EU module: ISM 868 MHz
  - Sigfox US module: ISM 900 MHz
- **TX power**
  - Sigfox EU module: up to 16 dBm
  - Sigfox US module: up to 24 dBm
- **ETSI limitation:** 140 messages of 12 bytes, per module per day
- **Range:** Typically, each base station covers some km. Check the Sigfox network.
- **Chipset consumption**
  - Sigfox EU module: TX 51 mA @ 14 dBm
  - Sigfox US module: TX 230 mA @ 24 dBm
- **Radio data rate:** 100 bps
- **Receive sensitivity:** -126 dBm
- **Sigfox certificate:** Class 0u (the highest level)

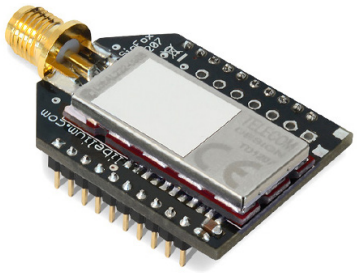


Figure: Sigfox module

The network operates in the globally available ISM bands (license-free frequency bands) and co-exists in these frequencies with other radio technologies, but without any risk of collisions or capacity problems.

Sigfox is being rolled out worldwide. It is the responsibility of the system integrator to consult the catalog of SNOs (Sigfox Network Operators) for checking coverage in the deployment area.

The Sigfox back-end provides a web application interface for device management and configuration of data integration, as well as standards based web APIs to automate the device management and implement the data integration.

Figure: Sigfox network

Related API libraries: **WaspSigfox.h, Waspsigfox.cpp**

All information about their programming and operation can be found in the Sigfox Networking Guide.

All the documentation is located in the Development section in the Libelium website.

13. WiFi PRO module

The WiFi PRO module offers and supports large variety of features, for example:

- Ten simultaneous TCP/UDP sockets
- DHCP client/server
- DNS client
- HTTP client
- HTTPS client
- FTP client
- NTP client
- Multiple SSIDs
- Roaming mode
- OTA feature. Refer to the Over the Air Programming Guide for more information.

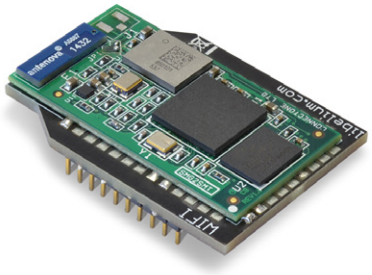


Figure: WiFi module

The WiFi PRO module supports the SSL3/TLS1 protocol for secure sockets. On the WLAN interface it supports WEP, WPA and WPA2 WiFi encryption.

The WiFi PRO module may connect to any **standard router** which is configured as Access Point (AP) and then send data to other devices in the same network such as laptops and smart phones. Besides, they can send data directly to a web server located on the Internet.

Instead of using a standard WiFi router as AP, the connection may be performed using a **Meshlium** device as AP. Meshlium is the multiprotocol router designed by Libelium which is specially recommended for outdoor applications as it is designed to resist the hardest conditions in real field deployments. For more information about Meshlium go to:
http://www.libelium.com/meshlium.

Related API libraries: **WaspWiFi_PRO.h, WaspWiFi_PRO.cpp**

All information about their programming and operation can be found in the WiFi Networking Guide.

All the documentation is located in the Development section in the Libelium website.

14. Bluetooth Pro module

Technical specifications:

- Bluetooth v2.1 + EDR. Class 2.
- TX power: 3 dBm
- Antenna: 2 dBi
- Up to 250 unique devices in each inquiry
- Received Strength Signal Indicator (RSSI) for each scanned device
- Class of Device (CoD) for each scanned device
- 7 power levels [-27 dBm, +3 dBm]
- Scan devices with maximum inquiry time
- Scan devices with maximum number of nodes
- Scan devices looking for a certain user by MAC address
- Classification between pedestrians and vehicles

Figure: Libelium Bluetooth module

Bluetooth uses 79 channels with a bandwidth of 1 MHz per channel. In addition, Adaptive Frequency Hopping (AFH) is used to enhance the transmissions.

Bluetooth module for device discovery:

The Bluetooth radio module has been specifically designed in order to scan up to 250 devices in a single inquiry (smart phones, tablets, computers, etc). The main purpose is to be able to detect as many Bluetooth users as possible in the surrounding area.

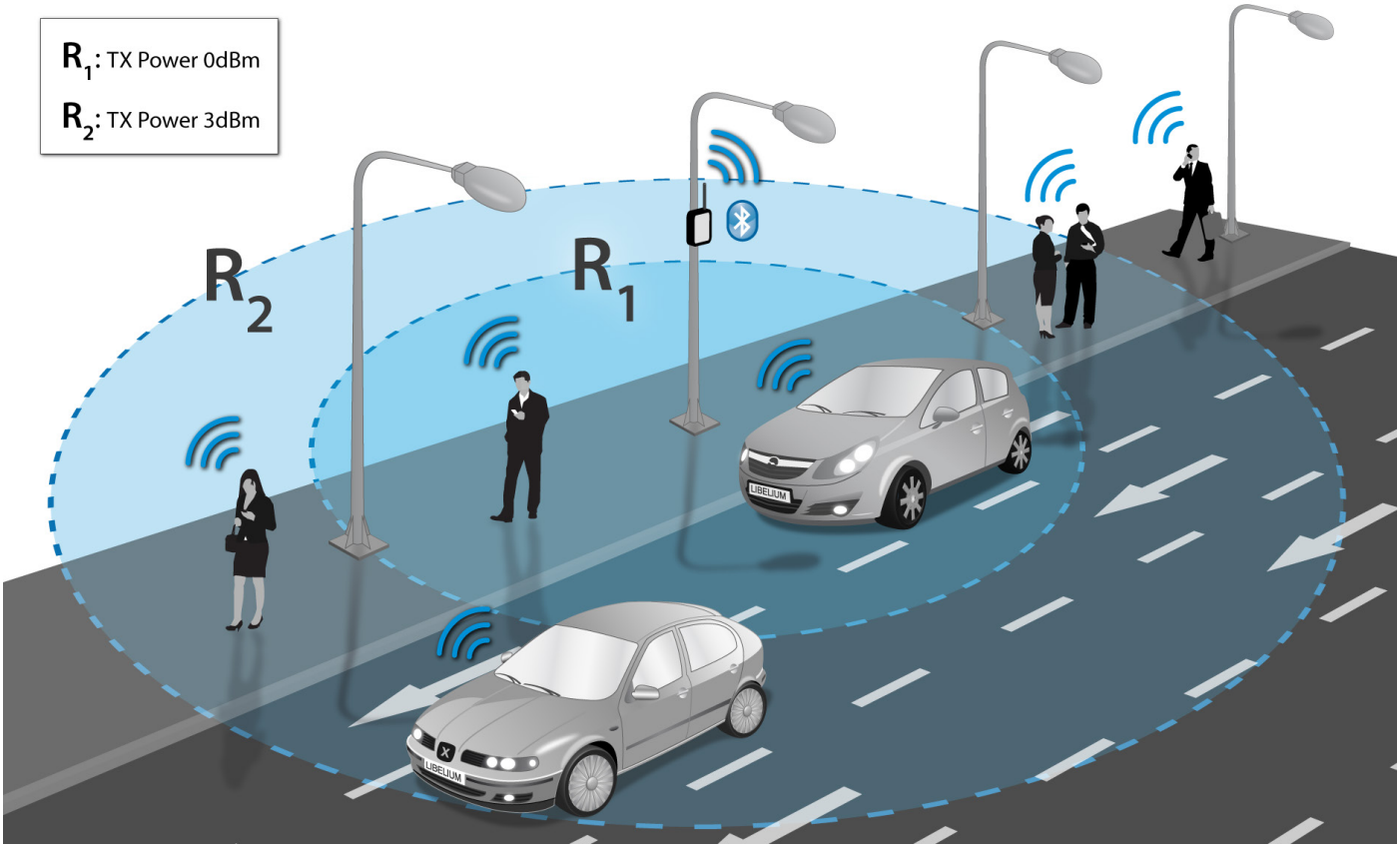


Figure: Bluetooth module for device discovery

Related API libraries: **WaspBT_Pro.h, WaspBT_Pro.cpp**

All information on their programming can be found in document: Bluetooth Networking Guide.

All the documentation is located in the Development section in the Libelium website.

> ***Note:*** *If you want to detect iPhone and Android devices using the WiFi interface as well as the Bluetooth radio go to the "Smartphone Detection" section in the Meshlium website: http://www.libelium.com/meshlium*

15. Bluetooth Low Energy module

Technical specifications:

- Protocol: Bluetooth v.4.0 / Bluetooth Smart
- Chipset: BLE112
- RX Sensitivity: -103 dBm
- TX Power: [-23 dBm, +3 dBm]
- Antenna: 2 dBi/5 dBi antenna options
- Security: AES-128
- Range: 100 meters (at maximum TX power)
- Consumption: sleep (0.4 uA) / RX (8 mA) / TX (36 mA)
- Send broadcast advertisements (iBeacons)
- Connect to other BLE devices as Master / Slave
- Connect with smartphones and tablets
- Set automatic cycles sleep / transmission
- Calculate distance using RSSI values
- Perfect for indoor location networks (RTLS)
- Scan devices with maximum inquiry time
- Scan devices with maximum number of nodes
- Scan devices looking for a certain user by MAC address

Figure: Waspmote Bluetooth Low Energy module

BLE modules use the 2.4 GHz band (2402 MHz – 2480 MHz). It has 37 data channels and 3 advertisement channels, with a 2MHz spacing.

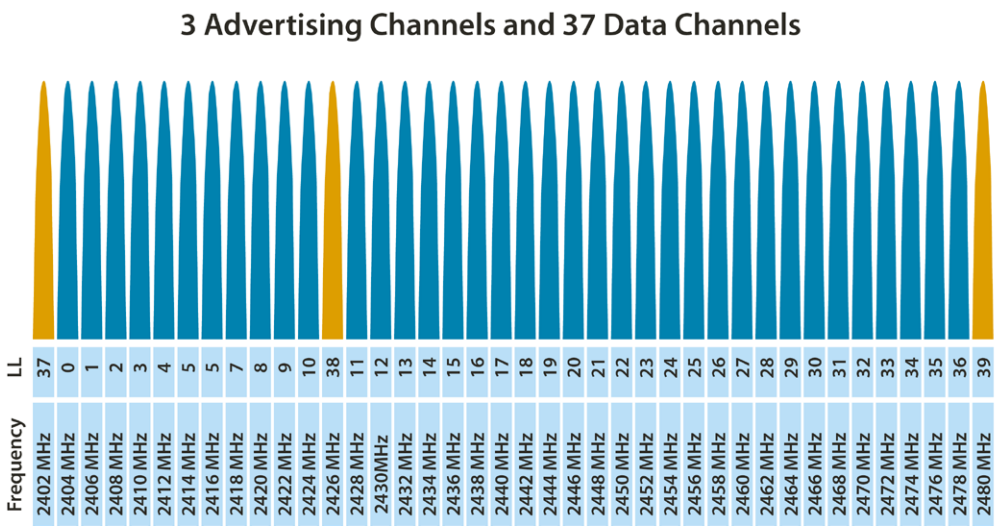


Figure: Channel distribution on the BLE standard

In the same way as Bluetooth classic modules, other BLE modules can be identified by their MAC address and public name. Also, the RSSI is provided to show the quality of each link.

Related API libraries: **WaspBLE.h, WaspBLE.cpp.**

All information on their programming can be found in document: Bluetooth Low Energy Networking Guide.

All the documentation is located in the Development section in the Libelium website.

16. GPRS module

Waspmote can integrate a GSM (Global System for Mobile communications) / GPRS (General Packet Radio Service) module to enable communication using the mobile telephone network.

- **Model:** SIM900 (SIMCom)
- **Quadband:** 850/900/1800/1900 MHz
- **TX power:** 2 W (Class 4) 850/900 MHz, 1 W (Class 1) 1800/1900 MHz
- **Sensitivity:** -109 dBm
- **Antenna connector:** U.FL
- **External antenna:** 0 dBi

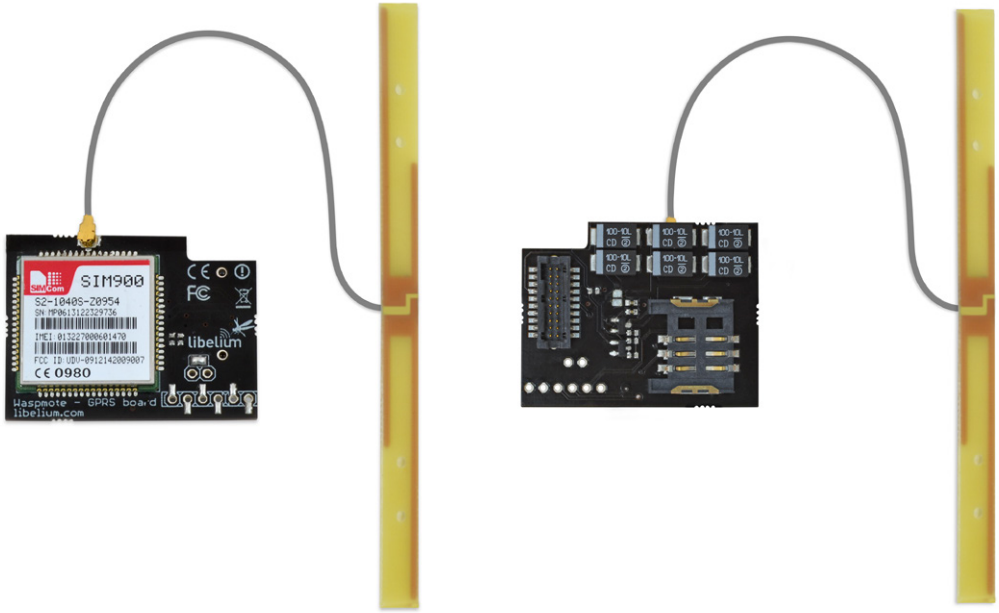


Figure: GPRS module

This module can carry out the following tasks:

- Making/Receiving calls
- Making 'x'-second lost calls
- Sending/Receiving SMS
- Single connection and multiple connections TCP/IP and UDP/IP clients
- TCP/IP server
- HTTP service
- FTP service (downloading and uploading files)

This model uses the UART1 at a baudrate of 57600 bps speed to communicate with the microcontroller.

Related API libraries: **WaspGPRS_Pro.h**, **WaspGPRS_Pro.cpp** , **WaspGPRS_Pro_core.h and WaspGPRS_Pro_core.cpp**

All information about their programming and operation can be found in the GPRS Programming Guide.

All the documentation is located in the Development section in the Libelium website.

Note: *A rechargeable battery must be always connected when using this module (USB power supply is not enough).*

17. GPRS+GPS module

Waspmote can integrate a GSM (Global System for Mobile communications) / GPRS (General Packet Radio Service) module to enable communication using the mobile telephone network. Also, this module integrates a GPS receiver.

Model: SIM928 (SIMCom)

GPRS features:

- **Quadband:** 850/900/1800/1900 MHz
- **TX power:** 2 W (Class 4) 850/900 MHz, 1 W (Class 1) 1800/1900 MHz
- **Sensitivity:** -109 dBm
- **Antenna connector:** U.FL
- **External antenna:** 0 dBi
- **Consumption in sleep mode:** 1 mA
- **Consumption in power off mode:** 0 mA

GPS features:

- **Time-To-First-Fix:** 30 s (typ.)
- **Sensitivity:**
  - Tracking: -160 dBm
  - Acquisition: -147 dBm
- **Accuracy horizontal position :** <2.5 m CEP

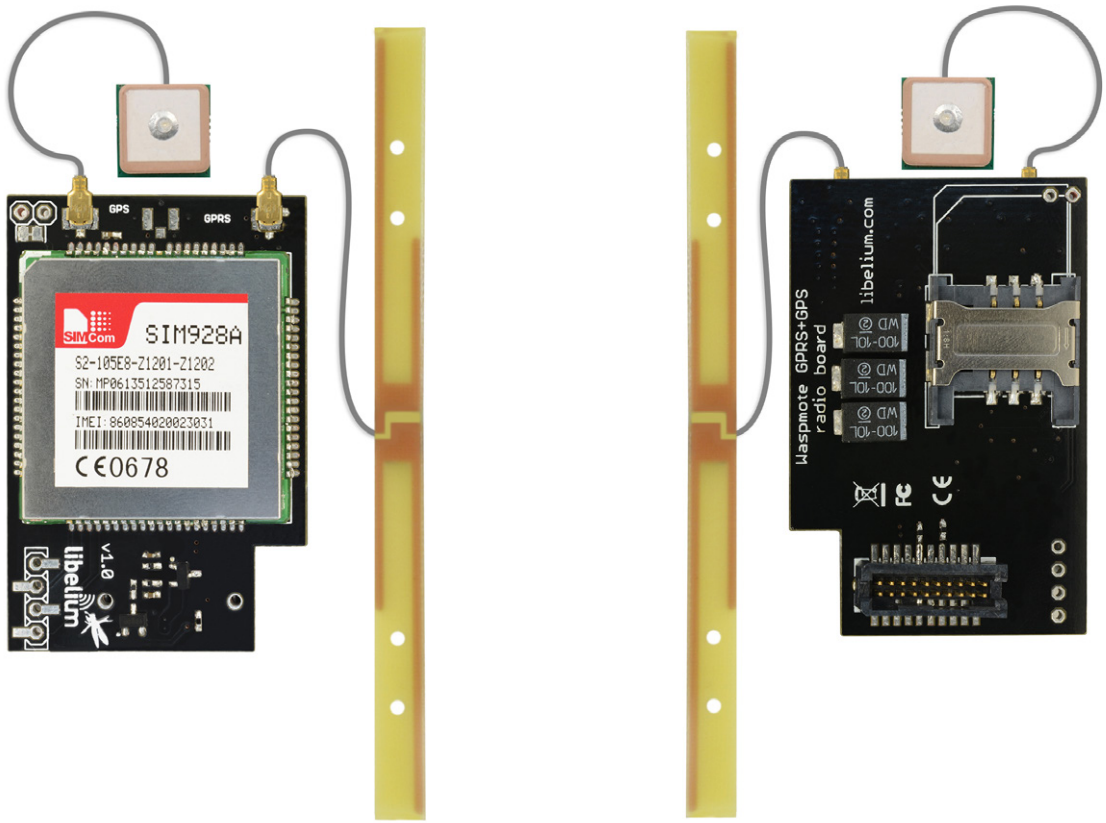


Figure: GPRS+GPS module

This module can carry out the following tasks:

- Making/Receiving calls
- Making 'x'-second lost calls
- Sending/Receiving SMS
- Single connection and multiple connections TCP/IP and UDP/IP clients
- TCP/IP server
- HTTP service
- FTP Service (downloading and uploading files)
- GPS receiver

This model uses the UART1 at a baudrate of 57600bps speed to communicate with the microcontroller.

Related API libraries: **WaspGPRS_SIM928A.h, WaspGPRS_SIM928A.cpp, WaspGPRS_Pro_core.h and WaspGPRS_Pro_core.cpp**

All information about their programming and operation can be found in the GPRS+GPS Programming Guide.

All the documentation is located in the Development section in the Libelium website.

Note: A rechargeable battery must be always connected when using this module (USB power supply is not enough).

18. 3G module

Waspmote can integrate a UMTS (Universal Mobile Telecommunication System based in WCDMA technology) / GPRS (General Packet Radio Service) module to enable communication using the 3G/GPRS mobile telephone network.

- **Model:** SIM5215 (SIMCom)
- **Versions:** Europe and America/Australia
- **Europe version:**
  - Dual-Band: 900/2100 MHz
  - Tri-Band: 850/900/1800 MHz
- **America/Australia version:**
  - Dual-Band: 850/1900 MHz
  - Quad-Band: 850/900/1800/1900 MHz
- **WCDMA (downlink):** up to 384 kbps
- **WCDMA (uplink):** up to 384 kbps
- **TX power:**
  - UMTS 850/900/1900/2100: 0.25 W
  - GSM 850/900: 2 W
  - DCS 1800 / PCS 1900: 1 W
- **Sensitivity:** -106 dBm
- **Antenna connector:** U.FL
- **External antenna:** 0 dBi

Figure: 3G module

This module can carry out the following tasks:

- Videocall using 3G network available with Video Camera Sensor Board
- Record video (res. 320 x 240) and take pictures (res. 640 x 480) available with Video Camera Sensor Board
- Support microSD card up to 32 GB
- 64 MB of internal storage space
- Making/Receiving calls
- Making 'x'-second lost calls
- Sending/Receiving SMS
- Single connection and multiple connections TCP/IP and UDP/IP clients
- TCP/IP server
- HTTP and HTTPS service
- FTP and FTPS service (downloading and uploading files)
- Sending/receiving email (SMTP/POP3)

This model uses the UART1 at a baudrate of 115200 bps to communicate with the microcontroller.

Related API libraries: **Wasp3G.h, Wasp3G.cpp**

All information about programming and operation can be found in the 3G/GPRS Networking Guide.

All the documentation is located in the Development section of Libelium website.

Note: *A rechargeable battery must be always connected when using this module (USB power supply is not enough).*

19. 4G module

The 4G module enables the connectivity to high speed LTE, HSPA+, WCDMA cellular networks in order to make possible the creation of the next level of worldwide compatible projects inside the new “Internet of Things” era.

This communication module is specially oriented to work with Internet servers, implementing internally several application layer protocols, which make easier to send the information to the cloud. We can make HTTP navigation, downloading and uploading content to a web server. We can also set secure connections using SSL certificates and setting TCP/IP private sockets. In the same way, the FTP protocol is also available which is really useful when your application requires handling files.

The module includes a GPS/GLONASS receiver, able to perform geolocation services using NMEA sentences, offering information such as latitude, longitude, altitude and speed; that makes it perfect to perform tracking applications.

The 4G module offers the maximum performance of the 4G network as it uses 2 different antennas (normal + diversity) for reception (MIMO DL 2x2), choosing the best received signal at any time and getting a maximum download speed of 100 Mbps.

We chose the LE910 chipset family from Telit as it comprises the most complete 4G/LTE set of variants released up to date. It counts with many different models, each one specifically designed for one market but all of them with the same footprint:

- LE910-EU (Europe/Brazil): CE, GCF, ANATEL
- LE910-NAG (US / Canada): FCC, IC, PTCRB, AT&T approved
- LE910-AU V2 (Australia): RCM, Telstra approved → [Available in Q3 2016]

Figure: 4G module

Model: LE910 (Telit)

Versions:

- Europe/Brazil
- America
- Australia

Europe/Brazil version:

- 2G: 900/1800 MHz
- WCDMA: 850/900/2100 MHz
- LTE: 800/1800/2600 MHz

America version:

- 2G: 850/1900 MHz
- WCDMA: 850/1900 MHz
- LTE: 700/850/1700/1900 MHz

Australia version:

- 4G: 700/1800/2600 MHz

LTE (downlink):

- Europe/Brazil version up to 100 Mbps
- America version up to 100 Mbps
- Australia version up to 150 Mbps

LTE (uplink): up to 50 Mbps

TX power:

- Europe/Brazil:
  - Class 4 (2 W, 33 dBm) @ GSM 900
  - Class 1 (1 W, 30 dBm) @ GSM 1800
  - Class E2 (0.5 W, 27 dBm) @ EDGE 900
  - Class E2 (0.4 W, 26 dBm) @ EDGE 1800
  - Class 3 (0.25 W, 24 dBm) @ UMTS
  - Class 3 (0.2 W, 23 dBm) @ LTE

- America:
  - Class 4 (2 W, 33 dBm) @ GSM 900
  - Class 1 (1 W, 30 dBm) @ GSM 1800
  - Class E2 (0.5 W, 27 dBm) @ EDGE 900
  - Class E2 (0.4 W, 26 dBm) @ EDGE 1800
  - Class 3 (0.25 W, 24 dBm) @ UMTS
  - Class 3 (0.2 W, 23 dBm) @ LTE
- Australia:
  - Class 3(0.2W, 23 dBm) @ LTE

Antenna connector:

- U.FL for main antenna
- U.FL for cellular diversity antenna
- U.FL for GPS antenna (only for Europe/Brazil and America modules)

External antenna: +5 dBi

GPS: GPS feature is supported only in Europe/Brazil and America versions

This module can carry out the following tasks:

- Sending/Receiving SMS
- Multisocket up to 6 TCP/IP and UDP/IP clients
- TCP/IP server
- TCP SSL
- HTTP service
- FTP service (downloading and uploading files)
- Sending/receiving email (SMTP/POP3)

Certifications:

- LE910-EUG (Europe / Brazil): CE, GCF, ANATEL
- LE910-NAG (US / Canada): FCC, IC, PTCRB, AT&T approved
- LE910-AU V2 (Australia): RCM, Telstra approved
- LE910-SKG (South Korea): KCC, SK Telecom approved
- LE910-JN V2 / LE910-JK V2 (Japan): NTT DoCoMo, KDDi
-

This model uses the UART1 at a baudrate of 115200 bps to communicate with the microcontroller.

Related API libraries: **Wasp4G.h, Wasp4G.cpp**

All information about programming and operation can be found in the 4G Networking Guide.

All the documentation is located in the Development section of Libelium website.

Note: *A rechargeable battery must be always connected when using this module (USB power supply is not enough).*

20. RFID/NFC module

Features:

- **Compatibility:** Reader/writer mode supporting ISO 14443 MIFARE / FeliCaTM / NFCIP-1
- **Distance:** 5 cm
- **Max capacity:** 4 kB
- **Tags:** cards, keyrings, stickers

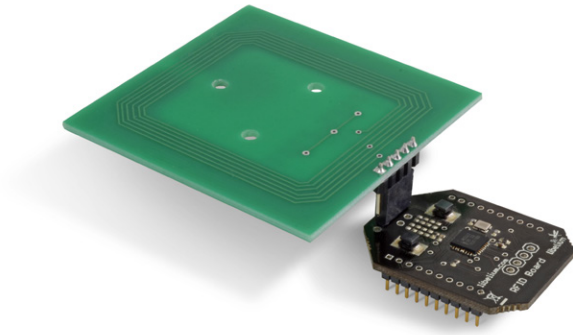


Figure: 13.56MHz RFID/NFC module

Applications:

- Located based services (LBS)
- Logistics (assets tracking, supply chain)
- Access management
- Electronic prepaid metering (vending machines, public transport)
- Smartphone interaction (NFCIP-1 protocol)

Related API libraries: **WaspRFID13.cpp** , **WaspRFID13.h**

All information on its programming can be found in the RFID/NFC 13.56MHz Networking Guide.

All the documentation is located in the Development section in the Libelium website.

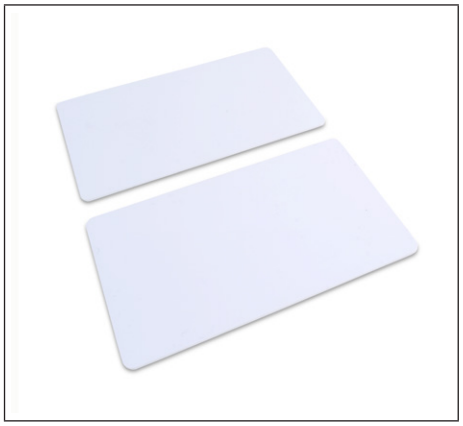
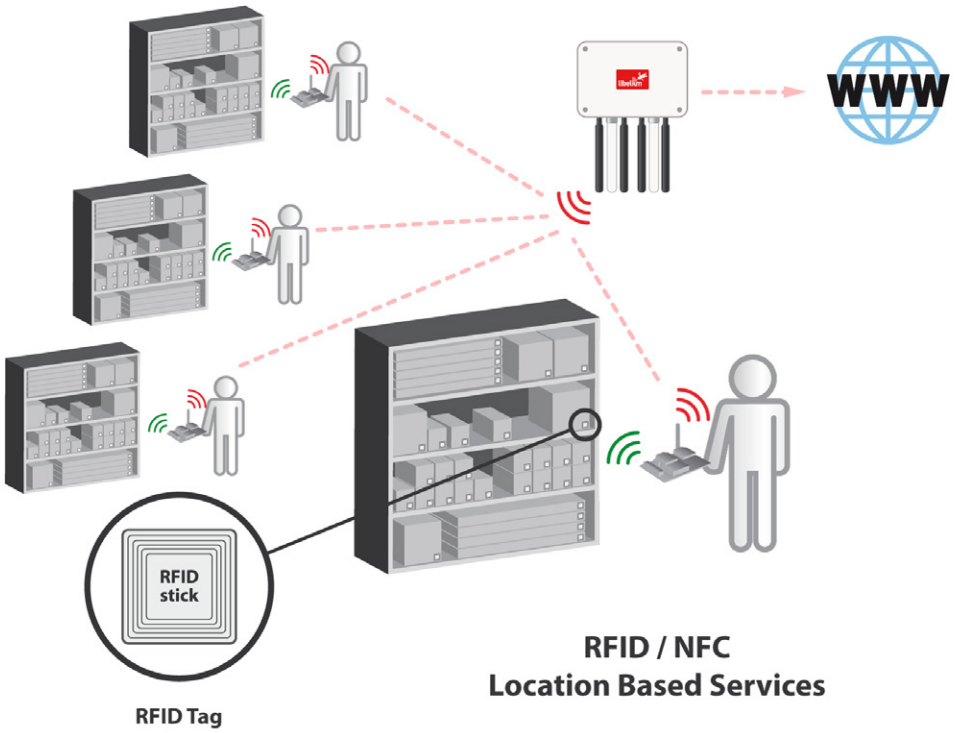
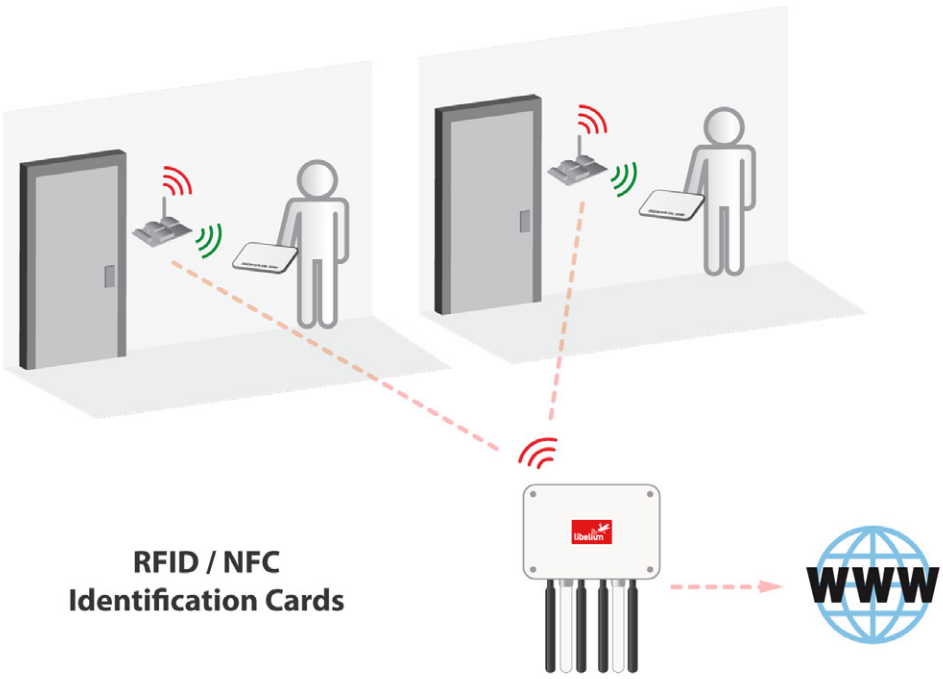


Figure: RFID cards

Figure: RFID keyrings

Figure: RFID sticker


WWW
RFID
stick
RFID Tag
RFID / NFC
Location Based Services


WWW
RFID / NFC
Identification Cards

21. Industrial Protocols

21.1. Introduction

Libelium offers communication modules for the most common wired communication protocols: RS-485, RS-232, CAN Bus and Modbus. These are widely used standards in the industrial and automation market for connecting devices and sensors, not in a wireless way but with cables. The user can interface Waspmote ecosystem with these protocols.

Waspmote allows to perform 3 main applications:

1º- Connect any sensor to an existing industrial bus

Waspmote can be configured to work as a node in the network, inserting sensor data into the industrial bus already present. Waspmote can obtain information from more than 100 sensors currently integrated in the platform by using specific sensor boards (e.g.: CO, CO_2, temperature, humidity, acceleration, pH, IR, luminosity, vibration, etc). This way, the sensor information can be read from any industrial device connected to the bus.

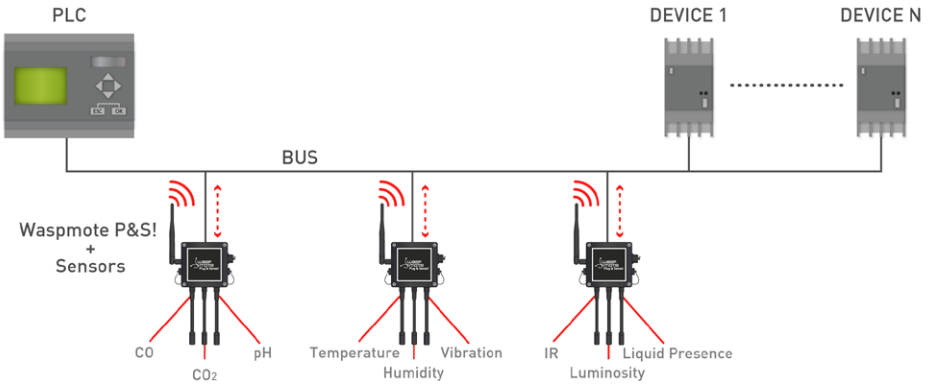


Figure: Module in wireless sensor network applications

2º- Add wireless connectivity to wired buses

Waspmote can be configured to read the information from the bus and send it to the Libelium IoT Gateway using any of the wireless radio modules available: 802.15.4, 868 MHz, 900 MHz, WiFi, 4G, Sigfox and LoRaWAN, Bluetooth Pro, Bluetooth Low Energy and RFID/NFC.

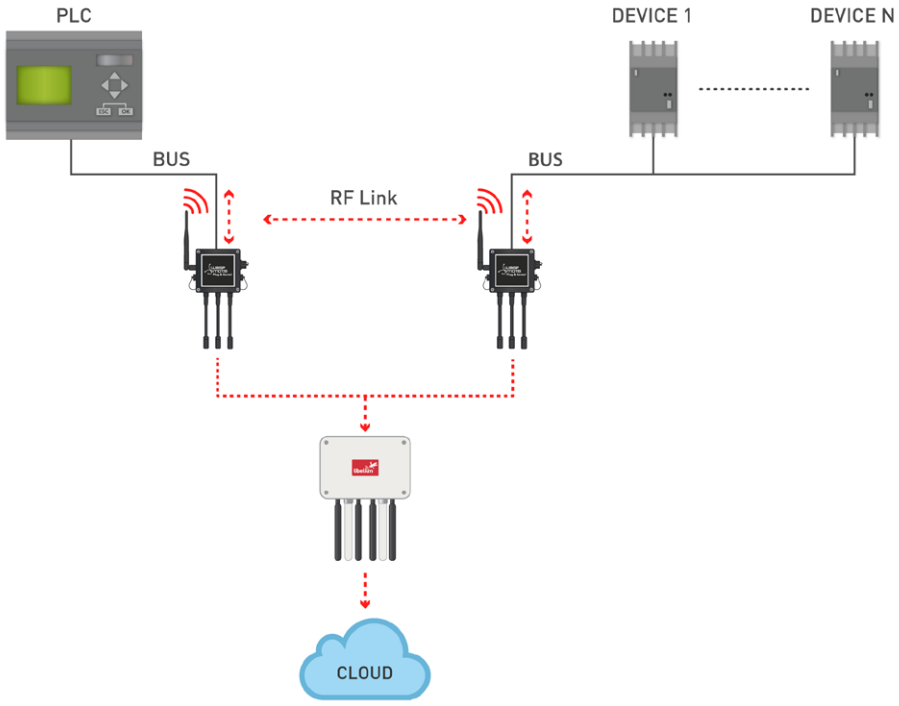


Figure: Waspmote for wire replacement

3º- Connect to the Cloud industrial devices

Waspmote can be configured to read the information coming from the bus and send it wirelessly directly to the Cloud using WiFi, GPRS, GPRS+GPS, 3G or 4G radio interfaces.

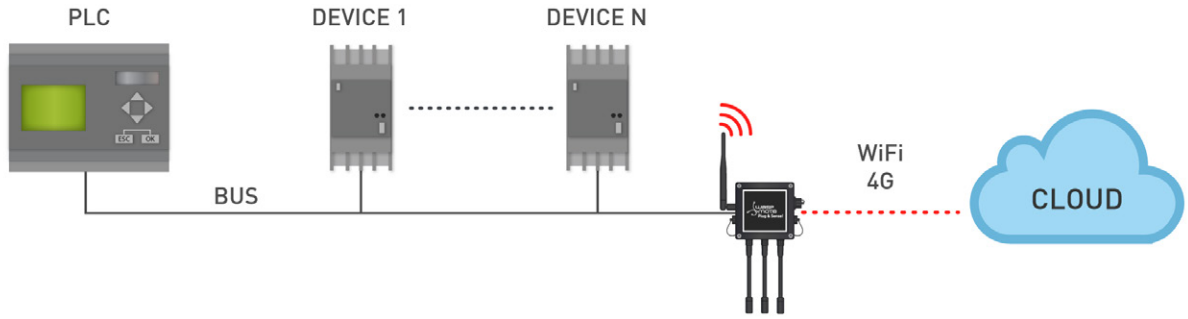


Figure: Cloud connection

21.2. RS-485/Modbus module

Technical details:

- **Protocols:** RS-485 and Modbus
- **Standard:** EIA RS-485
- **Physical media:** Twisted pair
- **Connector:** DB9
- **Network topology:** Point-to-point, Multi-dropped, Multi-point
- **Maximum devices:** 32 drivers or receivers
- **Mode of operation:** Differential signaling
- **Maximum speed:** 460800 bps
- **Voltage levels:** -7 V to +12 V
- **Mark(1):** Positive Voltages (B-A > +200 mV)
- **Space(0):** Negative voltages (B-A < -200 mV)
- **Available signals:** Tx+/Rx+, Tx-/Rx-(Half Duplex)Tx+, Tx-, Rx+, Rx- (Full Duplex)
- **Available sockets in Waspmote:** socket 0

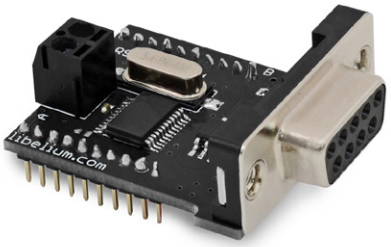


Figure: RS-485/Modbus module

Applications:

- Industrial Equipment
- Machine to Machine (M2M) communications
- Industrial Control Systems, including the most common versions of Modbus and Profibus
- Programmable logic controllers
- RS485 is also used in building automation
- Interconnect security control panels and devices

Related API libraries:

- Wasp485.h, Wasp485.cpp
- ModbusMaster.h, ModbusMaster.cpp
- ModbusSlave.h, ModbusSlave.cpp

All information about their programming and operation can be found in the RS-485 Communication Guide and the Modbus Communication Guide.

All the documentation is located in the Development section in the Libelium website.

21.3. RS-232 Serial/Modbus module

Technical details:

- **Protocols:** RS-232 Serial and Modbus
- **Standard:** TIA-232-F
- **Cabling:** Single ended
- **Connector:** DB9
- **Network topology:** Point-to-point
- **Maximum speed:** 115200 bps
- **Signaling:** unbalanced
- **Voltage levels:** -25...+25
- **Mark(1):** -5...-15
- **Space(0):** +5...+15
- **Signals:** Full Duplex (Rx, TX)
- **Available sockets in Waspmote:** sockets 0 and 1

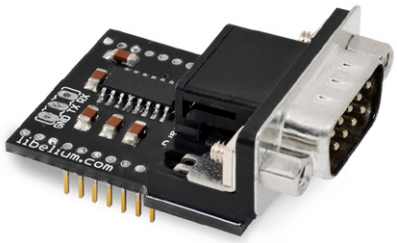


Figure: RS-232 Serial / Modbus module

Applications:

- Dialup modems
- GPS receivers (typically NMEA 0183 at 4,800 bit/s)
- Bar code scanners and other point of sale devices
- LED and LCD text displays
- Satellite phones, low speed satellite modems and other satellite based transceiver devices
- Flatscreen (LCD and Plasma) monitors to control screen functions by external computer, other AV components or remotes
- Test and measuring equipment such as digital multimeters and weighing systems
- Updating Firmware on various consumer devices.
- Some CNC controllers
- Uninterruptible power supply
- Stenography or Stenotype machines
- Software debuggers that run on a 2nd computer
- Industrial field buses

Related API libraries:

- Wasp232.h, Wasp232.cpp
- ModbusMaster.h, ModbusMaster.cpp
- ModbusSlave.h, ModbusSlave.cpp

All information about their programming and operation can be found in the RS-232 Communication Guide and the Modbus Communication Guide.

All the documentation is located in the Development section in the Libelium website.

21.4. CAN Bus module

Technical details:

- **Protocol:** CAN Bus
- **Standard:** ISO 11898
- **Cabling:** Twisted Pair
- **Connector:** DB9
- **Network topology:** Multimaster
- **Speed:** 125 to 1000 Kbps
- **Signaling:** differential
- **Voltage levels:** 0-5V
- **Signals:** Half Duplex
- **Available sockets in Waspmote:** socket 0

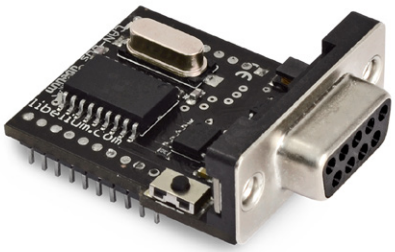


Figure: Can Bus module

Applications:

- Automotive applications
- Home automation
- Industrial Networking
- Factory automation
- Marine electronics
- Medical equipment
- Military uses

Related API libraries:

- WaspCAN.h, WaspCAN.cpp

All information about their programming and operation can be found in the CAN Bus Communication Guide.

All the documentation is located in the Development section in the Libelium website.

21.5. Modbus

The Modbus is a software library that can be operated physically on the RS-485 and RS-232 modules. Thus, Modbus is a software layer which provides with interesting services.

Technical details:

- **Protocol:** Modbus
- **Data area:** Up to 255 bytes per job
- **Interface:** Layer 7 of the ISO-OSI reference model
- **Connector:** DB9 (RS-485 / RS-232 modules)
- **Number of possible connections:** up to 32 in multi point systems
- **Frame format:** RTU

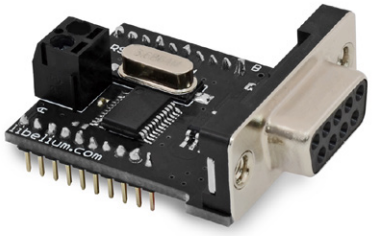


Figure: RS-485 module

Applications:

- Multiple master-slave applications
- Sensors and Instruments
- Industrial Networking
- Building and infrastructure
- Transportation and energy applications

Related API libraries:

- Wasp485.h, Wasp485.cpp
- Wasp232.h, Wasp232.cpp
- ModbusMaster.h, ModbusMaster.cpp
- ModbusSlave.h, ModbusSlave.cpp

All information about their programming and operation can be found in the RS-232 Communication Guide, RS-485 Communication Guide and Modbus Communication Guide.

All the documentation is located in the Development section in the Libelium website.

22. Expansion Radio Board

The Expansion Board allows to connect two communication modules at the same time in the Waspmote sensor platform. This means a lot of different combinations are possible using any of the wireless radios available for Waspmote: 802.15.4, ZigBee, DigiMesh, 868 MHz, 900 MHz, LoRa, WiFi, GPRS, GPRS+GPS, 3G, 4G, Sigfox, LoRaWAN, Bluetooth Pro, Bluetooth Low Energy and RFID/NFC. Besides, the following Industrial Protocols modules are available: RS-485/Modbus, RS-232 Serial/Modbus and CAN Bus.

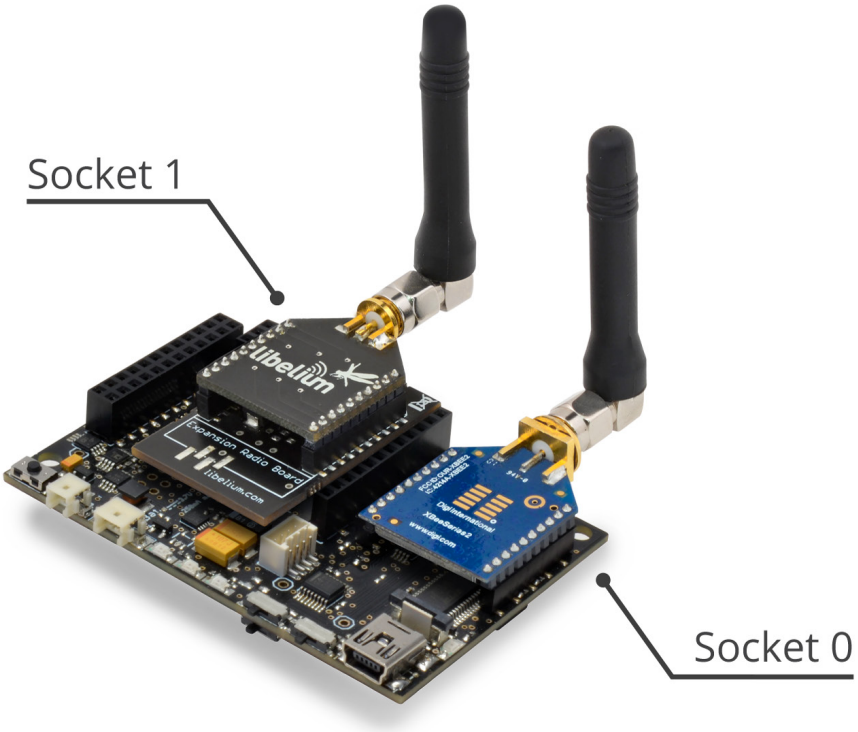


Figure: Expansion Radio Board

Some of the possible combinations are:

- LoRaWAN - GPRS
- 802.15.4 - Sigfox
- 868 MHz - RS-485
- RS-232 - WiFi
- DigiMesh - 4G
- RS-232 - RFID/NFC
- WiFi - 3G
- CAN Bus - Bluetooth
- etc.
-

Remark: *GPRS, GPRS+GPS, 3G and 4G modules do not need the Expansion Board to be connected to Waspmote. They can be plugged directly in the socket1.*

Applications:

- Multifrequency Sensor Networks (2.4 GHz – 868/900 MHz)
- Bluetooth - ZigBee hybrid networks
- NFC (RFID) applications with 3G/GPRS
- ZigBee - WiFi hybrid networks

23. Over the Air Programming (OTA)

23.1. Overview

The concept of Wireless Programming or commonly known as Programming Over the Air (OTA) has been used in the past years overall for the reprogramming of mobile devices such as cell phones. However, with the new concepts of Wireless Sensor Networks and the Internet of Things where the networks consist of hundreds or thousands of nodes OTA is taken to a new direction.

Libelium provides an OTA method based on FTP transmissions to be used with GPRS, GPRS+GPS, 3G, 4G and WiFi modules.

23.2. OTA with 4G/GPRS/WiFi modules via FTP

It is possible to update the Waspmote's program using Over The Air Programming and the following modules: 4G/3G, GPRS or WiFi module.

The Waspmote reprogramming is done using an FTP server and an FTP client (which is Waspmote itself). The FTP server can be configured by Meshlium. Otherwise, the user will have to setup an FTP server.

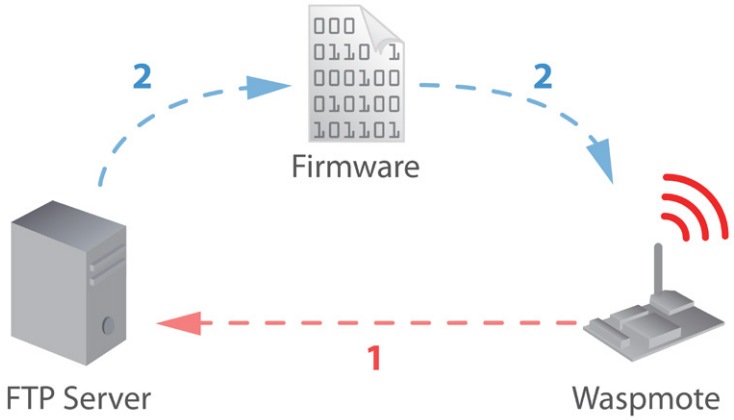


Figure: OTA via FTP protocol

There are 2 basic steps involved in OTA procedure:

- **Step 1:** Waspmote requests a special text file which gives information about the program to update: program name, version, size, etc.
- **Step 2:** If the information given is correct, Waspmote queries the FTP server for a new program binary file and it updates its flash memory in order to run the new program.

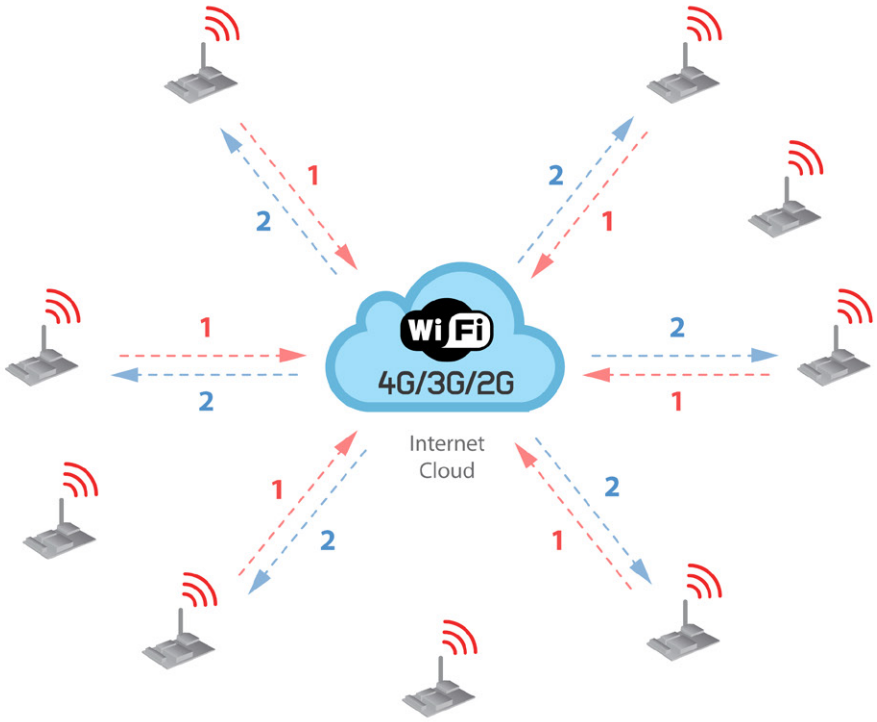


Figure: OTA steps via FTP protocol

24. Encryption libraries

The Encryption Libraries are designed to add to the Waspmote sensor platform the capabilities necessary to protect the information gathered by the sensors. To do so, 2 cryptography layers are defined:

- **Link Layer:** In the first one all the nodes of the network share a common preshared key which is used to encrypt the information using AES 128. This process is carried out by specific hardware integrated in the same 802.15.4/ZigBee radio, allowing the maximum efficiency of the sensor nodes energy consumption. This first security layer ensures no third party devices will be able to even connect to the network (access control).
- **Secure Web Server Connection:** The second security technique is carried out in Meshlium -the Gateway- where HTTPS and SSH connections are used to send the information to the Cloud server located on the Internet.

A third optional encryption layer allows each node to encrypt the information using the Public key of the Cloud server. Thus, the information will be kept confidentially all the way from the sensor device to the web or data base server on the Internet.

Transmission of sensor data:

Information is encrypted in the application layer via software with **AES 256** using the key shared exclusively between the origin and the destination. Then the packet is encrypted again in the link layer via hardware with **AES 128** so that only trusted packets be forwarded, ensuring access control and improving the usage of resources of the network.

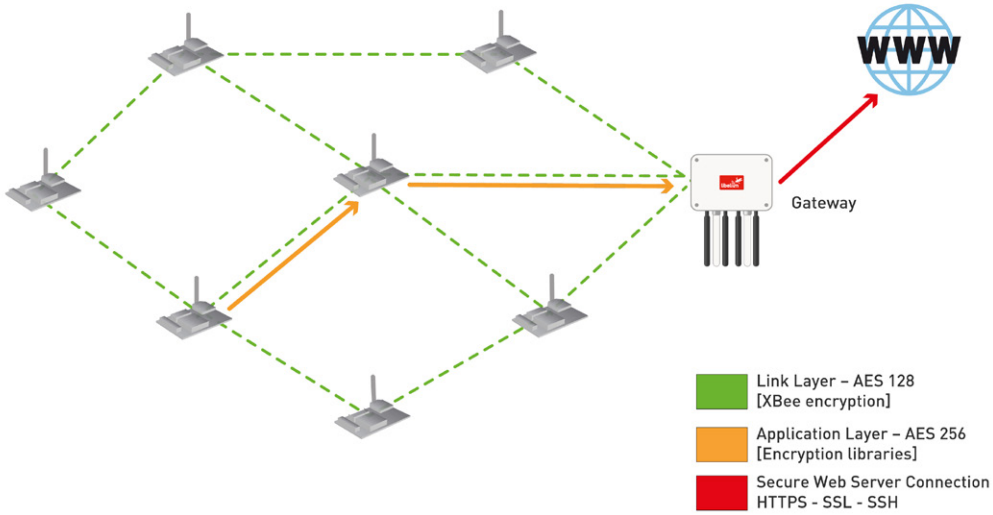


Figure: Communication diagram

Related API libraries:

- WaspAES.h, WaspAES.cpp
- WaspRSA.h, WaspRSA.cpp
- WaspHash.h, WaspHash.cpp

All information about their programming and operation can be found in the Encryption Programming Guide.

All the documentation is located in the Development section in the Libelium website.

25. GPS

Waspmote can integrate a GPS receiver which allows to know the exact location of the mote anytime. Thus, the exact position of the mote can be obtained and even the current time and date, to synchronize the Waspmote internal clock (RTC) with the real time. Besides, data can be geolocated on a map.

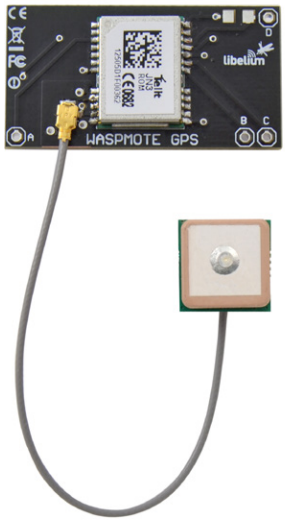


Figure: GPS module

The GPS module gives us information about:

- latitude
- longitude
- altitude
- speed
- direction
- date/time
- ephemeris

The functions implemented in the API allow this information to be extracted simply, calling functions such as:

```
{
  GPS.getAltitude();
  GPS.getSpeed();
  GPS.getLongitude();
  GPS.getLatitude();
}
```

The GPS receiver uses the UART_1 to communicate with the microcontroller, sharing this UART with the GPRS, GPRS+GPS, 3G or 4G modules. As up to 2 modules share this UART, a multiplexer has been enabled in order to select the module with which we wish to communicate at any time. This is not a problem; since all actions are **sequential**, in practice there is **parallel availability** of both devices.

The GPS starts up by default at 4800 bps. This speed can be increased using the library functions that have been designed for controlling and managing the module.

The GPS receiver has 2 operational modes: **NMEA** (National Marine Electronic Association) mode and **binary mode**. NMEA mode uses statements from this standard to obtain **location**, **time** and **date**. The binary mode is based on the sending of structured frames to establish communication between the microcontroller and the GPS receiver, i.e. to read/set ephemeris.

The different types of NMEA statements that the Waspmote's built-in GPS receiver supports are:

- NMEA GGA: provides location data and an indicator of data accuracy
- NMEA GSA: provides the status of the satellites the GPS receiver has been connected to
- NMEA GSV: provides information about the satellites the GPS receiver has been connected to
- NMEA RMC: provides information about the date, time, location and speed
- NMEA VTG: provides information about the speed and course of the GPS receiver
- NMEA GLL: provides information about the location of the GPS receiver

The most important NMEA statements are the GGA statements which provide a validity indicator of the measurement carried out, the RMC statement which provides location, speed and date/time and the GSA statement which provides information about the status of the satellites the GPS receiver has been connected to.

(To obtain more information about the NMEA standard and the NMEA statements, visit the website: http://www.gpsinformation.org/dale/nmea.htm)

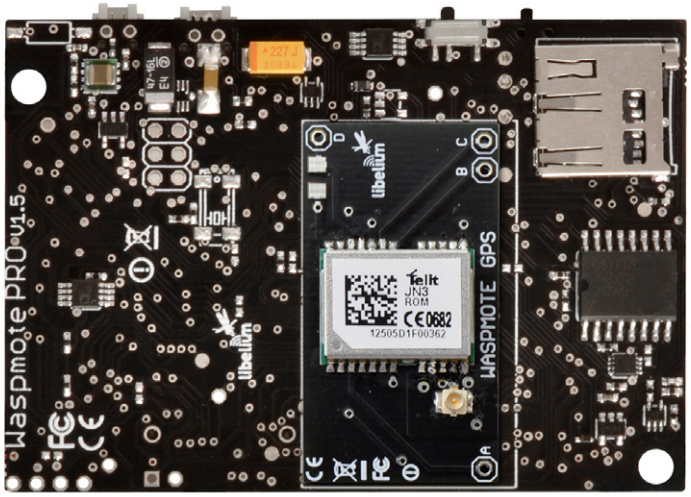


Figure: GPS module connected to Waspmote

The GPS receiver needs time to obtain and structure the information that the satellites send. This time can be reduced if there is certain prior information. This information is stored in the almanacs and ephemeris. The information that can be found out is relative to the current position of the satellites (ephemeris) and the trajectory they are going to follow over the next days (almanacs). The almanacs indicate the trajectory that the satellites are going to follow during the next days, having a validity of some 2-3 months. The ephemeris indicate the current position of the satellites and have a validity of some 3-5 hours.

Depending on the information that the GPS receiver has, the start ups can be divided into these types:

- Hot start: once the time and date are established and the **ephemeris** and valid almanacs are in the memory. Time: <1 s.
- Cold start: without having established the time, date, almanacs or ephemeris. Time: <35 s.

As can be observed, the start up time reduces greatly, particularly when **ephemeris are stored**. For this reason a series of functions have been created in the libraries to **store ephemeris on the SD card and enable them to be loaded later**.

Related API libraries: **WaspGPS.h, WaspGPS.cpp**.

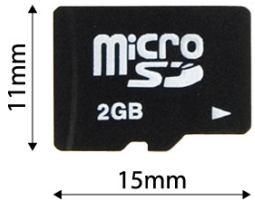
All information about their programming and operation can be found in the document: **GPS Programming Guide**.

All the documentation is located in the Development section in the Libelium website.

26. SD memory card

Waspmote has external storage support such as SD (Secure Digital) cards. These micro-SD cards are used specifically to reduce board space to the minimum.

Note: *Until February 2018, 2 GB SD cards were distributed; they operated with FAT16. The bigger and newer 8 GB SD cards need the #J bootloader or newer. Do not mix old bootloaders with 8 GB SD cards.*



Micro-SD card

Waspmote uses the **FAT32** file system and can support cards up to **8 GB**. The information that Waspmote stores in files on the SD can be accessed from different operating systems such as Linux, Windows or Mac-OS.

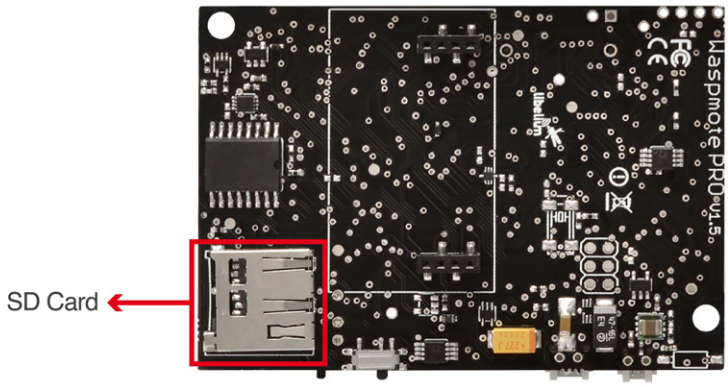


Figure: SD card slot

To communicate with the SD module we use the **SPI** bus. This bus is a communication standard used to transfer information between electronic devices which accept clock regulated bit flow.

The SD card is powered through a **digital pin** from the microcontroller. It is not therefore necessary to use a switch to cut the power, putting a low pin value is enough to set the SD consumption to **0 µA**.

To get an idea of the capacity of information that can be stored in a **8 GB** card, simply divide its size by the average for what a sensor frame in Waspmote usually occupies (approx. 100 bytes):

8 GB/100 B = 80 million measurements

The limit in files and directories creation per level is 256 files per directory and up to 256 sub-directories in each directory. There is no limit in the number of nested levels.

Related API libraries: **WaspSD.h, WaspSD.cpp**

All information about their programming and operation can be found in the SD Card Programming Guide.

All the documentation is located in the Development section in the Libelium website.

Note: *Make sure Waspmote is switched off before inserting or removing the SD card. Otherwise, the SD card could be damaged.*

Note: *Waspmote must not be switched off or reseted while there are ongoing read or write operations in the SD card. Otherwise, the SD card could be damaged and data could be lost.*

27. Energy Consumption

27.1. Consumption tables

Waspmote

On	17 mA
Sleep	30 µA
Deep Sleep	33 µA
Hibernate	7 µA

XBee

	SENDING	RECEIVING
XBee-PRO 802.15.4	250 mA	55 mA
XBee-PRO ZigBee	295 mA	45 mA
XBee 868LP	48 mA	27 mA
XBee-PRO 900HP	215 mA	29 mA

Bluetooth modules

	On	Off	Sleep	Scanning	Sending	Receiving
Bluetooth Pro	14 mA	0 mA	<0,5 mA	40 mA	34 mA	20 mA
Bluetooth Low Energy	8 mA	0 mA	0.4 µA	36 mA	36 mA	36 mA

GPS

On (tracking)	32 mA
Off (Waspmote switch)	0 µA

GPRS Pro

Connecting	~100 mA
Calling	~100 mA
Receiving calls	~100 mA
Transmitting GPRS	~100 mA
Sleep	1 mA
Off	~0 µA

GPRS+GPS

Connecting	~100 mA
Calling	~100 mA
Receiving calls	~100 mA
Transmitting GPRS	~100 mA
Sleep	1 mA
Off	~0 µA
GPS acquisition mode	72 mA
GPS tracking mode	67 mA

3G/GPRS

Connecting	~100 mA
Transmitting/Receiving GPRS	~100 mA (1.2A – 2 A during transmission slot every 4.7ms)
Transmitting/Receiving 3G	~300 mA - 500 mA
Sleep	1 mA
Off	~0 µA

SD

On	0.14 mA
Reading	0.2 mA
Writing	0.2 mA
Off	0 µA

Accelerometer

Sleep	0,08 mA
Hibernate	0,65 mA
Off	~0 µA

28. Power supplies

28.1. Battery

Libelium offers 2 types of battery for the Waspmote OEM line:

- a 6600 mA·h, rechargeable lithium-ion battery (Li-Ion), with 3.7 V nominal voltage
- a 52000 mA·h, non-rechargeable battery, with 3.4 V nominal voltage

Waspmote has a control and safety circuit which makes sure the battery charge current is always adequate.

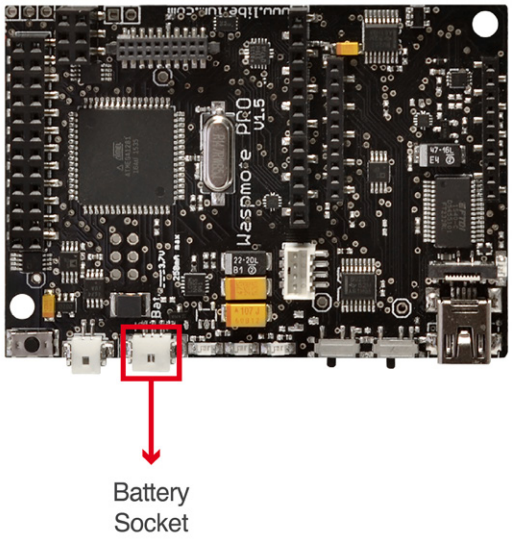


Figure: Battery connector

Battery connection

The figure below shows the connector in which the battery is to be connected. The position of the battery connector is unique, therefore it will always be connected correctly (unless the connector is forced).

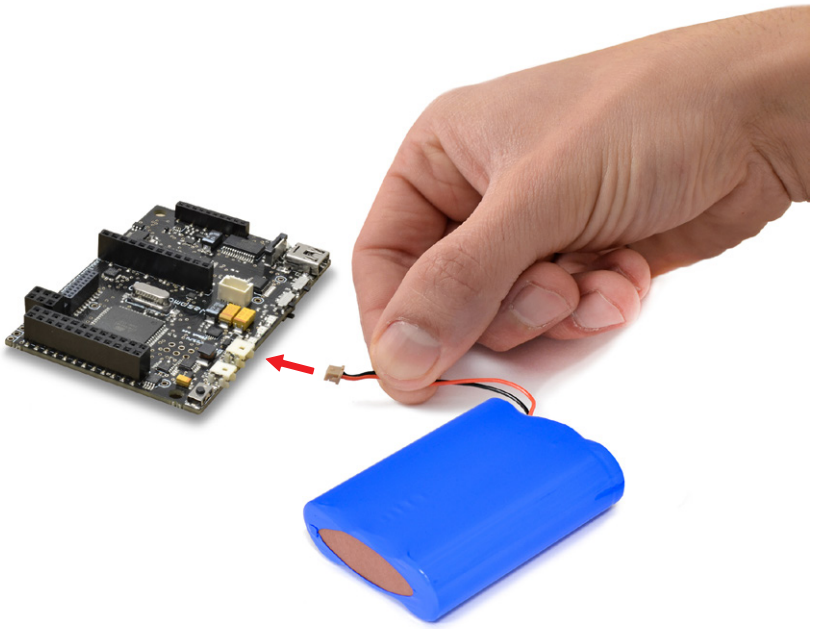


Figure: Battery connection

Battery discharging

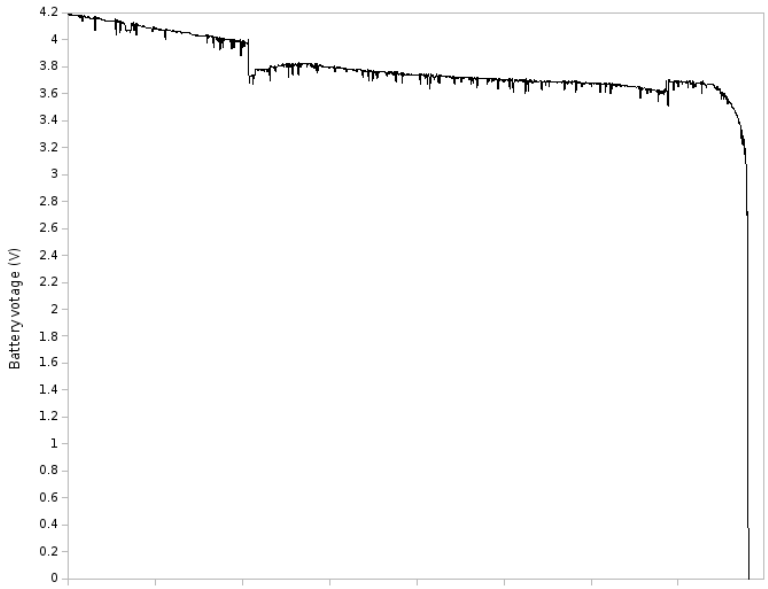


Figure: Typical discharging curve for battery

Characteristics of the equipment used to generate charging curves:

Battery used: 3.7 V - 6600 mA·h battery

As seen above, the rechargeable battery shows a nice slope on its output voltage as its level goes down. Waspmote monitors this voltage in order to calculate the current battery level. However, a rechargeable battery has a very plain discharge graph, so it is not possible to know the remaining energy inside it.

Notes about the rechargeable battery:

- When recharging, if the battery is near 0%, it will take some time before the battery level increases.
- It is normal to see some battery level variations during the charging periods due to the Waspmote charging circuitry. To know the real battery level of the node, it is recommended to measure it when the node is not being recharged and also with sensors and radio modules switched off.

Warning: Batteries with voltage over 3.7 V could irreparably damage Waspmote.
Incorrect battery connection could irreparably damage Waspmote.

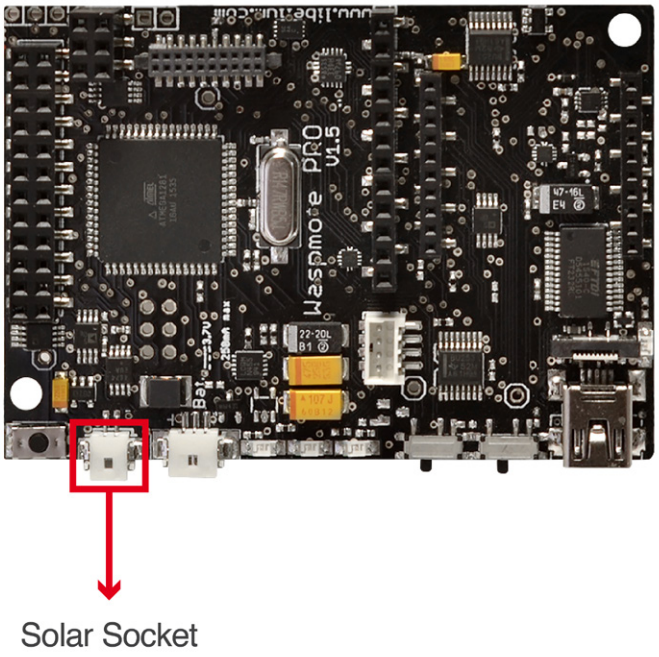
DO NOT TRY TO RECHARGE THE NON-RECHARGEABLE BATTERY, IT MAY EXPLODE AND CAUSE INJURIES AND DESTROY THE EQUIPMENT. USE NON-RECHARGEABLE BATTERIES ONLY WITH DEVICES PROPERLY PREPARED. PLEASE DOUBLE CHECK THIS CONDITION BEFORE CONNECTING THE USB OR THE SOLAR PANEL.

28.2. Solar panel

The solar panel must be connected using the cable supplied.

Both the mini USB connector and the solar panel connector allow only one connection position which must be respected without being forced into the incorrect position. In this way connection polarity is respected.

Solar panels up to **12 V** are allowed. The maximum charging current through the solar panel is **300 mA**.



Solar panel connector

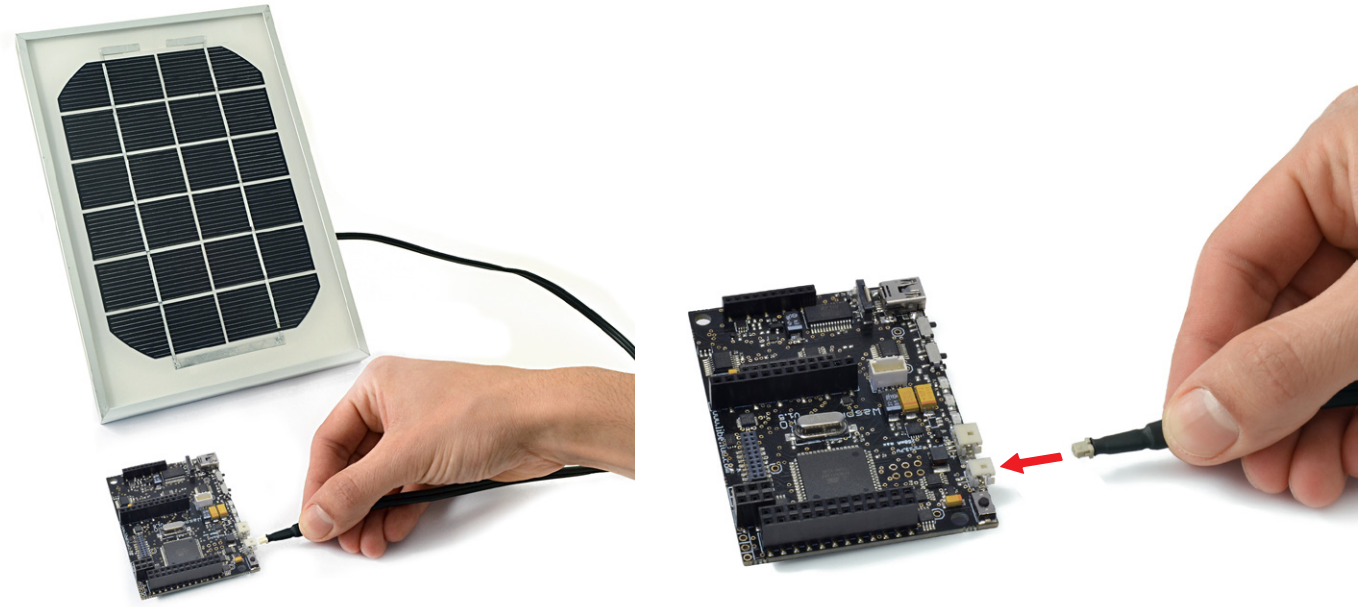


Figure: Solar panel connection

The models supplied by Libelium are shown below:

- **Rigid solar panel**
  - 7 V - 500 mA
  - Dimensions: 234 x 160 x 17 mm

Figure: Rigid solar panel

- **Flexible solar panel**
  - 7.2 V - 100 mA
  - Dimensions: 284 x 97 x 2 mm

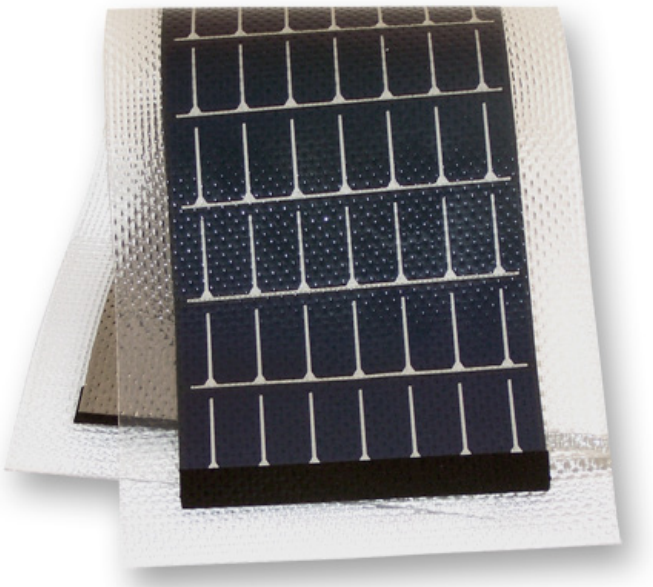


Figure: Flexible solar panel

28.3. USB

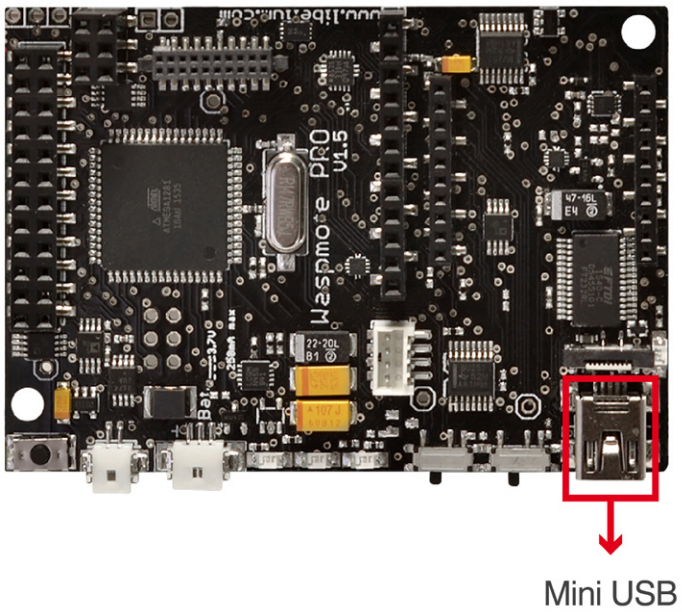


Figure: Mini-USB connector

Waspmote's USB power sources are:

- USB to PC connection
- USB to 220 V connection
- USB to vehicle connector connection

The charging voltage through the USB has to be 5 V.

The maximum charging current through the USB is 480 mA.

The mini USB connector must be standard mini USB model B.

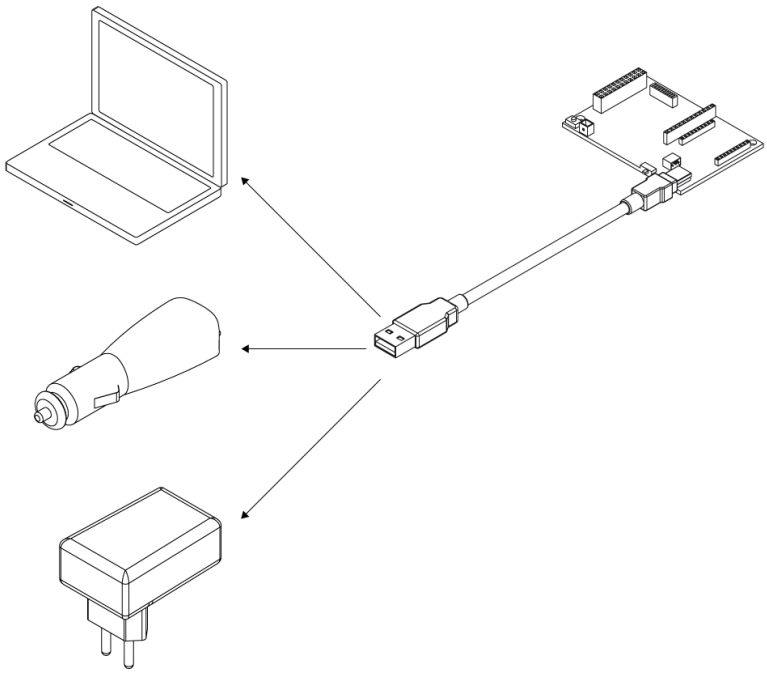


Figure: Possible connections for the USB

The models supplied by Libelium are shown below:

Figure: 220 V AC – USB adapter

Figure: 12 V DC – USB car lighter adapter

29. Working environment

The Integrated Development Environment (IDE) is used for writing the code and uploading it to Waspmote and Plug & Sense!. It is also used to monitor serial output and for debugging. This IDE contains the Waspmote API (the API is the set of all libraries Waspmote needs for compiling programs). New API versions are released instantly by Libelium whenever improvements are made or bugs fixed.

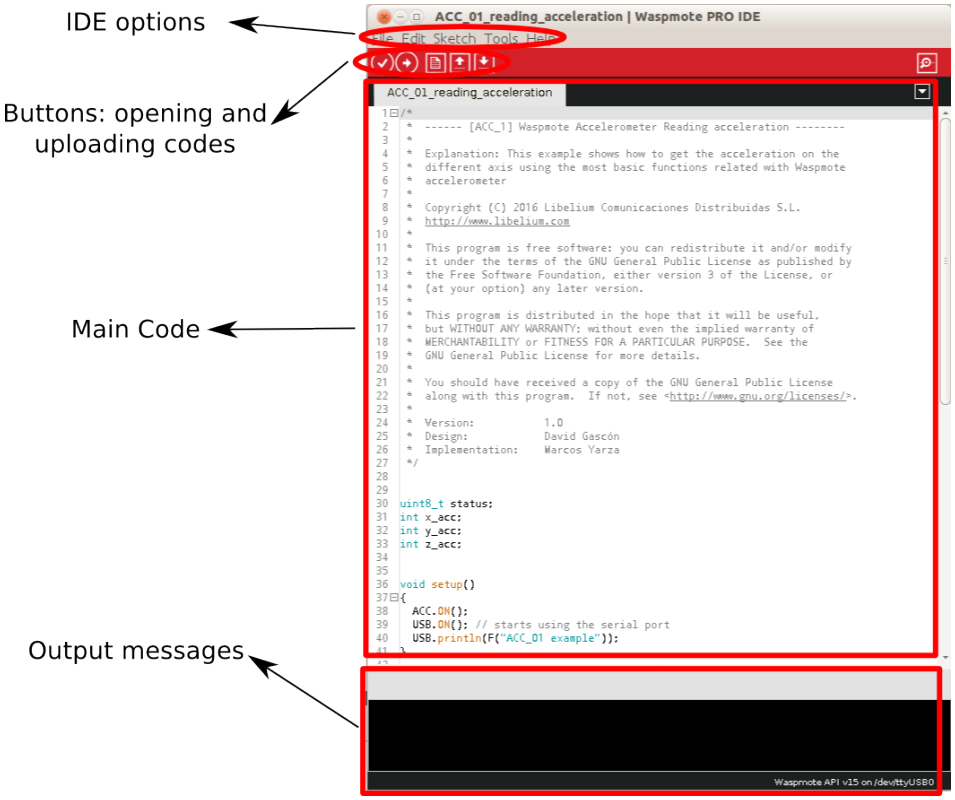


Figure: Waspmote IDE

All information about the IDE installation and operation can be found in the IDE User Guide.

All the documentation is located in the Development section in the Libelium website.

30. Interacting with Waspmote

30.1. Receiving XBee frames with Waspmote Gateway

30.1.1. Waspmote Gateway

This device allows to collect data which flows through the sensor network into a **PC** or device with a standard USB port. Waspmote Gateway will act as a ***"data bridge or access point"*** between the sensor network and the receiving equipment. This receiving equipment will be responsible for storing and using the data received depending on the specific needs of the application.

Figure: Waspmote Gateway

The receiving equipment can be a PC with Linux, Windows or Mac-OS, or any device compatible with standard USB connectivity. The gateway offers a male **USB A** connector, so the receiving device has to have a female USB A connector.

Once the Gateway is correctly installed, a new communication serial port connecting directly to the XBee module's UART appears in the receiving equipment, which allows the XBee to communicate directly with the device, being able to both receive data packets from the sensor network as well as modify and/or consult the XBee's configuration parameters.

Another important function worth pointing out is the possibility of **updating or changing the XBee module's firmware**.

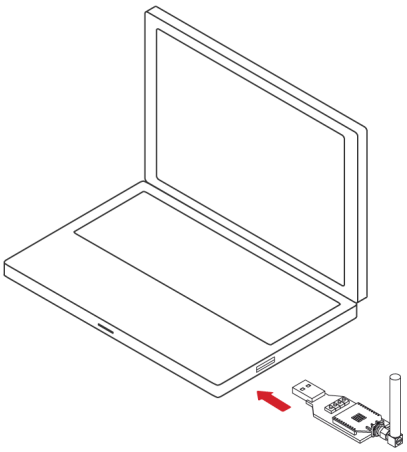


Figure: Waspmote Gateway connected to a PC

LEDs

Four indicator LEDs are included in the Gateway:

- USB power LED: indicates that the board is powered through the USB port
- RX LED: indicates that the board is receiving data from the USB port
- TX LED: Indicates that the board is sending data to the USB port
- I/O 5 configurable LED: associate

The configurable LED connected to the XBee's I/O 5 pin can be configured either as the XBee's digital output or as the XBee's indicator of association to the sensor network.

Buttons

- Reset: allows the XBee module to be reset
- I/O - 0: button connected to the XBee's I/O pin 0
- I/O -1: button connected to the XBee's I/O pin 1
- RTS - I/O – 6: button connected to the XBee's I/O pin 6

All the buttons connect each one of its corresponding data lines with GND with when pressed. None of these have pull-up resistance so it may be necessary to activate any of the XBee's internal pull-up resistances depending on the required use.

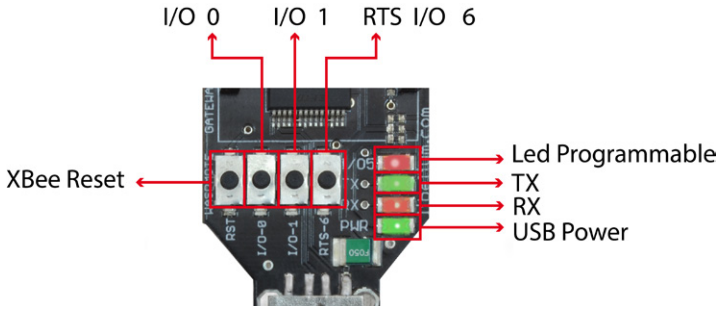


Figure: LEDs in Waspmote Gateway

30.1.2. Linux receiver

When using Linux it is possible to use various applications to capture the input from the serial port. Libelium recommends to use the 'Cutecom' application.

Once the application is launched, the speed and the USB where Waspmote has been connected must be configured.

The speed that must be selected is 115200 bps which is the standard speed set up for Waspmote.

The USB where Waspmote has been connected must be added the first time this application is run, adding USB0, USB1, etc (up to the USB number of each computer) according to where Waspmote has been connected. For this, the 'Device' window must be modified so that if Waspmote is connected to USB0, this window contains '/dev/ttyUSB0'.

Once these parameters are configured, capture is started by pressing the 'Open Device' button.

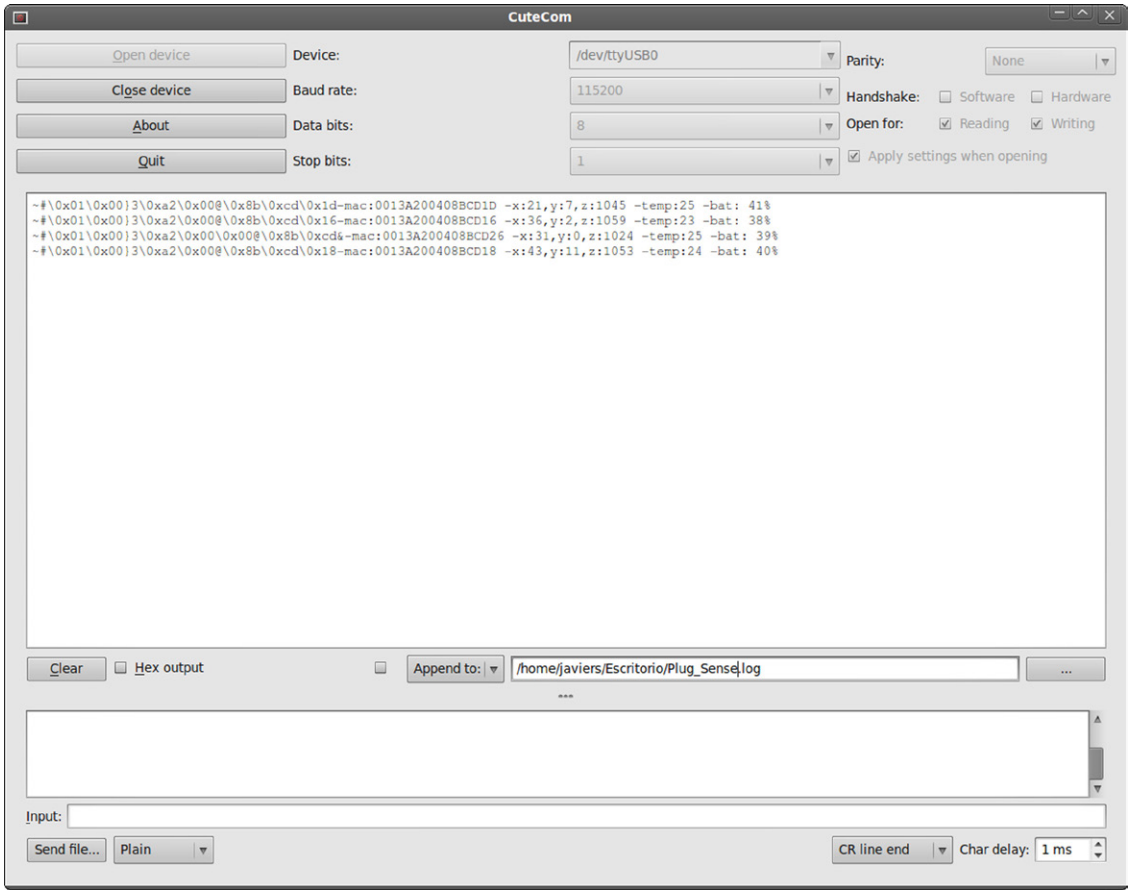


Figure: Cutecom application capturing Waspmote's output

Linux Sniffer

As well as using the terminal to see the sensor information, an application which allows this captured data to be dumped to a file or passed to another program to be used or checked has been developed.

File:
"sniffer.c"

Compilation on Linux:

```
gcc sniffer.c -o sniffer
```

Examples of use:

- Seeing received data: `./sniffer USB0`
- Dumping of received data to a file: `./sniffer USB0 >> data.txt`
- Passing received values to another program: `./sniffer USB0 | program`

Note: *The speed used for the example is 19200 bps. The final speed will depend on the speed the XBee module has been configured with (default value 115200).*

Code:

```
#include   <stdio.h>
#include   <string.h>
#include   <unistd.h>
#include   <fcntl.h>
#include   <errno.h>
```

```
          #include   <stdlib.h>
          #include   <termios.h> /* Terminal control library (POSIX) */

          #define MAX 100

          main(int argc, char *argv[])
          {
            int sd=3;
            char *serialPort="";

char *serialPort0 = "/dev/ttyS0";
char *serialPort1 = "/dev/ttyS1";
char *USBserialPort0 = "/dev/ttyUSB0";
char *USBserialPort1 = "/dev/ttyUSBS1";
char valor[MAX] = "";
char c;
char *val;
struct termios opciones;
int num;
char *s0 = "S0";
char *s1 = "S1";
char *u0 = "USB0";
char *u1 = "USB1";

 if(argc!=2)
  {
    fprintf(stderr,"Usage: %s [port]\nValid ports: (S0, S1, USB0, USB1)\n",argv[0], serial-
Port);
    exit(0);
  }

if (!strcmp(argv[1], s0))
{
  fprintf(stderr,"ttyS0 chosen\n...");
  serialPort = serialPort0;
}
if (!strcmp(argv[1], s1))
{
  fprintf(stderr,"ttyS1 chosen\n...");
  serialPort = serialPort1;
}
if (!strcmp(argv[1], u0))
{
  fprintf(stderr,"ttyUSB0 chosen\n...");
  serialPort = USBserialPort0;
}
if (!strcmp(argv[1], u1))
{
  fprintf(stderr,"ttyUSB1 chosen\n...");
  serialPort=USBserialPort1;
}
if (!strcmp(serialPort, ""))
{
  fprintf(stderr, "Choose a valid port (S0, S1, USB0, USB1)\n", serialPort);
  exit(0);
}

if ((sd = open(serialPort, O_RDWR | O_NOCTTY | O_NDELAY)) == -1)
{
  fprintf(stderr,"Unable to open the serial port %s - \n", serialPort);
  exit(-1);
}
```

```
else
{
  if (!sd)
  {
    sd = open(serialPort, O_RDWR | O_NOCTTY | O_NDELAY);
  }
  //fprintf(stderr,"Serial Port open at: %i\n", sd);
  fcntl(sd, F_SETFL, 0);
}
  tcgetattr(sd, &opciones);
  cfsetispeed(&opciones, B19200);
  cfsetospeed(&opciones, B19200);
  opciones.c_cflag |= (CLOCAL | CREAD);
  /*No parity*/

  opciones.c_cflag &= ~PARENB;
  opciones.c_cflag &= ~CSTOPB;
  opciones.c_cflag &= ~CSIZE;
  opciones.c_cflag |= CS8;
  /*raw input:
  * making the applycation ready to receive*/
  opciones.c_lflag &= ~(ICANON | ECHO | ECHOE | ISIG);
  /*Ignore parity errors*/
  opciones.c_iflag |= ~(INPCK | ISTRIP | PARMRK);
  opciones.c_iflag |= IGNPAR;
  opciones.c_iflag &= ~(IXON | IXOFF | IXANY | IGNCR | IGNBRK);
  opciones.c_iflag |= BRKINT;
  /*raw output
  * making the applycation ready to transmit*/
  opciones.c_oflag &= ~OPOST;
  /*aply*/
  tcsetattr(sd, TCSANOW, &opciones);
  int j = 0;
  while(1)
  {
    read(sd, &c, 1);
    valor[j] = c;
    j++;

    // We start filling the string until the end of line char arrives
    // or we reach the end of the string. Then we write it on the screen.

    if ((c=='\n') || (j==(MAX-1)))
    {
      int x;
      for (x=0; x<j; x++)
      {
        write(2, &valor[x], 1);
        valor[x] = '\0';
      }
      j = 0;
    }
  }
  close(sd);
}
```

The code can be downloaded from: http://www.libelium.com/development/waspmote

30.1.3. Windows receiver

If Windows is used, the application 'Hyperterminal' can be used to capture the output of the serial port.

This application can be found installed by default in 'Start/Programs/Accessories/Communication', but if it is not available it can be downloaded from: http://hyperterminal-private-edition-htpe.en.softonic.com/

Once this application is launched the connection must be configured. The first step is to give it a name:

Figure: Step 1 of establishing connection

The next step is to specify the port on which Waspmote has been connected, in this case the system recognizes it as 'COM9', (this will vary on each computer):

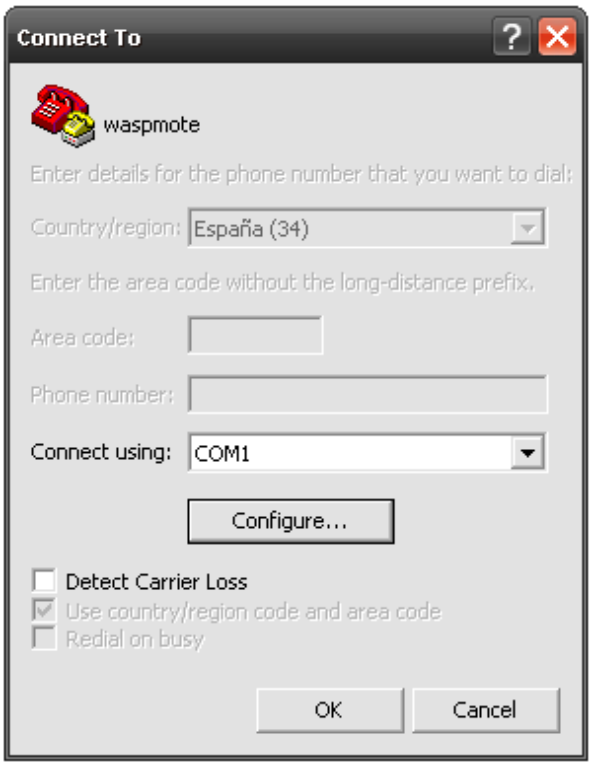


Figure: Step 2 of establishing connection

The next step is to specify the speed and configuration parameters:

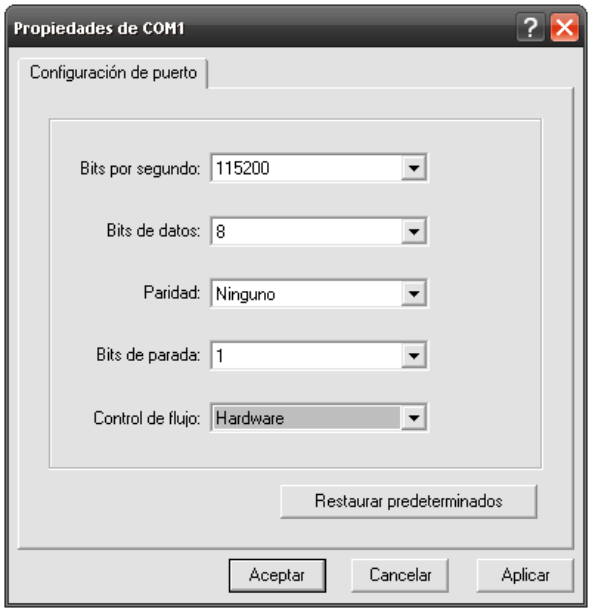


Figure: Step 3 of establishing connection

Once these steps have been performed connection with Waspmote has been established, and listening to the serial port begins.

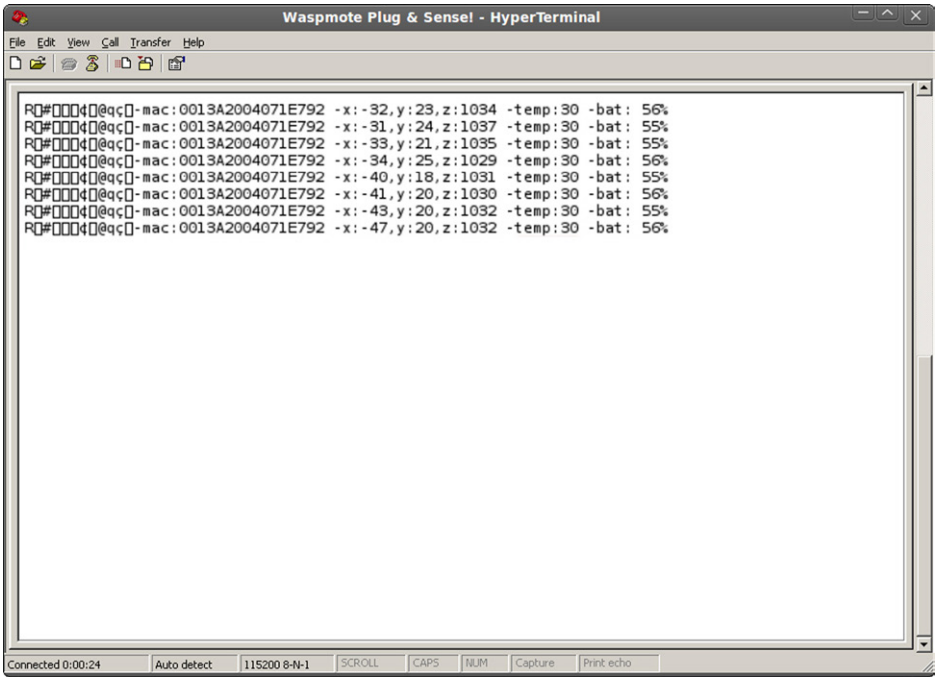


Figure: HyperTerminal application capturing Waspmote's output.

30.1.4. Mac-OS receiver

If Mac OS X is used (version later than 10.3.9) the application 'ZTERM' can be used to capture the serial port output. This application can be downloaded from: http://homepage.mac.com/dalverson/zterm/

This application is configured automatically, establishing the USB on which Waspmote has been connected and the speed.

The following image shows this application capturing Waspmote's output, while the example code 'Waspmote Accelerator Basic Example' is run.

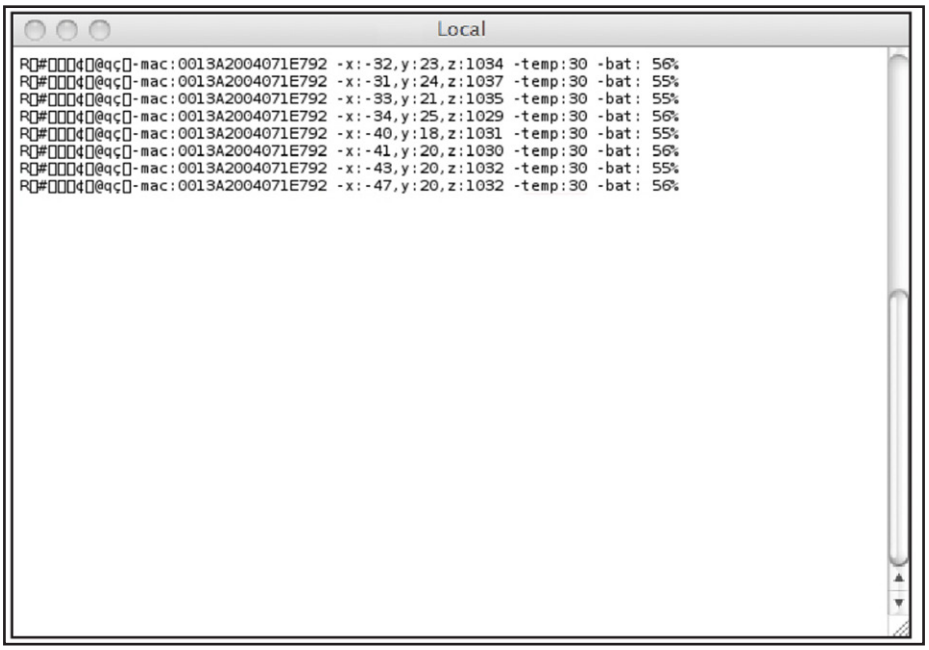


Figure: Waspmote's output capture

31. Meshlium - The IoT Gateway

Figure: Meshlium device

The sensor data gathered by the Waspmote Plug & Sense! nodes is sent to the Cloud by Meshlium, the IoT gateway router specially designed to connect Waspmote sensor networks to the Internet via Ethernet and 4G/3G/2G interfaces.

Meshlium can work as:

- an RF (XBee) to Ethernet router for Waspmote nodes*
- an RF (XBee) to 4G/3G/GPRS/GSM router for Waspmote nodes*
- a WiFi Access Point
- a WiFi to 4G/3G/GPRS/GSM router
- a GPS – 4G/3G/GPRS/GSM real-time tracker
- a smartphone scanner (detects iPhone and Android devices)

31.1. Meshlium Storage Options

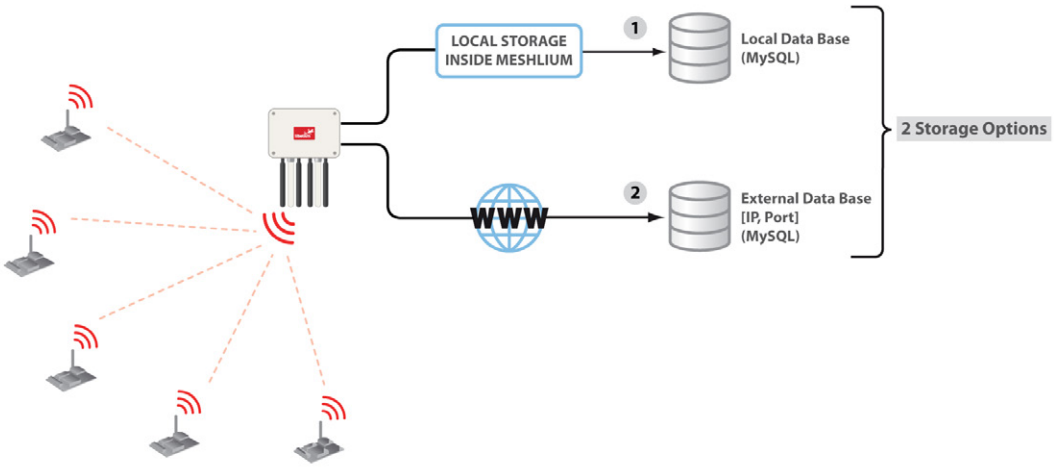


Figure: Meshlium storage options

- Local data base
- External data base

31.2. Meshlium connection options

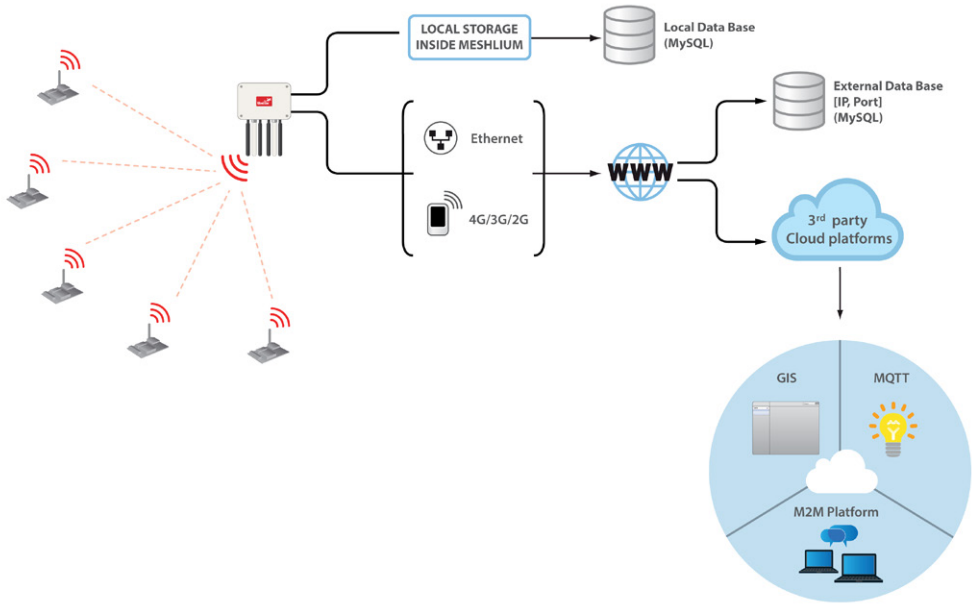


Figure: Meshlium connection options

- XBee / 4G / 3G / 2G / WiFi → Ethernet
- XBee / 4G / 3G / 2G / WiFi → 4G / 3G / 2G

All the networking options can be controlled from the **Manager System**, a web interface which comes with Meshlium. It allows to control all the interfaces and system options in a secure, easy and quick way.

Figure: Meshlium Manager System

All information about Meshlium can be found in the Meshlium Technical Guide.

All the Meshlium documentation is located in the Development section in the Libelium website.

31.3. Meshlium Visualizer

Meshlium Visualizer is a plugin which plots graphs and maps with the data stored in the database. It can also export data in common formats. Meshlium Visualizer is a special software feature only available in the Meshlium units included in the IoT Vertical Kits (Smart Cities IoT Vertical Kit, Smart Water IoT Vertical Kit, etc).

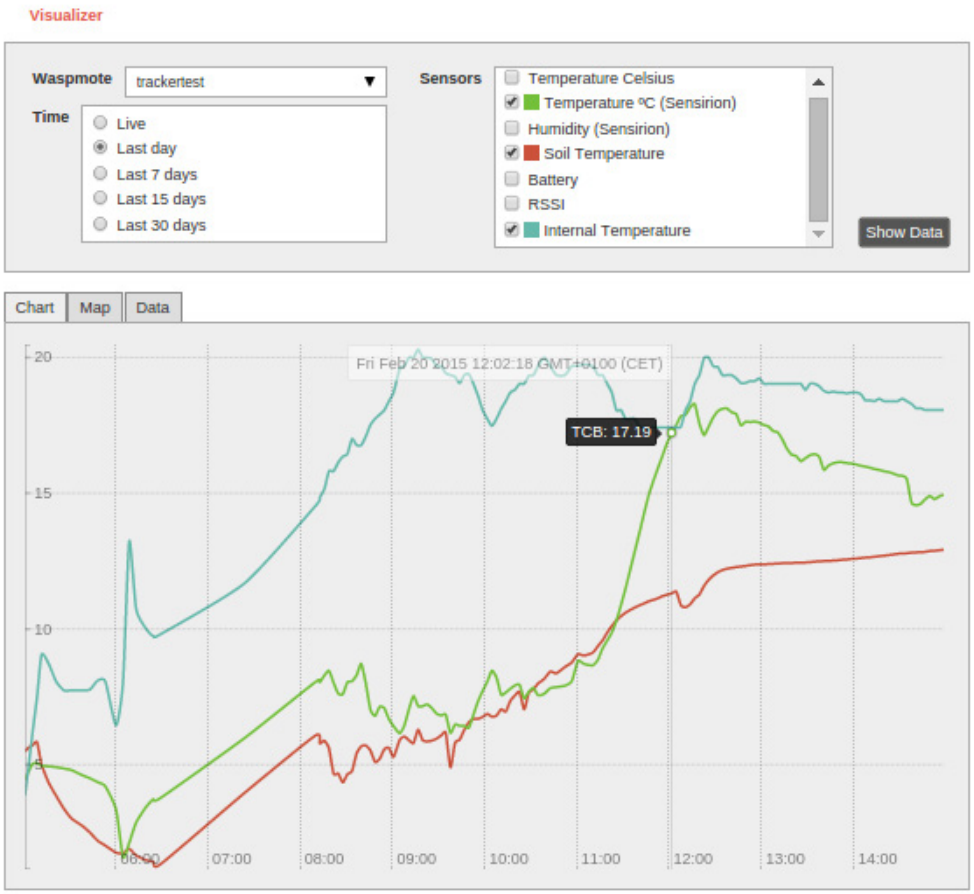


Figure: Meshlium visualizer

31.4. Cloud Connectors

Meshlium allows developers to connect easily with third party cloud servers such as Amazon, IBM, Telefónica, ESRI, Thingworks, etc. Just select the desired plugin in the Manager System and add the account info to synchronize the internal data base of Meshlium with the desired platform.

For more info about Meshlium go to:
http://www.libelium.com/products/meshlium/

32. Certifications

Libelium offers 2 types of IoT sensor platforms, Waspmote OEM and Plug & Sense!:

- **Waspmote OEM** is intended to be used for research purposes or as part of a major product so it needs final certification on the client side. More info at: www.libelium.com/products/waspmote
- **Plug & Sense!** is the line ready to be used out-of-the-box. It includes market certifications. See below the specific list of regulations passed. More info at: www.libelium.com/products/plug-sense

Besides, Meshlium, our multiprotocol router for the IoT, is also certified with the certifications below. Get more info at:

www.libelium.com/products/meshlium

List of certifications for Plug & Sense! and Meshlium:

- CE (Europe)
- FCC (US)
- IC (Canada)
- ANATEL (Brazil)
- RCM (Australia)
- PTCRB (cellular certification for the US)
- AT&T (cellular certification for the US)

Figure: Certifications of the Plug & Sense! product line

You can find all the certification documents at:

www.libelium.com/certifications

33. Maintenance

- In this section, the term “Waspmote” encompasses both the Waspmote device itself as well as its modules and sensor boards.
- Take care when handling Waspmote, do not let it fall, knock it or move it suddenly.
- Avoid having the devices in high temperature areas as it could damage the electronic components.
- The antennas should be connected carefully. Do not force them when fitting them as the connectors could be damaged.
- Do not use any type of paint on the device, it could harm the operation of the connections and closing mechanisms.

34. Disposal and recycling

- In this section, the term “Waspmote” encompasses both the Waspmote device itself as well as its modules and sensor boards.
- When Waspmote reaches the end of its useful life, it must be taken to an electronic equipment recycling point.
- The equipment must be disposed of in a selective waste collection system, and not that for urban solid residue. Please manage its disposal properly.
- Your distributor will inform you about the most appropriate and environmentally friendly disposal process for the used product and its packaging.

35. Documentation changelog

From v7.4 to v7.5

- Changed specifications of the SD card, now 8 GB
- Changed description of the new External SIM/USB Socket version for Plug & Sense!, now nano-SIM compliant
- Deleted references to the discontinued Internal Solar Panel in Plug & Sense!

From v7.3 to v7.4

- Added references to the Programming Cloud Service for Plug & Sense!

From v7.2 to v7.3

- Added references to the External Battery Module for Plug & Sense!
- The operating temperature range and maximum recharging current were updated
- Added notes about batteries

From v7.1 to v7.2:

- Added references to the GPS module
- Gases PRO sensors information was upgraded
- Added references to the discontinuation of Smart Environment
- Deleted references to the 13 and 26 A·h non-rechargeable batteries
- Warning about the use of non-rechargeable batteries was modified

From v7.0 to v7.1:

- Added references to the integration of Industrial Protocols for Plug & Sense!