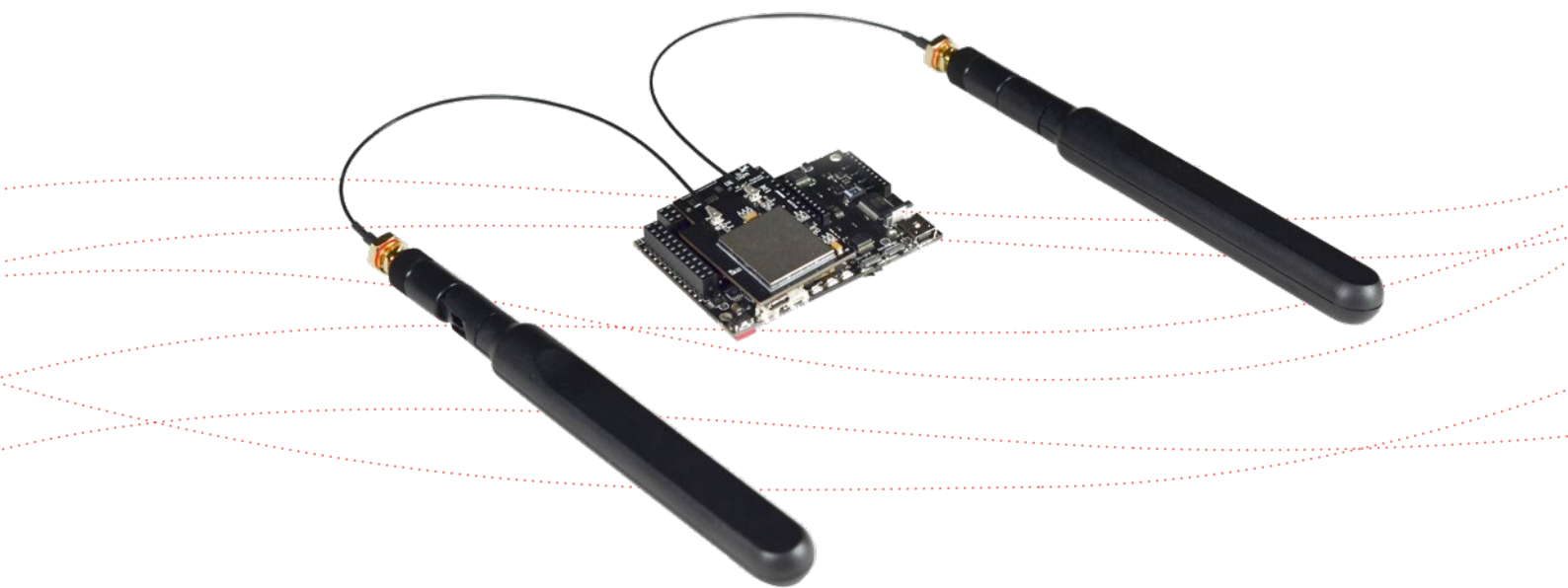
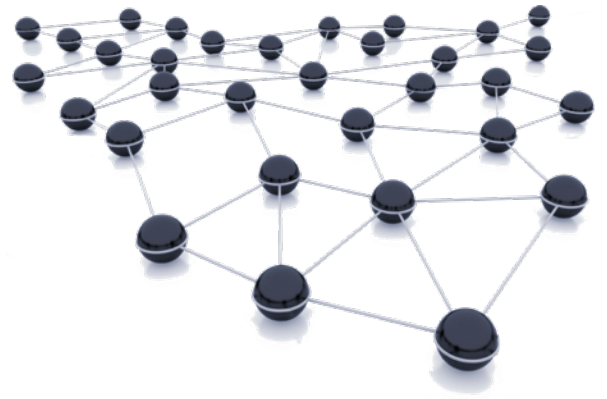


# NB-IoT / Cat-M Module

## Networking Guide



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# 1. Introduction

Due to the popularity of Low Power Wide Area Networks (LPWAN) such as LoRaWAN or Sigfox in the IoT industry, the traditional cellular networks like 4G has been ousted as the best choice, specially when low cost, low power consumption and long range are key characteristics. As a response to this market demand, the 3GPP association published 2 cellular narrow band IoT standards in the release 13: NB-IoT (“narrow band for the Internet of Things”) and Cat-M (“category machine”). They are also known as LTE Cat-NB1 and LTE Cat-M1. Libelium has integrated the BG96 chipset by Quectel to meet this requirement.

This module has been included in the Waspote ecosystem as an OEM development kit, where the NB-IoT and the Cat-M connectivities can be easily tested in pilot projects or proof of concepts applications.

The NB-IoT / Cat-M module also includes EGPRS connectivity, allowing to transmit information even if there is no coverage for NB-IoT or Cat-M and also maintaining ultra-low power consumption. Besides, the most common Internet protocols like HTTP(S), FTP(S), SSL, TCP or UDP are supported.

Moreover, the module integrates a GNSS engine supporting GPS, BeiDou, Galileo, GLONASS and QZSS systems, making it suitable for tracking applications where low cost and accurate positioning is needed.

Designed to be plugged on the socket1 of Waspote, the module can meet almost all requirements for IoT applications like smart cities, remote monitoring, smart logistics, real-time tracking, etc. Additionally, the NB-IoT / Cat-M module has a unique global version, allowing the usage all over the world with no fragmentation.

Like other radio modules, Libelium provides a dedicated library for Waspote and some example codes, which speed up the testing for the NB-IoT or the Cat-M connectivity with just a few high-level functions, and without dealing with large amounts of AT commands. Thus, the development of pilot projects and proof of concepts becomes easy.

**Note:** It is important to remark that the NB-IoT or Cat-M connectivities require a dedicated SIM card (not included by default). With a standard SIM card, only the EGPRS connectivity can be tested. Besides, the network coverage is only present in certain zones and strongly depends on the selected mobile network operator. It is recommended to check operators coverage in the location where the module will be used.

## 1.1. NB-IoT vs Cat-M

Despite both connectivities are available on the NB-IoT / Cat-M module, there are a few differences to be mentioned.

While Cat-M allows one of the highest bandwidth of the LPWAN technologies, NB-IoT is focused only for low data rate applications, being a great choice for single sensor applications. Also, Cat-M can support voice applications, while NB-IoT does not.

An advantage of Cat-M is that is compatible with the existing LTE network and that avoids operators to spend money building new antennas because just a software update is needed. On the other hand, NB-IoT is not compatible with the LTE network and it would require higher costs for operators to deploy a NB-IoT network. Despite of this fact, there are a lot of operators that are actively researching and making efforts to commercialize NB-IoT.

On the other hand, NB-IoT has a great advantage against Cat-M on indoor coverage due to its bigger sensitivity, reaching very good levels even inside basements and large buildings.

Recently, the 3GPP association has published the release 14, where the standards LTE Cat NB2 and LTE Cat M2 has been defined. However, the market will have to wait till they are available for commercialize.

### **Important:**

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## 2. Hardware

### 2.1. Specifications

The NB-IoT / Cat-M module is based on the Quectel's BG96 chipset. The module is managed by UART and it must be connected to socket 1 (direct connection, without Waspote Expansion Board).

**Model:** BG96 (Quectel)

**Frequency bands:**

- Cat NB1 / Cat M1: LTE FDD: B1/B2/B3/B4/B5/B8/B12/B13/B18/ B19/B20/B25\*\*/B26\*/B28
- LTE TDD: B39 (for Cat-M1 only)
- EGPRS: 850/900/1800/1900 MHz

**Data:**

- Cat-NB1: Max. 32 kbps (DL), Max. 70 kbps (UL)
- Cat-M1: Max. 375 kbps (DL), Max. 375 kbps (UL)
- EDGE: Max. 296 kbps (DL), Max. 236.8 kbps (UL)
- GPRS: Max. 107 kbps (DL), Max. 85.6 kbps (UL)

**SMS:**

- Point-to-point MO and MT
- SMS Cell Broadcast
- Text and PDU Mode

**GNSS:**

Embedded GNSS as optional. Supports GPS, GLONASS, BeiDou/Compass, Galileo and QZSS.

**Antenna connectors:**

- U.FL for main antenna (cellular)
- U.FL for GNSS antenna

**External antenna:** 5 dBi

**Sensitivity:**

- -113 dBm @Cat NB1, CE Level 0
- -107 dBm @Cat M1, 1.4 MHz Bandwidth, CE Mode A

**SIM size:** Nano-SIM (4FF standard) (not included)

**Protocols:**

PPP/TCP/UDP/SSL/TLS/FTP(S)/HTTP(S)/NITZ/ PING/MQTT

**Actions:**

- Sending/receiving SMS
- TCP/IP and UDP/IP clients
- HTTP and HTTPS service (fully secured comms)

**Certifications:**

- GCF/Vodafone (Global)
- CE/Deutsche Telekom (Europe)
- FCC/PTCRB/AT&T/Verizon/T-Mobile\*/Sprint\* (North America)
- RCM/Telstra (Australia)
- IC/Telus/Bell\* (Canada)
- Telefónica (Spain)
- JATE/TELEC/KDDI/SoftBank/DOCOMO\* (Japan)
- KC/SKT/LGU+\* (Korea)
- IFETEL (Mexico)
- IMDA (Singapore)
- NCC (Taiwan)
- CCC (China)

\* Under Development

\*\*LTE B25 will be supported on BG96 with R1.2 hardware version.

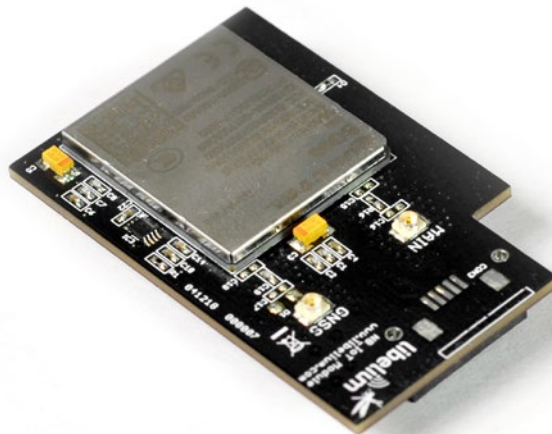
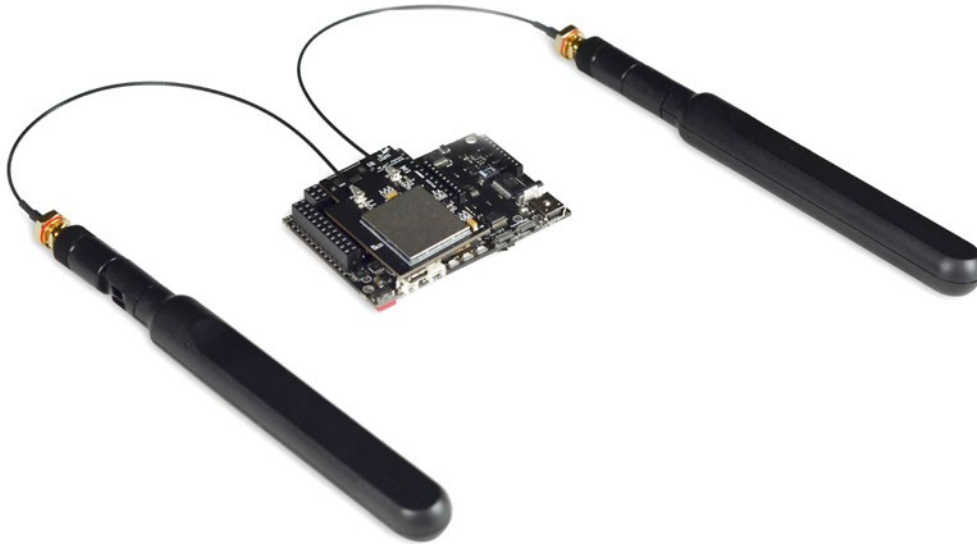


Figure: NB-IoT / Cat-M module

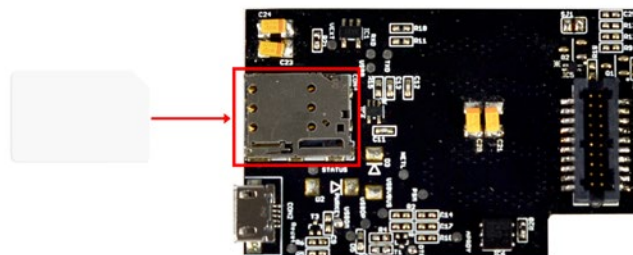
## 2.2. How to connect the module

This module must be connected directly to the SOCKET1 on the Waspote board. This radio does not need the Expansion Radio Board.



*Figure: Module connected to Waspote in SOCKET1*

The SIM card size used in the NB-IoT / Cat-M module is **nano-SIM**. The next picture shows how the nano-SIM card must be plugged in the module.



*Figure: SIM card installation in OEM version*



## 2.3. Antennas

The NB-IoT / Cat-M module comes with one cellular antenna for improving the signal reception. Besides, a GNSS antenna is also included for the GNSS receiver.

Both antennas are the same model and can be used in any of the 2 antenna connectors. The module's silkscreen identifies the connectors. The operating bands of the dipole antenna go from 698 to 960 MHz and from 1710 to 2690 MHz. The maximum gain of the antenna is observed at 2.6 GHz: 3.4 dBi.

To get the maximum performance, it is recommended to place the antennas like that:

- The main cellular antenna should be in vertical position, pointing to the sky, in order to radiate better to the cellular base stations around.
- The GPS antenna should be in horizontal position, because the GPS satellite signal will come from above.



Figure: NB-IoT / Cat-M module antennas

## 3. Software

### 3.1. Wasmote library

#### 3.1.1. Wasmote NB-IoT / Cat-M library

The files related to the NB-IoT / Cat-M module library are:

- /BG96/WaspBG96.h
- /BG96/WaspBG96.cpp

It is mandatory to include the NB-IoT / Cat-M library when using this module. So the following line must be added at the beginning of the code:

```
#include <WaspBG96.h>
```

#### 3.1.2. Class constructor

To start using the Wasmote NB-IoT / Cat-M library, an object from the [WaspBG96](#) class must be created. This object, called [BG96](#), is already created by default inside the Wasmote NB-IoT / Cat-M library. It will be used along this guide to show how Wasmote works.

When using the class constructor, all variables are initialized to their default values.

#### 3.1.3. API functions

Through this guide there are lots of examples, showing the use of functions. In these examples, API functions are called to execute the commands, storing in their related variables the parameter value in each case. The functions are called using the predefined object [BG96](#).

All public functions return different possible values:

- 0: OK
- Otherwise: ERROR. See corresponding function error code

## 3.2. Switching on

The `ON()` function switches on the NB-IoT / Cat-M module and it opens the MCU's UART bus for communicating with the module. After this step, the module will be able to receive commands to manage it.

Example of use:

```
{  
    BG96.ON();  
}
```

## 3.3. Switching off

The `OFF()` function allows the user to switch off the NB-IoT / Cat-M module and close the UART. This function must be called in order to save battery when the module is not going to be used.

Example of use:

```
{  
    BG96.OFF();  
}
```

## 3.4. SIM card

### 3.4.1. Entering PIN

The `enterPIN()` function allows the user to enter the PIN (Personal Identification Number) of the SIM (Subscriber Identification Module) card. If the SIM card has no PIN (or the PIN was disabled on the SIM card), it is not necessary to use this function.

Example for entering the PIN:

```
{
    BG96.enterPIN("1234");
}
```

Besides, there is another function prototype in order to set a new one. It is mandatory to specify the current PIN number and the new one.

Example for setting a new PIN:

```
{
    BG96.enterPIN("1234", "1111");
}
```

Example of entering the PIN number:

[www.libelium.com/development/waspmote/examples/nb-iot-01-enter-pin-code](http://www.libelium.com/development/waspmote/examples/nb-iot-01-enter-pin-code)

### 3.4.2. Getting module information

The `getInfo()` function can get more than one information field to the module. This function needs one input to indicate the type of information requested. The resulting information is stored in `_buffer`, and `_length` is the number of bytes in the buffer. The information possibilities are:

- `WaspBG96::INFO_HW`: To request the hardware revision
- `WaspBG96::INFO_MANUFACTURER_ID`: To request the manufacturer identifier
- `WaspBG96::INFO_MODEL_ID`: To request the model identifier
- `WaspBG96::INFO_REV_ID`: To request the firmware revision
- `WaspBG96::INFO_IMEI`: To request the IMEI (International Mobile Station Equipment Identity), which is the unique identifier of the module, similar to a MAC address
- `WaspBG96::INFO_IMSI`: To request the IMSI
- `WaspBG96::INFO_ICCID`: To request the ICCID

Examples of use:

```
{
    // get IMEI number
    BG96.getInfo(WaspBG96::INFO_HW);

    // get IMSI number
    BG96.getInfo(WaspBG96::INFO_IMSI);

    // get ICCID number
    BG96.getInfo(WaspBG96::INFO_ICCID);
}
```

Related variables:

`BG96._buffer` → Buffer which stores the information requested

`BG96._length` → Number of bytes in buffer

Example of getting module info:

[www.libelium.com/development/waspmote/examples/nb-iot-02-get-module-info](http://www.libelium.com/development/waspmote/examples/nb-iot-02-get-module-info)

## 3.5. Setting operator parameters

When the NB-IoT / Cat-M module uses data services like TCP/UDP connections, HTTP services, SMTP or FTP transfers, it is mandatory to configure the parameters provided by the user's Mobile Network Operator (MNO): APN, login and password. The owner of a SIM should be notified with these parameters by the MNO.

The `set_APN()` function allows the user to save these parameters into Waspote memory. Later, when data connection functions are called, Waspote will configure these parameters into the NB-IoT / Cat-M module.

Example of use:

```
{
    BG96.set_APN("apn", "login", "password");
}
```

The `show_APN()` function allows the user to display the current settings stored in Waspote's memory which are used by the libraries when data connections are performed.

Example of use:

```
{
    BG96.show_APN();
}
```

Related variables:

`BG96._apn` → Stores the APN name

`BG96._apn_login` → Stores the APN login

`BG96._apn_password` → Stores the APN password

## 3.6. Checking network connection status

There are 2 functions to check the network connection status: `checkConnection()` and `checkDataConnection()`.

The `checkConnection()` function checks the module's network connection status and returns whether the module:

- is connected to a network
- is not connected to a network
- is searching for a new operator to register to
- registration was denied

This function will wait for the module to be connected to a network for the specified time in second units.

Example of use:

```
{
    BG96.checkConnection(60);
}
```

Possible error codes for this function:

- 1: not registered, the Mobile Equipment (ME) is not currently searching for a new operator to register to
- 2: not registered, but ME is currently searching for a new operator to register to
- 3: registration denied
- 4: unknown

The `checkDataConnection()` function checks the module's network connection status, connects the module to data service and returns whether the module:

- is connected to data service
- is not connected to a network
- is searching for a new operator to register to
- registration was denied

This function will wait for the module to be connected to a network for the specified time in second units.

Example of use:

```
{
    BG96.checkDataConnection(60);
}
```

Possible error codes for this function:

- 1: not registered, ME is not currently searching for a new operator to register to
- 2: not registered, but ME is currently searching for a new operator to register to
- 3: registration denied
- 4: unknown
- 6: not registered, ME is not currently searching for a new operator to register to
- 8: not registered, but ME is currently searching for a new operator to register to
- 9: registration denied

- 10: unknown
- 12: if error setting APN
- 13: if error setting login
- 14: if error setting password
- 15: if error activating GPRS connection

Example of getting network information:

[www.libelium.com/development/waspmote/examples/nb-iot-03-get-network-info](http://www.libelium.com/development/waspmote/examples/nb-iot-03-get-network-info)

## 3.7. Basic network connection to NB-IoT

To demonstrate a basic connection through the NB-IoT network, the 1st step is to configure the connection using the function `nbiotConnection()`. The APN, the desired band and the network operator should be provided as arguments. Each band has been defined as a constant in the header file.

Then, use the `contextActivation()` function to connect the network.

Example of basic NB-IoT connection:

[www.libelium.com/development/waspmote/examples/nb-iot-04a-basic-connection-nb-iot](http://www.libelium.com/development/waspmote/examples/nb-iot-04a-basic-connection-nb-iot)

## 3.8. Basic network connection to Cat-M

In the same way as for NB-IoT connection, to demonstrate a basic connection through the Cat-M network, the 1st step is to configure the connection with `lteM1Connection()` function and then connect with `contextActivation()`.

Example of basic Cat-M connection:

[www.libelium.com/development/waspmote/examples/nb-iot-04b-basic-connection-cat-m](http://www.libelium.com/development/waspmote/examples/nb-iot-04b-basic-connection-cat-m)

## 3.9. Basic network connection to EGPRS

Moreover, the EGPRS link can be also tested with `GPRSConnection()` function.

Example of basic EGPRS connection:

[www.libelium.com/development/waspmote/examples/nb-iot-04c-basic-connection-egprs](http://www.libelium.com/development/waspmote/examples/nb-iot-04c-basic-connection-egprs)



## 3.10. HTTP client

### 3.10.1. HTTP connections

HTTP is a great protocol because it is a standard, simple and light way to send information to web servers.

Libelium has created a little web service in order to allow 4G, 3G, GPRS, GPRS+GPS, NB-IoT / Cat-M or WiFi modules to test the HTTP mode. This web service is a little code, written in PHP, which is continuously listening to the HTTP port (port number 80) of our test server "pruebas.libelium.com". This is a kind of RESTful service. These communication modules can send HTTP instances to our web service.

HTTP instances should have the following structures so that our web service can understand.

#### GET method

In GET method the data are sent to the server append to the main URL with the '?' character. The base sentence to perform GET method is shown below:

```
pruebas.libelium.com/getpost_frame_parser.php?<variable1=value1>&<variable2=value2>&<...>&view=html
```

Where:

- `getpost_frame_parser.php?`: It is the main URL, where the web service is running.
- `<variable1=value1>`: It is a couple with the variable name and value which we want the web service to parse.
- `view=html`: It is an optional argument. It shows a "pretty" response (HTML formatted).

All arguments must be separated by "&". The variable name and value must be separated by "=".

Some examples:

```
pruebas.libelium.com/getpost_frame_parser.php?var1=3.1415
pruebas.libelium.com/getpost_frame_parser.php?var1=3.1415&view=html
pruebas.libelium.com/getpost_frame_parser.php?var1=3.1415&var2=123456&var3=hello&view=html
```

#### POST method

Unlike GET method, with POST method the data are sent to the server into an extra data field. The URL only includes the site name and the PHP direction:

```
pruebas.libelium.com/getpost_frame_parser.php
```

The data field is very similar as the used in GET method:

```
<variable1=value1>&<variable2=value2>&<...>&view=html
```

Where:

`<variable1=value1>`: It is a couple with the variable name and value which we want the web service to parse.

All arguments must be separated by "&". The variable name and value must be separated by "=".

Some examples of data field:

```
pruebas.libelium.com/getpost_frame_parser.php?variable1=3.141592
pruebas.libelium.com/getpost_frame_parser.php?var1=3.1415&var2=123456&var3=hello
```

## Server response

If the web service receives one instance with the appropriate format, some actions will happen:

- The web service grabs the string and parses it. So the PHP code creates couples with the variables name and value.
- The web service responses to the sender device (to the sender IP) with an HTML-formatted reply.



*Figure: Operating with the web service from a PC browser*

Remember this PHP code is really simple and is offered with the only purpose of testing, **without any warranty**. The source code is available here:

[downloads.libelium.com/waspmote-html-get-post-php-parser-tester.zip](https://downloads.libelium.com/waspmote-html-get-post-php-parser-tester.zip)

The user may find it interesting to copy this code and make it run on his own server (physical or virtual). If the user wants to go further, he can complete the code. For example, once the couples are parsed, the user can modify the PHP to save data into a txt file, or insert couples into a database, or include a timestamp...

### 3.10.2. HTTP request methods

The `http()` function configures HTTP parameters, performs the request selected by the user and handles the data returned from the server.

This function needs several parameters to work properly depending on the method used. The 1st parameter required by the function is the request method. User can choose among 5 methods: GET, HEAD, DELETE, POST and PUT:

```
WaspBG96::HTTP_GET
WaspBG96::HTTP_HEAD
WaspBG96::HTTP_DELETE
WaspBG96::HTTP_POST
WaspBG96::HTTP_PUT
```

After choosing the method, the function needs the host URL, port and resource of the HTTP server requested. The data field is only necessary when POST or PUT methods are performed.

Example of use (GET, HEAD and DELETE methods):

```
{
    char host[] = "test.libelium.com";
    uint16_t port = 80;
    char resource[] = "/test-get-post.php?varA=1&varB=2&varC=3&varD=4";

    BG96.http(WaspBG96::HTTP_GET, host, port, resource);
}
```

Example of use (POST and PUT methods):

```
{
    char host[] = "test.libelium.com";
    uint16_t port = 80;
    char resource[] = "/test-get-post.php";
    char data[] = "varA=1&varB=2&varC=3&varD=4&varE=5";

    BG96.http(WaspBG96::HTTP_POST, host, port, resource, data);
}
```

Once the request has been sent, the function waits for data from the server and stores it in `_buffer`. It also stores the HTTP status code from the server in `_httpCode`.

Related variables:

`BG96._httpCode` → Stores the HTTP code from the server

`BG96._buffer` → Stores data received from server

`BG96._length` → Stores data length

Example of HTTP GET:

[www.libelium.com/development/waspmote/examples/nb-iot-06-http-get](http://www.libelium.com/development/waspmote/examples/nb-iot-06-http-get)

Example of HTTP POST:

[www.libelium.com/development/waspmote/examples/nb-iot-07-http-post](http://www.libelium.com/development/waspmote/examples/nb-iot-07-http-post)

### 3.10.3. Sending Wasp mote frames to Meshlium via HTTP

Since Meshlium Manager System v4.0.9, HTTPS method is the default method for sending data. HTTPS is the recommended technology because it provides many cyber security services. Therefore, the HTTPS service is always enabled on Meshlium.

However, Meshlium Manager System v4.1.0 and greater versions allow the user to **enable the HTTP** service in order to be able to receive HTTP non-secure requests. The user must go to: Manager System → System → Security → HTTP Service:

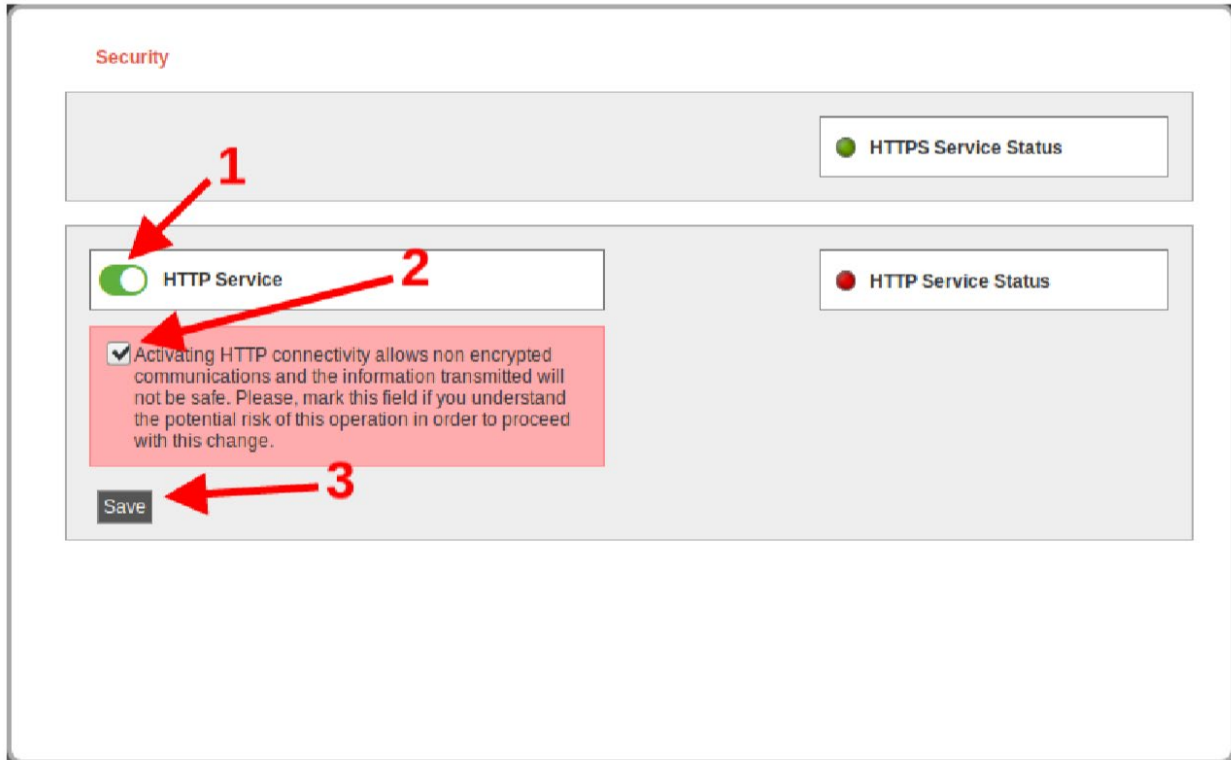


Figure: Enable HTTP service in Meshlium Manager System

The `sendFrameToMeshlium()` function has been developed to send Wasp mote frames from Wasp mote to Meshlium via non-secure HTTP request. Meshlium will parse (chop) the frame and will store it in its internal MySQL database. This function requires the following parameters:

- Meshlium's IP address
- Meshlium's remote port
- Data to send: `frame.buffer` will be used from the generated frame
- Data length: `frame.length` will be used from the generated frame

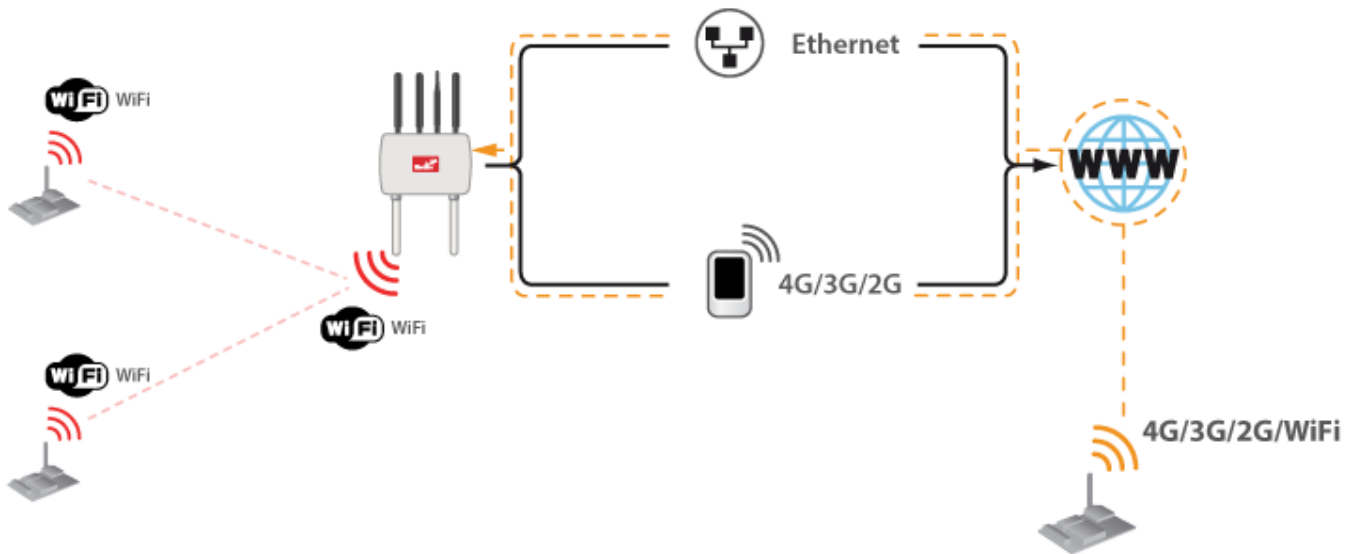


Figure: Send frames to Meshlium via NB-IoT

After calling the function, the response from Meshlium will be stored in `_buffer`. Besides, it will store the HTTP status code from server in `_httpCode`. Please refer to the [Data Frame Guide](#) in order to know more about how to create sensor frames with Waspmote libraries.

Example of use:

```
{
    char host[] = "pruebas.libelium.com";
    uint16_t port = 80;

    // after frame has been created
    BG96.sendFrameToMeshlium(host, port, frame.buffer, frame.length);
}
```

Related variables:

`BG96._http` → Code Stores the HTTP code from the server

`BG96._buffer` → Stores data received from server

`BG96._length` → Stores data length

`frame.buffer` → Stores data frame that will be sent to Meshlium

`frame.length` → Stores data frame length

### 3.10.4. Sending Wasmote frames to Meshlium via HTTPS

Since Meshlium Manager System v4.0.9, HTTPS is the default method for sending data.

For **HTTPS**, the user must keep in mind that the Meshlium's certificate has to be installed in the Wasmote or Plug & Sense! radio prior to opening secure connections. The next picture shows how the user can download the Meshlium's **certificate** from Manager System → System → Users Manager → Download Certificate:

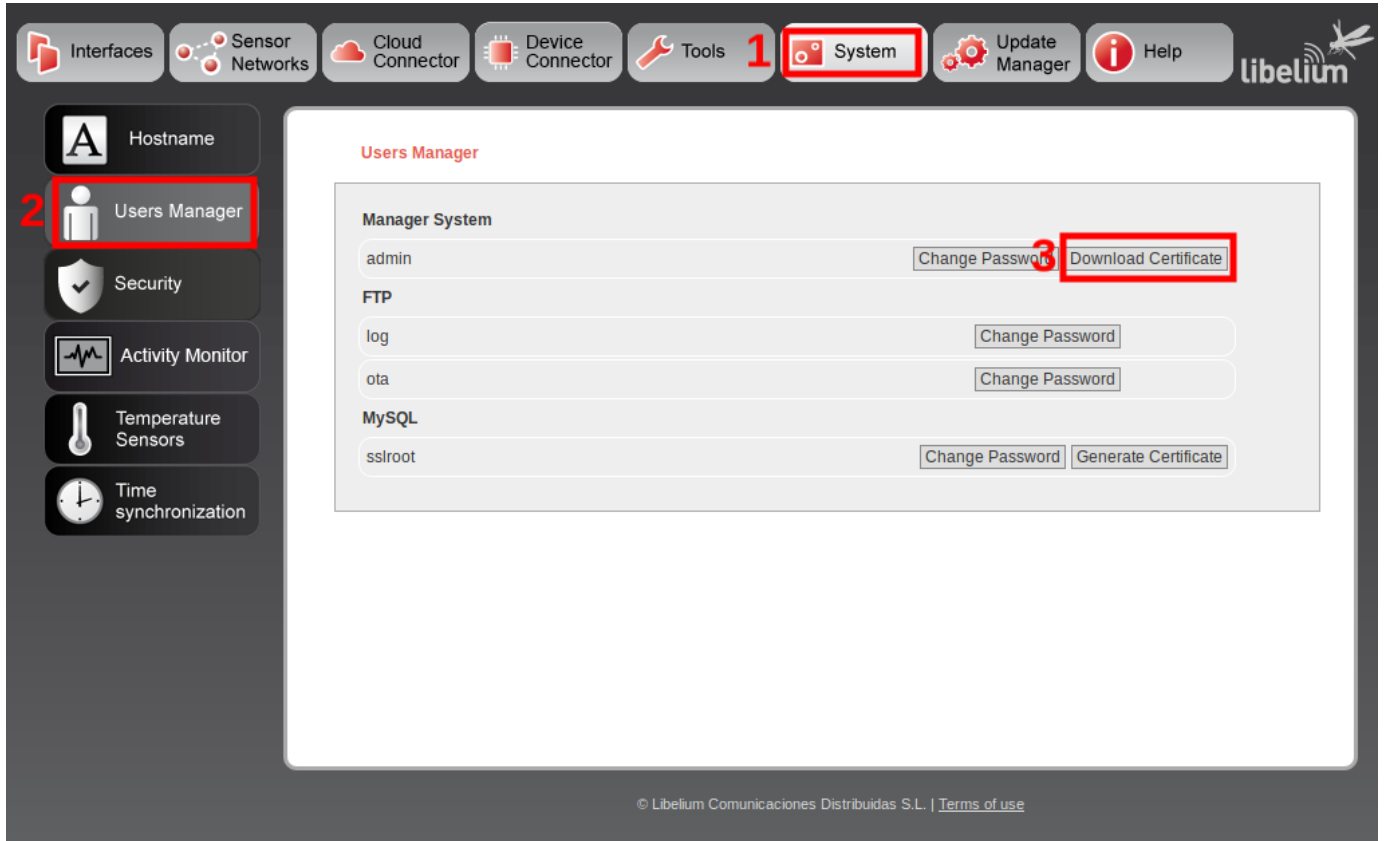


Figure: Meshlium certificate export process

The downloaded certificate must be installed following the steps explained in the "SSL sockets" section and the proper library function. Also, the example linked at the end of this section shows how to perform the installation.

Example of sending frames to Meshlium via HTTPS:

[www.libelium.com/development/wasmote/examples/nb-iot-08b-sending-frames-to-meshlium-via-https](http://www.libelium.com/development/wasmote/examples/nb-iot-08b-sending-frames-to-meshlium-via-https)

## 3.11. Making TCP/UDP connections

### 3.11.1. Socket identifiers

The NB-IoT / Cat-M module permits to have up to 6 simultaneous TCP/UDP connections. For that purpose, the library defines the following socket identifiers to be used when handling the multi-socket connections:

```
WaspBG96::CONNECTION_1
WaspBG96::CONNECTION_2
WaspBG96::CONNECTION_3
WaspBG96::CONNECTION_4
WaspBG96::CONNECTION_5
WaspBG96::CONNECTION_6
```

The NB-IoT / Cat-M library defines different structures in order to store the information related to all socket identifiers. After opening sockets or sending/receiving data, the structures are updated. So this is useful in order to manage the most important settings of the connection.

### 3.11.2. Socket status structure

The `SocketStatus_t` structure stores the status for all sockets. For each one of the connections, the status structure includes:

- Socket identifier
- Current socket status. The API defines several constants to describe it:

```
WaspBG96::STATUS_CLOSED
WaspBG96::STATUS_ACTIVE
WaspBG96::STATUS_SUSPENDED
WaspBG96::STATUS_SUSPENDED_DATA
WaspBG96::STATUS_LISTENING
WaspBG96::STATUS_INCOMING
WaspBG96::STATUS_OPENING
```

- Local IP address
- Local port
- Remote IP address
- Remote port

As it is possible to have up to 6 simultaneous connections, the global variable is defined as follows:

```
SocketStatus_t socketStatus[6];
```

The definition of the structure is:

```
struct SocketStatus_t
{
    uint8_t      id;
    uint8_t      state;
    char  localIp[16];
    uint16_t     localPort;
    char  remoteIp[16];
    uint16_t     remotePort;
};
```

The `getSocketStatus()` function allows the user to update the socket status structure from the NB-IoT / Cat-M module. It is mandatory to indicate the identifier of the socket to be updated. It is possible to update all socket status by calling the `getAllSocketStatus()` function which is faster than iterating through all different identifiers.

Example of use:

```
{
    uint8_t socketId = WaspBG96::CONNECTION_1;
    BG96.getSocketStatus(socketId);
}
```

Related variables:

`BG96.socketInfo[socketId].id` → Socket identifier

`BG96.socketInfo[socketId].state` → Socket status

`BG96.socketInfo[socketId].localIp` → Local IP address

`BG96.socketInfo[socketId].localPort` → Local port

`BG96.socketInfo[socketId].remoteIp` → Remote IP address

`BG96.socketInfo[socketId].remotePort` → Remote port

### 3.11.3. Creating a TCP/UDP client socket

The `openSocketClient()` function configures and opens a socket. This function expects several input parameters:

- **Socket ID:** The 1st parameter indicates the identifier to be associated to the new TCP/UDP connection. This identifier is needed in order to send or receive data through the corresponding socket after creating it.
- **Protocol:** This parameter indicates whether use TCP or UDP protocol for the new socket. The possibilities are:
  - `WaspBG96::TCP`
  - `WaspBG96::UDP`
- **Host:** Address of the remote host, string type. This parameter can be either:
  - Any valid IP address in the format: "xxx.xxx.xxx.xxx"
  - Any host name to be solved with a DNS query
  - Any valid IPv6 address in the format: xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx or xxx.xxx.xxx.xxx.xxx.xxx.xxx.xxx.xxx.xxx
- **Remote port:** Remote host port to contact from 1 to 65535.
- **Local port:** Parameter is valid for UDP connections only and has no effect (if used) for TCP connections. UDP connections local port from 1 to 65535.

Example of creating a **TCP client** connection:

```
{
    uint8_t socketId = WaspBG96::CONNECTION_1;
    char host[] = "xxx.xxx.xxx.xxx";
    uint16_t remote_port = 15010;

    BG96.openSocketClient(socketId, WaspBG96::TCP, host, remote_port);
}
```

Example of creating a **UDP client** connection:

```
{
    uint8_t socketId = WaspBG96::CONNECTION_2;
    char host[] = "xxx.xxx.xxx.xxx";
    uint16_t remote_port = 15010;
    uint16_t local_port = 4000;

    BG96.openSocketClient(socketId, WaspBG96::UDP, host, remote_port, local_port);
}
```



Possible error codes for this function:

- 1: not registered, ME is not currently searching for a new operator to register to
- 2: not registered, but ME is currently searching for a new operator to register to
- 3: registration denied
- 4: unknown
- 6: not registered, ME is not currently searching for a new operator to register to
- 8: not registered, but ME is currently searching for a new operator to register to
- 9: registration denied
- 10: unknown
- 12: if error setting APN
- 13: if error setting login
- 14: if error setting password
- 15: if error activating GPRS connection
- 16: if error getting socket status
- 17: Socket with an active data transfer connection
- 18: Socket suspended
- 19: Socket suspended with pending data
- 20: Socket listening
- 21: Socket with an incoming connection. Waiting for the user accept or shutdown command.
- 22: Socket in opening process. The socket is not closed but still not in Active or Suspended.
- 23: if error in Socket Configuration
- 24: if error in Socket Configuration Extended 3
- 25: if error sending the open command
- 26: if timeout opening the socket

### 3.11.4. Sending data

The `send()` function allows the user to send TCP/UDP packets once the socket is active. The function needs 2 different inputs parameters:

- **Socket ID:** the socket identifier used for opening the connection.
- **Data:** This is the stream of data to send to the TCP/UDP socket. This stream of data can be defined as a simple string message. On the other hand, the data can be defined as an array of bytes, specifying a 3rd input for the length of the array of bytes to send.

Example for sending a string message:

```
{
    BG96.send(WaspBG96::CONNECTION_1, "This_is_the_data_payload");
}
```

Example for sending an array of bytes:

```
{
    uint8_t data[] = {0x31, 0x32, 0x33, 0x34, 0x35}
    BG96.send(WaspBG96::CONNECTION_1, data, 6);
}
```

Possible error codes for this function:

- 1: if error checking socket status
- 2: if incorrect socket status
- 3: if error sending data
- 4: if error waiting confirmation from module
- 5: if error getting socket status
- 6: if timeout getting socket status

All examples related to TCP/UDP sockets (both client and server) show how to send data:

<http://www.libelium.com/development/waspmote/examples/nb-iot-11-tcp-client>

<http://www.libelium.com/development/waspmote/examples/nb-iot-13-udp-client>

### 3.11.5. Receiving data

The `receive()` function allows the user to receive TCP/UDP packets once the socket is active. The function needs different inputs:

- **Socket ID:** the socket identifier used for opening the connection.
- **Timeout (optional input):**
  - If no timeout input is specified, the receive function is a non-blocking function which answers if data has been received.
  - If the timeout is inserted as new input, the function will block until a new packet is received or time is up in the case no packet is received. This timeout must be specified in milliseconds units.

Example for instant reception:

```
{
    BG96.receive(WaspBG96::CONNECTION_1);
}
```

Example for blocking reception (i.e. 30 seconds):

```
{
    BG96.receive(WaspBG96::CONNECTION_1, 30000);
}
```

Related variables:

`BG96._buffer` → Pointer to the buffer where received data is stored

`BG96._length` → Length of the data received

Possible error codes for this function:

- 1: if no data received
- 2: if error getting socket info
- 3: if timeout waiting for data
- 4: if error receiving data from module
- 5: if error parsing length of data
- 6: if error reading incoming bytes

### 3.11.6. Closing a socket

The `closeSocketClient()` function allows the user to close a TCP/UDP client previously open. The function needs an input parameter for the socket identifier.

The `closeSocketServer()` function allows the user to close a TCP/UDP server previously open. The function needs 2 inputs:

- **Socket ID:** the socket identifier used for opening the connection.
- **Protocol:** This parameter indicates the protocol used by the socket:
  - WaspBG96 : : TCP
  - WaspBG96 : : UDP

### 3.11.7. SSL sockets

The NB-IoT / Cat-M module includes a stack for establishing SSL sockets. For this feature, the user must keep in mind that it is necessary to install the proper security data in the module. For handling the SSL socket new functions are defined for opening the socket, sending data, receiving data and closing the socket.

Currently, for SSL sockets only one single connection is permitted. So, regarding the socket identifiers the only available option is: `WaspBG96 : : CONNECTION_1`.

The `manageSSL()` function allows the user to store, delete and read security data (Certificate, CA certificate, private key) into the non volatile memory of the module. The function expects several inputs:

- **Socket ID:** the socket identifier used for opening the connection.
- **Action:** the action to perform:
  - `WaspBG96 : : SSL_ACTION_DELETE`: Delete data from memory
  - `WaspBG96 : : SSL_ACTION_STORE`: Store data into memory
  - `WaspBG96 : : SSL_ACTION_READ`: Read data from memory
- **Data type:**
  - `WaspBG96 : : SSL_TYPE_CERT`: Certificate
  - `WaspBG96 : : SSL_TYPE_CA_CERT`: CA certificate
  - `WaspBG96 : : SSL_TYPE_RSA`: RSA Private key
- **Data (optional):** this input is needed when the user selects to store a new security data into module's memory.

Possible error codes for this function:

- 1 if error setting security data
- 2 if error waiting module confirmation
- 3 if error getting security data
- 4 if error deleting security data
- 5 if invalid action input

The `openSocketSSL()` function allows the user to open a remote connection via socket secured through SSL. Several inputs are needed for calling this function:

- **Socket ID:** The socket identifier used for opening the connection
- **Host:** Remote SSL server address
- **Remote port:** Remote TCP port to contact from 1 to 65535.

Possible error codes for this function:

- 1: not registered, ME is not currently searching for a new operator to register to
- 2: not registered, but ME is currently searching for a new operator to register to
- 3: registration denied
- 4: unknown
- 6: not registered, ME is not currently searching for a new operator to register to
- 8: not registered, but ME is currently searching for a new operator to register to
- 9: registration denied
- 10: unknown
- 12: if error setting APN
- 13: if error setting login
- 14: if error setting password
- 15: if error activating GPRS connection
- 16: if error getting SSL Socket Status
- 17: if socket disabled
- 19: if socket already open
- 20: if error opening the socket
- 21: if no response from module

The `sendSSL()` function allows the user to send data through a secure socket. Several inputs are needed for calling this function:

- **Socket ID:** the socket identifier used for opening the connection.
- **Data:** Data to send.

Possible error codes for this function:

- 1: if error checking socket status
- 2: if incorrect socket status
- 3: if error sending data
- 4: if no response from module
- 5: if error getting socket status
- 6: if timeout waiting for correct socket status

The `receiveSSL()` function allows the user to receive data through a secure socket. Several inputs are needed for calling this function:

- **Socket ID:** the socket identifier used for opening the connection.
- **Timeout (optional input):**

- If no timeout input is specified, the receive function is a non-blocking function which answers if data has been received.
- If the timeout is inserted as new input, the function will block until a new packet is received or time is up in the case no packet is received. This timeout must be specified in milliseconds units.

Possible error codes for this function:

- 1: if no answer from module
- 2: if SSL socket disconnected
- 3: if error code from module
- 4: if no response from module
- 5: if error parsing length of received data
- 6: if error getting received data
- 7: if error waiting module confirmation

The `closeSocketSSL()` function allows the user to close a secure socket. The function needs an input parameter for the socket identifier.

Example for SSL socket:

[www.libelium.com/development/waspmote/examples/nb\\_iot-15-ssl-sockets](http://www.libelium.com/development/waspmote/examples/nb_iot-15-ssl-sockets)

## 3.12. GNSS – Getting position

The `gpsStart()` function allows the user to power on the GNSS engine. By default, the module selects the best GNSS network to acquire the position in a transparent process. However, the user is able to select the desired GNSS network if needed.

The `waitForSignal()` function waits until GNSS signal is received for valid data. The input parameter defines the timeout to wait for signal in millisecond units. If the function returns a correct answer means that the GNSS attributes have been updated:

- Latitude
- Latitude indicator: North or South
- Longitude
- Longitude indicator: East or West
- Time
- Date
- Number of satellites
- HDOP: Horizontal Dilution of precision. If this value is less than 1 indicates the highest possible confidence level to be used for applications.

The `convert2Degrees()` function performs the conversion from the latitude and longitude variables given by the module to degrees so it is more legible and intuitive. The input parameters must be the latitude/longitude and the corresponding indicator. The returning value is the converted value in degrees units.

The `gpsStop()` function powers down the GNSS engine of the module. It is possible to switch from a SUPL session to the autonomous GNSS mode. Firstly, the GNSS feature must be stopped, and then restart with the autonomous mode.

Example of GPS modes:

<http://www.libelium.com/development/waspmote/examples/nb-iot-16-GNSS>

## 3.13. Sleep mode

In order to save battery, the user can simply switch the module off with the `OFF()` function, but she must take into account that it will take about 20 seconds until the next on process is completed (the module and the network must redo the hand-shake process). So switching off could not be really efficient, because the power consumption during that 20 seconds is not trivial. To maximize the battery saving, the module offers sleep functions in which the module is not totally switched off, but it remains in a low-power state, sending paging frames to the network from time to time to keep the link active. Getting the module ready to work from a sleep state is much faster than from off state.

Thus, depending on the application, the user may find interesting not to switch the radio off, but to put it to sleep: nodes with frequent communications (<5 minutes) will probably prefer sleep mode over off mode. The user should test both modes and decide the best choice.

By default, the module sleep mode can be enabled by the `nbiotSleepMode()` function.

However, the NB-IoT / Cat-M module allows several configuration modes to minimize the power consumption. For example, the module can be configured in Power Saving Mode (PSM) using the function `nbiotSettingPSM()`, and the configuration can be check with `nbiotGetPSMValues()`.

A more detailed description of sleep modes will be added in this section.

Example of how to use the sleep mode:

<http://www.libelium.com/development/waspmote/examples/nb-iot-25-sleep-mode>



## 3.14. eDRX setup

The enhanced Extended Discontinuous Reception (eDRX) can be configured using the function `nbiotSettingeDRX()`.

For the proper configuration of the eDRX feature, first of all ensure that your operator has implemented this feature in its network (as of February 2019, many operators do not offer some advanced features yet).

Example of how to use the eDRX feature:

<http://www.libelium.com/development/waspmote/examples/nb-iot-24-edrx>

## 3.15. Scanning network operators

In order to see the coverage of NB-IoT or Cat-M in a certain location, use the function `scanOperator()`.

The list of the detected operators is stored in `_buffer`, and `_length` is the number of bytes in the buffer.

Related variables:

`BG96._buffer` → Buffer which stores the information requested

`BG96._length` → Number of bytes in buffer

Example of how to scan network operators:

<http://www.libelium.com/development/waspmote/examples/nb-iot-23-scan-operators>

## 3.16. Sending AT commands

The NB-IoT / Cat-M library allows to send custom AT commands directly to the module using the `sendATcommand()` function.

The AT command to be sent, the expected answer and an estimated timeout can be also provided as arguments to make the communication more robust.

Example of sending AT commands to the module:

<http://www.libelium.com/development/waspmote/examples/nb-iot-22-manual-AT-command>

## 4. Consumption

### 4.1. Consumption table

The NB-IoT / Cat-M module is directly powered by the battery. The next table shows the Waspote's peak current consumption in different states of the NB-IoT / Cat-M module.

State	Mean power consumption
On	TBD
Idle state (DRX = 1.28 s)	16 mA
PSM mode (only NB-IoT / Cat-M module)	25 uA
Cat-M data transfer (B20)	215 mA
NB-IoT data transfer (B20)	190 mA

Non-rechargeable batteries are not advised for the NB-IoT / Cat-M module, because the high peaks of current consumption could make the voltage of these batteries to go below the threshold, so Waspote would reset. The rechargeable battery will not suffer this effect as long as its level is above 20%.

The complete consumption table can be found in the manufacturer website.

## 5. Code examples and extended information

In the WaspMote Development section you can find complete examples:

[www.libelium.com/development/waspmote/examples](http://www.libelium.com/development/waspmote/examples)

## 6. API changelog

Keep track of the software changes on this link:

[www.libelium.com/development/waspmote/documentation/changelog/#nb\\_iot](http://www.libelium.com/development/waspmote/documentation/changelog/#nb_iot)

## 7. Certifications

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

- Waspote 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: <http://www.libelium.com/products/waspote/>
- 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: <http://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](http://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:

<http://www.libelium.com/legal>