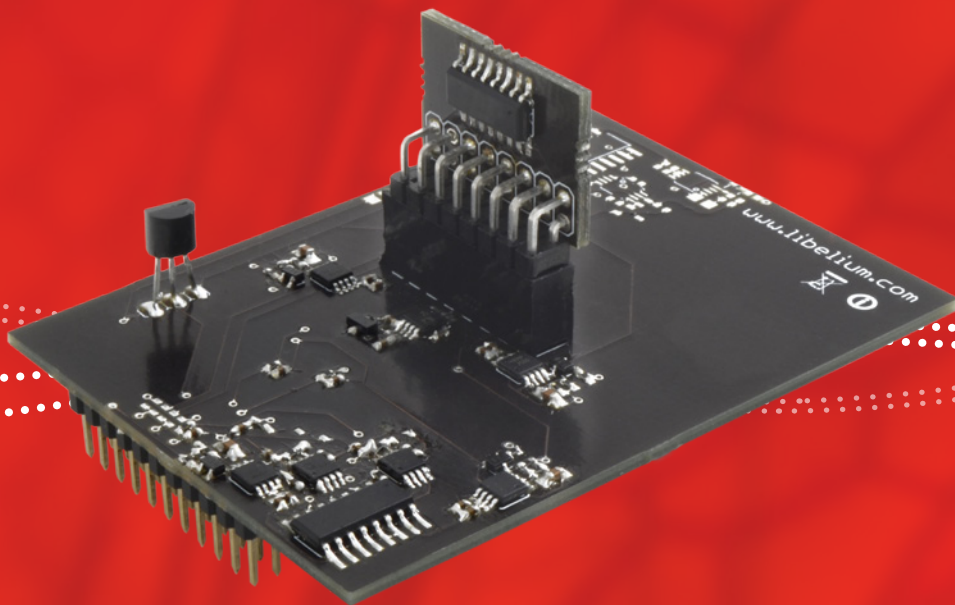


Smart Parking

Technical Guide



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0. General

0.1. General and safety information

- In this section, the term “WaspMote” encompasses both the WaspMote device itself and its modules and sensor boards.
- Read through the document “General Conditions of Libelium Sale and Use”.
- Do not allow contact of metallic objects with the electronic part to avoid injuries and burns.
- NEVER submerge the device in any liquid.
- Keep the device in a dry place and away from any liquid which may spill.
- WaspMote consists of highly sensitive electronics which is accessible to the exterior, handle with great care and avoid bangs or hard brushing against surfaces.
- Check the product specifications section for the maximum allowed power voltage and amperage range and consequently always use a current transformer and a battery which works within that range. Libelium is only responsible for the correct operation of the device with the batteries, power supplies and chargers which it supplies.
- Keep the device within the specified range of temperatures in the specifications section.
- Do not connect or power the device with damaged cables or batteries.
- Place the device in a place only accessible to maintenance personnel (a restricted area).
- Keep children away from the device in all circumstances.
- If there is an electrical failure, disconnect the main switch immediately and disconnect that 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 data specified in the “Power Supplies” section.
- If using a battery in combination or not with a solar panel as a power supply, be sure to use the voltage and current data specified in the “Power supplies” section.
- If a software or hardware failure occurs, consult the Libelium Web Support section.
- Check that the frequency and power of the communication radio modules together with the integrated antennas are allowed in the area where you want to use the device.
- WaspMote is a device to be integrated in a casing so that it is protected from environmental conditions such as light, dust, humidity or sudden changes in temperature. The board supplied “as is” is not recommended for a final installation as the electronic components are open to the air and may be damaged.

0.2. Conditions of use

- Read the “General and Safety Information” section carefully and keep the manual for future consultation.
- Use WaspMote in accordance with the electrical specifications and the environment 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 contain an enclosure to protect it from dust, humidity and other environmental interactions. In the event of outside use, this enclosure must be rated at least IP-65.
- Do not place WaspMote in contact with metallic surfaces; they could cause short-circuits which will permanently damage it.

Further information you may need can be found at <http://www.libelium.com/waspMote>

The “General Conditions of Libelium Sale and Use” document can be found at <http://www.libellium.com/legal>

Acknowledgement:

Libelium wants to thank to the Network Planning and Mobile Communications Group from the University of Cantabria on behalf of the Smart Santander project who contributed to the testing and performance improvement of the sensor board.

1. Hardware

1.1. General Description

The Waspote's Smart Parking Board principle of operation is based on the variation of the magnetic field above the board caused by the chassis of a vehicle placed on the parking lot where the mote has been deployed. This change is detected using a permalloy magnetic field sensor (MFS), a material whose electric resistance varies with the magnetic field through it, measured and processed to provide the system with an answer that can be used to determine the state of the parking spot.

1.2. Specifications

Weight: 20gr

Dimensions: 73.5 x 51 x 1.3 mm

Temperature Range: [-20°C, 65°C]

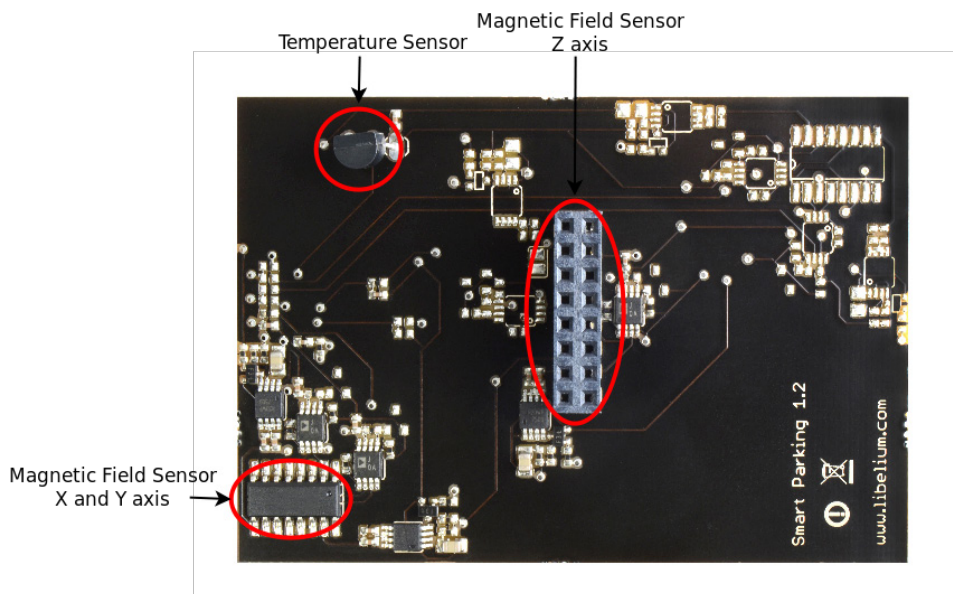


Figure 1: Upper side

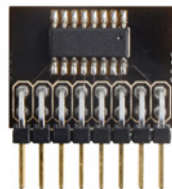


Figure 2: Image of the Z axis sensor

1.3. Electrical Characteristics

Board Power Voltages: 5V

Sensor Power Voltages: 5V

Maximum admitted current (continuous): 200mA

Maximum admitted current (peak): 400mA

1.4. Assembling

The MFS includes a module attached perpendicularly to the board, utilized to monitor the vertical axis (Z axis) of the magnetic field. Every board is prepared to operate with one single module, so it is important to maintain the correspondence between them, as it is to maintain the relationship between the board and the Waspote, prepared for the temperature compensation of a single given board. All the boards, modules and Waspotes are tagged to allow their identification. In the images bellow the assembling process is shown.

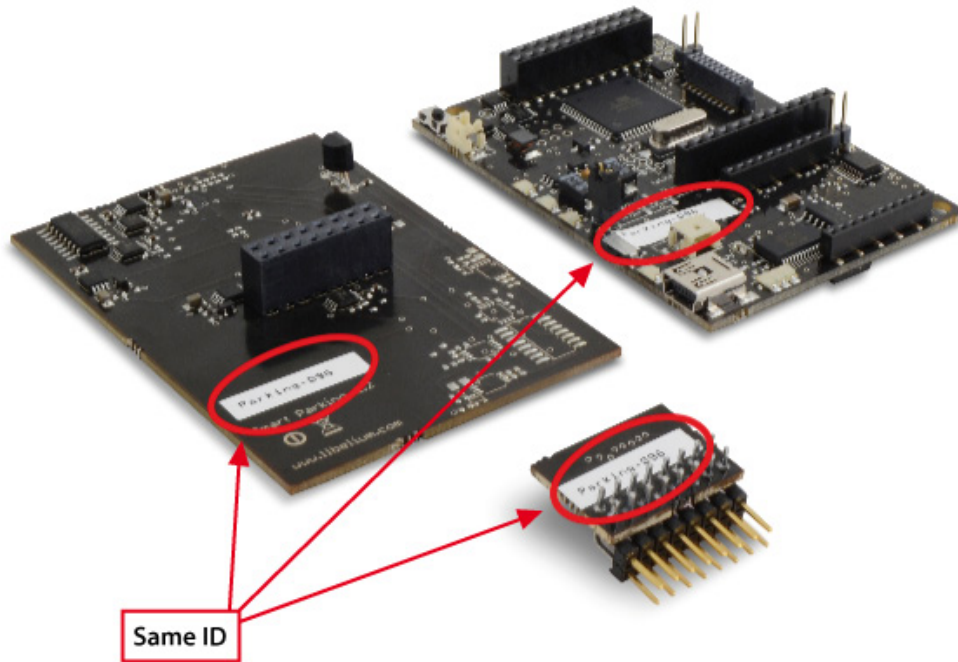


Figure 3: Image of the Smart Parking board, the Z axis sensor and the corresponding Waspote with the labels highlighted

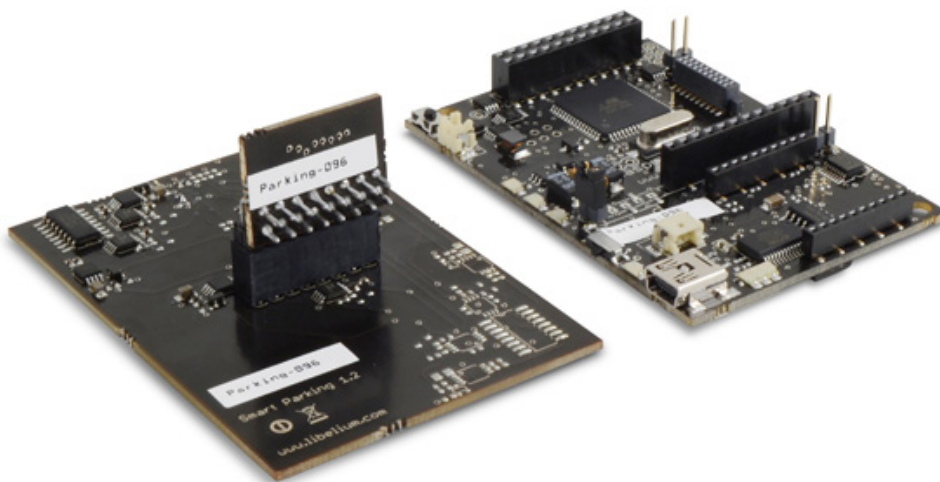


Figure 4: Image of the Smart Parking board with the Z axis sensor attached

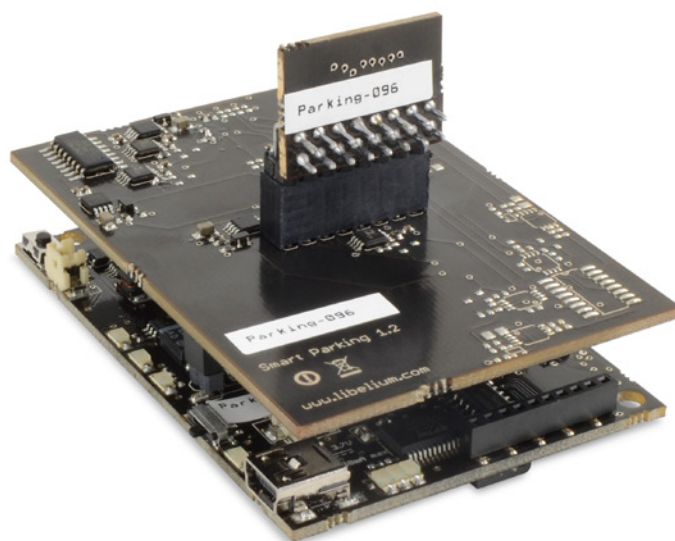


Figure 5: Image of the complete system 2. Sensor

2. Sensor

2.1. Specifications

Three axis magnetic field sensor

Maximum Supply Voltage: 12V

Operation Temperature: -40 ~ 125°C

Bridge Resistance: 600 ~ 1200Ω

Typical Output Voltage: 3,5mV/V/gauss

Average consumption: 15mA

Maximum consumption (peak): 500mA

2.2. Measurement Process

The MFS basically consists of a thin film of permalloy whose resistance is a function of the magnetic field through it (intensity and orientation). This film is integrated in a Wheatstone bridge of resistance between 600Ω and 1200Ω (typically 850Ω), thus between the two output terminals of the sensor we have a voltage in the order of the 3,5mV/V/gauss with a supply voltage of 5V.

Since the MFS is a three axis sensor it allows to monitor the magnetic field in any spatial direction. The output of each of the axis is amplified using an instrumentation amplifier and filtered to prevent glitches caused by external magnetic fields. The outputs of the three axis are directly read with the Waspmote's microprocessor's analog-to-digital converter in the analog input pins ANALOG1, ANALOG2 and ANALOG5.

To read the outputs it is enough with executing the commands `readParking` or `readParkingSetReset` from the board's library, in which the analog voltage in the input of the analog-to-digital converter is captured. In the second of these functions a small current pulse (500mA of peak, one microsecond wide) is applied to an internal circuit before reading the sensor so the molecules of the permalloy film are realigned with the magnetic field, eliminating non-desired effects owed to the hysteresis of the material.

The board also incorporates a temperature sensor with the purpose of compensating the effects that this parameter has on the sensor. The output of the sensor at pin ANALOG7 can be read using the function `readTemperature`, assigning its output to an integer variable. Regarding the temperature compensation, Libelium facilitates the sensors calibrated for an operating range between 0° and 45°, with the parameters necessary to calculate the reference in function of the new temperature stored in the EEPROM memory of the mote.

Bellow, the resulting graphs of two different applications are shown. In figure 6 the output of one axis sampled once every 10ms appears, with one car entering and leaving the spot twice. In figure 7 the outputs of the three axis sampled every 10 seconds are shown. In this case we can see four different vehicles entering and leaving the lot.

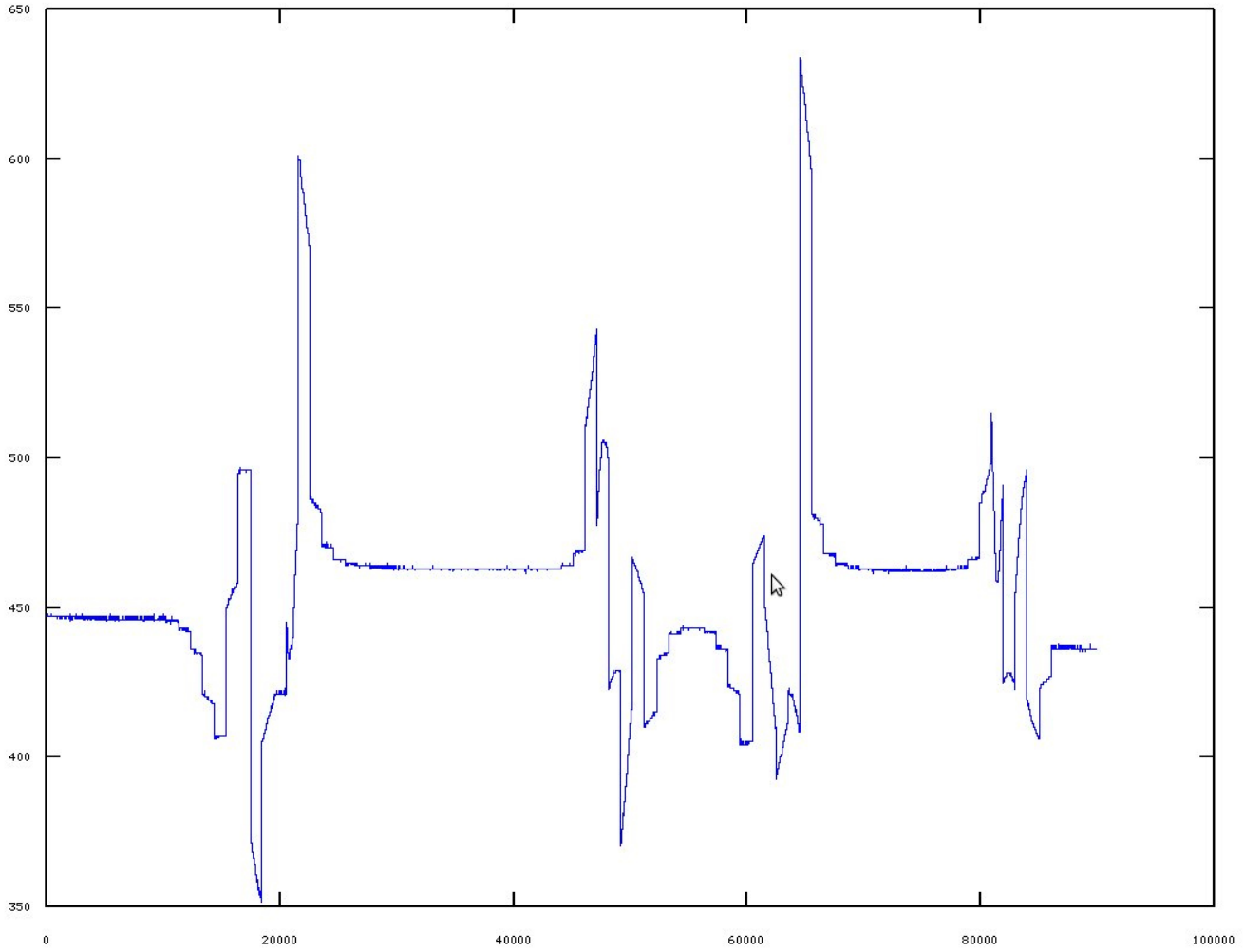


Figure 6: Image of one of the axis of the MFS sampled every 10ms

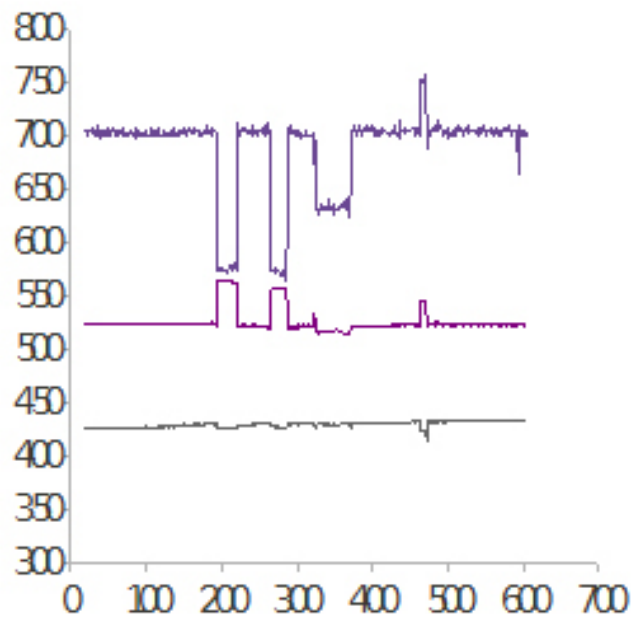


Figure 7: Image of the outputs of the three axis of the MFS sampled every 10 seconds

More information about the functions of the library, as long as an example code for reading the sensors, can be found in section 3 of this guide.

3. Board configuration and programming

3.1. Application considerations

3.1.1. Deployment of the motes

The optimum deployment point will be the one where the probability of detection is maximum, which means minimizing the probabilities of false detection (caused by other vehicles or objects near the lot under control) and false rejection (owed to a not high enough variation in the magnetic field above the mote with a vehicle parked in the spot).

This optimum deployment spot will depend on the kind of parking lot that we are going to monitor. In the case of parallel parking lots the mote should be deployed below one of the car sides, as shown in figure 8, while for perpendicular parking spots the most adequate place will be the one nearest to the center of the motor or the backside of the vehicle (see figure 9).

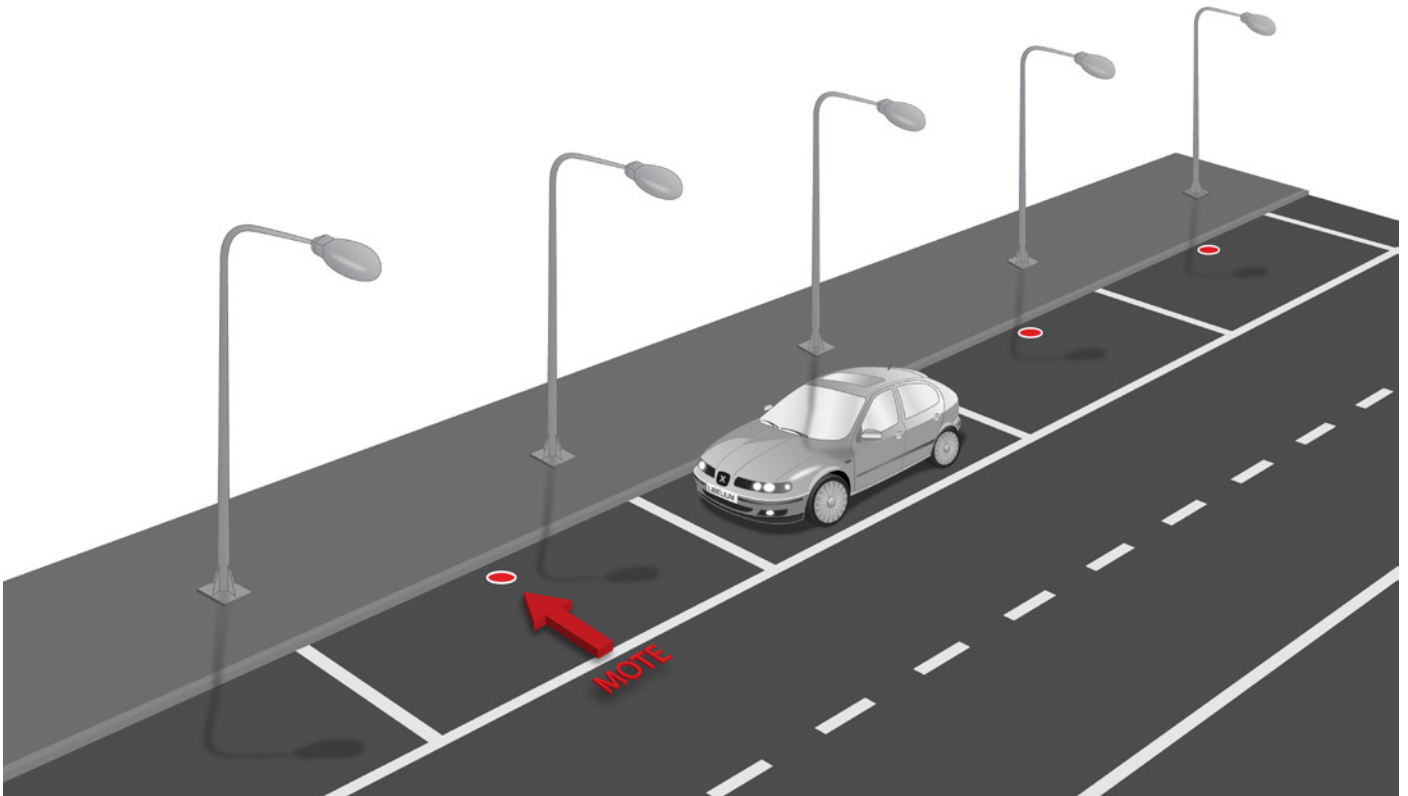


Figure 8: Diagram of the deployment points of the motes for parallel parking lots

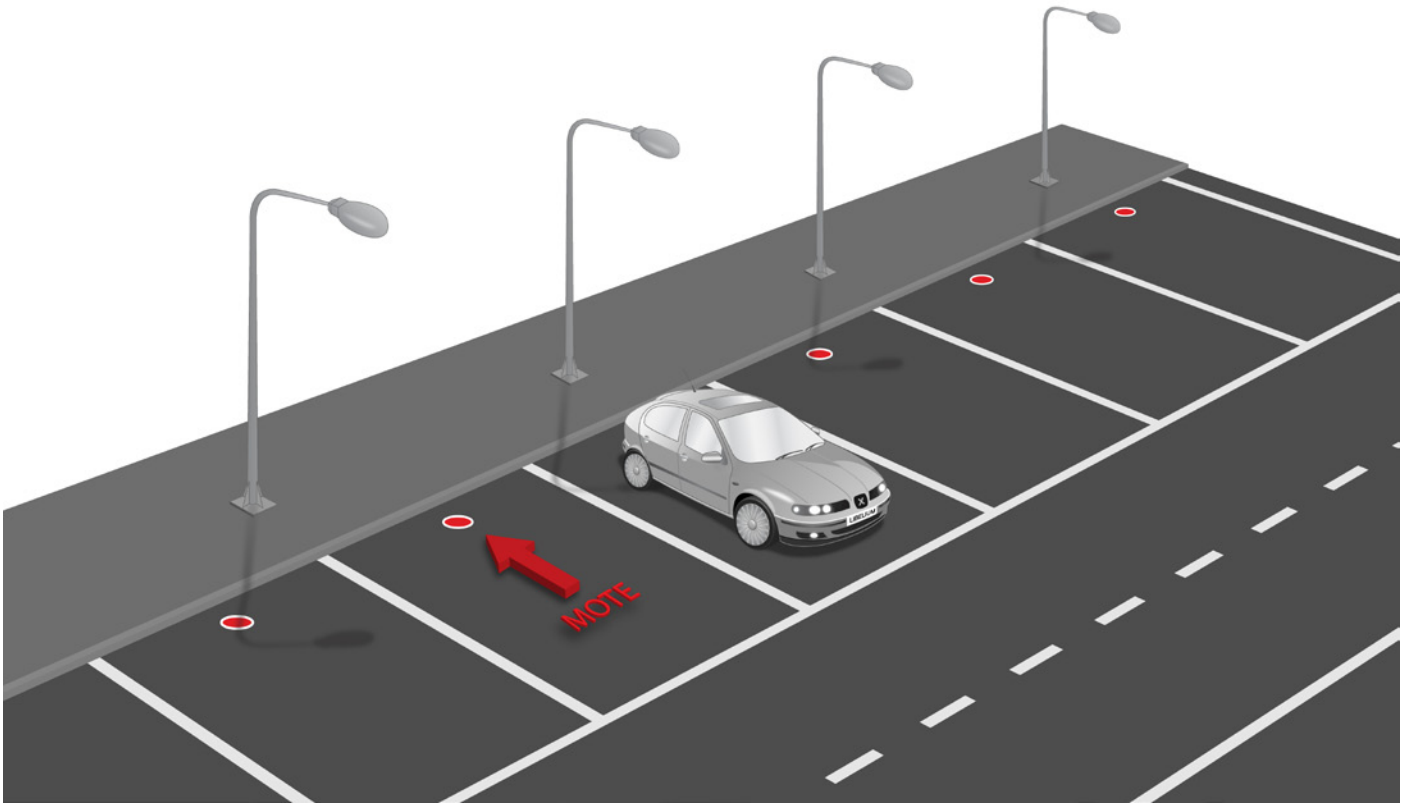


Figure 9: Diagram of the deployment points of the motes for perpendicular parking lots

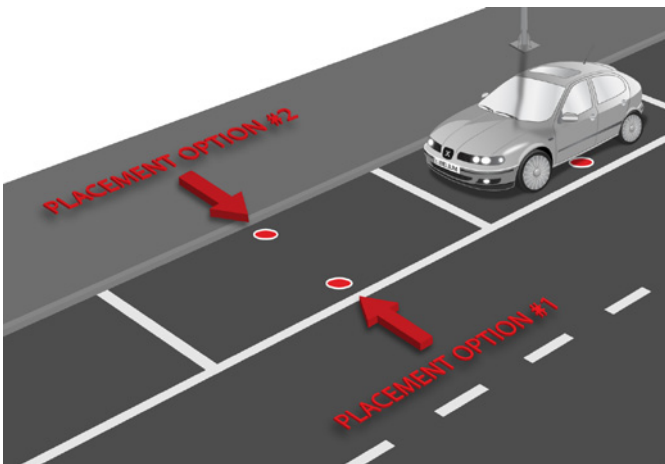


Figure 10: Placement options of the motes for parallel parking lots

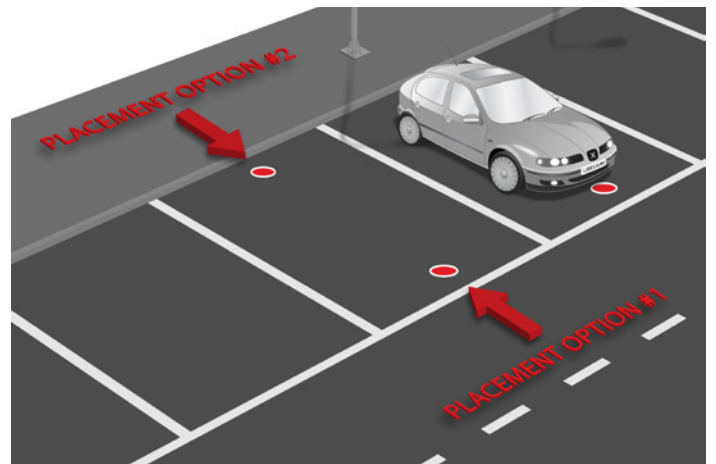


Figure 11: Placement options of the motes for perpendicular parking lots

Other consideration to be taken into account in mote deployment is the communication between this one and the gateway or router that will receive the data and process or redirect it. This is a very variable issue that will have to be analyzed independently for each scenario.

3.1.2. Interference of other vehicles

As pointed in section 3.1.1, the presence of other vehicles in contiguous spots or near places may influence in the detection, modifying the detection threshold. This influence earns special importance in perpendicular lots, where the distance between the mote and the contiguous vehicles is shortest, and in the non-delimited parallel lots. The best way to avoid this disturbance is to take into account the state of the near spots in the detection decision when the variation in the magnetic field is very close to the detection threshold.

3.1.3. Variation of the reference value

Owing to the variation of the environmental conditions (such as temperature, presence of external fields or small changes in the magnetic field of the earth) the reference value from which the state of the lot is determined doesn't remain constant, but shows a small oscillation that must be eliminated to maintain the reliability of the system. In the case of the small variations owed to the hysteresis of the permalloy under parasitic magnetic fields, the sensor is endowed with a readjustment system that permits to realign the molecules of the permalloy film with the present magnetic field through a small current pulse. In the case of the error for variations in the temperature of the sensor, Libelium supplies the sensors calibrated for an operation range between 0° and 45° approximately, so this alteration can be compensated through a degree two approximation that updates the reference value in function of the measured temperature in the moment of determining the magnetic field.

3.1.4. Determination of the state of the spot

The influence of external factors mentioned before make more difficult to make a decision about the state of the spot in the mote itself, lacking the information about the environmental conditions, such as the presence of vehicles in contiguous lots, which may lead to errors in the estimation. Owing to this, it may be advisable to carry out the calculation of the state of the spot on the routers or gateways which collect the information from all the motes at a zone. This entails an increase in the radio-frequency transmissions from the sensor motes, which involves a decrease of the battery's life. Given the wide casuistry of this kind of applications, a deep study of the conditions of the location will be necessary to assure this procedure is necessary.

3.1.5. Network structure

There are two possible Network topologies depending on the frequency and protocol used:

- 2.4GHz - Multihop ZigBee/Digimesh
- 868/900MHz Direct Access

2.4GHz - Multihop ZigBee/Digimesh Network

With this frequency band we need to use Wasp mote nodes acting as repeaters in the nearby street lights. Once they get the information they send using multihop topology to Meshlium, the Gateway of the network.

In order to communicate at this frequency band the high power module version (100mW) is recommended.

- 1° Step (Figure 12): The nodes send the information to the repeaters.
- 2° Step (Figure 13): The repeaters perform multihop routing and send the information to Meshlium.
- 3° Step (Figure 14): Meshlium sends the information to the Internet using the Wifi or GPRS radio.

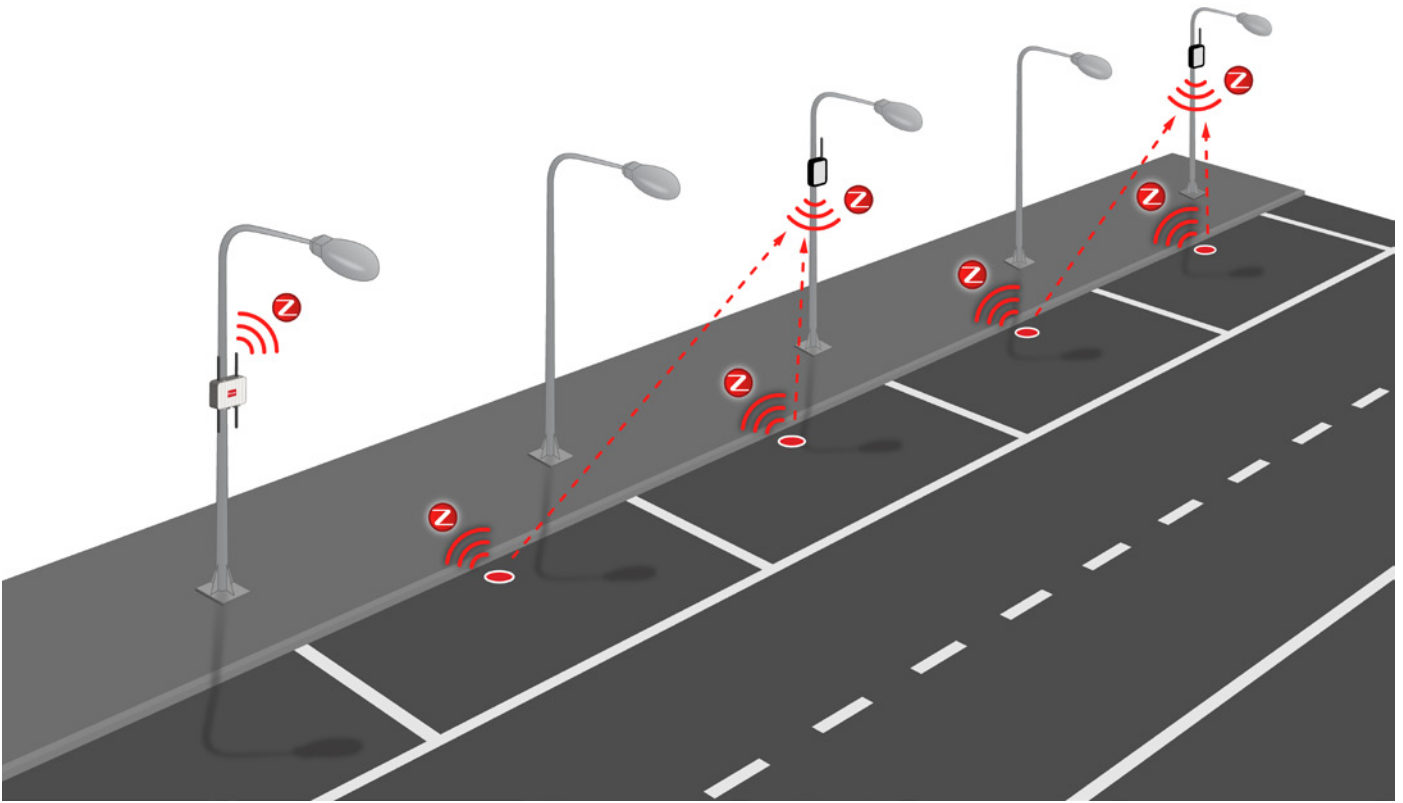


Figure 12: 2.4 GHz - Multihop ZigBee / Digimesh Network - The motes send the information to the repeaters

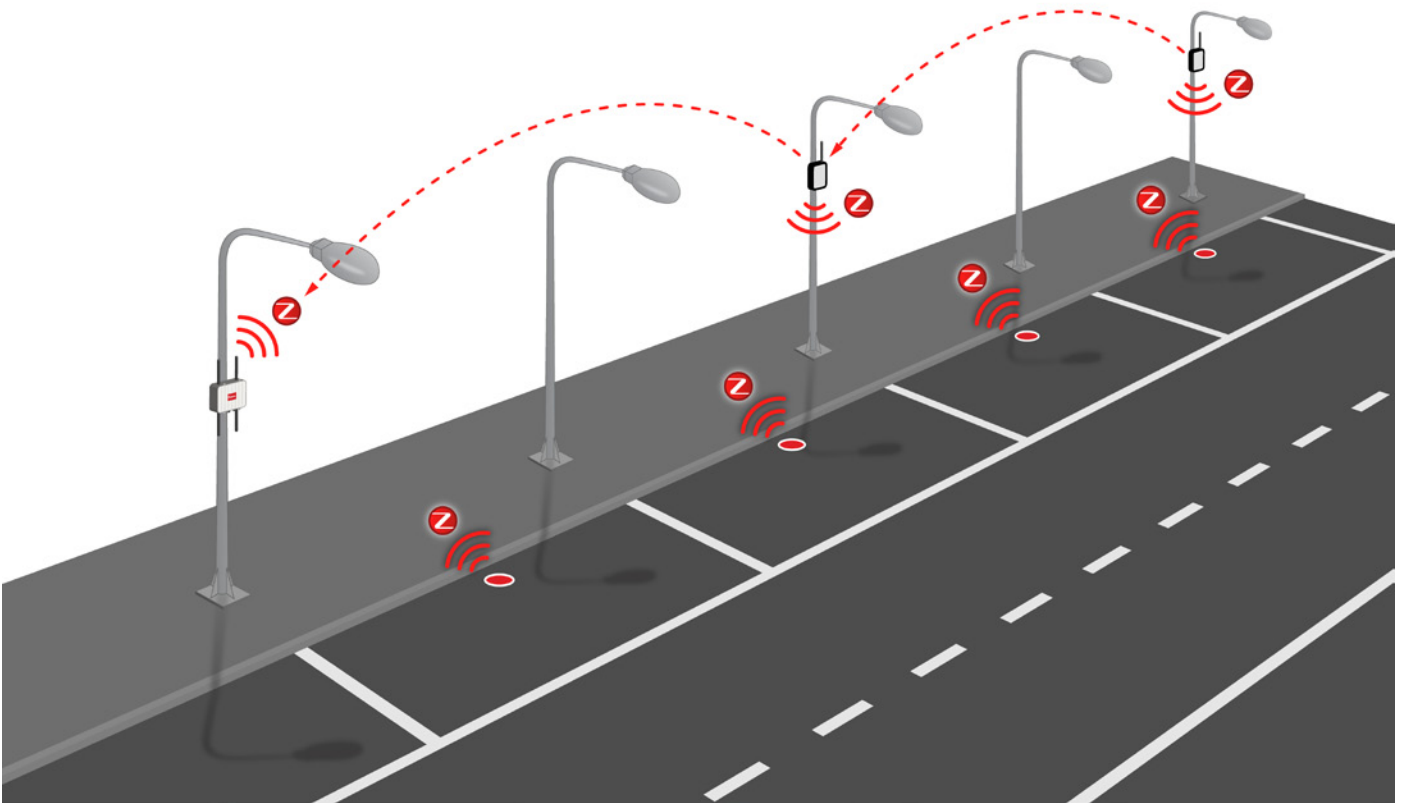


Figure 13: 2.4 GHz - Multihop ZigBee / Digimesh Network - The repeaters send the data using a multihop topology

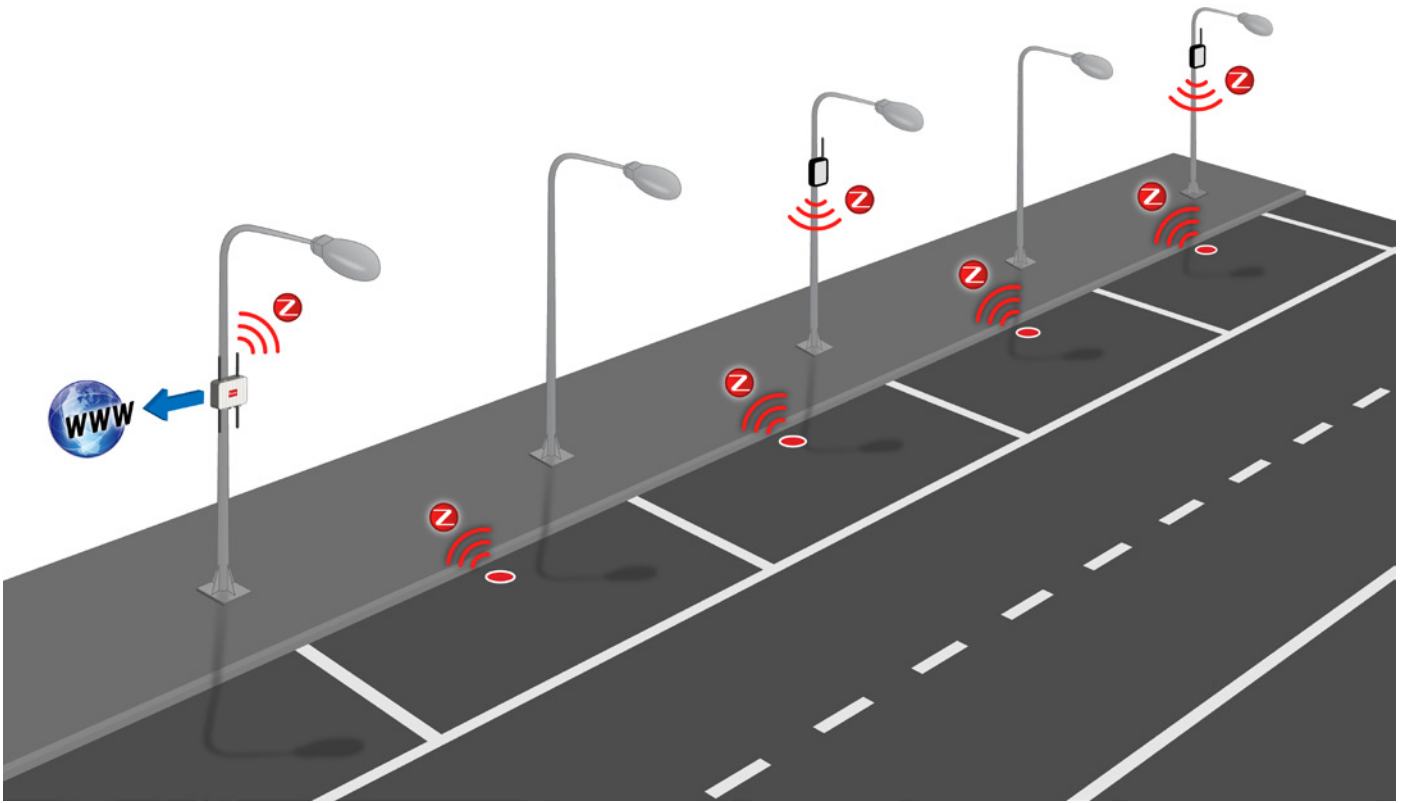


Figure 14: 868/900 MHz Direct Access Network - The Gateway sends the data to the Internet

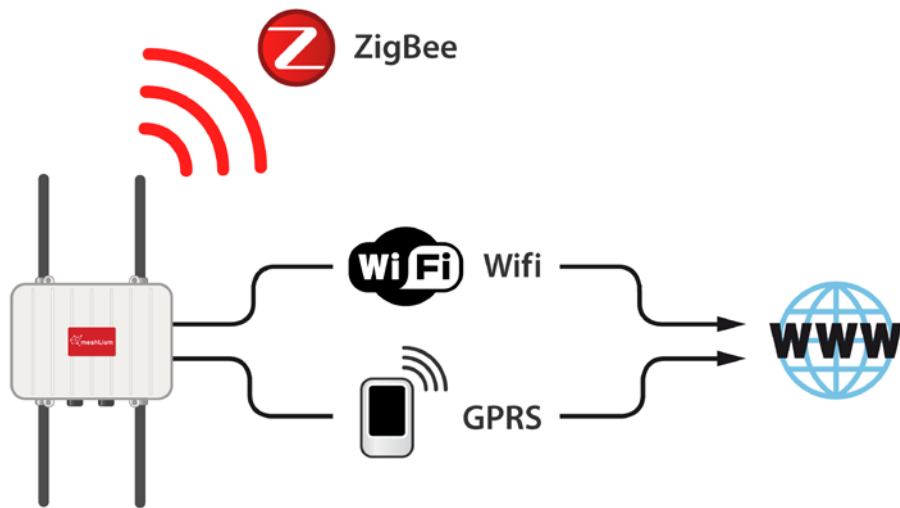


Figure 15: Meshlium: the ZigBee Internet Gateway

868/900MHz - Direct Access Network

With this frequency band we can send directly the data from Wasp mote to the Gateway located in the same street.

- 1° Step (Figure 16): The nodes send the information to Meshlium, the Gateway of the network.
- 2° Step (Figure 17): Meshlium sends the information to the Internet using the Wifi or GPRS radio.

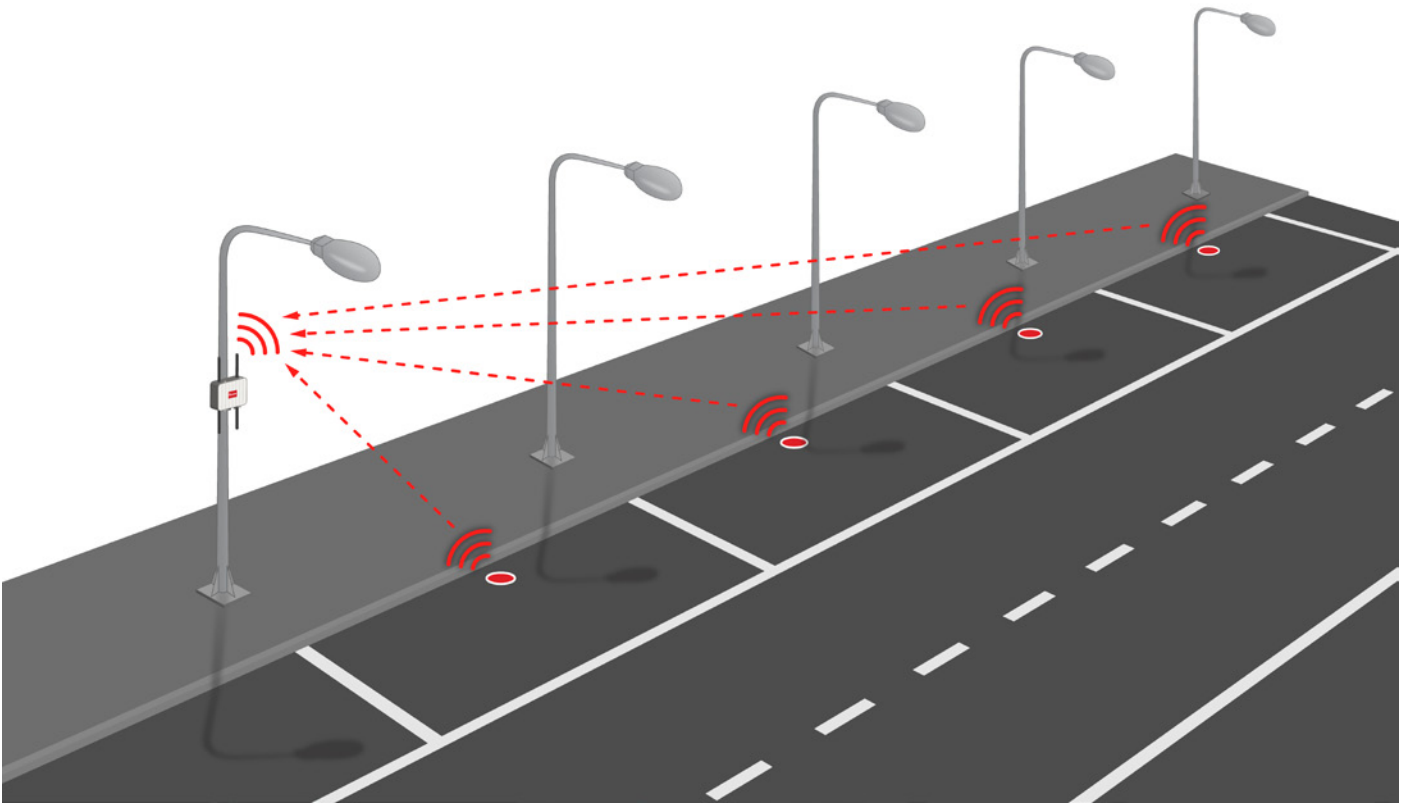


Figure 16: 868 / 900 MHz Direct Access Network - The nodes send directly the data to the Gateway

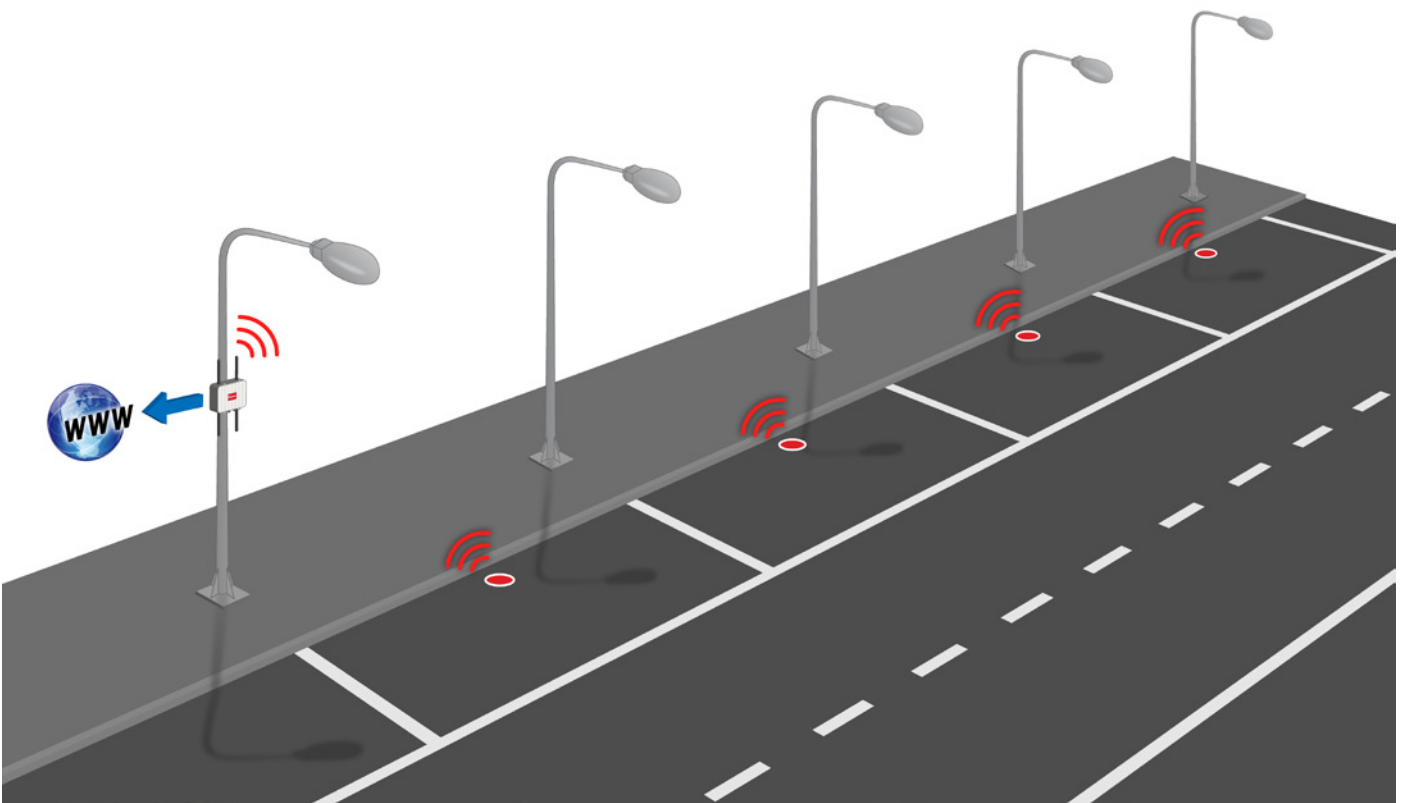


Figure 17: 868 / 900 MHz Direct Access Network - The Gateway sends the data to the Internet

3.2. Casing of the mote

Parking detection applications require a casing with a more restrictive characteristics than other wireless sensor networks application, owing to the need of lasting for a long time buried in asphalt, where they must resist the entry of water, owing to the possibility of puddles of water formed above it, and high pressures on it caused by vehicles parked or driven upon.

Libelium includes a PVC casing compliant with the IP-67 and IK-10 standards that may be installed in any environment of this characteristics. In figures 18, 19 and 20 we can see three images of the mote before and after the installation; while having in figure 21 a diagram of its dimensions.



Figure 18: Image of a mote for parking detection introduced in the case



Figure 19: Image of a mote installed in a perpendicular parking lot



Figure 20: Image of the inside of the former mote

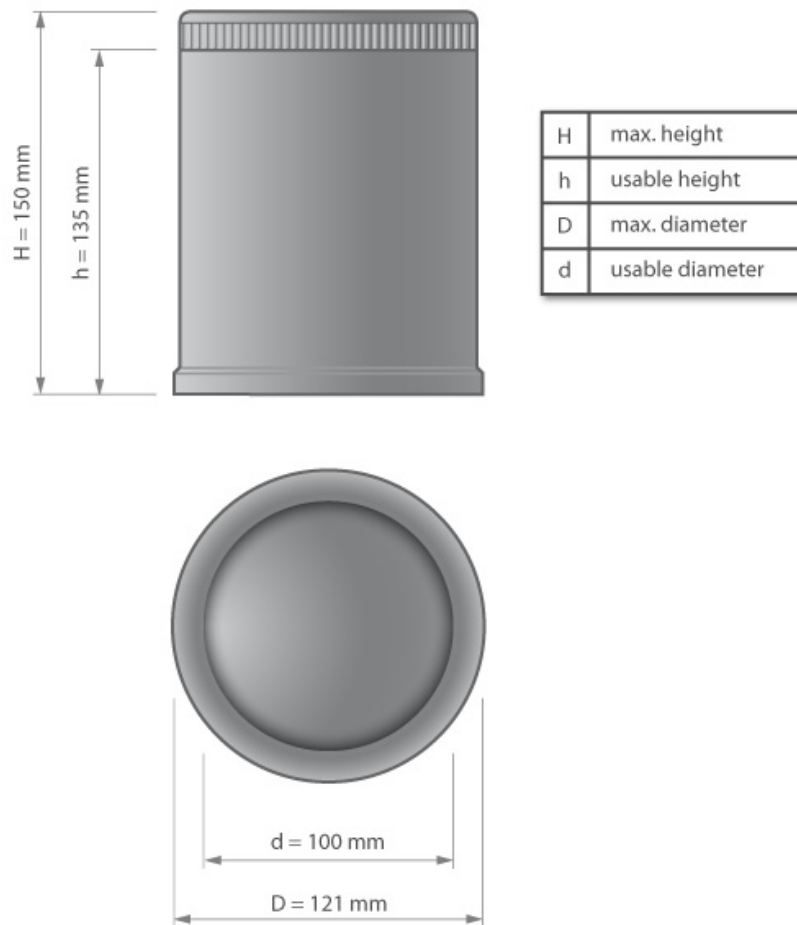


Figure 21: Diagram of dimensions of the case

3.3. Powering the mote

Since the mote in a parking monitoring application will be buried underground with no access to a system to recharge the battery, it is recommended to use a battery with the highest capacity available to extend as much as possible the life of the device. Under these conditions, Libelium recommends the utilization of the 13Ah Lithium non-rechargeable batteries (to obtain more information about them please contact Libelium's commercial department at commercial@libelium.com).

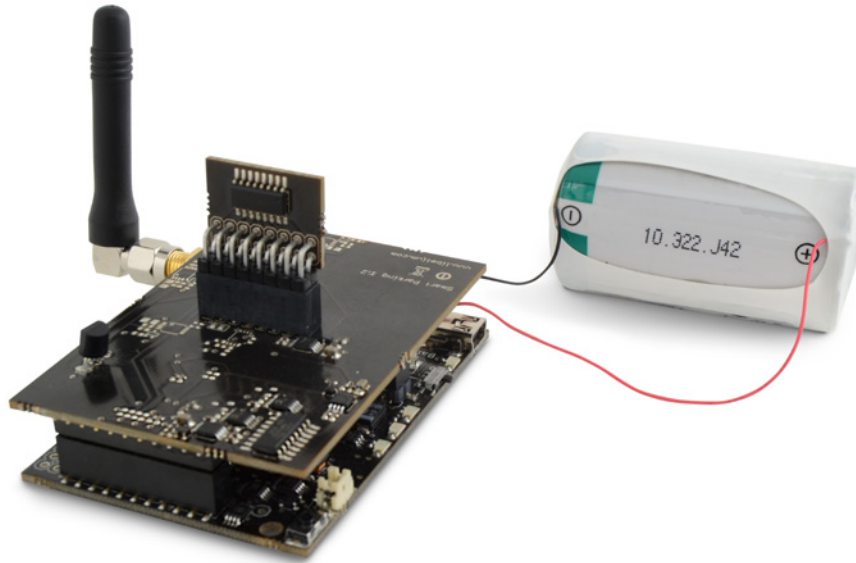


Figure 22: Image of the 13Ah Lithium non-rechargeable battery connected to the mote

3.4. API

The functions to handle all the features of the board, included in the WaspSensorSmart API library, are detailed below. The functions necessary to control the state of the spot in all kind of situations have been implemented, but take into account that not all of them will be needed in all the situations:

Variables de la librería:

- **Compensation coefficients:** this library includes those coefficients, in floating point format, necessary to estimate the compensation for the temperature variation using the function `calculateReference`. These coefficients are unique for each sensor board, are stored in the Waspmote's EEPROM memory and can be read using the function `loadReference`. The list of the names of the coefficients is shown below:
 - `coefX2`
 - `coefY2`
 - `coefZ2`
 - `coefX`
 - `coefY`
 - `coefZ`
 - `constX`
 - `constY`
 - `constZ`

- **Sensors' initial values:** after carrying out the calibration of the initial state of the parking lot the values read from the magnetic field and temperature sensors are stored in four integer variables that will be used to calculate the reference of the magnetic field for every measurement:
 - `initialX`
 - `initialY`
 - `initialZ`
 - `initialT`

- **Sensors' read values:** the values of the sensors read in the execution of functions `readParking` or `readParkingSetReset` are stored in three integer variables that will be used to estimate the state of the spot:
 - `valueX`
 - `valueY`
 - `valueZ`
- **Sensors' reference values:** after executing the `calculateReference` function the result is stored in three integer variables that contain the reference for each of the three sensors on the board.
 - `referenceX`
 - `referenceY`
 - `referenceZ`
- **Sensors' compensation indexes:** from the calibration temperature and the compensation coefficients three indexes, one for each sensor, that will be used in the calculation of the sensor's reference are extracted and stored as floating point variables.
 - `indexX`
 - `indexY`
 - `indexZ`
- **THRESHOLD:** defined as a constant instead of a variable, it defines the threshold used in function `estimateState` to determine the state of the parking lot. In case its value is to be modified, it must be done in the file `WaspSensorParking.h` of the library.

Reserved Memory Zone:

A zone of the EEPROM memory of the microcontroller between addresses 256 and 292 has been reserved to store the coefficients used in temperature compensation. **Under no circumstances should this zone of the memory be overwritten**, as long as it could lead to an irreparable error in most applications.

Library functions:

- **SensorSmart.setBoardMode(MODE)**

The `setBoardMode` function of this board activates or deactivates completely the supply voltage of the board assigning the values `SENS_ON` or `SENS_OFF` to the parameter `MODE`. In the case of the parking detection board only the 5V power supply is used, and all the electronics contained in it, included the sensors, are turned on or off using this function.
- **SensorParking.calibration()**

This function calculates the initial values of magnetic field for each of the three sensors in the empty parking lot, which are stored in variables `initialX`, `initialY` and `initialZ`, and the compensation indexes of each sensor from the temperature measured in that moment, staying those values stored in variables `indexX`, `indexY` and `indexZ`.
- **SensorParking.loadReference()**

In those applications that require temperature compensation this function loads the compensation coefficients stored in the EEPROM memory, characteristic of a specific parking board, in the variables mentioned before.
- **SensorParking.calculateReference(TEMPERATURE)**

The `calculateReference` function is used in applications that require temperature compensation to update the reference value in function of the current temperature of the mote. It utilizes the values stored in variables `initialX`, `initialY`, `initialZ`, `indexX`, `indexY`, `indexZ`, the compensation coefficients and the temperature, introduced in Celsius degree as an integer variable through the parameter `TEMPERATURE`, returning the new values in variables `referenceX`, `referenceY` and `referenceZ`.
- **SensorParking.readParking()**

The `readParking` function is used to read the output of each of the sensors at the input of the microcontroller's analog-to-

digital converter. When it is executed the voltage values at the analog inputs of the three sensors (ANALOG1, ANALOG2 and ANALOG5) are captured and stored in variables valueX, valueY and valueZ respectively.

- **SensorParking.readParkingSetReset()**

The function behaves in a very similar way to the former one, with the only difference that this one applies a current pulse in the internal circuit of every sensor to realign the molecules of the permalloy film, as indicated in section 2.2.

- **SensorParking.readTemperature()**

The temperature sensor attached to the Smart Parking board can be read through the readTemperature function that, with the purpose of obtaining a more accurate measurement, averages eight captures of the voltage value at the analog pin corresponding to the sensor output (ANALOG7). The value is returned in Celsius degree as an integer variable.

- **SensorParking.estimateState()**

This function uses the values read from the sensors and stored in variables valueX, valueY and valueZ and the reference values calculated with the function to estimate the state of the spot, returning a boolean variable ('1' in the case of an occupied spot, '0' in the case of an empty one). This calculation consists of a comparison between the difference between the value read from each sensor and its respective reference and a threshold stored in constant THRESHOLD. In the case any of these differences surpasses given threshold, the lot will be considered occupied.

3.5. Example code

We provide below with a code suitable for a simple parking detection application. Take into account that depending on the conditions of the application a more complex calculation in the decision of the state of the lot may be necessary.

```
#define ADDRESS "0123456789876543"
#define TIME "00:00:05:00"

int temperature;
boolean status;

void setup()
{
  SensorParking.loadReference();
  SensorParking.setBoardMode(SENS_ON);
  delay(2000);
  SensorParking.calibration();
  SensorParking.setBoardMode(SENS_OFF);
  RTC.ON();
  PWR.deepSleep(TIME,RTC_OFFSET,RTC_ALM1_MODE1,ALL_OFF);
}

void loop()
{
  SensorParking.setBoardMode(SENS_ON);
  delay(10);
  SensorParking.readParkingSetReset();
  temperature = SensorParking.readTemperature();
  SensorParking.calculateReference(temperature);
  status = SensorParking.estimateState();
  xbee802.init(XBEE_802_15_4,FREQ2_4G,NORMAL);
  xbee802.ON();
  if(status == PARKING_OCCUPIED){
    xbee802.send(ADDRESS,"OCCUPIED");
  }else{
    xbee802.send(ADDRESS,"EMPTY");
  }
  delay(100);
  xbee802.OFF();
  RTC.ON();
  PWR.deepSleep(TIME,RTC_OFFSET,RTC_ALM1_MODE1,ALL_OFF);
}
```

4. Consumption

4.1. Table of consumption

In the case of the Smart Parking board, the power supply is only controlled by the general switch of the 5V source in Waspote, so none of the components will be active once the board has been disconnected, so the consumption in this situation will be null.

Consumption	
Board Off	0 μ A
Board On (Average)	15mA
Board On (Peak)	500mA (1 microsecond)

5. Maintenance

- In this section, the term “Waspote” encompasses both the Waspote device itself as well as its modules and sensor boards.
- Take care with the handling of Waspote, do not drop it, bang it or move it sharply.
- Avoid putting the devices in areas of high temperatures since the electronic components may be damaged.
- The antennas are lightly threaded to the connector; do not force them as this could damage the connectors.
- Do not use any type of paint for the device, which may damage the functioning of the connections and closure mechanisms.

6. Disposal and recycling

- In this section, the term “Waspote” encompasses both the Waspote device itself as well as its modules and sensor boards.
- When Waspote reaches the end of its useful life, it must be taken to a recycling point for electronic equipment.
- The equipment has to be disposed on a selective waste collection system, different to that of urban solid waste. Please, dispose it properly.
- Your distributor will inform you about the most appropriate and environmentally friendly waste process for the used product and its packaging.

