LoRa Sensor node

USER GUIDE

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1 Preamble

The LoRa sensor node is a demo platform intended to showcase the capability of the SX1276 and especially the LoRa modulation. The platform is fitted with various sensors which provide a variety of application. We strongly recommend for the user to read thoroughly the datasheet of the SX1276 and the LoRaWAN specification prior to start working with on the LoRa sensor node.

2 Introduction

The SX1276 is a single-chip integrated circuit ideally suited for today's high performance ISM band RF applications. Added to the renowned, high-performance and low-cost, FSK / OOK RF transceiver modem, the SX1276 is also equipped with the LoRa proprietary transceiver modem. This advanced feature set, including a state of the art packet engine, greatly simplifies system design whilst the high level of integration reduces the external BOM to a handful of passive decoupling and matching components. It is intended for use as high-performance, long range, half-duplex bi-directional RF links, and where stable and constant RF performances are required over the full operating range of the device down to 1.8V.

The SX1276 is intended for applications over a wide frequency range, including 290MHz to 340MHz, the 434MHz/470MHz Asia ISM band, the 868 MHz European and the 902-928 MHz North American ISM bands. Coupled with a link budget in excess of 135 dB in FSK and in excess of 155 dB in LoRa, the SX1276 really offers the possibility of two modems in one single package. The SX1276 complies with both ETSI and FCC regulatory requirements and is available in a 5x5 mm QFN 28 lead free package.

The LoRa sensor node has been designed to demonstrate the capability of the SX1276 and is targeted to any potential user who would like to get familiar with the LoRa Modulation and the LoRaWAN protocol. Without going into too many details, this document should guide the reader through the potential use of the LoRa sensor node as a standalone transmitter/receiver, or as part of a more complex IOT system. The LoRa sensor node being a battery powered device with charging, a strong emphasis on the power consumption is described within the documents.

3 Ordering Information

When ordering, please refer to the following parts numbers:

LoRa sensor node v4 – 434/470MHz – External antenna
LoRa sensor node v4 – 868/915MHz – External antenna

4 Product specifications

Product Name	LoRa Sensor Node V4

ITEMs	Parameter	Specifications	Unit
General Specifications	Enclosure color	**Red**	
	outline dimension	100(L) X 60(W) X17(H)	mm
	Weight	76	g
	Input/Output Interface	Micro USB	
	Antenna connector	SMA for External antenna used	
	Operate temperature Range	-10℃ +60℃ (limited to the battery)	℃
	Storage temperature Range	-40℃ +80℃	℃
Electrical Characteristics	Power Voltage (USB)	+5.0	V
	Battery voltage	3.7 to 4.2	V
	Battery capacity	800	mAh
	GPS operation current (Transceiver in sleep)	32	mA
	Operation current max (Transmit and GPS)	90mA@TXOP=14dBm, 434MHz/470MHz； 75mA@TXOP=14dBm, 868MHz； 175mA@TXOP=20dBm, 434MHz/470MHz；	mA
	Operation current max (Receive and GPS)	47	mA
	Charging current max	500	mA
	Output power	14dBm default	dBm
	Max Output power	20dBm@434MHz/470MHz 14dBm@868MHz/915MHz	dBm
	Receiver sensitivity	-139dBm @300bps	dBm
	Operation Band	434MHz/470MHz; 868MHz/915MHz;	MHz
	Antenna Gain (External)	0	dBi
	Antenna Gain (Internal)	2dBi @434MHz/470MHz; 2dBi @868MHz/915MHz	dBi
Functions	GPS	GPS position update when there is GPS signal	
	Temperature measurement	Temperature update	
	Atmospheric pressure measurement	Atmospheric pressure update	
	Altitude Measurement	Altitude value update	
	Battery level measurement	Battery level update	
	Chargeable	Chargeable with USB	
	Boot loader with USB	SW update with boot loader via USB	
Interface	Power ON/OFF switch	Power on/off for LoRa sensor node	
	Radio ON/OFF	No used default	

	LED "TX"	Red LED, blink when transmit	
	LED "RX"	Green LED, blink when receive a packet	
	LED "FCT"	Orange LED, could be lighted by the command from GW	
	LED "GPS"	Blue LED, blink one time one second when the node get the GPS signal	
	LED "Power ON"	The Red LED of Bi-color LED would be ON when Power ON	
	LED "Charging"	The Green LED of Bi-color LED would be ON when Charging	
	Micro USB	External power supply or for Charging	
	Connector for External Antenna	SMA	

5 Operation of the Sensor node

The sensor node being integrated with LoRaWAN protocol, an IOT server with LoRa concentrator or Gateway (SX1301IOT Starter kit) is needed to do the demo.

When there is a server with GW working, press the “power on” button and then release it to start the node. The Node would operate in default mode, i.e. GPS-Sensor Demo. The 4 LEDs would blink together for one time. The inside “power status” LED would be ON. Later on, the “TX” LED would blink periodically, which means the node is transmitting the sensor data to GW. After several minutes, the “GPS” LED would blink one time one second if the node get the GPS signal. Please put the node outside to make sure that the node could get a good GPS signal when you need the GPS position.

When you want to shut down the node, you need just press the “power on/off” button again and then release it. Then the node will be powered off.

“TX” LED: The “TX” LED would blink when transmitting the data to GW. The “TX” LED is red.
“RX” LED: The “RX” LED would blink when receiving the data from GW. The “RX” LED is green.
“FCT” LED: The “FCT” LED could be lighted by the command from GW/Server. The “FCT” LED is Orange.
“GPS” LED: The “GPS” LED would blink one time one second when the node get the GPS signal. The “GPS” LED is blue.
“Radio” button: The button printed with blue arc lines is the “Radio on/off” button. Only used for bootloader for SW upgrade in current.
“Power” button: “Power on” button is the red button on the face of the node, which is also used to power off. This is a toggle switch.
Inside LED for power on and charging: on the bottom of the node, near the USB connector, there is a hole. You could see the bi-color LED status via the hole. The Red LED would be ON when you power on the node, and would be off when shutting down; the Green LED would be on when the node is in charging, would be off when charging finished or there is no usb cable connected.
Micro-USB connector: The usb connector would be used for charging or bootloader for SW upgrade.

Figure 1: keyboard and connector of LoRa sensor node

6 Hardware of the Sensor node

The LoRa sensor node is targeted to be a development platform for the SX1276. This idea has been to group into a single, user friendly, battery powered with charging handheld device. Figure below is a schematic block diagram for the sensor node.

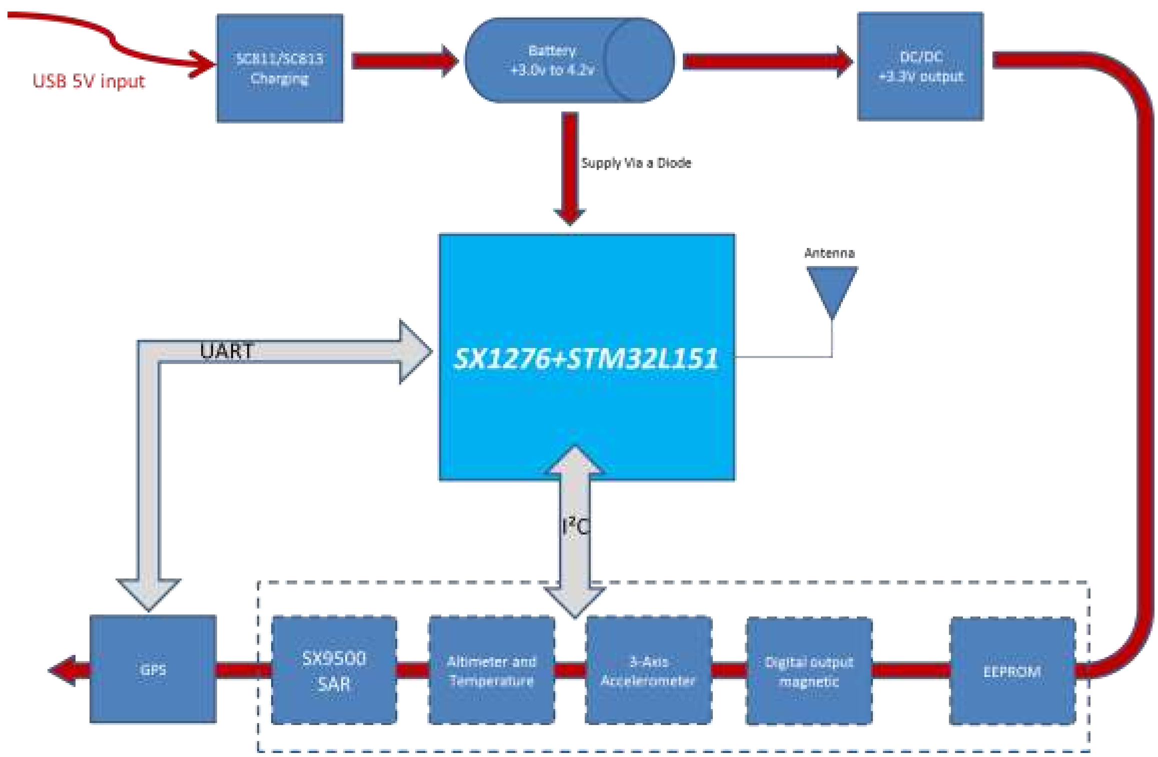
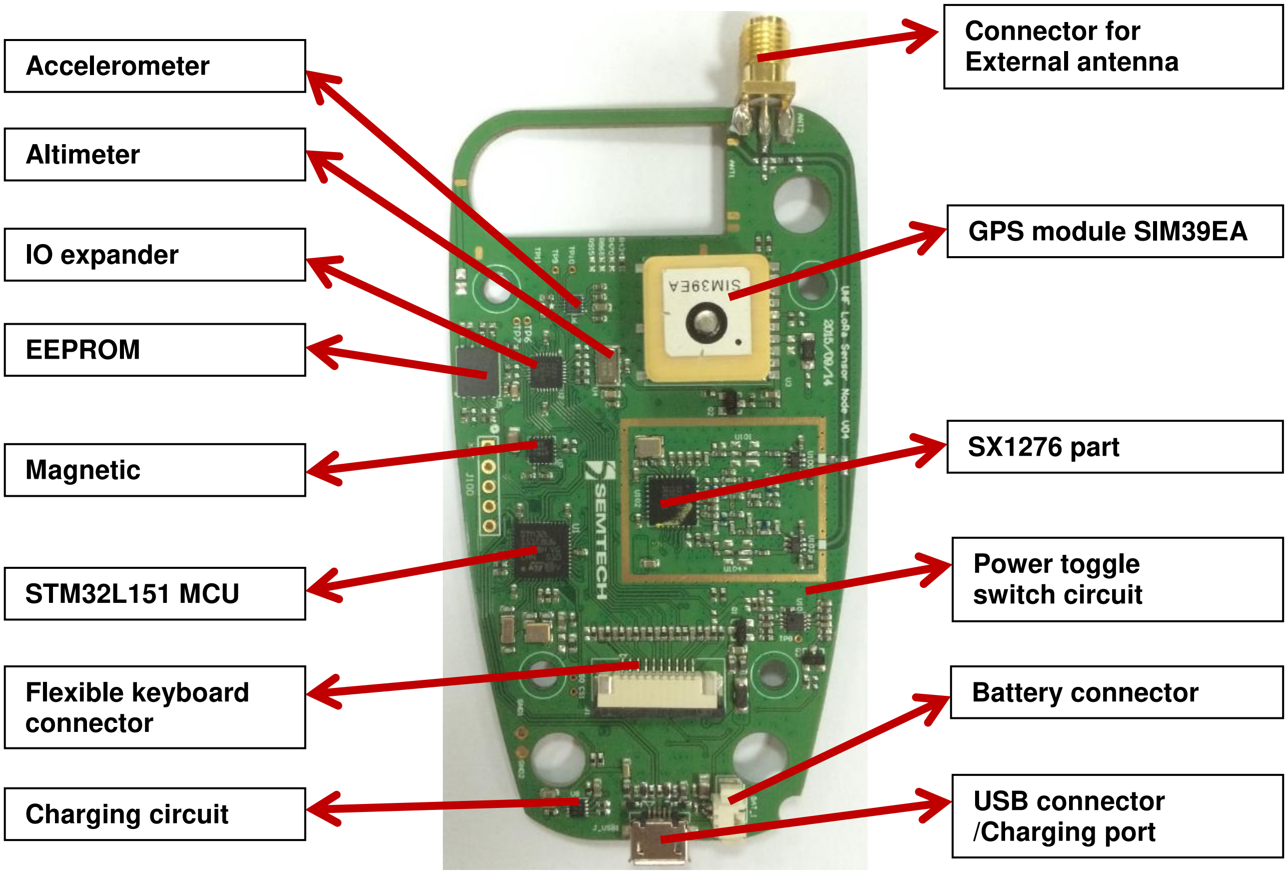
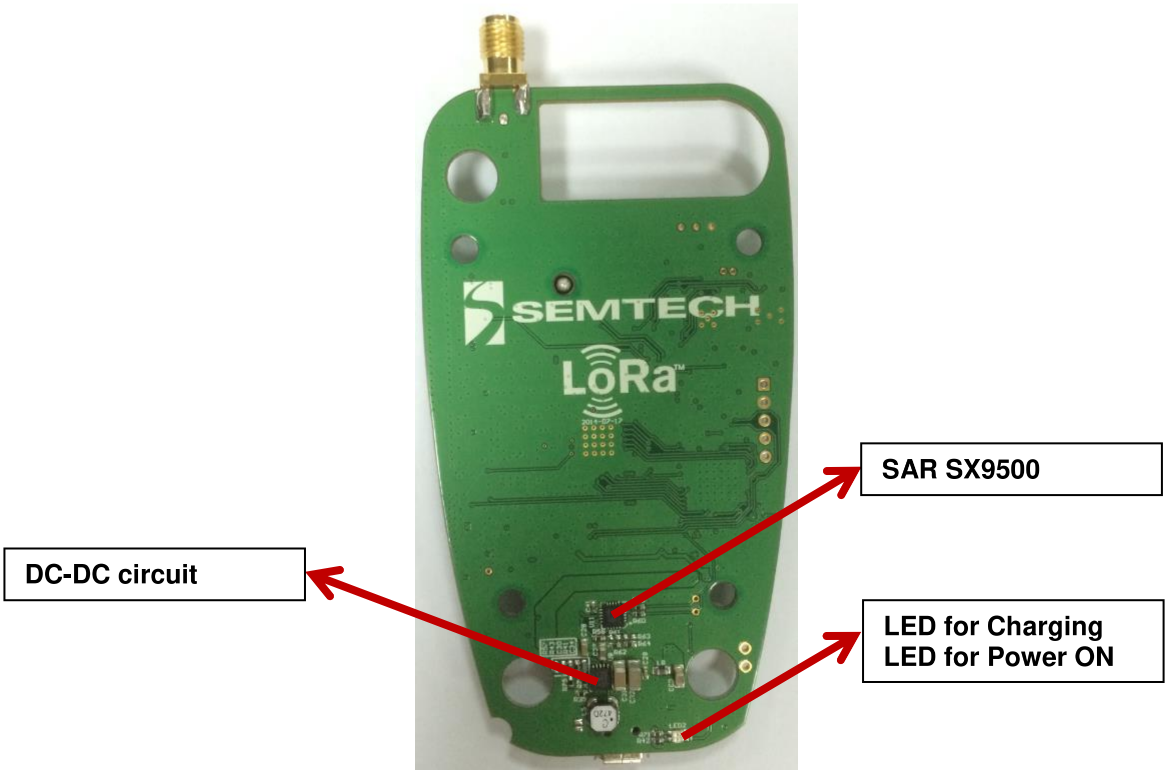


Figure 2: Block diagram of LoRa sensor node



(Top side)

Figure 3: HW arrangement of layout-Top layer



(Bottom side)

Figure 4: HW arrangement of layout-Bottom layer

The schematic of the LoRa sensor node is displayed below. The full design details of the LoRa sensor node (schematic, layout, BOM) are available upon request.

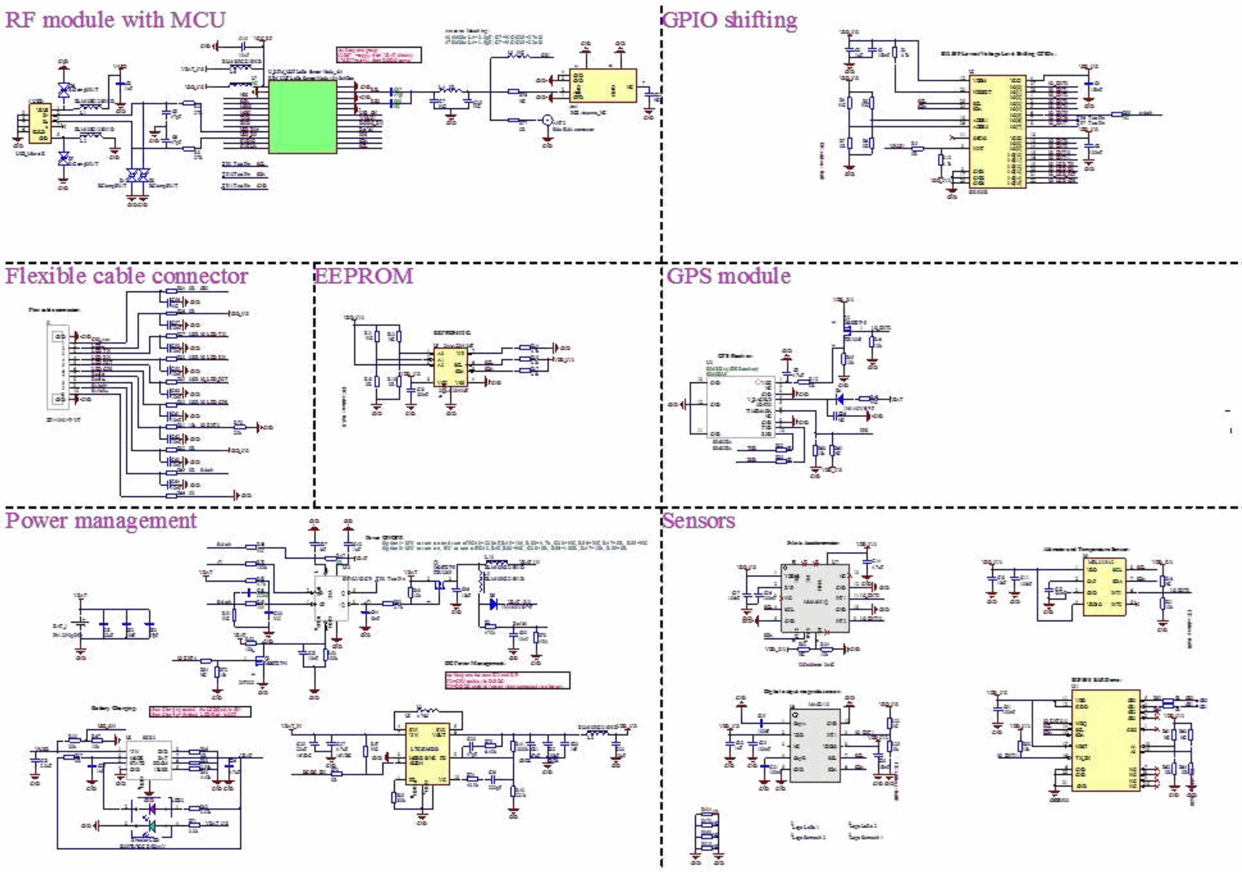


Figure 5: LoRa sensor node Schematics_1—Maiboard

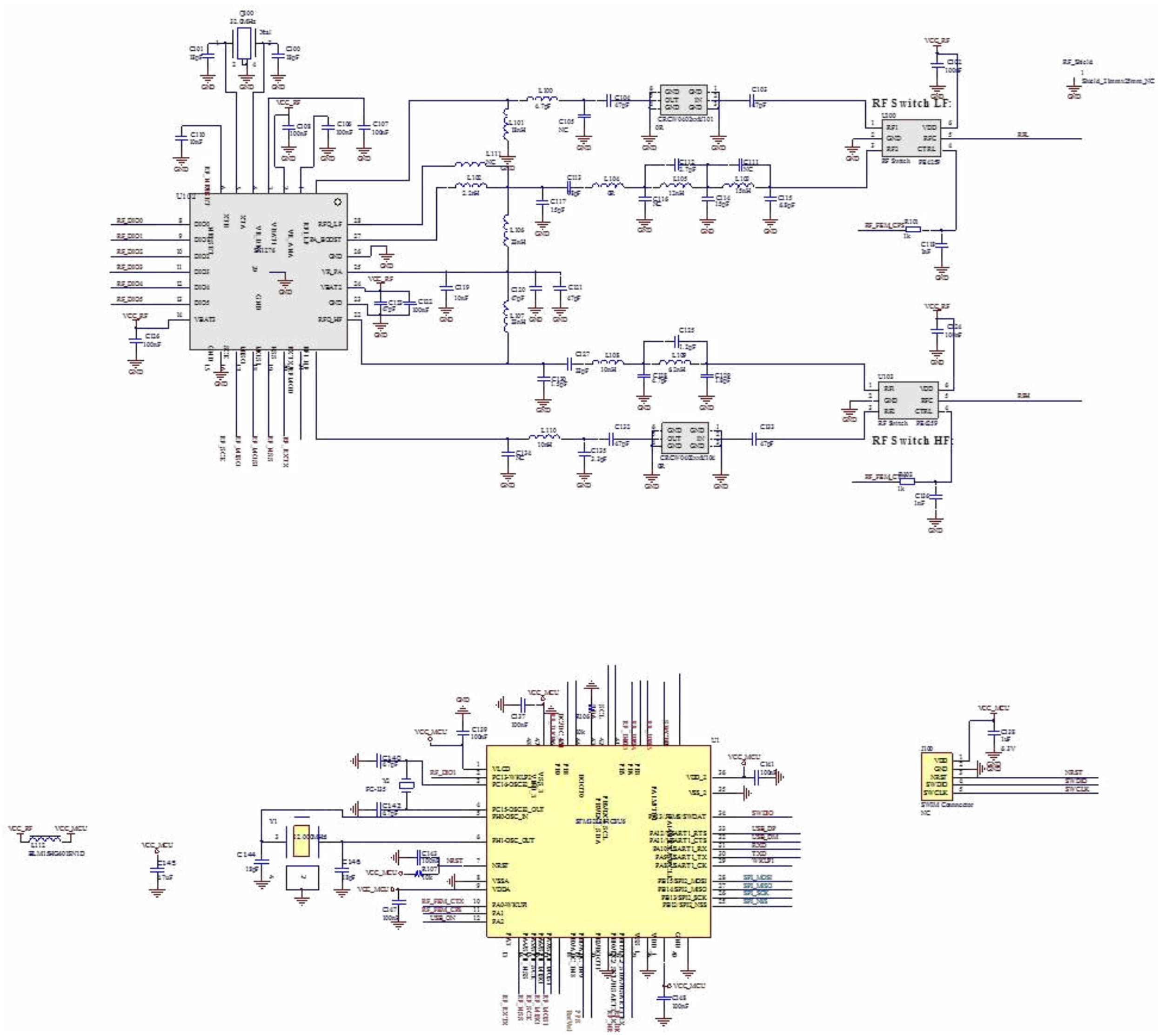


Figure 6 LoRa sensor node Schematics_2—RF+MCU part

The LoRa sensor node can either be supplied with an internal 4.2V lithium battery or through the USB connector. The internal circuitry is however powered at 3.3V. The RF module(SX1276+STM32L151 part) is powered directly from the battery via a diode; others are powered by a buck- boost DC-DC.

6.1 SX1276+MCU part

This part is the core part of the Sensor node. With Semtech's high performance LoRa transceiver SX1276 and ST's 32bit MCU STM32L151C8U6 which embedded with LoRaWAN protocol, the sensor node could work well with LoRaWAN GW/Server.

6.2 External antenna

For this sensor node Demo, an external antenna would be used. Below is some information for the external antenna tracking.

1) PN： AC-Q433-ZW-SMA
   Gain： 2.5dBi
   Freq: 434MHz /470MHz
   Size： Φ8*135MM
   Vendor: Asian Creation
   http://www.ycantenna.com/
2) PN: AC-QGC-L20
   Gain： 2.5dBi
   Freq: 868MHz /915MHz
   Size： Φ13*210MM
   Vendor: Asian Creation
   http://www.ycantenna.com/
3) PN: ANT-916-CW-HWR-SMA
   Gain: 1.9dBi
   Freq: 915MHz
   Size: 142mm
   Vendor: Linx Tech.

6.3 Others Hardware Details

As a handheld platform, the LoRa sensor node is mainly targeted to be battery powered and is thus equipped with a 4.2V lithium battery. To simplify the development of software on the LoRa sensor node, the platform can also be powered directly from a USB port, thus removing the need for a battery while developing software.

The LoRa sensor node is targeted to a wide range of applications and is therefore fitted with a variety of sensors which gives flexibility of use, and allows showcasing the IOT capabilities of the LoRa sensor node.

6.3.1 3-Axis Accelerometer sensor MMA8451Q

Made by Freescale, the MMA8451Q is a low-power, three-axis, capacitive accelerometer with 14 bits of resolution. This accelerometer is packed with embedded functions with flexible user programmable options, configurable to two interrupt pins. The device can be configured to generate inertial wakeup interrupt signals from any combination of the configurable embedded functions allowing the MMA8451Q to monitor events and remain in a low-power mode during periods of inactivity. The MMA841Q is accessible through the I2C bus at the address 0x1C. Please, consult Freescale website for more detailed information on the device.

6.3.2 3-Axis Magnetometer sensor MAG3110

The MAG3110 is a small, low-power digital 3-D magnetic sensor with a wide dynamic range to allow operation in PCBs with high extraneous magnetic fields. The MAG3110 magnetometer measures the three components of the local magnetic field which will be the sum of the geomagnetic field and the magnetic field created by components on the circuit board. The MAC3110 can be used in conjunction with a 3-axis accelerometer; orientation-independent accurate compass heading information can be achieved. The MAG3110 is accessible through the I2C bus at the address 0x0E. Please, consult Freescale website for more detailed information on the device.

6.3.3 Altimeter, Thermometer and Pressure sensor MPL3115A2

Freescale's MPL3115A2 provides highly precise pressure, temperature and altitude data with variable sampling rate capability. It has low-power consumption and requires zero data processing. The Xtrinsic MPL3115A2 pressure sensor smart features include digital output, two interrupts for auto-wake, minimum/maximum threshold detection and autonomous data acquisition. MCU usage is limited since the MPL3115A2 pressure sensor can process sensor data locally, reducing communications required with the host processor. The MPL3115A2 is accessible through the I2C bus at the address 0x60. Please, consult Freescale website for more detailed information on the device.

6.3.4 SAR proximity sensor SX9500

The SX9500 is a low-cost, very low power 4-channel SAR controller that can operate either as a proximity or button sensor. The SX9500 includes sophisticated on-chip auto-calibration circuitry to regularly perform sensitivity adjustments, maintaining peak performance over a wide variation of temperature, humidity and noise environments, providing simplified product development and enhanced performance. A dedicated transmit enable (TXEN) pin is available to synchronize capacitive measurements for applications that require synchronous detection, enabling very low supply current and high noise immunity by only measuring proximity when requested. The SX9500 is accessible through the I2C bus at the address 0x28. Please, consult Semtech website for more detailed information on the device.

6.3.5 GPS module SIM39EA

The SIMCom SIM39EA GPS receiver module with embedded GPS antenna enables high performance navigation in the most stringent applications and solid fix even in harsh GPS visibility environments. The SIM39EA is implemented with a Deep Sleep mode allowing reducing the power consumption while the positioning of the device is not mandatory. Connected to the UART of the MCU, the GPS module is providing directly the NMEA data from the GPS. Please, consult the SIMCom for more detailed information on the device.

6.3.6 IO Expander

The LoRa sensor node is equipped with the Semtech SX1509 ultra low voltage IO- expander which allows connecting some of the less vital part of the circuitry such as spare IOs and LEDs. The IO expander is accessible through the I2C at the address 0x3E. Please, consult the Semtech website for more detailed information on the device.

6.3.7 EEPROM

The LoRa sensor node is also equipped with a Microchip 24AA1287 EEPROM which can hold up to 128 Kbit (16K x 8) of data. The EEPROM is accessible Through the I2C at the address 0xA8. Please, consult the Microchip website for more detailed information on the device.

6.3.8 Battery charging SC811/SC813

The SC811 and SC813 are highly versatile single input triple mode (adapter/USB high current, USB low current) linear single-cell Li-ion battery chargers, each in an 8 lead 2x2 MLPD ultra-thin package. The input will survive sustained input voltage up to 30V to protect against hot plug overshoot and faulty charging adapters. The SC811 has 9.6V rising, 8.2V falling OVP thresholds for general purpose charging with low cost adaptors. The SC813 has 6V rising, 5.6V falling OVP thresholds for customers utilizing charging adapters with specific cations that are similar to a USB Vbus supply. The SC811 and SC813 differ only in OVP threshold. Please consult Semtech website for more detailed information on the device.

6.3.9 Battery GT423450AR

Battery used in the sensor node is GT423450AR from GTNY. The GT423450AR is a Li-ion rechargeable battery pack, with 3.7V 800mAh output, which is used in mobile and any other handheld devices. This battery had past Material Safety test, Cargo Transportation test, and UN38.3 test. Picture below shows the test report. Please consult with GTNY in Shenzhen for more details.

Figure 7: Passed test report of battery GT423450AR

7 LoRa sensor node Demo Software

The LoRa sensor node is normally delivered fully programmed and is ready to be used. While the current software is still being worked on, it is already an advanced snapshot of the LoRa sensor node capability.

The current implementation is based around the LoRaWAN which takes all its values when operated in conjunction with LoRa Gateway and LoRa Server (a simple LoRa receiver can nevertheless be used to receive the LoRa sensor node packets).

7.1 Sensor node Firmware Upgrade

Although there is a SWIM port for SW download inside the node, using the bootloader to upgrade the firmware is strongly suggested. Please ask for the newest firmware from local Semtech FAE.
Paragraph below show the details how to upgrade the firmware for the sensor node with bootloader.

7.1.1 Tools Installation

Extract and install “DfuSe” tool, DfuSe_Demo_V3.0.3_Setup.exe for 32 bits PC, DfuSe_Demo_V3.0.3_Setup_amd64.exe for 64 bits PC.

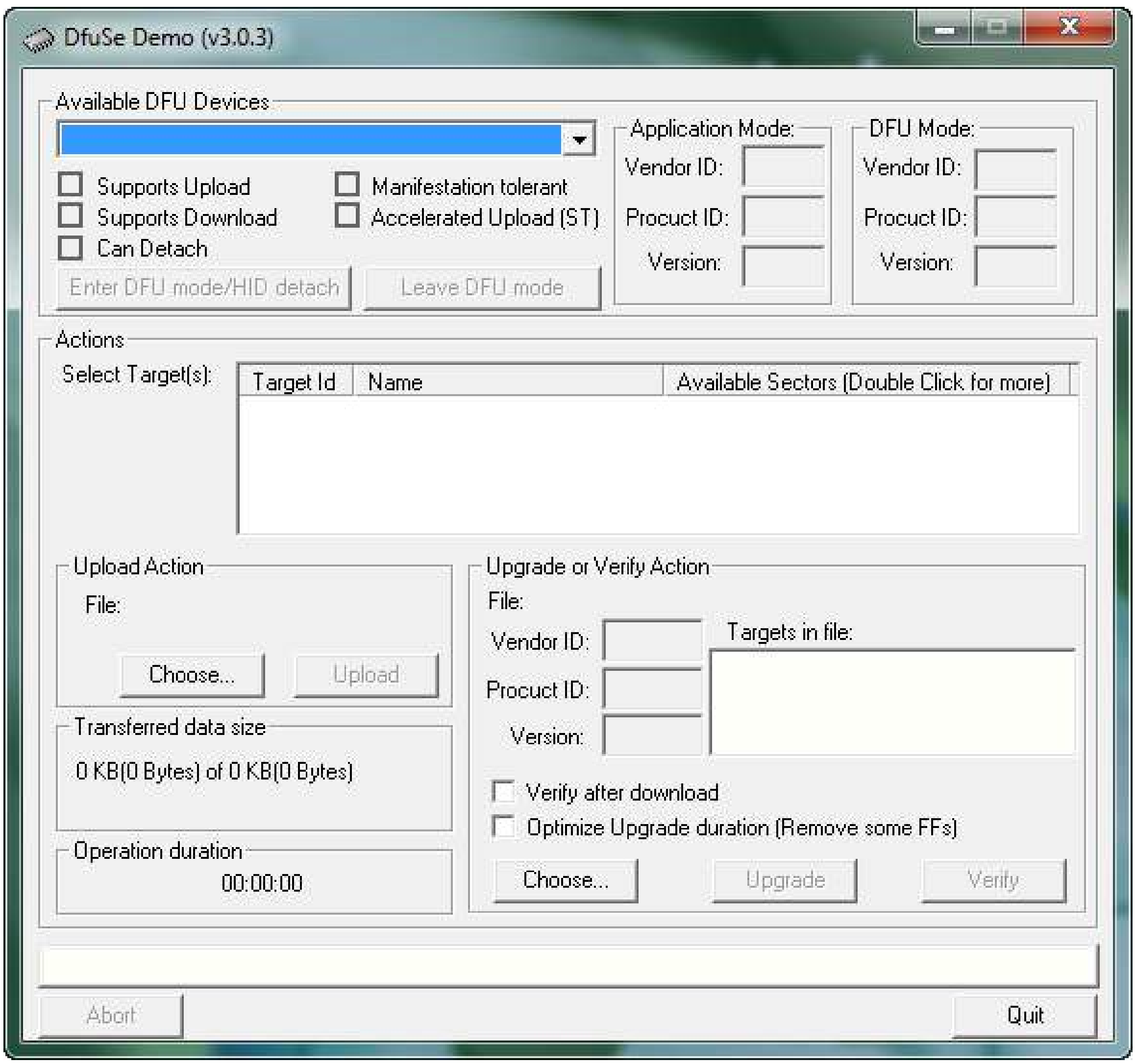


Figure 8: DfuSe Demo for bootloader

7.1.2 Enter Bootloader Mode

To enable bootloader, please hold the radio button first, then press power button, then release both buttons after SensorNode is powered on, at this time four LEDs on the panel will be turned on.

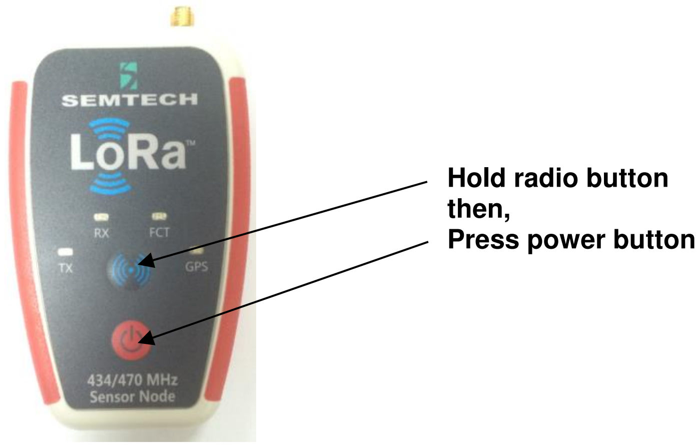


Figure 9: How to enter bootloader mode with LoRa Sensor Node

7.1.3 Connect SensorNode to PC and Install Driver

Once connected, windows7 will search the driver automatically. Once installed, a STM device could be seen from Device Manager. If installed failed, please try to install driver manually. The driver is placed at ***C:\Program Files (x86)\STMicroelectronics\Software\DfuSe\Driver***, if you don't change the installation directory.

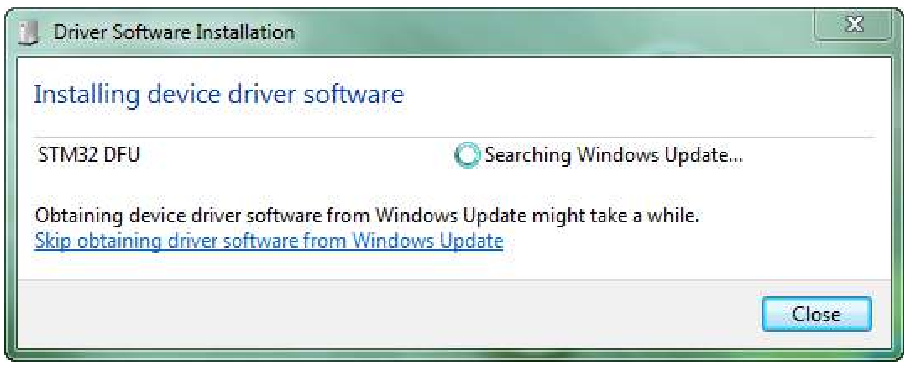


Figure 10: STM32 DFU Installing Driver

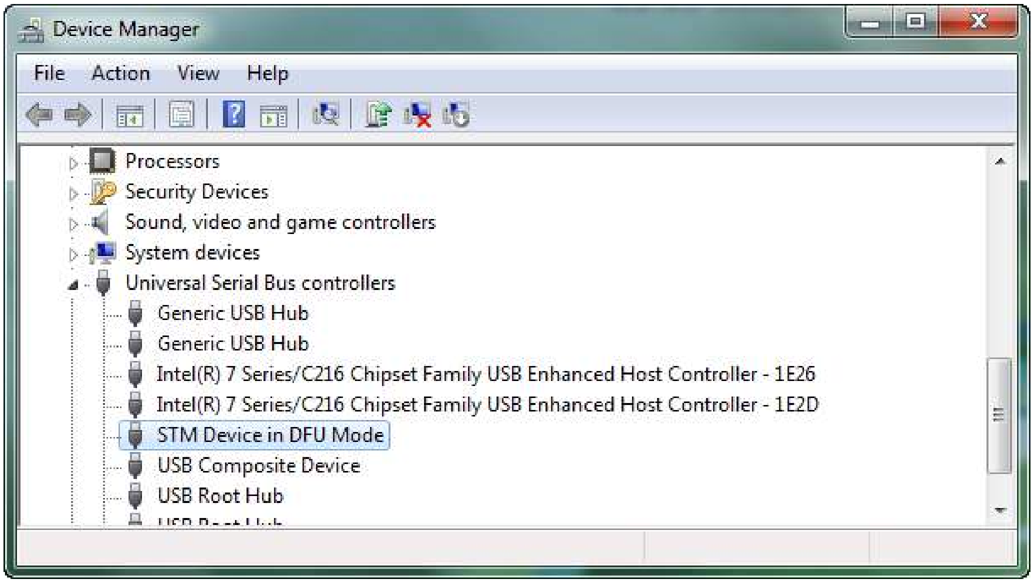


Figure 11: Sensor Node DFU Bootloader Mode

7.1.4 Upgrade

Please follow the pictures below to upgrade. (Note: Please leave verify after download option unchecked) Firmware is in **.dfu** format.

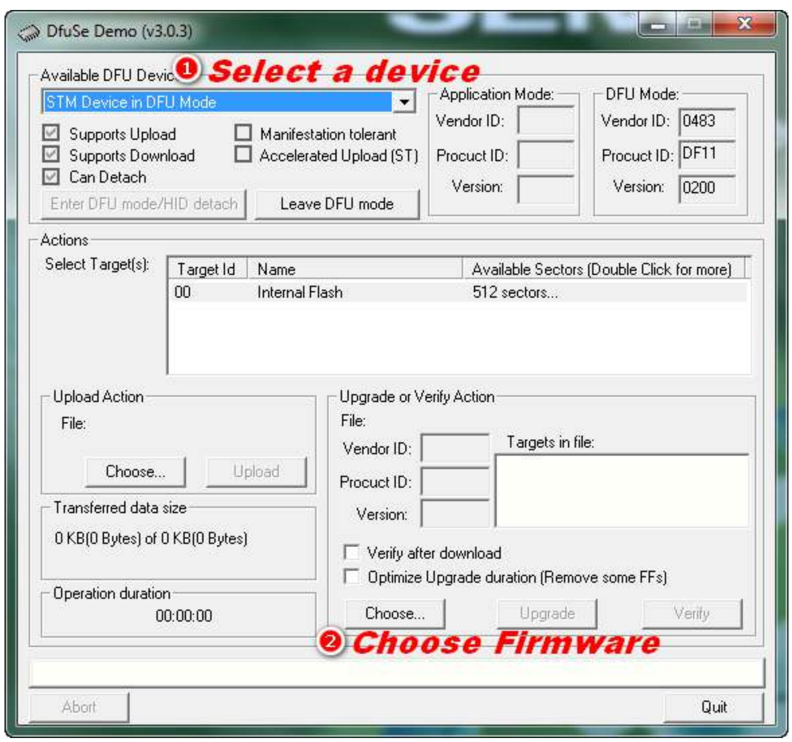


Figure 12: DfuSe Panel

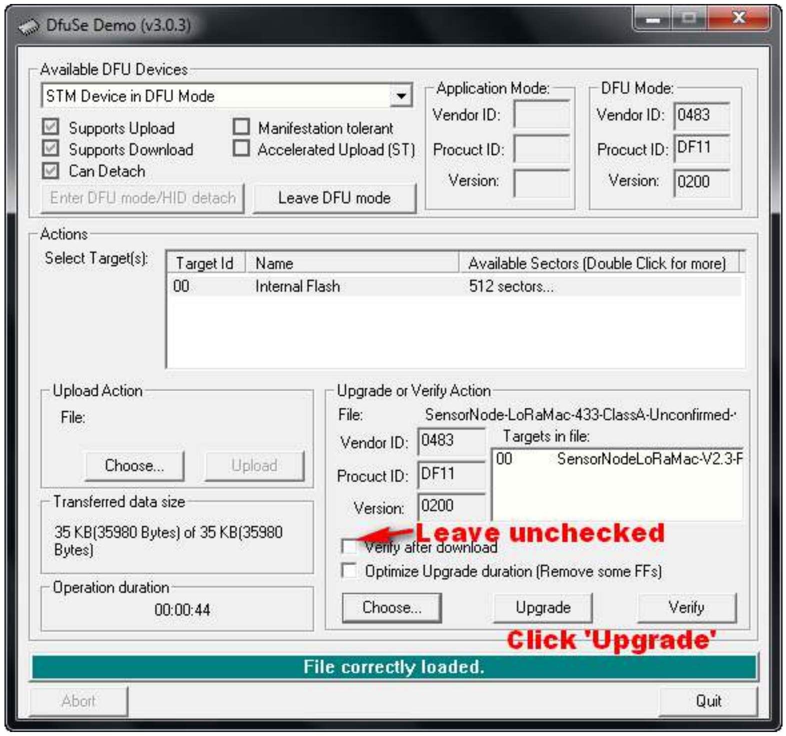


Figure 13: Dfu Firmware Choosed

Figure 14: Confirm to Upgrade

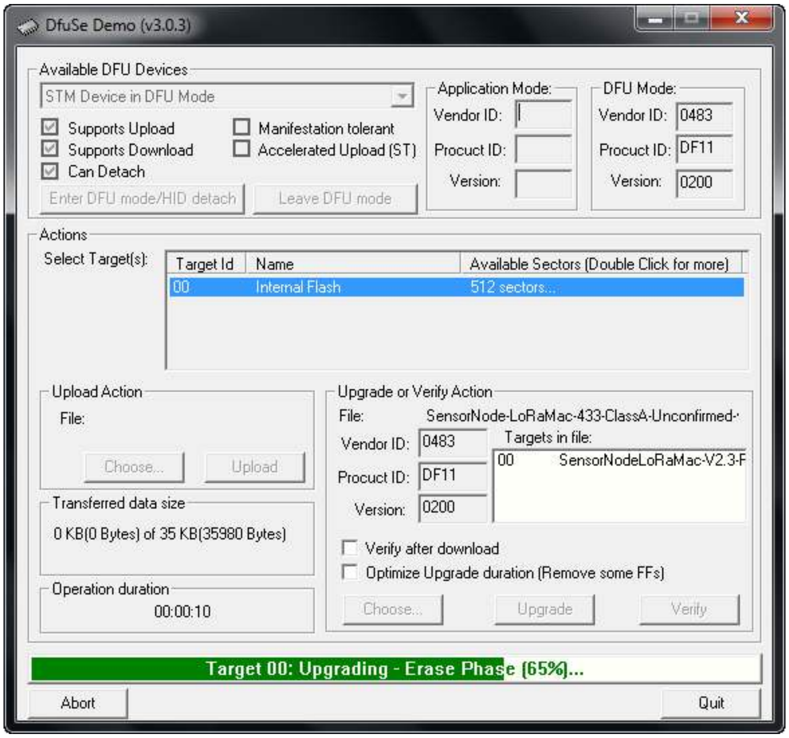


Figure 15: Erasing when bootloader

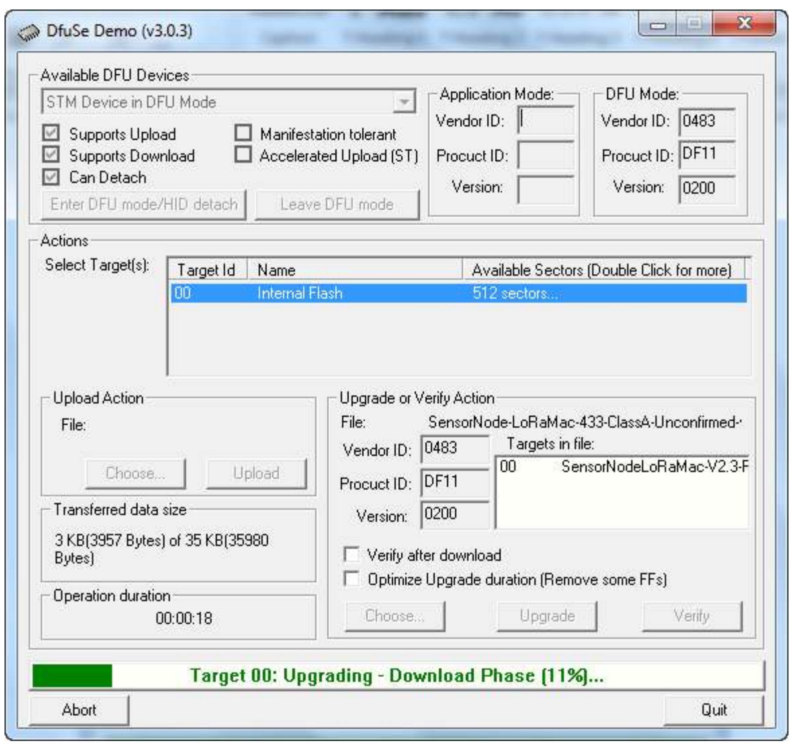


Figure 16: Downloading when bootloader

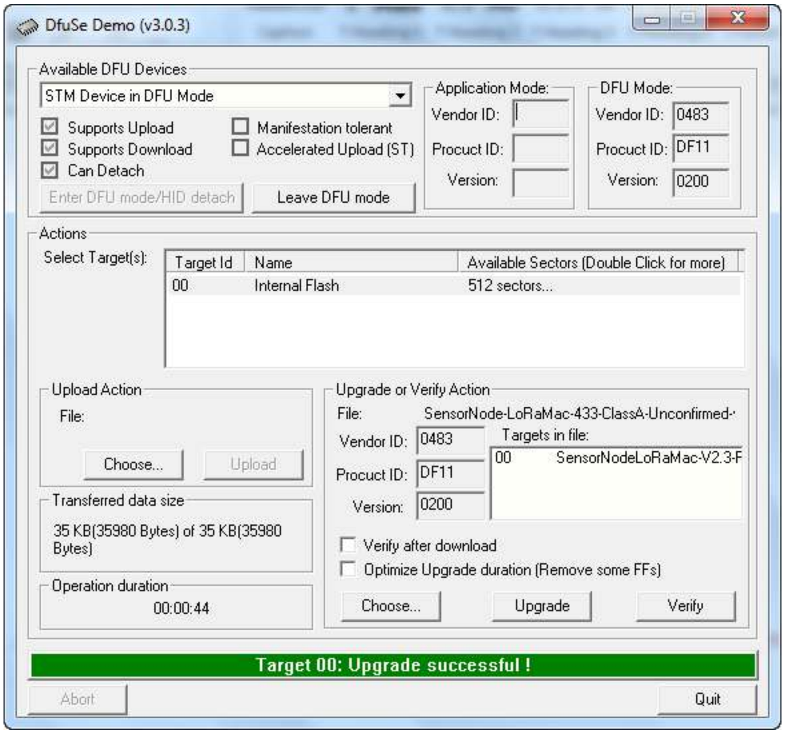


Figure 17: bootloader successful

7.2 Payload Format

The implemented software is based around the GPS and the MPL3115A2 and the packets payload is composed of 16 bytes. Of course, this payload is only given as an example and the user is free to change it or to add further information coming from other sensors: The current payload is composed of:

Byte [0]	>	Value:	0x00 or 0x01

The first byte of the payload indicates the status of LED “FCT” on the face of the node which is controllable from the LoRaServer. The server can remotely switch this LED ON or OFF.

Byte [1]	>	Value:	MSB of the MPL3115A2 measured atmospheric pressure
Byte [2]	>	Value:	LSB of the MPL3115A2 measured atmospheric pressure

Byte 1 and 2 represent the atmospheric pressure in dPa (deci-Pascal) as it is measured through the MPL3115A2. This value can easily be divided by 10 to get the standard hPa value.

Byte [3]	>	Value:	MSB of the MPL3115A2 measured Temperature
Byte [4]	>	Value:	LSB of the MPL3115A2 measured Temperature

Byte 3 and 4 represent the signed value of the temperature (x 100) as it is measured through the MPL3115A2. This value can easily be divided by 100 to get the temperature with decimal values

Byte [5]	>	Value:	MSB of the MPL3115A2 measured Altitude
Byte [6]	>	Value:	LSB of the MPL3115A2 measured Altitude

Byte 5 and 6 represent the signed value of the altitude (x 10) as it is measured through the MPL3115A2. This value can easily be divided by 10 to get the altitude with decimal values. It is important to notice that the value returned is not calibrated. The MPL3115A2 returns the estimate altitude relative to the atmospheric pressure. Depending on the measurement condition, the value may be within plus or minus 100m. Please, refer to the component datasheet for more details.

Byte [7]	>	Value:	0x00 to 0xFF, battery level

The seventh byte of the payload indicates the status of the battery. The status of the battery is returned as described in the LoRaWAN specification:

0x00:	The device is connected to an external power source
0x01 to 0xFE:	The battery level, 1 being the minimum and 254 the maximum. This measurement is a linearized discharge function of the battery and is thus battery dependent
0xFF:	The LoRa sensor node was not able to read the battery level

Byte [8]	>	Value:	MSB of the SIM39EA received Latitude
Byte [9]	>	Value:	CSB of the SIM39EA received Latitude
Byte [10]	>	Value:	LSB of the SIM39EA received Latitude

Byte 8, 9 and 10 represent the latitude as defined by the LoRaWAN specification. The north-south latitude is encoded using a signed 24 bit word where -2^{23} corresponds to 90° south (the South Pole) and $2^{23}-1$ corresponds to 90° north (the North Pole). The equator corresponds to 0.

Byte [11]	>	Value:	MSB of the SIM39EA received Longitude
Byte [12]	>	Value:	CSB of the SIM39EA received Longitude
Byte [13]	>	Value:	LSB of the SIM39EA received Longitude

Byte 8, 9 and 10 represent the longitude as defined by the LoRaWAN specification. The east-west longitude is encoded using a signed 24 bit word where -2^{23} corresponds to 180° west and $2^{23}-1$ corresponds to 180° east. The Greenwich meridian corresponds to 0.

Byte [14]	>	Value:	MSB of the SIM39EA received Altitude
Byte [15]	>	Value:	LSB of the SIM39EA received Altitude

Byte 14 and 15 represent the value of the altitude (in meters) as it is received through the SIM39EA.

Table 1: An example for node data to GW

Function	LED Status (FCT)	Air pressure		Temperature		Altitude		Battery Level	GPS latitude			GPS longitude			Gps Altitude	
byte num	byte00	byte01	byte02	byte03	byte04	byte05	byte06	byte07	byte08	byte09	byte10	byte11	byte12	byte13	byte14	byte15
example	00	25	db	09	ab	0b	78	a9	42	da	7a	04	f4	2d	01	b0
Value	FCT off	2273.3hPa		24.75℃		2936m		67%	43.81306°			3.24653°			432m	

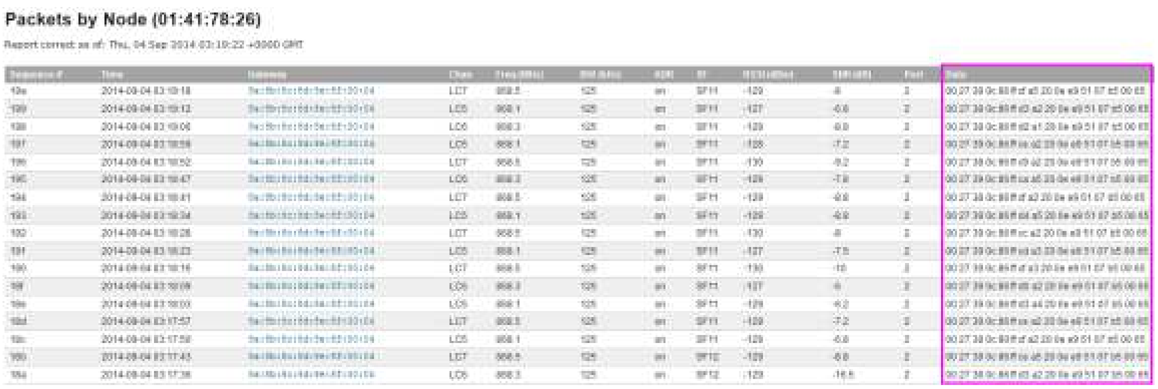


Figure 18: The data on IOT server from sensor node

7.3 PER Analysis

It is also important to notice that some of the LoRaWAN protocol frames can be used to perform network testing such a PER test. A PER test can be perform thanks to the sequence number which is maintained between the LoRa Server and the LoRa sensor node. Every packet send from the LoRa sensor node is numbered and thus can be extracted from the LoRaWAN on the server side to perform the PER analysis. For more information on the sequence numbering or on any other aspect of the protocol, please refer to the LoRaWAN specifications

7.4 LoRaWAN Configuration

With LoRaMoteConfig.exe tool, customer could configure the sensor node with new parameters like frequency channel, RXWIN2, DevAddr, Key, OTAA mode, ABP mode and so on.
For this part, please refer to “LoRaMote_SensorNode_ConfigGUI_usersguide.pdf” for more details.

8 LoRaWAN transceiver energy profile

The figure below shows the power consumption of the LoRaWAN transceiver (SX1276+ STM32L151C8u6). The code is organized so that the MCU and all peripherals are in sleep mode most of the time. The blue line shows the current consumption of the RF module across a 10 ohm resistor (L6 on the schematics is a magnetic bead which can be removed to allow measuring the current).

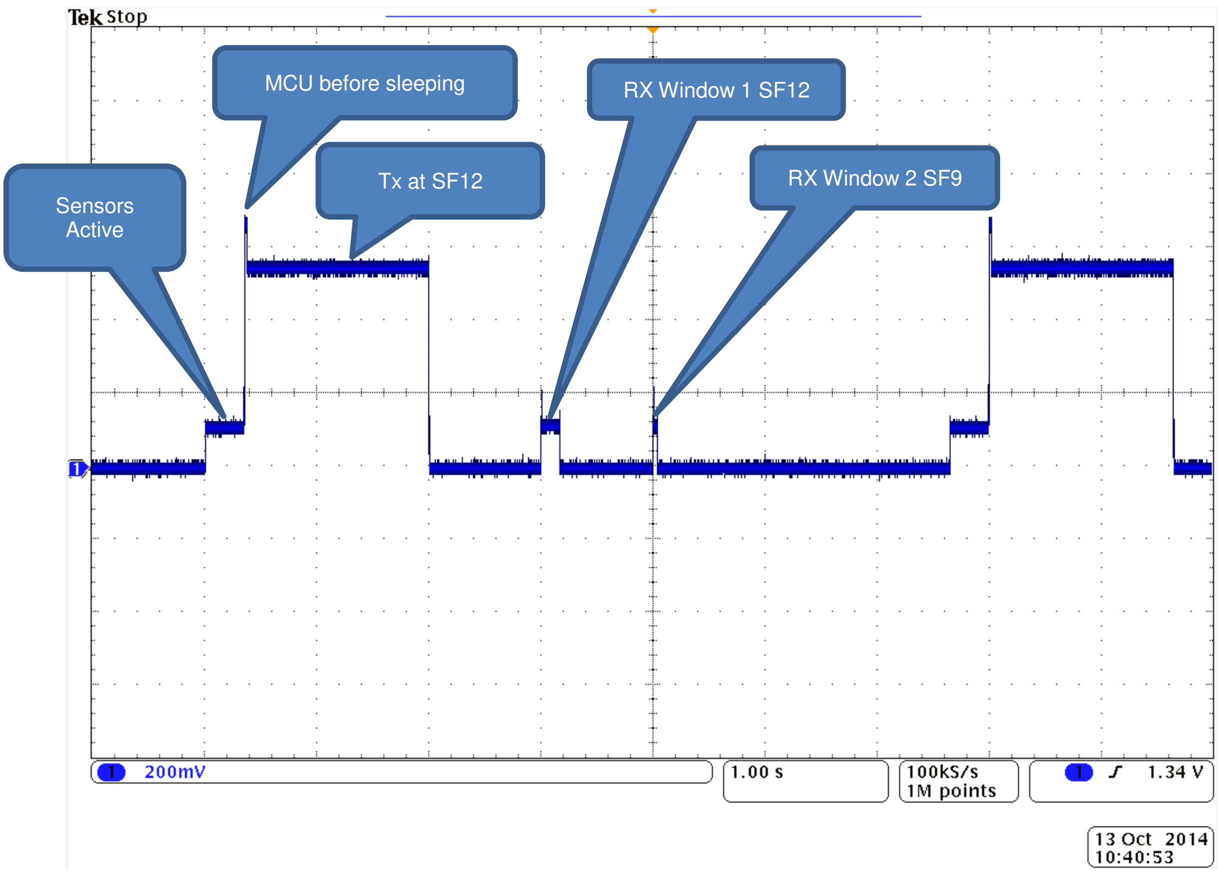


Figure 19: RF module Energy Profile

For details information on the LoRa protocol, it is advised to read the LoRaWAN specifications. The principal aspect of the protocol is the opening of two reception windows after each transmission.

The figure below highlights the timing of the events:

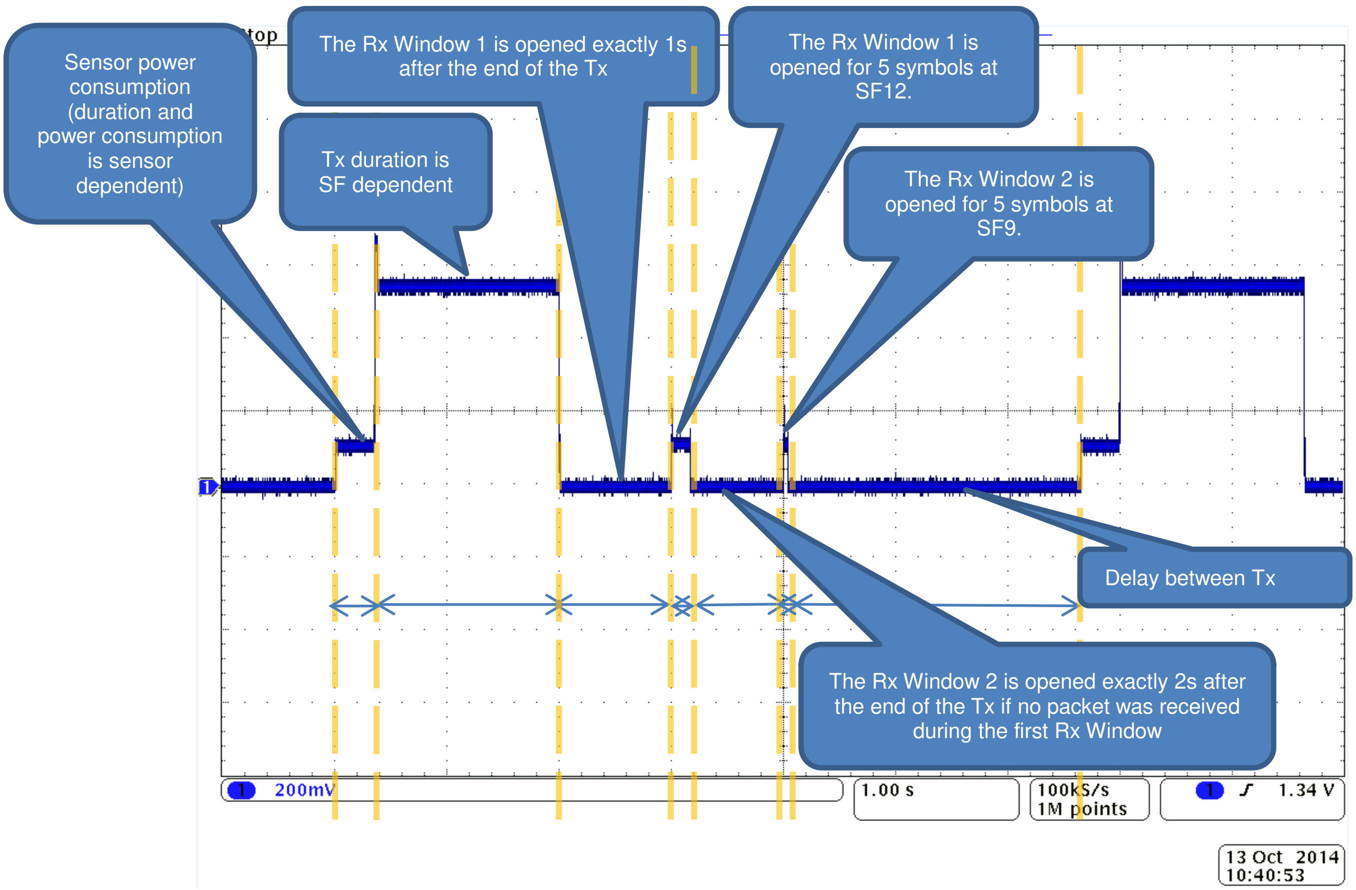


Figure 20: Power Consumption Across Time

The figure below highlights the power consumption of the RF module during a successful reception.

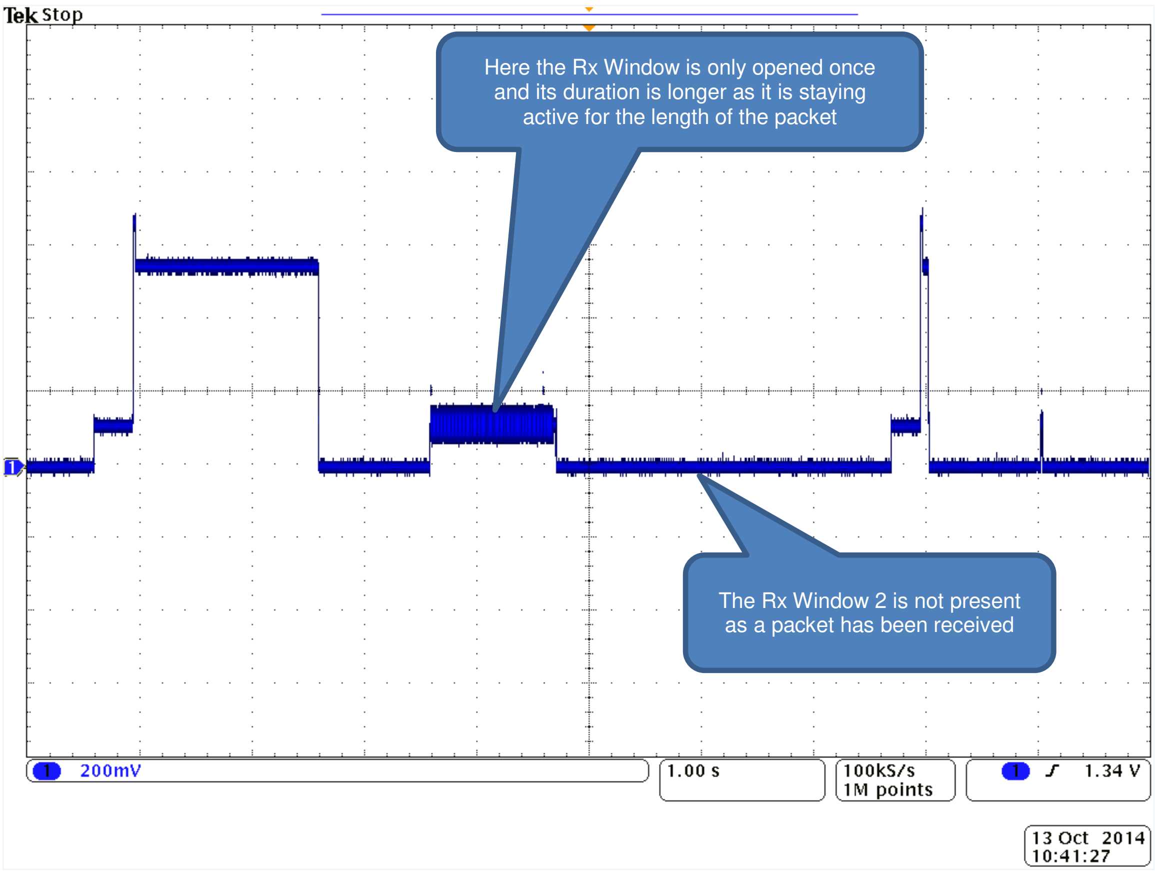


Figure 21: Power Consumption with successful Rx

When the ADR (Adaptative Data Rate) is active, the Gateway can send the information to the Node to switch to a lower SF. Here, the power consumption is greatly reduced during the transmission and reception as the SF is much lower.

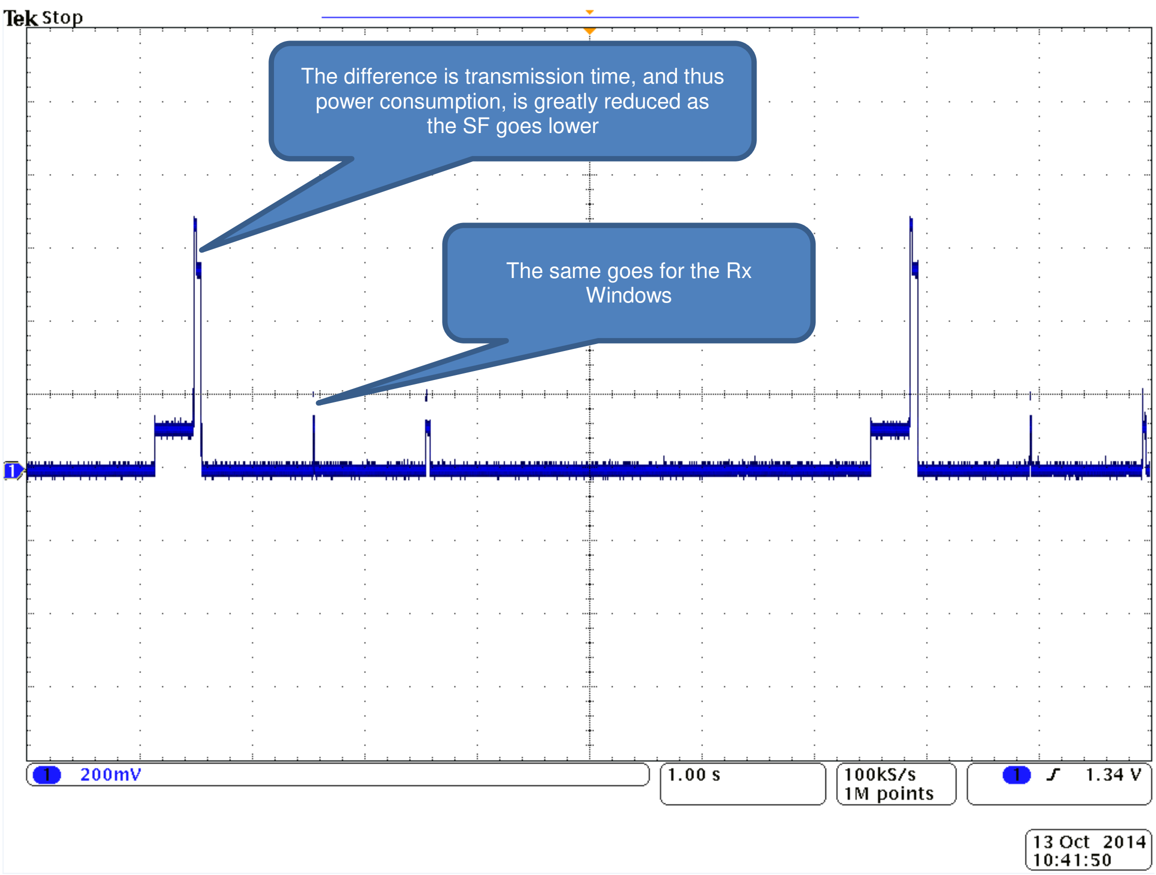


Figure 22: Power Consumption at SF7

Revision History

Rev #	Date	Editor	Changes
0.1	2014-11-21	R.Lei	Creation for draft
0.2	2014-12-18	R.Lei	Add Product specifications
0.3	2015-11-23	R.Lei	Update with Sensor node v4

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