Vodafone Technical Documentation

> **Welcome**
> Welcome to the technical documentation center of Exelonix GmbH for Vodafone products. Here you will find all technical resources of our Vodafone NB-IoT products.

Vodafone USB Connect LPWA

Description

The **Vodafone USB Connect LPWA** (Low Power Wide Area) has been designed for customers who want to connect to the cellular IoT Networks (NB-IoT/LTE- M) in a simple way. It offers a standard LPWA IoT module device for any hardware, with a USB-connector.

Supported Features :

- LTE Category NB1 (Release 13)
- LTE Category M1 (Release 13)
- 3GPP Frequency Bands: B2, B3, B4, B5, B8, B12, B13, B20, B28
- Small USB-dongle form factor
- Vodafone global IoT SIM embedded
- Integrated and external antenna connector for improved coverage

Supported operating systems:

- Linux Kernel 4.14 or above
- Windows 10
- Android 4.0 and above

Supported Cellular Networks:

- International multi-region coverage in Cat M1 / NB1 radio access technologies.

IoT Module & Chipset:

- IoT module: u-blox SARA R410
- based on Qualcomm MDM9206

Device Management:

Ressources

High Level Data Sheet

Getting Started (NB|Easy)

Getting Started (NB|METER)

Software & Drivers

Firmware Update

Hardware Manual

AT Command Cookbook

AT Command Manual

IoT module Specification

Certifications

FAQ

External Ressources (Websites):

Vodafone IoT Terminals

IoT module

Chipset

NB|METER App in Play Store

- AT commands
- OTA firmware delivery

Typical applications:

Applications with low data consumption :

- Collection of sensor data
- Industrial or environmental monitoring
- Connectivity for smart city applications
- E-health
- Predictive maintenance
- Metering
- Smart building sensors
- Network monitoring & troubleshooting

Vodafone NB-IoT Development Kit (Available in Germany)

Description

The **Vodafone NB-IoT Development Kit** has been designed for customers who want to start an NB-IoT development.

Supported Features :

- Small form factor
- Interfaces: UART,RS232, USB
- Integrated into an IoT cloud
- Quick start-up
- NB|EASY programming interface to control modem functionality
- Comparison of NB-IoT against 2G/3G/4G standards

The Vodafone NB-IoT Development Kit can also be controlled via Android smartphones with the NB|METER App. Beside these tools, the standard u-blox tools (m-center) works as well.

Ressources

Presentation

Getting Started (NB|EASY)

NB | EASY interface

Getting Started (NB|METER)

Software & Drivers

NB | DEV KIT Hardware Manual

Declaration of Conformance

IoT Manager

Flyer

Website (Vodafone)

Antenna Specification

FAQ

USB Connect LPWA

Content

Frequently Asked Questions

High Level Data Sheet

Features	Content
Dimensions	88 mm x 28 mm x 11.5 mm
Weight	< 20 g
Power	5 V/500 mA
Management	AT commands, OTA firmware upgrade, NB|Easy, NB|Meter
Hardware platform	ublox R410
IoT RAT Technologies	CAT M1, NB-IoT
Cellular bands and peak data rates EU variant	3/8/20/28
Cellular bands and peak data rates NA variant	2/4/5/12/13
Cellular bands and peak data rates Australia & New Zealand variant	3
Antenna	Internal Antenna
Operating system	1. Win 7/8/8.1/10 2. MAC OS X 10.9~10.12 3. Linux Kernel 2.6.21 thru 4.11 4. Android: 4.0 thru 7.1
Physical interfaces	USB External Antenna Connector (TS9) 2xLED
Humidity range	5% to 95%
Temperature range	Operating temperature: -20°C to 65°C Storage temperature: -40°C - +85°C
Certifications	CE (RED), FCC, RCM

USB connect LPWA Datasheet

LPWA product sh... 136902 (3).pdf

IoT Modul Documentation

The USB Connect LPWA with Model-No. VODEXL-01 uses the IoT Module ublox SARA R410.

In the following, useful documents and weblinks of the SARA R410 are listed.

ublox SARA R410

Ublox Web Resources

Data Sheet

AT CMD Manual

Hardware Manual

USB Connect LPWA - Hardware Manual

USB Connect LPWA - Hardware Manual

- 1 Version
- 2 General Information
- 3 Description
- 4 Physical Dimensions
- 5 Printed Circuit Board
- 6 External Interfaces
    - 6.1 USB
    - 6.2 External Antenna Connector (RF)
- 7 Supported Frequency Bands
- 8 Internal Antenna Characteristics
- 9 Integration USB Connect LPWA
    - 9.1 Peripheral Layouts
        - 9.1.1 Recommended layout for low frequency bands (5, 8, 12, 13, 20, 28)
        - 9.1.2 Recommended layout for high frequency bands (2,3,4)
        - 9.1.3 Not recommended layout
    - 9.2 Working and Storage Environment
- 10 Current Consumption
- 11 RF Noise Considerations
    - 11.1 Noise from the Processor Board:
    - 11.2 Noise from an active USB-Connection:

This section describes the hardware part of the product which details the information about the PCB , the internal antenna as well as the

integration part

Version

current Version: v83 (06.11.19)

General Information

Name	Vodafone USB Connect LPWA
Model	VODEXL-01
Manufacturer	Exelonix GmbH Washingtonstrasse 16/16a , 01139 Dresden Germany

Description

The USB Connect LPWA is a USB-Device for cellular machine type communication and supports the cellular 3GPP LPWA-standards NB-IoT and CAT-M1 (LPWA - Low Power Wide Area)

The device is connected to the host device by a USB interface, which supplies the USB-Device with power and transmit and receive data.

The radio signals are transmitted and received by an internal or external antenna via a TS9 connector (external antenna is not included).

The status is indicated by LED:

- RED: Device is powered on
- GREEN: device is registered to the network
- GREEN/RED alternating: device is registered to the network and roaming (this will be the usual pattern)

Remark: The LED can be configured differently with a different GPIO configuration of the ublox R410 Module via AT-commands (see AT Comand cook book)

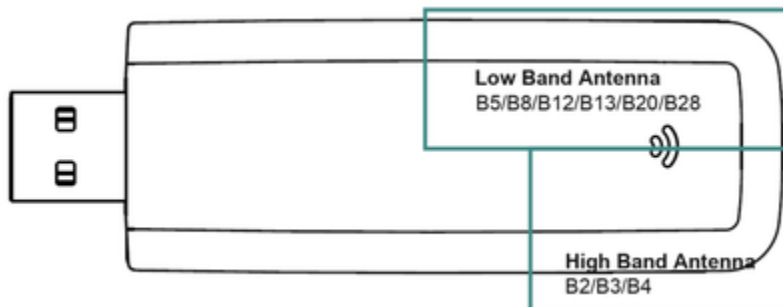**Figure 1: USB connect LPWA Device**

Figure 2: USB connect LPWA Device Bottom view / Top view
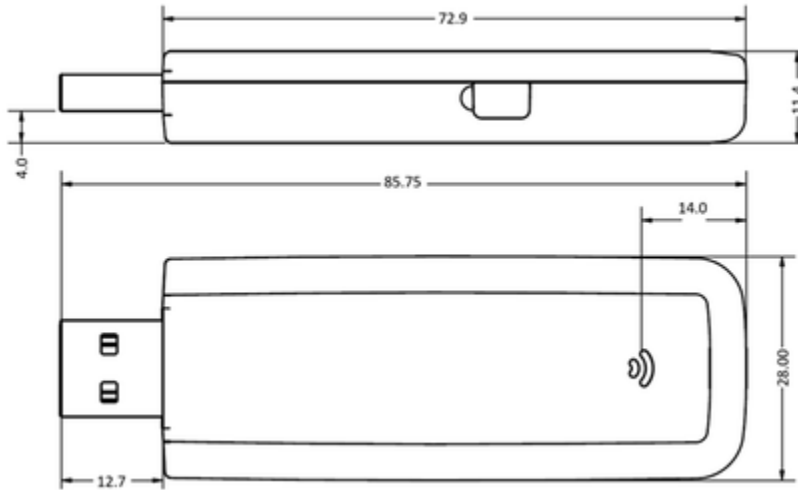
Physical Dimensions

Figure 3: Physical Dimension

Length x Width x Height = (85,75 +/-0,3) x 28,0 +/-0,2) x (11,4 +/- 0,2) mm

Weight: 35 g

IP Rating: IP40 (protected against Solid particles >1 mm, no Liquid ingress protection)
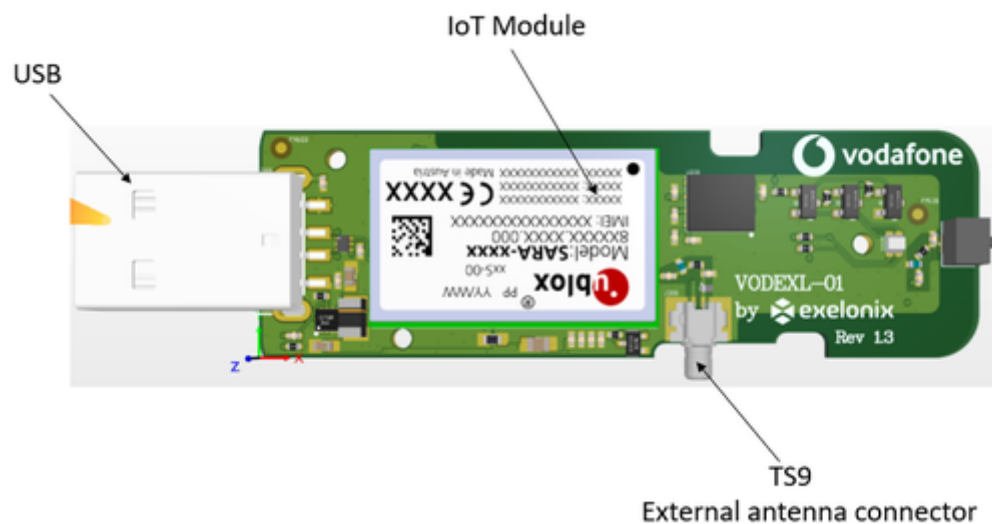
Printed Circuit Board

Figure 4: General USB layout

External Interfaces

The device has two interfaces:

- USB-A (male)
- TS9 RF-interface for external antenna

USB

The USB connector provides power and data-interface with host devices (e.g. Laptop, Raspberry Pi, SBC, ...).

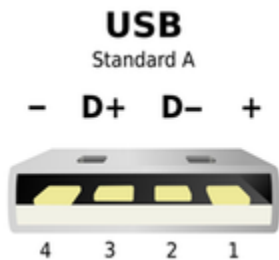The connection is specified as defined by the USB standard.

Figure 5: USB-A connector (male)

PIN	Description
1	VCC (5V)
2/3	Differential data wires
4	GND

Table 1: USB PIN Description

EXTERNAL ANTENNA CONNECTOR (RF)

In order to connect an external antenna, the device has an TS9 connector (female).

Figure 6: TS9 (female) external antenna connector

(Inside RF-Signal, Outside GND)

Examples for recommended external antennas:

- Model, Link
- ...

Supported Frequency Bands

Following LTE-Frequencies are supported.

LTE Band	Range (MHz)	Uplink (MHz)	Downlink (MHz)
12	700	699-716	729-746
13	700	777-787	746-756
28	700	758 - 803	703 - 748
20	800	832-862	791-821
5	850	824-849	869-894
8	900	880-915	925-960
2	1900	1850-1910	1930-1990
3	1800	1710-1785	1805-1880
4	1700	1710-1755	2110-2155

Table 2: LTE Frequency Bands

Internal Antenna Characteristics

Transmission Characteristic (Uplink)

Total Radiated Power (TRP) is a measure of how much power is radiated by an antenna when the antenna is connected to an actual radio (or transmitter). TRP is an active measurement, in that a powered transmitter is used to transmit through the antenna. The total received power is calculated and summed up over all possible angles (hence, it is a spherical or 3d measurement) and the result is the Total Radiated Power.

Reception Characteristic (Downlink)

Total Isotropic Sensitivity (TIS) is a commonly quoted specification in the mobile phone industry. This sensitivity on the antenna and the receiver that make up the communication link. The sensitivity of a receiver is the smallest amount of power that can be input to the receiver, such that the receiver can still maintain reliable communication. This means that data can be transmitted reliably as long as the Block Error Rate (BLER) is 2.0 %. To determine this sensitivity, a known data signal is input to the receiver, and the BLER is recorded. The first data signal typically has a high power, to ensure that the BLER is lower than the threshold BLER. The power on the data signal is gradually dropped until the BLER reaches the threshold. (QPSK and a Subcarrier Spacing of 180kHz 12 Subcarrier)

TRP & TIS are parameters directly related to the antenna radiation efficiency, and are well proven measurements in reverberation chambers. The TRP and TIS measurements in a reverberation chamber are standardized and included in the 3GPP Test Specification TS 34.114.

Table 3 describes the working bands in LTE NB-IOT and LTE -Cat M1 that the USB connect LPWA supports.

LTE Band	Channel	Downlink (MHz)	TIS (dBm)	Channel	Uplink (MHz)	TRP (dBm)
12	5095	737,5	-105	23095	707,5	21,7
13	5230	751,0	-106	23230	782,0	21,6
28	9435	780,5	-102	27435	725,5	21,7
20	6300	806,0	-99	24300	847	20,3
5	2525	881,5	-102,9	20525	836,5	20,3
8	3625	942,5	-112	21625	897,5	21,9
3	1575	1842,5	-116	19575	1747,5	20,1
2	900	1960	-114	18900	1880	21,7
4	2175	2132,5	-112	20175	1732,5	21,3

Table 3: NB-IoT Antenna Performance

LTE Band	Channel	Downlink (MHz)	TIS (dBm)	Channel	Uplink (MHz)	TRP (dBm)

|	12	5095	737,5	-94,6	23095	707,5	20,8
	13	5230	751,0	-94,9	23230	782,0	22,4
	28	9435	780,5	-91,5	27435	725,5	22,6
	20	6300	806,0	-91,8	24300	847	21,6
	5	2525	881,5	-97,4	20525	836,5	20,7
	8	3625	942,5	-100,1	21625	897,5	22,2
	3	1575	1842,5	-107,0	19575	1747,5	20,4
	2	900	1960	-105,8	18900	1880	22,5
	4	2175	2132,5	-105,2	20175	1732,5	20,3

Table 4: Cat-M1 Antenna Performance

Integration USB Connect LPWA

PERIPHERAL LAYOUTS

For optimal antenna performance we recommend the use of the layouts detailed in the following figures. To avoid poor antenna performance an incorrect layout is also illustrated.
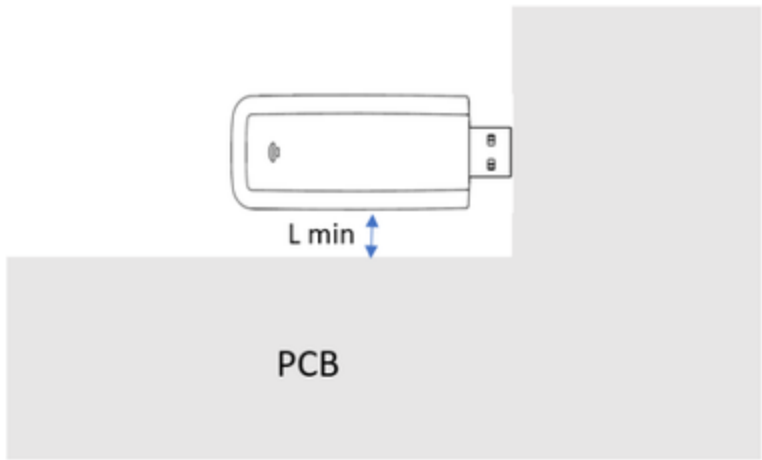
Recommended layout for low frequency bands (5, 8, 12, 13, 20, 28)
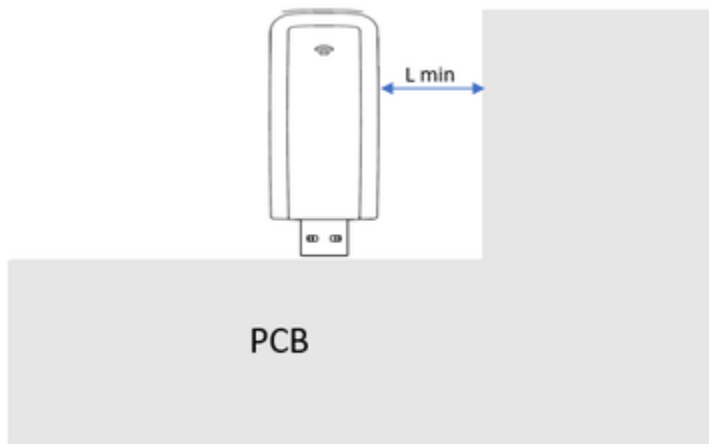
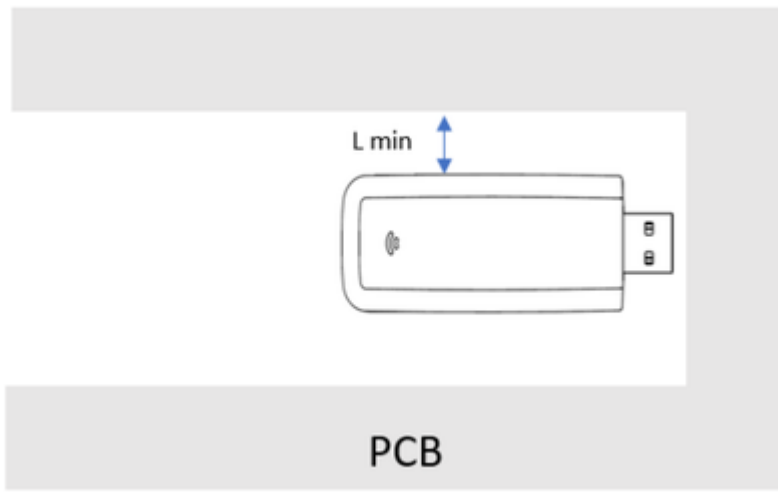**Lmin >2 cm:** The minimum distance between the dongle and the PCB

- The USB dongle is connected to a PCB min 10 cm* 10 cm (L*W)
- Ensure that the dongle is not covered by any metal shielding (such as an earpiece or loudspeaker) unless recommended by the layout.
- Optimum performance can only be achieved if any surrounding metal has a min distance of 2 cm to the dongle.
- Maintain a distance between any other auxiliary devices and the dongle to avoid RF coupling.
- Critical RF exposing device components such as a crystal oscillator and switched-mode power supply must be filtered or shielded to minimize potential impact on the dongle.
- Do not place any components that interfere with antenna performance above the dongle's antenna to avoid a drop in antenna gain.
- The USB dongle is embedded in the longer edge of the PCB, therefore the internal antenna for lower frequency bands is not blocked by the PCB.

Recommended layout for high frequency bands (2,3,4)

The USB dongle is embedded in the longer edge of the PCB, therefore the internal antenna for higher frequency bands is not blocked by the PCB.

Not recommended layout

This set-up affects both internal antennas and therefore cannot achieve the optimum performance. For such conditions the use of an external antenna is recommended. If that is no option than the minimum gap of **Lmin >2 cm** between the dongle an PCB must be ensured.

WORKING AND STORAGE ENVIRONMENT

Parameter	Minimum Value	Maximum Value	Unit	Remarks
Normal operating temperature	-20	+65	°C	fully functional and meet 3GPP / ETSI specifications
Extended operating temperature	-40	+85	°C	RF performance may be affected outside normal operating range, though module is fully functional
Storage temperature	-40	+85	°C	
Humidity Range	5	95	%	

Table 5: Environmental Conditions

Current Consumption

The IoT module has 3 distinct operating modes with different current consumption.

Deep-Sleep

The RF section and the application interfaces are temporarily disabled and switched off. The module is temporarily not ready to communicate with an external device by means of the application interfaces as configured to reduce the current consumption.

Active

Module is switched on with application interfaces enabled or not suspended. The module is ready to communicate with an external device by means of the application interfaces unless power saving configuration is enabled.The module is prepared to accept data signals from an external device.

Connected

RF Tx/Rx data connection is in progress.The module is prepared to accept data signals from an external device.

Mode	Current Consumption Nb-IoT	Current Consumption Cat-M1
Deep-Sleep	8 µA	8 µA
Active	8 mA	8 mA
Connected	60 mA (min TX-Power) 65 mA (0 dBm) 80 mA (12dBm) 100 mA (18dBm) 140 mA (max TX-Power)	100 mA (min TX-Power) 105 mA (0 dBm) 125 mA (12dBm) 150 mA (18dBm) 190 mA (max TX-Power)

Table 6: Module Current Consumption

RF Noise Considerations

For optimum performance of the device some RF-constraints need to be considered.

NOISE FROM THE PROCESSOR BOARD:

The processor board which the USB Connect LPWA is connected to may emit RF noise signals which results from the clocks of the processor as well as the data rate of digital interfaces such as USB. This RF noise may be received by the internal antenna of the USB Connect LPWA and therefore may limit your receive sensitivity. This may lead to a considerable lower RX-sensitivity in the down link. Therefore the following is recommended:

- Ensure proper EMC-shielding of the processor board.
- Use an external antenna placed outside the RF-noise area to improve RX-performance.

NOISE FROM AN ACTIVE USB-CONNECTION:

The USB-connection is a high speed data interface with a clock, which might also cause interfering RF-noise. The USB 2.0 clock noise shows up at multiples of 480 MHz since the USB clock is 48 MHz * 10 = 480 MBit/s. This type of RF-noise is quite commonly seen at 480/960 MHz on USB powered wireless devices. This might affect performance of the USB Connect LPWA in the lower frequency bands.

Therefore the following is recommended:

- Avoid long USB-Cables between the processor board and the device.
- Ensure proper EMC-shielding of the USB-Connection.
- Use an external antenna placed outside the RF-noise area to improve RX-performance.

USB Drivers

USB driver for Linux (Kernel 4.14 or above) and Windows 10 (Download)

Vodafone NB|EASY

The NB|EASY app for Windows and LINUX controls NB-IoT devices (e.g. Vodafone USB Connect LPWA) in order to enable E2E connectivity tests with mobile networks.

Version	Date	Download	Changelog
1.7.7	05.12.2019	Vodafone-NB-EASY-Installer-1.7.7.exe Vodafone-NB-EASY-1.7.7.jar	• Bugfix: mehrere geöffnete sockets
1.7.5	21.10.2019	Vodafone-NB-EASY-Installer-1.7.5.exe Vodafone-NB-EASY-1.7.5.jar	• Auto reopening of inactive COM port • Improved program stability during automatic data transfer
1.7.4	17.07.2019	Vodafone-NB-EASY-Installer-1.7.4.exe Vodafone-NB-EASY-1.7.4.jar	• Add new device "VODEXL-01" with MNO profile

Supported IoT devices:

- Vodafone USB Connect LPWA
- Vodafone NB-IoT Development Kit
- NB|USB211,
- NB|USB280
- NB|USB410

Remark: The Java 8 environment is needed on PC to operate the NB|EASY Software Tool (Java 8 download)

NB|METER (Android App)

The NB|Meter app controls NB-IoT devices (e.g. Vodafone USB Connect LPWA) with an Android smartphone in order to enable E2E connectivity tests with mobile networks.

The App is available in the Google Play Store.

Supported IoT devices:

- Vodafone USB Connect LPWA
- Vodafone NB-IoT Development Kit
- NB|USB211,
- NB|USB280
- NB|USB410

Certifications

- Scope
- Markings on device housing
- PTCRB
- Country Certifications
- IP rating (Ingress protection rating)
- Safety (according to IEC 62368-1:2014)
- RoHs
- REACH
- WEEE

Scope

This section describes the different certifications of the **Vodafone USB connect LPWA.** This ensures that it meets the international and regional directives and regulations.

Markings on device housing

The figure below shows a draft version of the laser marking on the housing of the **Vodafone USB connect LPWA.**

As shown, the laser marking includes all certifications of the device.

Figure 1 : Laser Print Design

Abbreviation	Description
IMEI	International Mobile Equipment Identity
IMSI	International mobile Subscriber Identity (from embedded SIM)
FCC	Federal Communications Commission: The United State's Federal Communication Commission's identifier for authorizing wireless devices for sale within the USA.
IC	Industry Canada identifier: The wireless certification approval number for all devices sold within Canada
CE	CE marking is a certification mark that indicates conformity with health, safety, and environmental protection standards for products sold within the European Economic Area
QR code	The QR-code on the device is a bar code that contains following information IMEI, IMSI... It uses four standardized encoding modes (numeric, alphanumeric, byte/binary, and kanji) to store data efficiently.

Table 1: Data Label

PTCRB

The product manufactured by Exelonix GmbH is in compliance with PTCRB.

PTCRB certification is based on standards developed by 3rd Generation Partnership Project (3GPP), Open Mobile Alliance (OMA) and other standards-developing organizations (SDOs) recognized by the PTCRB. In some cases, PTCRB certification may accommodate North American standards and additional requirements from the U.S. Federal Communications Commission (FCC), Innovation, Science and Economic Development Canada (ISED) or any other government agency that may have jurisdiction and/or competence in the matter.

For further information you can visit this page : PTCRB Certification

Country Certifications

Region	Frequency Bands	Certification	Declaration of Conformance
Europe	3, 8, 20	CE-RED	2019-11-18_DoC_exelonix_VODEXL-01.pdf
US	2, 4, 5, 12, 13	FCC	t.b.d.
Canada	2, 4, 5, 12, 13	RCM	t.b.d.
Australia & New Zealand	3, 5, 5, 28	ISED	t.b.d.

The Vodafone USB connect LPWA includes the ability to configure the device in the following ways Mobile Network Operator Profile (AT+UMNOPROF), Radio Access Technology (AT+URAT) and LTE band selection (AT+UBANDMASK). As these configuration decisions are made, Exelonix reminds customers that the end device regulatory compliance shall be verified. In case the end device enables bands that are not within the country specific module approved configuration the customer will incur in additional measurements that were not covered by the product certification.

IP rating (Ingress protection rating)

The IP rating of Vodafone USB connect LPWA is IP40 (IP Test Report)

IP rating is defined in international standard EN 60529 (British BS EN 60529:1992, European IEC 60509:1989). It is used to define levels of sealing effectiveness of electrical enclosures against intrusion from foreign bodies (tools, dirt etc) and moisture.

Safety (according to IEC 62368-1:2014)

The product manufactured by Exelonix GmbH is in compliance with IEC 62368-1:2014 (Safety Test Certificate)

RoHs

The product manufactured by Exelonix GmbH is in compliance with the directive

2011/65/EU (including delegated directive 2015/863/EU) - restriction of the use of

Hazardous Substances in EEE (RoHS) of the European Parliament.

The products do not contain any of the following substances in more than the

following concentrations in any of the homogeneous materials:

- Cadmium (Cd) 0.01 % in weight
- Chromium VI (Cr6+) 0.1 % in weight
- Mercury (Hg) 0.1 % in weight
- Lead (Pb) 0.1 % in weight
- Polybrominated biphenyls (PBB) 0.1 % in weight
- Polybrominated diphenyl ethers (PBDE) 0.1 % in weight
- Bis(2-ethylhexyl)phthalate (DEHP) 0.1 % in weight
- Butyl benzyl phthalate (BBP) 0.1 % in weight
- Dibutyl phthalate (DBP) 0.1 % in weight
- Diisobutyl phthalate (DIBP) 0.1 % in weight*) with exemption Annex 7(c)-I:

The data provided are correct to the best of our knowledge.

2019-11-18_RoHS_Compliance_Statement.pdf

REACH

Under the definition of the REACH regulations EC1907/2006, Exelonix GmbH is a producer of "articles". REACH requires article suppliers to inform recipients if an article contains a Substance of Very High Concern (SVHC) in excess of 0.1% by weight. The EU announced on June 15th, 2019 an updated list of the candidate 197 SVHC chemicals. The list can be found at: http://echa.europa.eu/chem_data/authorisation_process/candidate_list_table_en.asp

In addition to changes made in Annex XVII fall within this list of SVHC: Per COMMISSION REGULATION (EU) No 276/2010 of 31 March 2010

Based on the material content certifications provided by Exelonix's suppliers, none of these substances are present in the materials we use in our products, including packing and shipping materials. Therefore, Exelonix products do not contain any of these SVHC in excess of 0.1% by weight. Exelonix GmbH will continue to comply with REACH requirements and notify customers of any change in article content.

2019-11-18_REACH_Compliance_Statement.pdf

WEEE

Exelonix GmbH fully endorses the environmental objectives of the WEEE. All electronic products must be collected and sent to approved operators for safe disposal of electronic equipment.

The WEEE Directive (2012|19|EU) aims to reduce the amount of waste electrical and electronic equipment that ends up in landfill. Its primary purpose is the prevention of waste electrical and electronic equipment (WEEE) and requires the re-use, recycling and recovery of such waste, to

reduce its disposal to landfill or incineration. All electrical and electronic waste must be stored, collected, treated, recycled and disposed of separately from other waste. Therefore, if you are intending to discard these at the end of their useful life, please contact your local re-seller for disposal. Local authorities will also provide information on free disposal of electronic equipment.

FAQ

⌄ 1. The definition of USB Connect LPWA

The USB Connect LPWA is a USB-Dongle for cellular machine type communication which supports the cellular 3GPP standards NB-IoT and CAT-M1.

The device is connected to a host device by a USB interface, which supplies the USB-Dongle with power ,transmit and receive data via by using the Vodafone USB Connect LPWA

The radio signals are transmitted and received by an internal (not included by default) or external antenna.

⌄ 2. How can I order a Vodafone USB connect LPWA

Please get in touch with your local Vodafone IoT sales representative.

⌄ 3. Abbreviations

LPWA: A low-power wide-area network is a type telecommunication wide area to allow long-range communications at a low bit rate among things (connected objects), such as sensors operated on a battery. The low power, low bit rate and intended use distinguish this type of network from a wireless WAN that is designed to connect users or businesses, and carry more data, using more power. The LPWAN data rate ranges from 0.3 kbit/s to 50 kbit/s per channel.
https://en.wikipedia.org/wiki/LPWAN

3GPP: The 3rd Generation Partnership Project (3GPP) is a standards organization which develops protocols for mobile telephony. Its best known work is the development and maintenance of:

- GSM and related 2G and 2.5G standards, including GPRS and EDGE.
- UMTS and related 3G standards, including HSPA.
- LTE and related 4G standards, including LTE Advanced and LTE Advanced Pro.
- 5G NR and related 5G standards.
- An evolved IP Multimedia Subsystem (IMS) developed in an access independent manner.

https://en.wikipedia.org/wiki/3GPP

NB-IoT or NB1: Narrowband Internet of Things is a Low Power Wide Area Network (LPWAN) radio technology standard developed by 3GPP to enable a wide range of cellular devices and services. The specification was frozen in 3GPP Release 13 (LTE Advanced Pro), in June 2016. NB-IoT focuses specifically on indoor coverage, low cost, long battery life, and high connection density. NB-IoT uses a subset of the LTE standard, but limits the bandwidth to a single narrow-band of 200kHz. It uses OFDM modulation for downlink communication and SC-FDMA for uplink communications.
https://en.wikipedia.org/wiki/Narrowband_IoT

CAT-M1: (LTE-MTC [Machine Type Communication]), which includes eMTC (enhanced Machine Type Communication), is a type of low power wide area network (LPWAN) radio technology standard developed by 3GPP to enable a wide range of cellular devices and services (specifically, for machine-to-machine and Internet of Things applications). The specification for eMTC (LTE Cat-M1) was frozen in 3GPP Release 13 (LTE Advanced Pro), in June 2016.
https://en.wikipedia.org/wiki/LTE-M

USB: Universal Serial Bus (USB) is an industry standard that establishes specifications for cables and connectors and protocols for connection, communication and power supply between computers, peripheral devices and other computers.Released in 1996, the USB standard is currently maintained by the USB Implementers Forum (USB-IF).
https://en.wikipedia.org/wiki/USB

UDP: User Datagram Protocol (UDP) is one of the core members of the Internet protocol suite. The protocol was designed by David P. Reed in 1980 and formally defined in RFC 768. With UDP, computer applications can send messages, in this case referred to as datagrams, to other hosts on an Internet Protocol (IP) network. Prior communications are not required in order to set up communication channels or data paths. UDP uses a simple connectionless communication model with a minimum of protocol mechanisms. UDP provides checksums for data integrity, and port numbers for addressing different functions at the source and destination of the datagram. It has no handshaking dialogues, and thus exposes the user's program to any unreliability of the underlying network; there is no guarantee of delivery, ordering, or duplicate protection. If error-correction facilities are needed at the network interface level, an application may use Transmission Control Protocol (TCP)

or Stream Control Transmission Protocol (SCTP) which are designed for this purpose. UDP is suitable for purposes where error checking and correction are either not necessary or are performed in the application; UDP avoids the overhead of such processing in the protocol stack. Time-sensitive applications often use UDP because dropping packets is preferable to waiting for packets delayed due to retransmission, which may not be an option in a real-time system.
https://en.wikipedia.org/wiki/User_Datagram_Protocol

4. How can I connect to another cloud?

There are different ways to direct NB-IoT data to different cloud backends.

via UDP

NB-IoT devices support primarily the UDP-protocol. The IP address of the cloud can be specified with the AT-Command. *Remark:* The IP address of your cloud server must be reachable from the operators APN (the gateway between the mobile network and the public internet). If the traffic is blocked, whitelisting of your servers IP address might be necessary.

via TCP

Standard cloud servers often request TCP for interfacing IoT devices (often requesting IPsec). **This is not supported with NB-IoT.** Therefore, Exelonix offers a proxy server, which receives the UDP data packets and forwards that data via TCP protocols like HTTP or MQTT. The format can be adapted to your cloud server requirements. If you are interested in this solution, contact the team of **exelonix GmbH**.

Exelonix GmbH
Washingtonstr. 16/16A
D-01139 Dresden
Germany

 Phone: +49 (0) 351 – 219 71 444
E-Mail info@exelonix.com
Website: www.exelonix.com

via NB|EASY (Windows Software)

You can use the NB|EASY for transmitting data into your cloud. Just change the backend IP-address via the NB|EASY tool.

- NB|EASY User Manual - (see section: Change Endpoint)

5. I have problems with the USB Connect LPWA

Please contact :

Oliver.Wierichs@vodafone.com

6. How do I update the firmware?

Firmware Update

7. IoT Manager Troubleshooting

You forgot your password

- Click on the link "Forgot password"
- Please enter your registered e-mail address
- We will send you a link to a page where you can enter a new password

You have entered an invalid username or password!

- Please check your provided details. Make sure you sign in with your registered email address
- If necessary, reset your password with the "Forgot password" link

Could not send email to reset your password. Check the email address you typed in and your mailbox.

- Please check your e-mail inbox if you have receive an e-mail from no-replay@exelonix.com
- Make sure you have entered your correct e-mail address, if so then contact us under info@exelonix.com

The website https://vodafone.exelonix.com/iot-manager is not loading

- Delete the browser cache. Press CTRL + F5 at the same time.
- Delete your browsing history in the settings of the browser.
- How to delete the Browser history in Firefox
- How to delete the Browser history in Internet Explorer
- How to delete the Browser history in Chrome
- How to delete the Browser history in Safari

AT Command cookbook

This chapter describes the different instructions used to control the u-blox SARA-R410M modem.

Read Available Operator Profiles

This AT-commands reads the operator profiles available on the device.

- 19: Vodafone (used for Vodafone Germany only)
- 197: Vodafone-global-roaming (used for roaming scenarios)

```
> AT+UMNOPROF=,1
OK

> AT+UMNOPROF=?
+UMNOPROF:
0: SW default
1: SIM ICCID select
2: ATT 7.1
6: China Telecom 7.0
31: DT 7.0
8: Sprint 7.0
100: Standard Europe 7.0
4: Telstra 7.0
21: TELUS 7.0
5: TMO 7.0
19: Vodafone 7.0
3: Verizon 7.0
197: Vodafone-global-roaming 7.2
OK
```

Vodafone Global Roaming Profile Activation (Before First Time Registration of the Device)

This AT-commands activate the Vodafone global roaming profile. Usually used for the initial attach of the device to a cell.

```
//activate the Vodafone global roaming profile
> AT+UMNOPROF=197
OK
//reboot the device
> AT+CFUN=15
OK
```

Vodafone Germany Roaming Profile Activation (Before First Time Registration of the Device)

This AT-commands activate the Vodafone Germany profile. This should be used in Germany only. It results in a much faster initial attach. Usually only used for the initial attach of the device to a cell.

```
//Set the Vodafone profile
> AT+UMNOPROF=19
OK

//Module reboot for saving changed profile
> AT+CFUN=15
OK
```

Full functional test of modem (Attach, UDP Socket, TX, RX, Detach)

This AT-commands performs a full E2E data transmission to the cloud. Please make sure that the proxy IP address (213.136.81.171) is whitelisted at the operators APN (Access Point Name).

```
// Start network registration
> AT+CFUN=1
OK
> AT+CEREG=2
OK

// Wait till registered to network
> AT+CEREG?
+CEREG: 2,5,"AB7D","790066",9
OK

// Open UDP socket
> AT+USOCR=17
+USOCR: 0
OK

// Transmit "Test" to Exelonix UDP proxy
> AT+USOST=0,"213.136.81.171",9876,4,"Test"
+USOST: 0,4
OK

// Data indication (seems to be unreliable)
+UUSORF=0,3

// Receive response data "400"
> AT+USORF=0,3
+USORF: 0,"213.136.81.171",9876,3,"400"
OK

// Close socket
> AT+USOCL=0
OK

// Disable modem
> AT+CFUN=0
```

The LED can be configured

This AT-commands configures the default LED operation

The status is indicated by LED:

- RED: Device is powered on
- GREEN: device is registered in the network
- GREEN/RED alternating: device is registered in the network and roaming (this will be the usual pattern)

```
/ GPIO2, red LED: global LED enable
> AT+UGPIOC=23,0,1
OK

// GPIO1, green LED: Power, Attached
> AT+UGPIOC=16,2
OK

// Reset the device to make setting effective
> AT+CFUN=15
OK
```

NB|METER

Version history

	Version	Date	Changes
	1.0	10.17.2019	Initial version

Content

Introduction

|METER is an android application (app) developed to control the **USB Connect LPWA** device via smartphone. After successful connection establishment, the device is able to perform an end-to-end-connectivity tests. The application is split into four main parts. Each can be selected by king on the corresponding tab. The following sections describe these tabs

Software Installation

u can download the NB|Meter app from Google Play Store.

Device Selection

nnect the USB-Device to your smart phone by using:

- USB-C to USB-A Adapter (your Smartphone supports USB-C)
- mini USB to USB-A Adapter (your Smartphone supports mini USB)

*te: Make sure that your smartphone or tablet supports the **USB OTG** standard before connecting the USB Connect LPWA or any other Vodafone -IoT device, otherwise, the connection will fail, as your smartphone will not consider itself as a host for the device.*

er starting NB|Meter, the Device Selection page appears. Here the actual and the previously connected devices are displayed. The connected vice can be selected by a simple click.

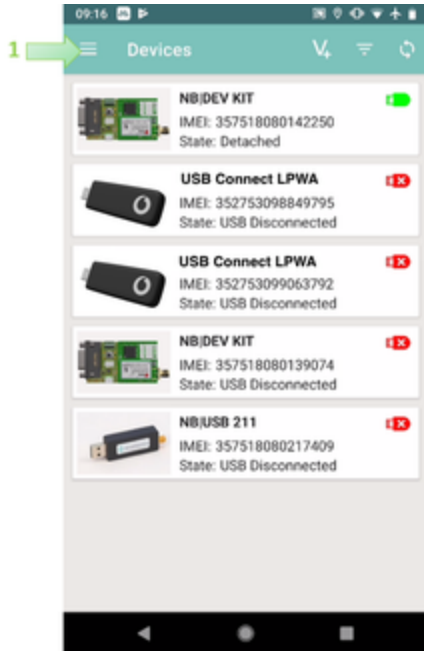clicking on the settings menu (1) multiple options to proceed are available as shown in **figure 2.**
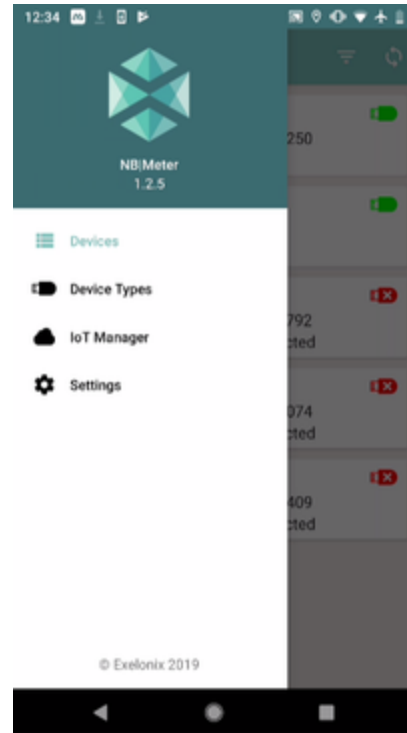
Figure 1 : Device selection


Figure 2 : Settings Menu

etwork

er clicking on the "**USB connect LPWA**" device, the network tab is displayed.

shows the modem status of the USB Connect LPWA.

a drop down menu to select the NB-IoT network to attach to. Here the local network can be chosen. Alternatively automatic option can be ected.

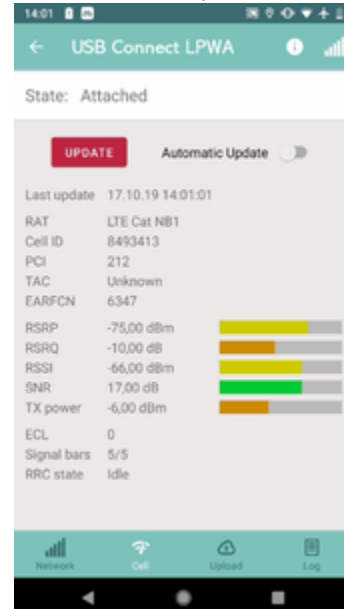"**ATTACH & E2E TEST**" button starts the attachment procedure to the selected NB-IoT network.

Information about the last event
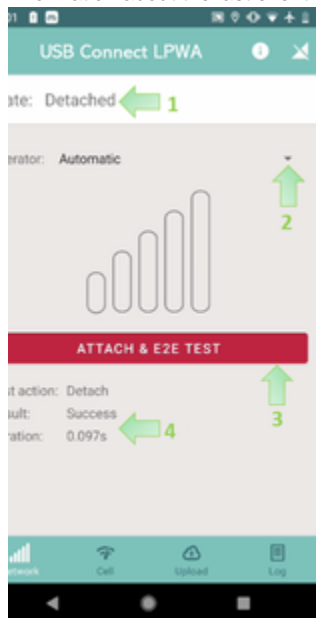
Cell Information

Cell Tab shows cell parameters that are measured by the modem.

The table shows typical values of the different cell information:

| arameters	Typical Value	Acceptable value
ARFCN	6347	0..65535
SRP	-75 dBm	-140dBm…-44dBm
SRQ	-10 dB	-19.5…-3dB dB
SSI	-66 dBm	-113 dBm...-51dBm
NR	17 dB	10 dB
X power	-6 dBm	-40 dB…+23 dB
CL	0	0..2
gnal bars	4	0..5

pload

th this tab, the user can send a message (1) into the IOT Manager. along with the Location information of the smart phone. It is possible to start ntinuous data transmissions (2) for drive tests. Hereby, the transmission period can be individually configured.
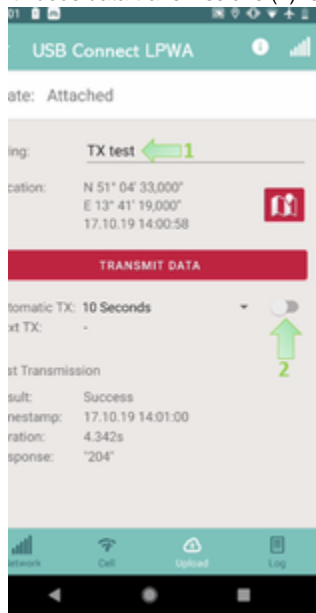
Log

The Log tab is a console all AT-commands that are sent to the device are listed and can be used for debugging. The log-data can be shared (1) via email.
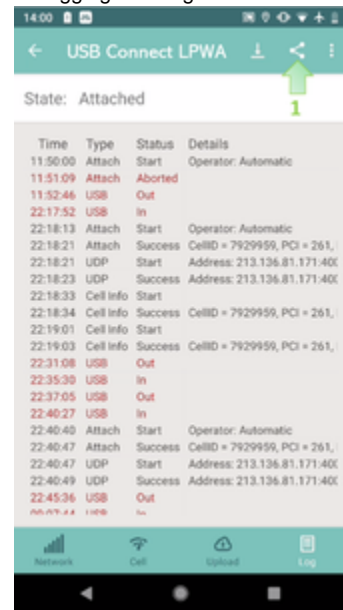
Abbreviations

bbreviations	Description
B-IoT	Mobile communication standard "Narrowband Internet-of-Things"
B	Short version of "NB-IoT"
ARFCN	E-UTRA Absolute Radio Frequency Channel Number
SRP	Reference Signal Receive Power
SRQ	Reference Signal Received Quality
SSI	Received Signal Strength Indicator
NR	Signal to noise ratio
AT	Radio Access Technology
ell ID	Cell Identity

CI	Physical Cell Identity
AC	Type Allocation Code
RC state	Radio Resource Control state

2 : Abbreviations

Firmware Update

Introduction

There are three methods to update the USB connect LPWA modem firmware :

- Firmware update over AT (FOAT)
- Firmware update over the Air (uFOTA)
- EasyFlash (restricted use)

Firmware update over AT (FOAT)

FOAT is a method to update the firmware by transferring the related file from an external device (e.g.application host processor) to the module through the AT interface.

t.b.d.

Automatic Firmware update over the Air - uFOTA

uFOTA is a managed and automated FOTA service based on WM2M protocol by u-blox. This service is able to manage the upgrading of multiple modules to new firmware version with one campaign.

Recommendations:

- uFOTA campaign shall only be planned, if the USB connect LPWA devices are ensured to have a proper power supply while the update is conducted.
- If the devices are battery powered, be aware that the uFOTA will shorten the battery lifetime.
- The update of individual devices might take up to 20min.
- Devices shall check for FW updates once per day (AT+UFOTACONF=2,86400)
- FW updates will consume data volume from your data plan.

Remark:

- **By default-setting, the devices are configured not support regular uFOTA update checks.**
- **Exelonix GmbH can not grant warranty on devices that conducted a uFOTA campaign.**

Immediate uFOTA on individual Devices

VERSION & PROFILE CHECK

Check if you have installed the latest firmware. And the version number should now be higher than L0.0.00.00.05.08 [Apr 17 2019 19:34:02]

> *> ATI*
>
> *Manufacturer: u-blox*
> *Model: SARA-R410M-02B*
> *Revision: L0.0.00.00.05.08 [Apr 17 2019 19:34:02]*
> *SVN: 03*
> *IMEI: 352753098853359*
>
> *OK*

uFOT requires Vodafone Global Roaming" profile (197), therefore check if the "Vodafone Global Roaming" profile (197) is present and has

> AT+UMNOPROF=,1

OK

> AT+UMNOPROF=?

+UMNOPROF:

0: SW default

1: SIM ICCID select

2: ATT 7.1

6: China Telecom 7.0

31: DT 7.0

8: Sprint 7.0

100: Standard Europe 7.0

4: Telstra 7.0

21: TELUS 7.0

5: TMO 7.0

19: Vodafone 7.0

3: Verizon 7.0

197: Vodafone-global-roaming 7.2

OK

UFOTA PREPARATION

Execute the following commands:

> ATI

Manufacturer: u-blox
Model: SARA-R410M-02B
Revision: L0.0.00.00.05.08 [Apr 17 2019 19:34:02]
SVN: 03
IMEI: 352753098853359

OK

> ATI9

L0.0.00.00.05.08,A.02.04

OK

> AT+COPS?

+COPS: 0,0,"262 02 DATA ONLY",9

OK

> AT+CGDCONT?

+CGDCONT: 1,"IP","vgesace.nb.iot","10.254.46.22",0,0,0,0

OK

Activate uFOTA (must return +UFOTACONF: 1, 1)

> AT+UFOTACONF=1

+UFOTACONF: 1, 1

OK

For immediate uFOTA update: set the Timer to one update check per hour (AT+UFOTACONF=2,3600).

Shorter timers <20min are not recommended, since URC may not be presented correctly or you may experience problems with the LWM2M client.

After the uFOTA update, set the update timing back:

- to one update check per day: AT+UFOTACONF=2,86400 or
- deactivate uFOTA (recommended): AT+UFOTACONF=2,-1

How to specify a campaign (automated updates on multiple USB Connect LPWA devices)

Devices need to be configured to check for FW updates (i.e. once per day: AT+UFOTACONF=2,86400), otherwise a campaign of firmware updates is not possible.

The following information is required to be sent to ublox:

- The product type: USB Connect LPWA (SARA-R410-02B)
- Old FW version: L0.0.00.00.05.08 *please specify*
- New FW version: L0.0.00.00.05.?? *please specify*
- The IMEI list of the device participating in the campaign:*please specify*
- The MNO provider: Vodafone
- The location area: *please specify*
- The requested schedule (date, time, duration) for the campaign: *please specify*

To initiate a uFOTA campaign (roll-out of new Firmware) send the information to support_eu@u-blox.com.

Remark:

- **After the confirmed start of the campaign, do not disconnect the power supply of the devices before the update has been carried out.**

```
ATI
ATI
Manufacturer: u-blox
Model: SARA-R410M-02B
Revision: L0.0.00.00.05.08 [Apr 17 2019 19:34:02]
SVN: 03
IMEI: 352753098853359
OK
ATI9
ATI9
L0.0.00.00.05.08,A.02.04
OK
AT+COPS?
AT+COPS?
+COPS: 0,0,"262 02 DATA ONLY",9
OK
AT+CGDCONT?
AT+CGDCONT?
+CGDCONT: 1,"IP","vgesace.nb.iot","10.254.46.22",0,0,0,0
OK
AT+UFOTACONF=1
AT+UFOTACONF=1
+UFOTACONF: 1, 1
OK
AT+UFOTACONF=2,3600

AT+UFOTACONF=2,3600
OK
+ULWM2MSTAT: 0,0
+ULWM2MSTAT: 1,13
+ULWM2MSTAT: 1,26
+ULWM2MSTAT: 1,39
+ULWM2MSTAT: 1,52
+ULWM2MSTAT: 1,65
+ULWM2MSTAT: 1,78
+ULWM2MSTAT: 1,91
+ULWM2MSTAT: 2,100
//After the successful download (+ ULWM2MSTAT: 2,100), the update may
take some time (up to 20min).
Manufacturer: u-blox
Model: SARA-R410M-02B
Revision: L9.9.00.00.05.08 [Jul 11 2019 16:05:05]
SVN: 03
IMEI: 352753098853359
OK
```

EasyFlash

Definition

EasyFlash is a tool for the Windows OS to download the firmware from a PC through a serial interface (USB or UART).

Note : The EasyFlash Tool is not a public tool and could only be used internally !

If you are interested in this solution, contact the team of **exelonix GmbH**.

Exelonix GmbH
Washingtonstr. 16/16A
D-01139 Dresden
Germany

Phone: +49 (0) 351 – 219 71 444
E-Mail info@exelonix.com
Website: www.exelonix.com

Getting Started (NB|Easy)

Introduction

NB|EASY is a software tool developed to control the **USB Connect LPWA** device via PC. After successful connection establishment, the device is able to perform an end-to-end-connectivity tests. After successful connection establishment, the device is able to transmit and receive data via the NB-IoT network.

Version History

The following table shows the changes done with every NB|EASY documentation version:

Version	Date	Changes
1.4	15 Oct 2019	• Support of Vodafone USB connect LPWA device
1.3	16 Aug 2018	• Add installation instructions for SARA R410M devices
1.2	06 Jul 2018	• Add installation instructions
1.1	01 May 2018	• Add performance tab description
1.0	11 Apr 2018	• Initial Version

Software Installation

Basic software requirements

- Java 8 runtime environment.
- USB Connect LPWA driver (also included in NB|EASY installation package).

Windows

- Use windows executable from the Software & Drivers to install NB | EASY software.
- The installer will take care of installing the Java environment and the required drivers.
- Start the program via desktop shortcut or start menu entry.

Linux

- The required UART driver are usually distributed as part of Linux kernel since v4.4.132.
- Check whether the required kernel module is loaded: `lsmod | grep option`.
- Check whether you have read/write access to USB-UART bridge: `ls -la /dev/ttyUSB*`.
- Download NB | EASY jar-file from Software & Drivers.
- Start the program via command line: `java -jar Vodafone-NB-EASY-x.x.x.jar`.

LINUX SETUP & TROUBLESHOOTING

Currently, the ModemManager package (confirmed for version `1.10.0-1~ubuntu18.04.2`) detects the **USB Connect LPWA** (R410) as a general QMI-WWAN modem and tries to configure it. Beside failing this task it blocks any "user" AT commands, e.g. using `minicom`.

The following shell commands stop and disable the ModemManager service:

```
$> sudo systemctl stop ModemManager.service
$> sudo systemctl disable ModemManager.service

// checking status after disabling
$> sudo systemctl status ModemManager.service
● ModemManager.service - Modem Manager
   Loaded: loaded (/lib/systemd/system/ModemManager.service; disabled; vendor preset: enabled)
   Active: inactive (dead)

Aug 08 16:22:18 x systemd[1]: Starting Modem Manager...
Aug 08 16:22:19 x ModemManager[416]: <info>  ModemManager (version 1.10.0) starting in system bus...
Aug 08 16:22:20 x systemd[1]: Started Modem Manager.
...
Aug 09 12:37:04 x systemd[1]: Stopping Modem Manager...
Aug 09 12:37:04 x ModemManager[416]: <info>  Caught signal, shutting down...
Aug 09 12:37:04 x ModemManager[416]: <info>  ModemManager is shut down
Aug 09 12:37:04 x systemd[1]: Stopped Modem Manager.
```

Device Selection

After starting the application, the Device Selection tab is shown first. Here, the connected NB device can be selected.

(1) The Refresh button starts a new search for all USB-connected devices. An ongoing search is indicated by a progress bar below the button.

(2) After the search is finished, all available devices are displayed. By clicking on the device, it will be is selected for usage. After that, the Quick Start tab is shown.
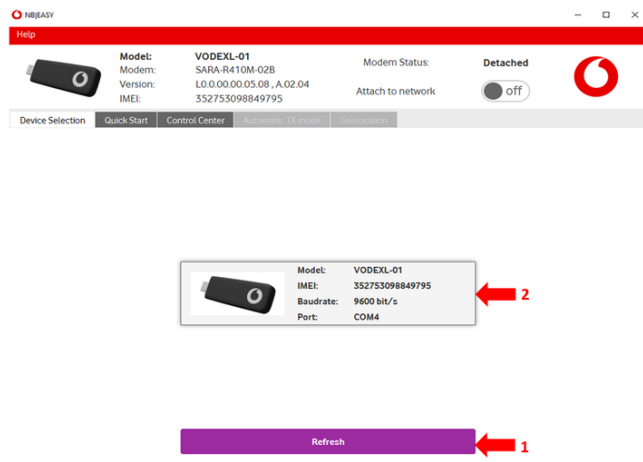

Quick Start

The Quick Start tab controls the connected USB Connect LPWA device.

"Attach to network" attaches the USB Connect LPWA to the cellular network. A drop down menu to select the NB-IoT network to attach to. Here the local network can be chosen. Alternatively automatic option can be selected.

"Update" lists the UE-statistics (RSRP, SNR, …) measured at the USB Connect LPWA device

"Open IoT Manger" opens the IoT test-cloud

Here, the device can be triggered to attach to the NB-IoT network and transmit sample data to the cloud.
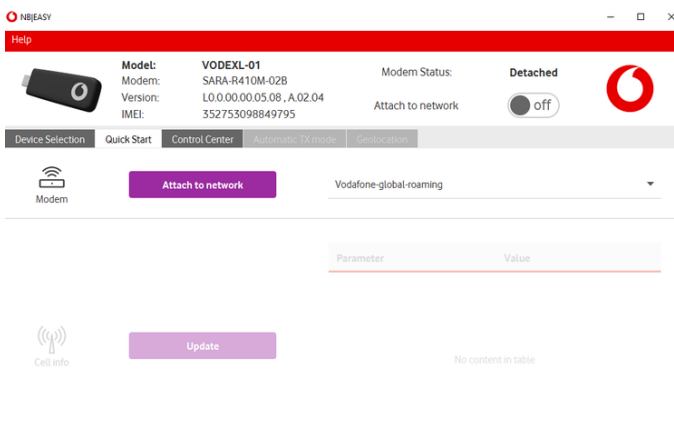

Device Status

The top area of the application shows the selected device and its current state. It contains the following information:

1. Device specific parameters:
a. Name of selected NB-IoT device
b. Modem type number
c. Modem version, application version
d. IMEI: International mobile equipment identity.
2. Modem Status: shows the current status of the device.
3. Attach to network button: triggers an attach or detach depending on modem status.

Modem Status
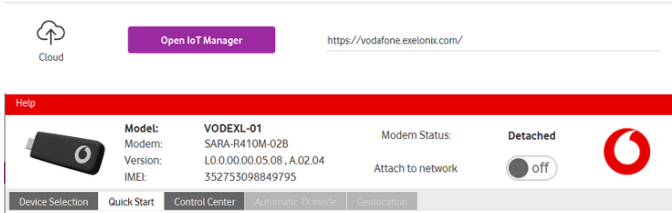
The modem status indicates the following values:

Modem Status	Description
Detached	The modem is powered on but not attached to the network.
Attaching	The modem is currently trying to attach to the network.
Attached	The modem is attached to the network
Detaching	The modem is currently detaching from the network.
Transmitting	The modem is transmitting data.
Receiving	The modem is receiving data.

DETACHED

In the detached state, the device is not able to transmit data to the NB-IoT network. First, an attach procedure needs to be triggered, including the following steps:

1. **Select the NB-IoT network** in the drop down menu.
2. Click on the **Attach to network** button to start the attachment procedure to the selected NB-IoT network

Note: Be aware that the embedded SIM card requires either "Vodafone-global-roaming", a Vodafone Profile or a Vodafone partner profile, to be selected, otherwise the attach procedure will fail.
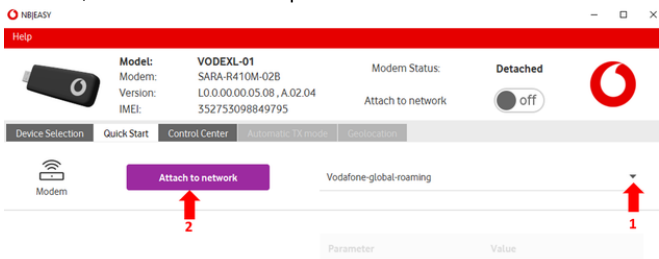

ATTACHED

In the attached state, the device is now able to transmit data to the NB-IoT network by the following control elements:

1. **Text field** button **:** to enter text to be transmitted when button (2) is pressed.
2. **Transmit to Cloud** button: to start transmission to the cloud of the entered text (1) as well as the current cell information.
3. **Update** button (3): to start a cell information update.
4. **Cell information list** (4): which shows all received cell information of the last successful cell information update (see Displayed parameters in Table below).
5. **Open IoT Manager** button (5): to open IoT Manager website to view all successfully transmitted values as described in **figure 6**.
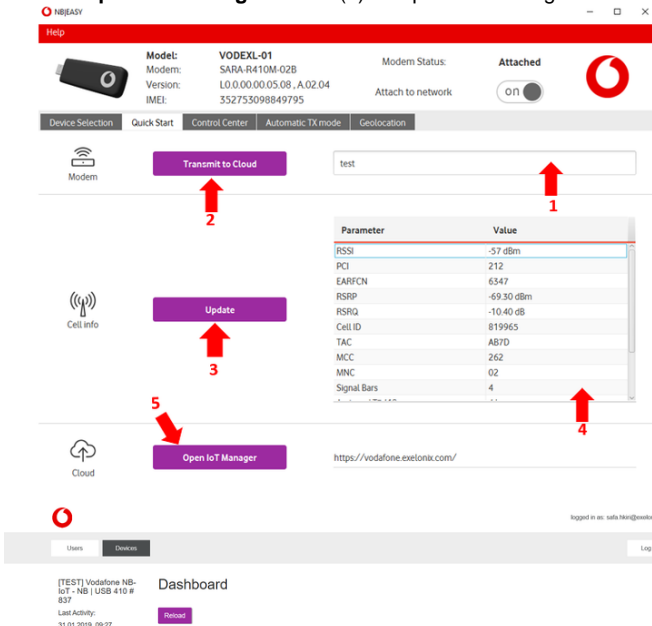
IoT Manager web site

Control Center

The control center is a more advanced and detailed view of the communication between the NB|EASY tool with the connected IOT device.
Here, the user can send individual messages to the device. The incoming messages are monitored as well.

1. Switch between "AT" and "Easy" mode (The USB connect LPWA does only support the "AT" mode)
2. Message log: tracks all messages.
3. Button to clear the message log (2)
4. Button to save the current message log in a text file.
5. List of all possible AT commands
6. Select a single AT command to be sent to the device. The message string will be copied to message text field (8).
7. Button to start sending of the AT command (8) to the device.
8. Message text field. The message to be sent to the device can be edited further.
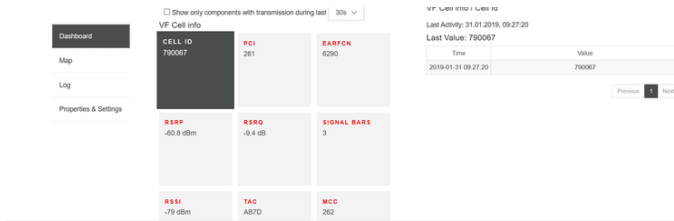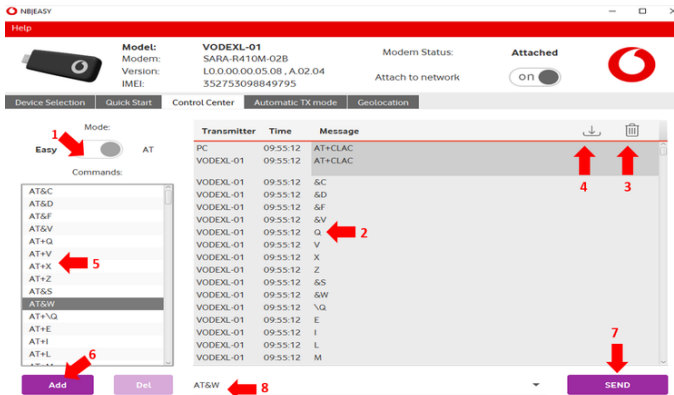
Automatic TX mode

This section allows setting automatic data transmission events. The event interval period is configurable.

The transmission status is displayed as detailed in the Tab 1 and the sent data can be verified on the cloud.
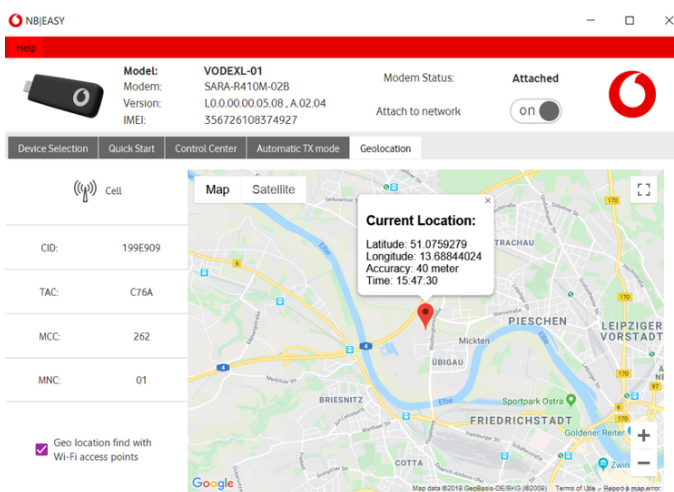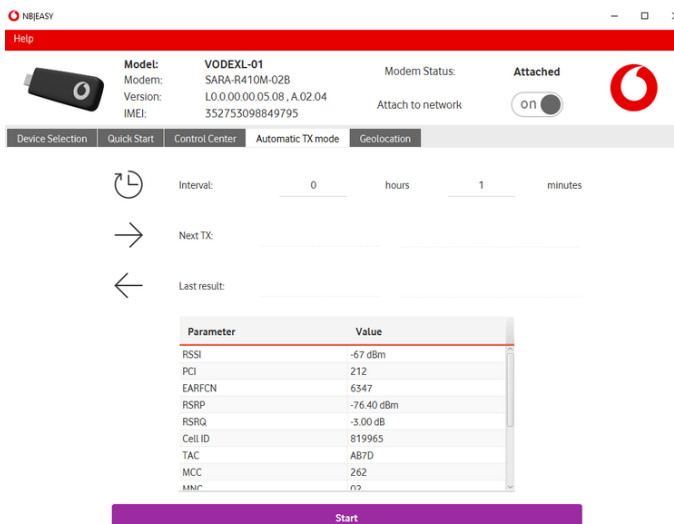
Figure 8: Automatic TX mode

Geolocation

This tab allows the user to display the current location parameters of the NB device (Latitude, Longitude,Accuracy). It uses the characteristics of nearby Wi-Fi hot spots to discover where the host computer is located.

The cell parameters displayed are detailed in the **Tab 1** above.

Abbreviations

Abbreviation	Description
NB-IoT	Mobile Communication standard "Narrowband Internet-of-Things"

NB	Short Version of "NB-IoT"
RAT	Radio Access Technology

Annex

Parameter	Description	Definition	Example Value	Acceptable Range
RSSI	Received Signal Strength Indicator	RSSI is a measurement of the power present in a received radio signal	-67 dBm	-113 dBm..-51dBm
PCI	Physical Cell Identidy	PCI is an identification of a cell at physical layer. It has similar role as Primary Scrambling Code of UMTS cell.This physical cell ID is determined by Primary Sync Signal and Secondary Sync Signal.	212	
EARFCN	E-UTRA Absolute Radio Frequency Channel Number	EARFCN is a unique number given to each radio channel within the frequency bands used by the network . It can be used to calculate the carrier frequency	6374	0..65535
RSRQ	Reference Signal Received Quality	RSRQ is a C/I type of measurement and it indicates the quality of the received reference signal. The RSRQ measurement provides additional information when RSRP is not sufficient to make a reliable handover or cell reselection decision.	-3 dBm	-3..-19.5dBm
RSRP	Reference Signal Received Power	RSRP is the average power of Resource Elements that carry cell specific Reference Signals over the entire bandwidth. It is the average received power of a single RS resource element.	-76.4 dBm	-140 dBm..-44 dBm
TAC	Type Allocation Code	TAC is the initial eight-digit portion of the 15-digit IMEI and 16-digit IMEISV codes used to uniquely identify wireless devices.	AB7D	
MCC	Mobile Country Code	MCC consists of three decimal digit and it is used to identify the country. The first digit identifies the geographic region .	262	consists on 3 decimal digits
MNC	Mobile Network Code	MNC identifies the home PLMN of the mobile subscriber. The length of the MNC (two or three digits) depends on the value of the MCC.	02	consists on 2 or 3 decimal digits
Assigned T3412	Assigned Timer 3412	The periodic tracking area update timer to periodically notify the availability of the UE to the network. The procedure is controlled in the UE by (timer T3412). The value of timer T3412 is sent by the network to the UE in the ATTACH ACCEPT message and can be sent in the TRACKING AREA UPDATE ACCEPT message. The UE shall apply this value in all tracking areas of the list of tracking areas assigned to the UE, until a new value is received.	4h	0..35712000 sec
Assigned T3324	Assigned Timer 3324	The T3324 active timer determines the duration during which the device remains reachable for mobile terminated transaction on transition from connected to idle mode. The device starts the active timer when it moves from connected to idle mode and when the active timer expires, the device moves to Power Saving Mode	6s	0..11160 sec