WIRELESS COMMUNICATION SYSTEM
NB-IoT

NB-CH4

Revision 1.0

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1 Introduction

This document describes the configuration options of the NB-CH4 radio module, which is used to measure methane (CH4) concentration in air and transmit information about methane concentration to a central control room via NB-IoT services of a GSM mobile operator.

1.1 NB-IoT mobile data services

Mobile data services NB-IoT are global data services provided by some operators of GSM services. The services are focused on the communication with a huge quantity of devices, that transfer only an extremely limited volume of data. Networks with such purpose and features are commonly labeled as „Internet of Things", or by its acronym "IoT". NB-IoT ("Narrow Band Internet of Things") is an open standard developed by 3GPP organization (3rd Generation Partnership Project) which is concerned with standardization in the GSM network development. NB-IoT is a cellular technology based on the LTE, that was developed specially for wireless communication with terminals of IoT category, that produces only limited volume of data, but they are miniature, inexpensive, with a very low energy consumption and they are commonly installed in the places with high demands on the signal coverage. Typical example of such device is a reading module of the water/gas/electro-meter installed in the basement without electricity, that should be able to run reliably many years on the internal battery even in weak signal conditions, where other services fail.

NB-IoT technology maximally utilizes technological infrastructure of LTE data services in licensed radio band. Combination of narrow frequency band and the most advanced modulation techniques enable increasing of receiver sensibility to the -135 dBm level, so that an existing infrastructure of mobile operator provides global coverage with high signal penetration even in build-up urban areas. Thus, the service is available in the places, where IoT category devices are typically installed - in shafts, distribution boards and cellars.

Terminal devices are identified in the network by standard SIM of GSM operator. Global system of SIM evidence and single communication standard enable providing of international services (roaming). Bi-directional communication is carried by standard Internet protocol with UDP transport layer. Messages are transferred from the GSM operator network to the IoT-terminal operator through the designated data gateway (Access Point - AP) either to public Internet, or to operator's private IP network (i.e. same way as any similar mobile data services). Addressing and routing details depend on the network configuration and policy of particular GSM operator. Typical example of addressing and routing is a solution, when the GSM network automatically assigns private IP addresses to IoT terminals, IP-packets with messages are routed through the private IP network to a single Access Point, where they are re-addressed and resend through a single pre-arranged public IP-address to the public Internet. The IoT terminal assigns packets by target server public IP-address, that is preset in its configuration. Target system can identify original source of the message by using of device unique identifier (IMEI), which is a requisite part of the message content.

1.2 Monitoring methane concentration

The NB-CH4 module can be used to monitor methane (CH4) content in air. The module measures methane content in air every 15 seconds, displays the current methane concentration value on an LCD display, and sends information messages with measured values at set intervals in the form of NB-IoT radio messages from the mobile operator (hereinafter "INFO message").

The content of the INFO message is configurable. In addition to the current methane concentration value, the message can also contain temperature and humidity values if the sensor type used measures these data. The message can contain only currently measured values, or a set of previously measured "historical" values stored in the module's memory. The period for storing historical values in memory is configurable. Up to **48 historical readings** can be transmitted in one data message. Each message always contains operational data of the module measured by internal sensors (processor temperature, internal battery voltage, signal strength).

Messages are transmitted to the module operator's application server via the NB-IoT service in the form of standard IP packets routed to the user's IP network through an access point contractually defined between the GSM network operator and the module operator. The device operator's application server decodes the messages and further processes the data contained in them.

1.3 Signaling when methane concentration threshold is exceeded

A **threshold value** for methane concentration (alarm limit) can be set in the configuration of the NB-CH4 module, upon exceeding which the module switches to an alarm state. The alarm state is signaled by **flashing of a red**

LED under the transparent cover of the module and by **closing of an integrated electronic switch** of the Solid State Relay type - the so-called "alarm relay", which can trigger an external signaling circuit.

When the alarm limit is exceeded, the module can send an **alarm message** of the "TRAP" type, which also contains the currently measured concentration value at the time of exceeding. This message is sent immediately after detecting the alarm state and it is possible to set its repeated transmission at one-minute intervals. This function increases redundancy in alarm message delivery and allows the message recipient to monitor the time course of methane concentration change at one-minute intervals.

When the concentration falls below the set value, a TRAP message is automatically sent indicating that the methane concentration has returned to normal state. At the same time, the warning LED stops flashing and the alarm relay opens.

1.4 Other module functions

The module is equipped with a **position sensor**. Based on the data from this sensor, it reports any physical **manipulation with the module**, such as its dismantling or relocation, in the form of an alarm message.

The module has a built-in **LCD display** that shows the current methane concentration value detected at the last measurement (concentration is measured every 15 seconds by default). During transitional and error states of the methane sensor, the display shows sensor error codes, the meaning of which is given in the sensor documentation. Error code "99" indicates interruption of communication with the sensor due to sensor microprocessor overload (temporarily) or sensor failure (permanently).

The NB-CH4 module is equipped for **two-way communication** and is capable of receiving "SET" type messages from the GSM network generated by a remote computer. These messages can be used to set module parameters remotely, from a remote server.

1.5 Module features

The NB-CH4 module is enclosed in a moisture-resistant plastic box (IP65 rating) and is suitable for use in both indoor and outdoor environments. The box is designed for mounting on a wall or similar structural element.

The module is powered by an internal battery with a capacity of 17 Ah, which allows it to operate for **up to ten years** at a message sending frequency of 4 times a day (one message can contain up to 48 readings). Battery life can be negatively affected not only by a shorter set interval for measuring and sending messages, but also by operating the device in buildings with temperatures outside the recommended operating temperature range. The battery life is also negatively affected by frequent switching to alarm state or long-term persistence in alarm state, when the closed alarm relay significantly increases power consumption.

The module is equipped with a SIM card holder for use with a "Micro-SIM" (3FF) format SIM card measuring 15 x 12 x 0.76 mm. The SIM holder is located inside the module on the main board. The module can be manufactured with an integrated SIM module (eSIM) of a specific GSM operator upon request.

The module can be controlled and configured using a configuration cable, or wirelessly, using an optical converter. The module can also be configured remotely, using the return channel of two-way communication.

The appearance of the NB-CH4 module is shown in Figure 1.

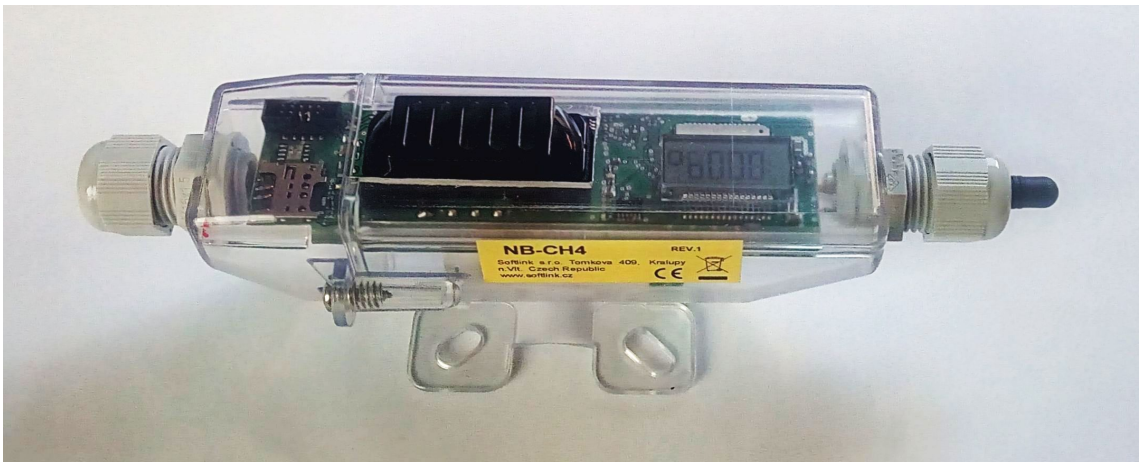


Figure 1: Appearance of the NB-CH4 module

2 Overview of technical parameters

Table 1: Overview of technical parameters of the NB-CH4 module

Transmitter and receiver parameters		
Frequency band 800 MHz (RX/TX)	791-821 / 832-862	MHz
Frequency band 850 MHz (RX/TX)	869-894 / 824-849	MHz (on request)
Frequency band 900 MHz (RX/TX)	925-960 / 880-915	MHz (on request)
Modulation type	GMSK, 8PSK	(adaptive)
Transmit power	200	mW
Receiver sensitivity	135	dBm
Communication protocol	NB-IoT	(bidirectional)
Transmission speed	0.35 ÷ 240	Kb/s (adaptive)
Antenna connector	SMA female	50 Ω
RS-232 configuration interface		
Transmission speed	9600	Baud
Operation mode	asynchronous	
Transmission parameters	8 data bits, 1 stop bit, no parity	
Signal level	TTL/CMOS	
Optical configuration interface		
Transmission speed	115 200	Baud
Optical band	870	nm
Optical interface specification	complies with IrPHY 1.4 standard	
CH4 sensor parameters		
Sensor type	optical (NDIR)	
Measurement range (in % CH4 volume)	(0 ÷ 5)	%
Measurement accuracy	(0.1 ÷ 0.25)	%
Resolution	0.01	%
Temperature range	(-40 ÷ 60)	°C
ATEX certification	IEC 60079-0, IEC 60079-11	
Sensor calibration period	30	months
Alarm relay		
Type	DC SSR	
Maximum voltage	30	V DC
Maximum switched current	1.0	A DC
Isolation voltage	1500	V
On-state resistance R(on)	0.25	Ω
Power supply parameters		
Lithium battery voltage	3.6	V
Lithium battery capacity	17	Ah
Battery life (6-hour transmission period)	10	years
Mechanical parameters		
Length (without antennas)	210	mm
Width	70	mm
Height	68	mm
Weight	approx. 300	g
SIM card dimensions	(15x12x0.76)mm)	"Micro-SIM"
Storage and installation conditions		
Installation environment (according to ČSN 33 2000-3)	normal AA6, AB4, A4	
Operating temperature range	(-20 ÷ 40)	°C
Storage temperature range	(0 ÷ 40)	°C

IMPORTANT NOTE! The methane concentration sensor is a device **sensitive to shocks and temperature changes**. When handling the device, take care not to subject it to unnecessary shocks. During installation and commissioning, **strictly follow the device installation instructions** given in chapter 4.6 "Module Installation".

3 Configuration of the NB-CH4 module

Configuration parameters of the NB-CH4 module can be displayed and changed from the common computer (PC) or smartphone by one of these methods:

- with using of **„USB-CMOS"** converter and configuration cable connected to the module;
- wirelessly, with using of **„USB-IRDA"** or **„BT-IRDA"** converter;
- **remotely**, by using of bi-directional communication system.

Technique of interconnection of the module with configuration computer and general rules of configuration are described in detail in the chapter 2 of **„Configuration of wacoSystem product family devices"**, that can be downloaded from the producer website:

www.wacosystem.com/support/
www.softlink.cz/en/documents/

The description and meaning of all configuration parameters that can be checked and changed by cable can be found in the section 3.1 „Setting of NB-CH4 parameters via configuration cable".

Description of interconnection of the converter with PC („USB-IRDA") or smartphone („BT-IRDA") and general rules of configuration with using of **optical converters** are described in the chapter 3 of above mentioned manual „Configuration of wacoSystem product family devices". The description and meaning of the parameters that can be changed by optical converter can be found in the section 3.2 „Setting of parameters by using of optical „IRDA" converter".

Principles and short description of communication through the **NB-IoT reverse channel** can be found in paragraph i 3.3 „Remote setting of module parameters through the NB IoT reverse channel".

3.1 Setting parameters of the NB-CH4 module using a configuration cable

The following part of the manual describes those parameters of the NB-CH4 module whose current values can be determined by directly connecting the module to a PC using a configuration cable and possibly changing them with configuration commands (configuration "from the command line").

3.1.1 Listing of configuration parameters and commands of the NB-CH4 module

We can display the configuration parameters by entering the command **"show"** into the command line and pressing the "ENTER" key. The following output will appear in the terminal window:

```
mon#show
----- Configuration -----
 Timezone : 1
 Server IP : '92.89.162.105'
 Ping IP : '10.0.0.1'
 Server port : 2000
 Reply to server : no
 My src port : 2000
 APN : '' "
Max session time 172800 sec - 2d, 0:00:00
Send periode : 120 min.
 Hist. periode : 15 min.
   in message 8 records, max. is 48 recs
Send mask is 3 : ch4,temp

 Data will be unencrypted
 Next send : 88 min.
  No. sent : 11 msg(s)
  No. recv : 0 msg(s)

-- Modem status --
Modem state : 0
Session count : 1
Session timeout : 172796 sec - 1d, 23:59:56
Modem IMEI : 863703038894247
  SIM CCID : 898823900000037252304
  SIM IMSI : 901288001028645
 Last RSSI : -61 dBm
Sensor CH4 type 3
CH4 alarm 200 1/100 %
 Conf. version : 1
 SW version 1.01, date Sep 7 2021
mon#
```

We can display a summary of configuration commands ("HELP") and their parameters by entering the command **"?"** into the command line and pressing the "ENTER" key. The following output will appear in the terminal window:

```
mon#?
 Help :
 --- System commands ---
deb               : Show or set debug level
ta                : Show tasks
mb                : Show mail boxes
du addr           : Dump memmory
rb addr           : Read byte from addr
rw addr           : Read word from addr
rd addr           : Read dword from addr
sb addr val       : Set byte on addr
sw addr val       : Set word on addr
sd addr val       : Set dword on addr
port              : Show port [a,b,..]
show              : Show info
write             : Write configuration to flash
cread             : Read configuration from flash
clear             : Clear configation and load defaults
ppm               : Set RTC ppm
--- Narrow band ---
smask             : Send mask bits, 0 - CH4, 1 - temp. ,default 1 - CH4
hist              : History periode 0 - disable, >0 periode in minutes
hdata             : Show history data
server            : Server IP address
sport             : Server UDP port
testip            : Ping IP address
sreply            : Send reply to server
apn               : Access Point Name
sess              : Set max session time in minutes
band              : Set NB band, default 20 - Europe
tshort            : Set modem short timeout
tlong             : Set modem long timeout
tconn             : Set modem connetion timeout
sping             : Send ping
at                : Send at command to modem
 --- Sensor CH4 ---
ch4alarm          : CH4 alarm in 1/100 %, 0 - off
ch4warmup         : CH4 sensor warm up time in sec
ch4comm           : CH4 command
ch4talr           : CH4 test alarm
ch4malr           : CH4 number of msg to be sent after alarm is set
ch4per            : CH4 measure periode in sec.
 --- Motion sensor ---
lisreg            : LIS registers
lisval            : LIS values
lcd               : Test lcd
 --- Utils ---
ekey              : Set encrypt key, point '.' no encrypt
periode           : Send periode 0 - disable, >0 periode in minutes
sendp             : Send x NB messages
send              : Send data
tz                : Time offset in hours
info              : Show or set manuf. info string (0-30 chars)
time              : Show or set rtc time, set as BCD : 0x102033 is 10:20:33
date              : Show or set rtc date, set as BCD : 0x171231 is 2017-12-31
uptime            : Show uptime
sens              : Show sensors
reset             : Reset device
?                 : Show this help
mon#
```

An overview of configuration parameters with a brief description of their meaning is given in Table 2 on page 18. The procedure for setting individual parameters with a more detailed explanation of their meaning is given below.

3.1.2 „System commands" group for general diagnostics

Commands „**"deb", "ta", "mb", "du addr", "rw addr", "rb addr", "rd addr", "sw addr val", "sb addr val", "tshort", "tlong", "port", "ppm"** and **"at"** are used for troubleshooting and repair of the device in a factory. **Manufacturer strongly recommends not to use these commands during common operation.**

3.1.3 „Configuration" group of commands for writing of configuration

The module contains two sets of configuration: operating configuration and saved configuration. At the start of the system the module copies saved configuration to operating configuration, with which continues to work. If the user changes configuration parameters, it does so only in operating configuration.

If the current operating configuration was not stored to FLASH memory, the module returns to the saved configuration after reset. If the parameter should be changed only temporarily (for example shorten of the broadcasting period during installation), it is not necessary to save operating configuration into FLASH memory (after finishing a work the module can be returned to normal configuration by its reset). If the parameter should be changed permanently, there is necessary to save configuration to FLASH memory.

If operating configuration corresponds to the saved set (ie. there are no differences between commands in FLASH and in the operating set), the module will „report" prompt in the format "mon#". If operating configuration was changed so that it no longer matches to the saved set, the module will report prompt in the format „cfg#".

Every time the current configuration is saved into FLASH memory the value of the „Configuration version" parameter increases by one and the prompt changes to „mon#". The parameter resets to zero by erasing of FLASH.

Current operating configuration can be displayed by using of **"show"** command (see paragraph 3.1.1):

```
cfg#show
```

Current operating configuration can be rewrite the to FLASH memory by using of **"write"** command:

```
cfg#write
Writing config ...  OK, version 13
mon#
```

Reading of the configuration from FLASH memory can be done by using of **"cread"** command:

```
cfg#cread
Reading config ...  OK, version 13
mon#
```

The configuration can be erased in Flash memory by using of **"clear"** command:

```
cfg#clear
Clearing config ...  OK, version 13
mon#
```

This command deletes all configuration parameters from the FLASH memory, so it is necessary to set them again. If after erasing all parameters in FLASH memory the module goes to reset, default set of parameters (configured in the program of the device) is duplicated to FLASH memory. There is only one exception - frequency constant keeps the actual value also after cleaning of FLASH memory by "clean" command.

This command is recommended to use only by users with good knowledge of the system or after consultation with the manufacturer.

3.1.4 Commands for setting communication with the NB-IoT network

This group of commands is used to set up the subsystem for communication with the NB-IoT network. These are the following commands:

smask	*setting message content (selection of transmitted values)*
hist	*setting the period for storing historical readings*
hdata	*display current records of historical readings in the module memory*
server	*setting the IP address of the target server*
sport	*setting the port number of the target server*
testip	*setting IP address for control ping*
sping	*sending a control "ping" to the specified address*
sreply	*redirecting the response to the target server*
apn	*setting the name of the private network access point (Access Point Name)*
sess	*maximum time for establishing a connection with the server*
tconn	*maximum time to wait for a server response*
tshort	*timeout for modem command response (short)*
tlong	*timeout for modem command response (long)*
band	*setting the NB frequency band (default "20" = Europe)*
at	*sending any command to the modem (according to modem documentation)*

The **"smask"** command is used to set the content of information transmitted in the information message. The methane concentration sensor also measures the temperature and humidity of the environment, and these values can also be transmitted in the information message. The structure of the message content is described in the "mask" table (see Figure 2), where in each row of the table, the transmitted data are marked with a value of "1". The 0/1 data from all three columns of the table (Humidity, Temperature, Concentration) together form a binary number, the decimal form of which is given in the "Mask" column.

Mask	Humidity	Tempetarure	CH4
1	0	0	1
3	0	1	1
5	1	0	1
7	1	1	1

Figure 2: Table for selecting message content ("mask")

We set the message content by writing the mask number from the "Mask" column after the "smask" command. Example:

```
cfg#smask 3
Send mask changed to 3 :  ch4,temp
cfg#
```

As is clear from the example, in messages with mask "3", the methane concentration and temperature values will be transmitted, without the humidity data. By default, the value "1" is set, where only the methane concentration value is transmitted.

NB-IoT services are typically charged based on the volume of transmitted data, so it is important to set the messages to transmit only values that are meaningful to the recipient. If the temperature and humidity values are not of interest to the message recipient, we do not recommend transmitting them also because they unnecessarily reduce the number of records in the history table (see below).

To reduce the number of transmissions (saving battery capacity), the NB-CH4 module allows sending a larger number of previously read values in one message. Such a message then does not contain the current measured values, but a set of previously measured values stored in the internal memory of the module (hereinafter "historical readings"). Each set of historical readings is assigned the time of their acquisition and this time data is transmitted to the central system. The length of the transmitted packet in the NB-IoT network allows the transmission of **up to 48 historical readings** of methane concentration. Historical readings are stored in memory with a configurable period, which must be chosen with respect to the message transmission period so that there are no more than 48 historical readings in the transmitted message. After each message is sent, the table of historical readings is emptied. If temperature or humidity data is transmitted along with the methane concentration reading, a maximum of 24 historical readings can be transmitted.

Example: *If the transmission period is set to 720 minutes (12 hours) and the period for storing historical readings is 15 minutes, 720/15 = 48 values will be inserted into the memory during the entire transmission period. In this case, the transmitted message will contain 48 historical readings, which is the maximum capacity of the message.*

In the configuration listing, the setting for storing historical readings is displayed as follows:

```
Send periode : 1440 min.
 Hist. periode : 60 min.
   in message 24 records, max. is 48 recs
```

From the listing, it is clear that the transmission period is 1440 minutes (24 hours), the period for storing readings in history is 60 minutes, and therefore each message will contain 24 records.

We set the **period for storing readings in memory** using the **"hist"** command. The value is set in minutes, allowed setting values are 10, 15, 30 and 60 minutes (if another number is entered, the closest of these values is set). When set to "0" (default setting), readings are not stored in memory.

Example of setting storage of readings in memory with a period of 60 minutes:

```
cfg#hist 60
History changed from 0 to 60 min.
cfg#
```

Using the **"hdata"** command, we can display the currently stored historical readings. Example:

```
cfg#hdata
History data :
2018-01-04, 13:30:00+01
ch4 : 0.01
2018-01-04, 13:45:00+01
ch4 : 0.00
2018-01-04, 14:00:00+01
ch4 : 0.01
cfg#
```

From the example, it is clear that since the last message was sent, three sets of historical readings have been inserted into the table of historical readings.

The module sends messages wrapped in UDP packets of the Internet protocol to a preset **target server**, on which the remote data collection application runs. The following commands are used to **set the IP address and target port number** and to set the **name of the communication gateway** between the GSM operator network and the Internet (so-called "APN" = Access Point Name).

Using the **"server"** command, we set the **IP address of the target server**. The address is entered in decimal format in the commonly used way.

Example of setting the target server IP address to "92.89.162.105" and verifying the setting:

```
cfg#server 92.89.162.105
Server changed from '0.0.0.0' to '92.89.162.105'
cfg#
cfg#server
Server is : '92.89.162.105'
cfg#
```

Using the **"sport"** command, we set the **UDP port number** of the target server, which corresponds to the remote data collection application. Example of setting the UDP port number of the target server to "2000" and verifying the setting:

```
cfg#sport 2000
UDP port changed from 0 to 2000
cfg#sport
UDP port : 2000
cfg#
```

Using the **"testip"** command, we set the **IP address for the control ping**. The address is entered in decimal format in the commonly used way. The control ping is sent after the maximum time for establishing a connection with the operator's server (see the previous "sess" parameter) has elapsed. The control ping is addressed to the set address of a suitable computer in an accessible IP network (a computer that reliably responds to control "ping" queries). If a response to the ping arrives, the connection to the NB-IoT network is verified and it is not necessary to establish it again.

Example of setting the IP address of the computer for sending a control "ping" to the value "10.0.0.1":

```
mon#testip 10.0.0.1
Test ip changed from '10.0.0.8' to '10.0.0.1'
mon#
```

We can check the availability of the server for the control "ping" message using the **"sping [address]"** command. By entering this command, the system sends a control ping and displays the result.

The **"sreply"** command is used to specify the setting of **communication via the reverse channel** (see section 3.3 "Setting module parameters from a remote computer using the reverse channel"). In some NB-IoT networks/services, it is only possible to send reverse messages to the module from a different IP address than the standard set IP address of the target server for sending messages. When the module is set to "Reply to server : no", the module responds to messages in a way that is standard for IP networks - i.e., it responds to the address from which the query came. When set to "Reply to server : yes", the module always responds to queries from any server to the set target server address (see the "server" command). We set the module to the "yes" state by entering parameter "1", we set the module to the "no" state with parameter "0".

Example of checking the reverse channel communication setting and then making a change:

```
cfg#sreply
Reply to server : no
cfg#sreply 1
Reply to server : yes
cfg#
```

If the GSM network operator transfers data from modules to their operator in the form of a virtual network, we use the **"apn"** command to set the name of the communication gateway between the GSM network and the Internet (so-called "APN" = "Access Point Name"), reserved for the given virtual network within the GSM network. The APN name is assigned to virtual network operators by the GSM network operator. We cancel the APN setting by entering the value "." (dot).

Example of setting the APN name to "cms.softlink":

```
cfg#apn cms.softlink
APN changed from '' to 'cms.softlink'
cfg#apn
APN is : 'cms.softlink'
cfg#
```

The current setting of the target server and communication gateway is displayed in the configuration listing as follows:

```
 Server IP : '92.89.162.105'
 Server port : 2000
 My src port : 2000
 APN :  'cms.softlink'
```

The value "My src port" is the UDP port number of the module itself. This value is "read only" and cannot be changed.

Using the **"sess"** command, we set the **maximum time for establishing a connection with the operator's server ("session time")** in minutes. Some GSM service operators charge for each connection establishment ("session"), so establishing a connection before sending each message can be financially disadvantageous (and sending a message also takes longer). On the other hand, if the server loses this connection for some reason during a permanent connection, the module does not receive any message about it from the network and the sent messages are lost. The "sess" parameter can be used to set the time after which the module itself terminates the connection and establishes it again when sending data next time. By default, this time is set to **2 days** (172800 seconds, 2880

minutes), which is a reasonable compromise between costs and message delivery reliability. If the GSM operator does not charge for establishing a connection, the parameter can be set to a shorter time (or even to zero, when a connection is established when sending each message), but for the sake of shortening the communication time, we recommend keeping the default setting even in this case.

The current setting of the maximum connection time is displayed in the configuration listing as follows:

```
Max session time 172800 sec - 2d, 0:00:00
```

Example of setting the maximum connection time to 2880 minutes:

```
cfg#sess 2880
Max session time : 2880 min.
cfg#
```

Using the **"tconn"** command, we set the **maximum time to wait for a network response when establishing a connection**. If the GSM operator's network does not respond to connection requests within this time, the module's GSM modem turns off and will attempt to establish a connection when sending the next message. The parameter is set by default to **5 minutes** (300 seconds). We recommend changing the value if the GSM network operator guarantees a significantly different response from the network.

Example of changing the setting of the maximum time to wait for a network response when establishing a connection from 200 to 300 seconds (5 minutes):

```
mon#tconn
Connection timeout is 200 sec
mon#tconn 300
Connection timeout is 300 sec
cfg#
```

*Both of the above parameters ("sess" and "tconn") affect power consumption and **battery life**. If a connection to the server is established when sending each message, the active state of the modem is extended, when it consumes a lot of energy. If the waiting time for the network response ("tconn") is set too long, the modem is unnecessarily on for a long time while waiting for the connection to be established. From this point of view, it is advantageous to set the longest possible "sess" time and the shortest possible "tconn" time. However, such a setting **reduces the reliability of message delivery**, because in the event of a "session" failure on the operator's side, messages are lost until the "sess" time expires, and with a short "tconn" timeout, it may happen that the connection is not established in time and the message is not sent. The setting of both parameters must be a compromise between energy efficiency and message delivery reliability.*

Using the **"tshort"** and **"tlong"** commands, you can set timeouts for the modem's response to commands from the module processor. These parameters are used to adapt the communication interface between the module processor and the modem to the given modification of the NB-IoT modem. The "tshort" command sets the timeout for commands related to the modem itself, the "tlong" command sets the timeout for commands related to the network. Both commands are used **exclusively during the initial setting of the module in the production process**.

Using the **"band"** command, you can set the **NB-IoT modem frequency band**. By default, the most commonly used frequency band B20 in Europe is set (value "20"). The used modem may support multiple frequency bands, in which case it is possible to switch the module to another frequency band. In different production series of the NB-CH4 module, the used modem modification may differ depending on the current availability and price of the modem at the time of production. **If you are interested in using the modem in a band other than B20 (800 MHz), always include this information in your order or contact the manufacturer**.

Using the **"at"** commands, we can manually enter any modem command according to the modem documentation. The command is used **exclusively for diagnostic purposes**.

3.1.5 Commands for setting the methane concentration sensor

The next group of commands is used for setting and diagnostics of the methane concentration sensor and the position sensor. These are the following commands:

ch4alarm	*setting the alarm level in 1/100 % (0 = off)*
ch4warmup	*setting the interval for sensor warm-up*
ch4comm	*manual entry of command for the sensor*
ch4talr	*manual sending of methane concentration exceeded alarm*
ch4malr	*number of alarm messages to be sent (0 = do not send)*
ch4per	*methane concentration measurement period in seconds*
lisreg	*listing of position sensor registers*
lisval	*listing of current position sensor values*

The command **"ch4alarm"** is used to set the threshold for methane concentration, exceeding which the module will send an alarm message with Trap Code = 31 ("High methane concentration"). If the methane concentration drops below the set threshold, the module will send an alarm message with Trap Code = 32 ("Methane concentration normal"). The methane concentration threshold is entered in hundredths of a percent (0.01%), so entering the value "1500" sets the threshold to 1.5%.

Example of checking the current setting and then setting the threshold level for triggering the alarm to 0.6 %:

```
mon#ch4alarm
CH4 alarm 44 1/100 %
mon#ch4alarm 60
CH4 alarm 600 1/100 %
cfg#
```

The command **"ch4warmup"** is used to set the time interval (timeout) for sensor warm-up. This interval applies only immediately after turning on the module. The interval is factory set to the optimal time for the current version and modification of the sensor and we do not recommend changing it.

The command **"ch4comm"** is used to enter any command into the methane sensor according to the documentation for the given sensor type. If we enter an original command according to the documentation for the given sensor after the "ch4comm" command, the module will send this command to the sensor. In this way, for example, recalibration of the MIPEX sensor can be performed.

The command **"ch4talr"** is used to manually send an alarm for exceeding the methane concentration value. The command can be used when testing the generation, sending and passage of an alarm message.

The command **"ch4malr"** is used to set the number of repetitions of the alarm message when the alarm level is exceeded. Alarm messages are sent with a period of 1 minute, so with a set value of "5", 5 alarm messages will be sent at 1-minute intervals. Each message contains the measured methane concentration value at the given time, so from a series of messages it is possible to read at what rate the methane concentration is increasing. With a set value of "0", the alarm is detected, the alarm relay switches, but the message is not sent.

Example of checking the current setting and then setting the number of alarm message repetitions to 2:

```
cfg#ch4malr
CH4 alarm msgs 5
cfg#ch4malr 2
CH4 alarm msgs 2
cfg#
```

The command **"ch4per"** is used to set the measurement period for methane concentration. The interval is factory set to 15 seconds, which is a compromise between possible delay in information about the presence of methane and battery life. We do not recommend changing the value of this parameter.

The command **"lisreg"** displays the registers of the position sensor. It is used for diagnostics of the position sensor.

The command **"lisval"** (without parameter) can be used to display the current X, Y and Z values of the position sensor. The command "lisval 1" starts periodic reading of position values with a period of 1 second. We end position reading by entering the "lisval" command without a parameter.

3.1.6 Commands of the "Utils" group for setting and controlling basic module functions

This group of commands is used to set and control other functions of the module. These are the following commands:

ekey	*setting the encryption key (”.” - encryption disabled)*
periode	*setting the period for spontaneous message sending*
send	*immediate sending of a message with current values*
sendp	*command for immediate sending of a series of messages*
tz	*setting the time zone (UTC + n)*
time	*display/set hh:mm:ss of real time RTC*
date	*display/set YY.MM.DD of real time RTC*
uptime	*display time since last reset (”Uptime”)*
sens	*display current values of temperature and voltage sensors*
info	*setting individual module identification*
reset	*command to perform module reset*
?	*list configuration commands (”Help”)*

The **”Encryption key”** variable is used to set the encryption key for encrypting messages using the AES-128 key. We enter the 16-byte encryption key using the **”ekey”** command followed by a string of 16 bytes, which can be entered in decimal or hexadecimal format (see examples).

Example of entering the encryption key in hexadecimal format:

```
cfg#ekey 0x1a 0x2b 0x3c 0x4d 0x5e 0x6f 0xa1 0xb2 0xc3 0xd4 0xe5 0xf6 0x77 0x88 0x99 0xaf
Setting encryption key : 1a 2b 3c 4d 5e 6f a1 b2 c3 d4 e5 f6 77 88 99 af
cfg#
```

Example of entering the encryption key in decimal format:

```
cfg#ekey42 53 159 188 255 138 241 202 136 21 98 147 235 15 145 136
Setting encryption key : 2a 35 9f bc ff 8a f1 ca 88 15 62 93 eb 0f 91 88
cfg#
```

After entering the encryption key, the information about encryption being enabled ***”Data will be encrypted by AES”*** is displayed in the list of set parameters (see section 3.1.1).

We disable encryption by entering the parameter ”.” (dot) after the **”ekey”** command:

```
cfg#ekey.
Encyption disabling
cfg#
```

After disabling encryption, the information ***”Data will be unencrypted”*** appears in the parameter listing (see section 3.1.1).

The **”Periode”** variable is used to set the period for spontaneous sending of information messages. During production, the period is set to **value ”0”**, which means **transmission is disabled**. Using the **”periode”** command (without parameter), the current setting value can be displayed. If we enter the desired number of minutes as a parameter after the ”periode” command (theoretically up to 65535 minutes can be set), we set the period for sending information messages to the specified number of minutes.

Example of checking, setting, saving and re-checking the period for sending information messages:

```
cfg#periode
Periode is 60 min.
cfg#periode 30
Periode changed from 60 to 30
cfg#periode
Periode is 30 min.
cfg#
```

During normal operation, the module automatically sends information messages with the set period. Using the **”send”** command, we can send an information message immediately, which can be useful, for example, when verifying radio range during module installation.

Example of sending an information message using the ”send” command:

```
cfg#send
Sent 55 bytes
cfg#
```

With the **"sendp"** command, we immediately ("out of order") send a series of standard information messages with measured data at 1-minute intervals. This command can be used when installing the system. The command allows us to test the reliability of message sending, for example, even after closing the mounting box or leaving the water meter shaft. The number of sent messages is determined by the command parameter. Example of a command to send a series of 5 messages:

```
cfg#sendp 5
sending 5 msgs
mon#
```

Using the **"tz"** command, we set the **time zone** (Time Zone) in which the remote reading system operates. The module supports **only one** time zone, which is set in hours from UTC.

Example of setting the time zone to UTC+1 (Central European Time):

```
cfg#tz 1
Tz change from 0 to 1
cfg#
```

In the configuration listing, the set time zone value is displayed as:

```
Timezone : 1
```

Using the **"time"** or **"date"** command, we can display the current RTC setting. By entering either of these commands without parameters, we display the current RTC value of the module. Example:

```
cfg#time
RTC time : 15:30:17 2019-01-30
 systime 1548858617 : 2019-01-30, 15:30:17+01
cfg#
```

We set the RTC value using the **time** and **date** commands as follows:

```
cfg#time 0x182555
RTC time : 18:25:55 2019-01-30
 systime 1548869155 : 2019-01-30, 18:25:55+01
cfg#date 0x190128
RTC time : 18:26:58 2019-01-28
 systime 1548696418 : 2019-01-28, 18:26:58+01
cfg#
```

As is clear from the example, the "time" value is given in the format "0x**hhmmss**", the "date" value is given in the format 0x**YYMMDD**.

Note: *Setting the RTC (including setting the time zone) is not necessary for normal functionality of the module, no current application of the module requires RTC setting.*

Using the **"uptime"** command, we display the time since the module was turned on or since its last reset. We use this command only when checking and diagnosing the module. From the "Uptime" value, we can tell when the last module reset occurred. The variable is of the "read only" type. Example:

```
cfg#uptime
Uptime 0d, 0:13:26
```

Using the **"sens"** command, we display the values of the module's A/D converters for measuring processor temperature and battery voltage. We use this command only when checking and diagnosing the module.

```
cfg#sens
-- Sensors --
CPU : 25.8 °C
VDA : 3.586 V
```

Using the **"info"** command, we can set an individual identification for the module. Up to 29 alphanumeric characters can be entered. The entered identification will be displayed in the "Info text" field of the optical configuration form. The identification can contain any identification data (installation site code, customer code, serial number...). Example of setting individual module identification:

```
cfg#info NB-X 123456
Change manuf info from :  ''  to :  'NB-X 123456
```

The **"reset"** command performs a module reset. After the reset is performed, the saved set of configuration parameters is loaded from FLASH memory. If we want to keep the currently created configuration, it is necessary to save the working set of configuration to FLASH memory before performing the reset (see section 3.1.3). Example of using the command to reset the module:

```
cfg#reset
 -- Reset code 0x14050302 --
 PIN Reset
 SFT Reset
 SW version 1.01, date Sep  8 2021
Monitor started ..
mon#
```

The **"?"** command displays a list of the module's configuration commands with their brief description ("Help"). An example of this command is given in the introductory part of section 3.1.

3.1.7 Display of additional data in the module configuration parameter listing

In the last part of the module configuration parameter listing (see use of the "show" command), some **identification and operational data of the module** are displayed, which are of the "read only" type. These are the following data:

```
 Next send : 88 min.
  No. sent :  11 msg(s)
  No. recv : 0 msg(s)
-- Modem status --
Modem state : 0
Session count : 1
Session timeout : 172796 sec - 1d, 23:59:56
Modem IMEI : 863703038894247
  SIM CCID : 89882390000037252304
  SIM IMSI : 901288001028645
 Last RSSI : -61 dBm
Sensor CH4 type 3
CH4 alarm 200 1/100 %
 Conf. version : 12
 SW version 1.01, date Sep  7 2021
```

In the first part of the listing is information about sent messages. The **"Next send"** value is the time until the next regular message is sent. The **"No. sent"** and **"No. recv"** values contain the numbers of sent and received messages since the last reset.

In the **"Modem status"** section are identification data of the internal GSM module (IMEI), number of the inserted SIM card (SIM CCID) and unique number of the SIM card user (SIM IMSI). The **"Last RSSI"** line shows the signal strength with which the last message was received from the GSM network. Also displayed here are the number of connections established since the last reset **"Session count"** and the time until the maximum connection time expires **"Session timeout"**.

The **"Sensor CH4 type"** line shows the type of sensor for measuring methane concentration. The **"CH4 alarm"**

line shows the set threshold value of methane concentration, exceeding which generates an alarm message.

The **"Conf. version"** line shows the number of the set of configuration parameters, which increases with each new saving of the configuration to memory. The number is reset by erasing the FLASH memory. The **"SW version"** line shows the software version and its release date.

3.2 Setting module parameters using an optical converter

The module is equipped with an infrared optical interface "IRDA", which is used for configuration using the **"USB-IRDA"** converter (from optics to USB cable), or using the **"BT-IRDA"** converter (from optics to Bluetooth radio). The optical interface sensor is located on the printed circuit board between the LCD display and the methane concentration sensor. When configuring using an optical converter, it is necessary to place the optical head at a distance of about 15 cm from the module and rotate it so that its axis points approximately to this location.

When configuring using the **"USB-IRDA"** optical converter, the module parameters can be set via the configuration table of the OptoConf program (if a table for the given module type is available in the program).

Using the **"BT-IRDA"** optical converter, those parameters that are included in one of the configuration forms of the mobile application **"SOFTLINK Configurator"** can be set. The current version of the "SOFTLINK Configurator" application supports configuration of all basic module parameters, as well as performing those basic tests that need to be performed at the installation site.

Figure 3 shows the identification form of the NB-CH4 module (in a grey frame), the form selection window (in a yellow frame) and the administration form (in a blue frame).

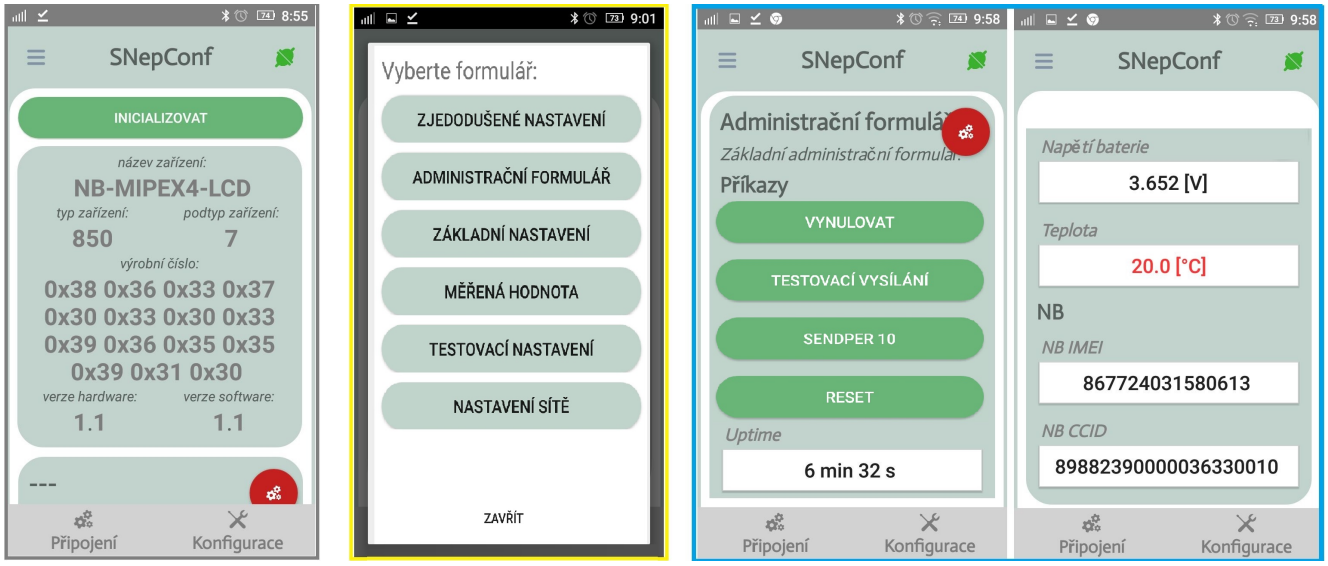


Figure 3: Basic forms of the NB-CH4 module in the "SOFTLINK Configurator" application

Figure 4 shows the basic form for setting the alarm threshold value, measurement parameters and message sending parameters (in a red frame), a simplified form for quick setup at the installation site (in a green frame) and a form for reading the current value and performing recalibration (in an orange frame).

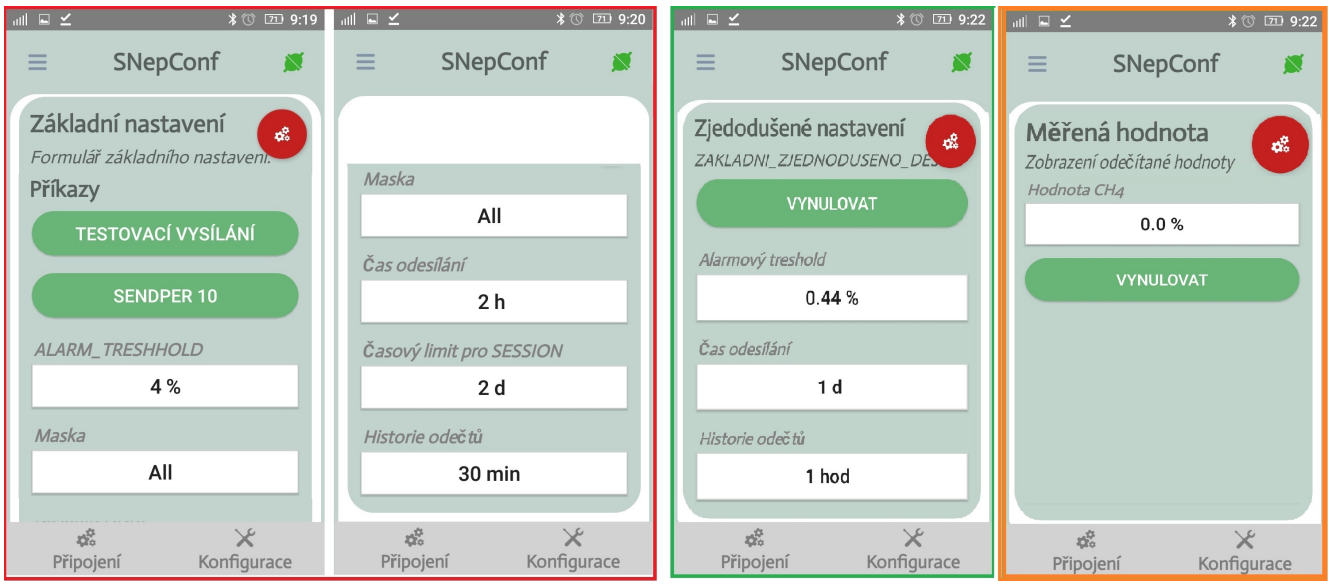


Figure 4: Input settings form and NB-IoT network configuration form

As evident from the figures, the application allows the following settings to be made:

- setting the threshold value of methane concentration for generating an alarm
- setting the message content (mask for selecting transferred values)
- setting the period for sending NB-IoT information messages
- setting the maximum time for establishing a connection with the operator's server
- setting the period for measuring and storing historical readings
- setting the IP address of the NB-IoT server
- setting the target UDP port number
- displaying the source UDP port number
- setting the name of the communication gateway to the NB-IoT network (APN)
- enabling one-time test transmission
- enabling a series of 10 test transmissions (SENDPER 10)
- sending a command to recalibrate the module (ZERO)
- sending a command to reset the module (RESET)

The "SOFTLINK Configurator" application is continuously being developed and improved, so the above previews of information and configuration forms of the NB-CH4 module may change over time.

3.3 Setting module parameters from a remote computer using the reverse channel

The NB-IoT network communicates via the standard Internet Protocol (IP), which naturally allows **communication in both directions**. The NB-CH4 module uses the possibility of two-way communication for remote setting of parameters from a remote computer via the so-called **"reverse channel"**, which opens for only two seconds after sending a message (INFO, TRAP, or RESPONSE) to save battery capacity. During this time, the module's receiver is open and the module is able to receive a message from the remote server.

Messages in the reverse direction are used to set module parameters. These **"setting messages"** are encoded using the NEP protocol, so they have essentially the same structure as messages sent by the module (individual variables in NEP encoding are transmitted in the data content of the UDP packet).

The first variable in each setting message is always the **message type**. Setting messages are always of type **"SET"** (OiD 63 = **"1"**). This variable is followed by one or more variables for which a change is requested.

The NB-CH4 module performs the setting of the requested parameters (update of the specified variables) and sends back a message of type **"RESPONSE"** (OiD 63 = **"4"**), which contains the values of the changed variables after the change is made. The module sends the RESPONSE type message either to the IP address from which the SET type request came, or to the set IP address of the target server (depending on the setting of the "Reply" parameter using the "sreply" command).

Using setting messages of the reverse channel, the same parameters can be set as when setting the module using an optical converter, which communicates with the module on the same principle. More detailed information about the possibilities of communication via the reverse channel can be obtained by contacting the module manufacturer.

3.4 Overview of module configuration parameters

An overview of the configuration parameters used for user setting of the NB-CH4 module is given in Table 2. The parameters are listed in the table in the same order in which they are displayed when the configuration is listed (see paragraph 3.1.1).

Table 2: Overview of configuration parameters of NB-CH4module

No.	Name	Type	Description	Default
1	Timezone	number	time zone (time from UTC)	1
2	Server IP	code	IP address of target server	
3	Ping IP	code	IP address for availability check	
4	Server port	number	port number of target application	2000
5	Reply	yes/no	setting response to message from network	no
6	My src port	number	port number of source application	read only
7	APN	text	private network access point name	
8	Max session time	number	maximum connection duration	2 days
9	Send period	0 - 65535	transmission period in minutes	60
10	Hist. period	number	period for storing historical readings	0
11	Send mask	number	number of message content mask	3
12	Encryption	code	encryption key	disabled
13	Next send	curr. state	number of minutes until next message	read only
14	No. sent	curr. state	number of messages sent since reset	read only
15	No. recv	curr. state	number of messages received since reset	read only
16	Modem state	curr. state	status of internal GSM module	read only
17	Session count	curr. state	number of connections established since reset	read only
18	Session timeout	curr. state	time until "session timeout" expires	read only
19	Modem IMEI	curr. state	unique identifier of GSM module	read only
20	SIM CCID	curr. state	unique number of inserted SIM card	read only
21	SIM IMSI	curr. state	unique number of SIM card user	read only
22	Last RSSI	curr. state	signal level of last received message from network	read only
23	Sensor CH4 type	number	type of methane concentration sensor	3
24	CH4 alarm	number	setting of methane concentration threshold value	440
25	Version	curr. state	serial number of stored configuration	read only
26	SW version	curr. state	software version number and release date	read only

The **"Type"** column indicates the type of value for the given parameter. The designation "code" means that the set value is displayed in the form of a hexadecimal code, where a pair of hexadecimal characters always represents one byte. The exception is the IP address, which is entered in the usual way, i.e. in the form of four octets described by decimal code, separated by dots. The designation "curr. state" means that the given data is an operational value that cannot be influenced. A numerical range means that the given value is a number from the specified range.

The **"Default"** column shows the default values set during module production. The color marking of this field has the following meaning:

- green color - most frequently changed parameters, we set them depending on the specific application
- red color - parameters that we do not recommend changing
- gray color - values that cannot be changed ("read only")

Yellow highlighting in the "No." column indicates those parameters that can be set using the **USB-IRDA or BT-IRDA optical converter** as described in detail in section 3.2 "Setting module parameters using an optical converter". These messages can also be set remotely (from a remote server), using the NB IoT network reverse channel.

3.5 Data messages of the NB-CH4 module

3.5.1 Structure and types of module data messages

The NB-CH4 module is used for monitoring methane (CH4) concentration in air and sending methane concentration data to a superior automatic data collection system via the NB-IOT service of a GSM operator.

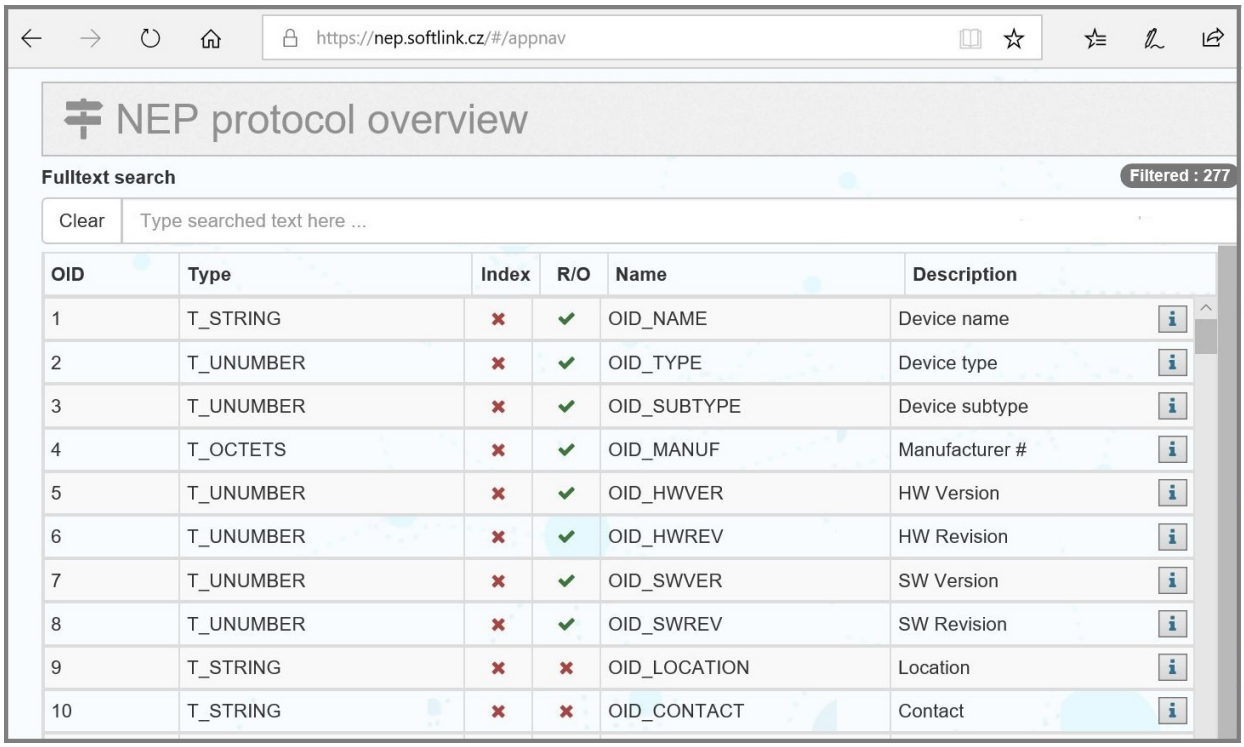
NB-IOT services use UDP (User Datagram Protocol) messages for data transmission, which is the transport layer of the Internet Protocol (IP).

The UDP datagram header of the NB-CH4 module consists of three fields:

- source port (16 bits) - fixed to "2000"
- destination port (16 bits) - set by "Server port" parameter
- length (number of Bytes) of UDP packet (16 bits)

The UDP packet header is followed by the packet data content, in which individual variables are transmitted.

Individual variables are coded into the data content of the message by using of "NEP" proprietary coding system invented by SOFTLINK. In this system each type of variable has its own designation called "OID" (Object ID), which determines meaning, character and data type of the variable. These variables, that could be used multiple times (as multiple inputs, temperatures, voltages...) must be used jointly with order number of the variable called „Index". „NEP coding table" is centrally maintained by SOFTLINK and it is available on the public WEB address NEP Page. Preview of „NEP coding table" for coding of variables in the WACO system is shown in the figure 5.



OID	Type	Index	R/O	Name	Description
1	T_STRING	✖	✔	OID_NAME	Device name
2	T_UNUMBER	✖	✔	OID_TYPE	Device type
3	T_UNUMBER	✖	✔	OID_SUBTYPE	Device subtype
4	T_OCTETS	✖	✔	OID_MANUF	Manufacturer #
5	T_UNUMBER	✖	✔	OID_HWVER	HW Version
6	T_UNUMBER	✖	✔	OID_HWREV	HW Revision
7	T_UNUMBER	✖	✔	OID_SWVER	SW Version
8	T_UNUMBER	✖	✔	OID_SWREV	SW Revision
9	T_STRING	✖	✖	OID_LOCATION	Location
10	T_STRING	✖	✖	OID_CONTACT	Contact

Figure 5: Preview of „NEP coding table" for coding of variables in WACO system

Each variable is transferred together with its decoding information „Type" and „Length" that enables decoding of the information (i.e. determine variable's OID, index and value) on the receiving side even without knowledge of variable meaning. More detailed description of the NEP protocol can be downloaded in PDF format at the NEP Page.

The data content of the message has a fixed part containing identification data and operational values of the NB-CH4 module itself and a variable part of the message, which contains measured variables. The module generates two basic types of messages:

- periodically generated messages of **"INFO"** type about the state of variables (readings from consumption meters and sensors)
- alarm messages of **"TRAP"** type generated by the module immediately after detecting a given event

The module generates these messages either in open or encrypted mode. In addition to these basic types of messages, the module can also generate confirmation messages of **"RESPONSE"** type, which respond to setting messages from a remote server (see paragraph 3.3).

3.5.2 Description of INFO type message

The main part of INFO type messages are measured methane concentration values ("readings") taken by the module. Along with the readings, identification and operational data of the module are also sent. INFO messages are sent at regular intervals, the sending period is set by the "periode" parameter (see paragraph 3.1.4).

The fixed part of the message consists of the first nine variables, which are part of every message. In the examples of messages below, the fixed data are always marked with yellow color in the OID column.

The variable part of the message contains reading values. If **current data** is transmitted, only one (currently measured) concentration value is transmitted, without a time stamp. If **historical readings** are transmitted (see setting of "hist" parameter in paragraph 3.1.4 "Commands for setting communication with the NB-IoT network"), a **time stamp** ("timestamp") is always transmitted before each reading value, which is associated with that value.

One set of variables always contains variable values selected by the "smask" command. The following variables can be selected:

OID 82/1 - methane concentration value in hundredths of a percent (0.01%)
OID 105/2 - temperature according to the built-in sensor (*)
OID 90/1 - humidity according to the built-in sensor (*)

(*) Can only be used if the methane concentration sensor used also measures temperature and humidity.

Example of an INFO type message from the NB-CH4 module with **current data** with setting to transmit all variables ("full mask"):

OID	Index	OID Name	Description	Example
63		Message type	DATA/INFO type message	6
2		Device Type	Device type	850
3		Device Subtype	Device modification	5
4		Manufacturer No.	Device identification	IMEI
12		Uptime	Time since last reset (sec)	186552
61		Sequence No	Unique message number	
105	1	Temperature	Processor temperature in tenths of Celsius	223
106	1	Voltage	Battery voltage in mV	3765
462	1	RSSI	Last RSSI value	-61
82	1	Methane concentration	Current concentration value in 0.01%	3
105	2	Temperature	Sensor temperature in tenths of Celsius	238
90	1	Humidity	Relative humidity in percent	42

Example of an INFO type message from the NB-CH4 module with **current data** with setting to transmit only the state of the first pulse input ("minimum mask"):

OID	Index	OID Name	Description	Example
63		Message type	DATA/INFO type message	6
2		Device Type	Device type	850
3		Device Subtype	Device modification	5
4		Manufacturer No.	Device identification	IMEI
12		Uptime	Time since last reset (sec)	186552
61		Sequence No	Unique message number	
105	1	Temperature	Processor temperature in tenths of Celsius	223
106	1	Voltage	Battery voltage in mV	3765
462	1	RSSI	Last RSSI value	-61
82	1	Methane concentration	Current concentration value in 0.01%	3

Example of an INFO type message with **historical data** with setting to transmit methane concentration values (mask "1"):

OID	Index	OID Name	Description	Example
63		Message type	DATA/INFO type message	6
2		Device Type	Device type	850
3		Device Subtype	Device modification	5
4		Manufacturer No.	Device identification	IMEI
12		Uptime	Time since last reset (sec)	186552
61		Sequence No	Unique message number	
105	1	Temperature	Processor temperature in tenths of Celsius	223
106	1	Voltage	Battery voltage in mV	3765
462	1	RSSI	Last RSSI value	-61
*TimeStamp and data for the **first** historical reading*				
17		Timestamp	Reading time (Epoch Unix Time Stamp)	1549031954
82	1	Methane concentration	Current concentration value in 0.01%	3
*TimeStamp and data for the **second** historical reading*				
17		Timestamp	Reading time (Epoch Unix Time Stamp)	1549032854
82	1	Methane concentration	Current concentration value in 0.01%	2
*TimeStamp and data for the **third** historical reading*				
17		Timestamp	Reading time (Epoch Unix Time Stamp)	1549033754
82	1	Methane concentration	Current concentration value in 0.01%	3

As evident from the example shown in the table, each historical reading creates its own sequence of variables in the message, which begins with a time stamp (TimeStamp) to which the following values relate. The "Timestamp" variable (= reading time) is followed by the values of the transmitted variables for that reading time.

The number of sequences with historical readings depends on how many readings have been stored in memory since the previous message was sent, with a maximum of 48 historical readings possible in the message due to the limited length of the NB-IoT message.

3.5.3 Description of TRAP type message

TRAP type messages are used for immediate transmission of information about an event detected by the NB-CH4 module. Generally, they contain information about the type of detected event, supplemented by one or more parameters of the given event. In this way, the message recipient receives information that an event has occurred (for example, exceeding the methane concentration), supplemented by other parameters (for example, the concentration value and the threshold that was exceeded).

The type of detected event is encoded in the **"Alarm code"** variable (OID 60 - TRAP CODE), where the value of the variable determines the type of event. The current version of the NB-CH4 module supports the following types of events:

- OID 60 - value "0" - "RESET" type event
- OID 60 - value "1" - "Configuration change" type event
- OID 60 - value "31" - "High methane concentration" type event
- OID 60 - value "32" - "Normal methane concentration" type event
- OID 60 - value "33" - "Device in motion" type event
- OID 60 - value "34" - "Device at rest" type event

The "Alarm code" variable may be followed by one or more other variables that specify the parameters of the event.

For the "RESET" type event, it is always one variable of the **"Reset code"** type (OID 14 - RESET CODE), which carries information about what caused the reset. In NEP coding, these types of reset are defined:

- value "0" - Cold start
- value "1" - Warm start
- value "2" - Watchdog reset
- value "3" - Error reset
- value "4" - Power reset

For "High methane concentration" and "Normal methane concentration" type events, the alarm code is always followed by the **current methane concentration status** and the set **threshold value**.

The **"Device in motion"** type event is automatically generated whenever there is an above-threshold change in the position sensor data compared to the previous measurement. The threshold value is set so that the event is

generated only with a significant change in position, caused by apparent manipulation of the module. If the device is at rest for more than 1 minute, a "Device at rest" type event is automatically generated. "Device in motion" and "Device at rest" type events do not require any clarification, so no additional variable is added to them.

The **"Configuration change"** type event is automatically generated whenever a new configuration is saved to FLASH memory. This event does not require any clarification, so no additional variable is added to it.

Example of a "TRAP" type message with information that the NB-CH4 module has undergone a "Warm start" type reset (reset given by a regular command):

OID	Index	OID Name	Description	Example
63		Message type	TRAP type message	5
2		Device Type	Device type	850
3		Device Subtype	Device modification	5
4		Manufacturer No.	Device identification	IMEI
12		Uptime	Time since last reset (sec)	0
61		Sequence No	Unique message number	
60		Trap code	RESET alarm code	0
14		Reset code	WARM START reset code	1

Example of a "TRAP" type message with information that the methane concentration threshold has been exceeded:

OID	Index	OID Name	Description	Example
63		Message type	TRAP type message	5
2		Device Type	Device type	850
3		Device Subtype	Device modification	5
4		Manufacturer No.	Device identification	IMEI
12		Uptime	Time since last reset (sec)	0
61		Sequence No	Unique message number	
60		Trap code	"Methane concentration exceeded" alarm code	31
82	1	Methane concentration	Current concentration value in 0.01%	157
81	1	Methane threshold	Threshold concentration value in 0.01%	150

3.5.4 Principle of message encryption

Message encryption using an AES key is enabled by setting the encryption key using the **"ekey"** command as described in paragraph 3.1.4 "Commands for setting the message sending system". The message is marked as an "Encrypted message" in the first variable ("Message type") (OID 63 has the value **127** - ENCRYPTED MESSAGE). The first six variables of the message are always sent in clear text because they contain identification data and auxiliary data for decryption. The other variables are encrypted using **CFB block encryption** and are transmitted in the message as one encrypted value of the **"Encrypted part of the message"** variable (OID 19 ENCRYPTED BLOCK).

The structure of an encrypted message always looks like this:

OID	Index	OID Name	Description	Example
63		Message type	ENCRYPTED MESSAGE type message	127
2		Device Type	Device type	850
3		Device Subtype	Device modification	1
4		Manufacturer No.	Device identification	IMEI
12		Uptime	Time since last reset (sec)	186552
61		Sequence No	Unique message number	
19		Encrypted block	Encrypted part of the message	other variables

In the encrypted part of the message, all other variables are block-encrypted. The first variable in the encrypted block is always "Message type" (OID 63 MESSAGE TYPE), which determines whether it is an INFO type message (value 6) or a TRAP type message (value 5). Other variables follow in the same composition and order as in an unencrypted message (starting from the seventh variable to the end of the message).

4 Operational conditions

This section of the document describes basic recommendations for transportation, storage, installation and operation of NB-CH4 radio modules.

4.1 General operational risks

The NB-CH4 radio modules are electronic devices powered by an internal battery that register the status of connected consumption meter counters.

During operation, the following risks are of particular concern:

4.1.1 Risk of mechanical and/or electric damage

The devices are enclosed in plastic boxes, so that the electrical components are protected from the direct damage by human touch, tools, or static electricity. In normal operation no special precautions are needed, besides avoiding of the mechanical damage from strong pressure or shocks.

Special attention is required for cables that connect the radio modules with the meters, sensors, or external antennas. In operation it is necessary to ensure that the cables are not stressed by mechanical tension or bending. In case of damage of any cable isolation it is recommended to replace the cable immediately. If the module is equipped with a remote antenna on a coaxial cable, much attention should be paid for the antenna and the antenna cable as well. The minimum bending radius of the antenna cable with 6 mm diameter is 4 cm, for the antenna cable with the 2,5 mm diameter the bending radius is 2 cm. Violation of these bending parameters can lead to breach of homogeneity of the coaxial cable that can cause reducing of radio range of the device. Further it is necessary to ensure that the connected antenna cable will not stress the antenna connector of the device by tension or twist. Excessive loads can damage or destroy antenna connectors.

Installation of the module can be performed only by a person with necessary qualification in electrical engineering and at the same time trained for this device installation. It is recommended to lead antenna and signal cables as far from 230/50 Hz power cables as possible.

4.1.2 Risk of premature battery discharge

The devices are equipped with the long duration batteries. Battery life can be influenced by these factors:

- storage and operation temperature – in high temperatures the spontaneous discharging current increases, in low temperature the battery capacity reduces;
- frequency of radio-transmitting.

Modules are delivered with preset period of regular transmitting of info-messages as stated in the configuration table in section of this document and the battery life cycle is quoted for this period. If the transmitting period is significantly reduced, battery life will be proportionally shortened.

4.1.3 Risk of damage by excessive humidity

Radio modules could be (as any other electronic devices) damaged by water, that could cause a short-circuit among some electronic elements or corrosion of the elements. Correctly assembled plastic box protects the module's printed circuit board against direct penetration of water, but the damage could be caused also by gradual penetration of humid air which can cause corrosion or other damage by condensed water inside the box.

Modules are enclosed in IP65 grade plastic boxes (proof against short-time squirted water) or with additional sealing by high-adhesion silicon filling, that can ensure proof against inundation by water (IP68 grade). Modules, that are delivered with IP68 sealing from factory are clearly assigned by IP68 degree of protection on the manufacturer's production label (e.g.: "NB-CH4/B13/IP68").

Risks of damage of the device in basic **"IP65"** design caused by penetration of excessive humidity can be eliminated by these precautions:

- install only modules that are correctly assembled, with undamaged box and undamaged rubber seal;
- in case of any doubt perform additional sealing of connection of both parts of the box and both cable bushings by silicon sealant;
- install modules only to the sites where relative humidity exceed value of 95% only occasionally;

- install modules only to the sites where they can be squirted or sprayed by water only occasionally and only for a short time;
- do not install modules to the sites where they can be dipped into the water.

Risks of damage of the device in waterproof **"IP68"** design caused by penetration of excessive humidity can be eliminated by these precautions:

- do not open the module with silicon filling without serious reason;
- if (from some reason) the module was already opened, manipulate with it very carefully or renew its silicon filling by pouring of a few milliliters of special silicon (same as original - consult the technique with manufacturer). **In case the module has been opened, there is no manufacturer's guarantee of IP68 degree of protection.**;
- install modules only to the sites where they can be dipped into the water only occasionally and only for a short time;
- do not install modules to the sites where their antenna could be submerged under water. Antenna must be installed to such place, where there is no possibility to be flooded. **Operating of the module with antenna submerged under water could cause irretrievable damage of the device!**

For the NB-CH4 module type, additional sealing with silicone filling can only be performed at the installation site, using a special procedure that must be consulted with the manufacturer. **The module manufacturer does not perform modification of the module to IP-68 protection.** The module manufacturer recommends performing this modification only when absolutely necessary.

IMPORTANT WARNING! The module is equipped with an optical methane concentration sensor that is **sensitive to shocks and temperature changes**. Please follow the instructions below for storage and transport. When handling the device, ensure it is not unnecessarily exposed to shocks. During installation and commissioning, **strictly follow the instructions for mounting the device** given in paragraph 4.6 "Module installation".

4.2 Module state upon delivery

The modules are supplied in standard cardboard boxes. The modules are always delivered with the battery switched off.

The manufacturer strongly advises against handling modules in the powered on state!

Always turn on the modules only after installation according to the procedure below. If it is necessary to turn on the module in the preparatory phase of installation, before turning on, leave the modules **for at least one hour** in a steady state so that the **temperature of the module equalizes** with the temperature at the given location.

4.3 Module storage

Storage should be in dry rooms with a temperature range of $(0 \div 30)$ °C. Keep the power supply turned off during storage.

NB-IoT services are charged, so we recommend inserting the SIM and activating the device in the operator's network only immediately before installing the device.

4.4 Safety warnings

Warning! Mechanical and electrical installation and removal of the module must be performed by a person with the necessary qualifications in electrical engineering.

4.5 Environmental protection and recycling

The device contains a non-rechargeable lithium battery. When disposing of the device, the battery must be removed and disposed of separately from the rest of the device in accordance with hazardous waste regulations. Damaged, destroyed or discarded devices cannot be disposed of as household waste. The device must be disposed of through collection yards that dispose of electronic waste. Information about the nearest collection yard can be obtained from the appropriate administrative office.

4.6 Module installation

The NB-CH4 radio modules are enclosed in plastic boxes with IP65 or IP68 protection, prepared for wall or pipe mounting. The battery switch, configuration connector and antenna connector are located on the printed circuit board, so access to them is only possible after opening the box. The module is standardly equipped with a "Micro-SIM" (3FF) format SIM card holder located inside the module on the main board. Based on a specific order, it can alternatively be equipped with an integrated SIM module (chip-SIM), powered directly on the printed circuit board.

Figure 6 shows the NB-CH4 module disassembled into individual components.

Figure 6: Assembly of NB-CH4 module with stick antenna

Figure 7 shows a detail of the module's printed circuit board with the location of the sensor (marked in green), configuration connector (marked in red), SIM card holder (marked in purple), NB-IoT uplink antenna connector (marked in blue), alarm relay (marked in orange) and battery switch (marked in yellow). The appearance of the printed circuit board may vary slightly depending on the modification of the module.

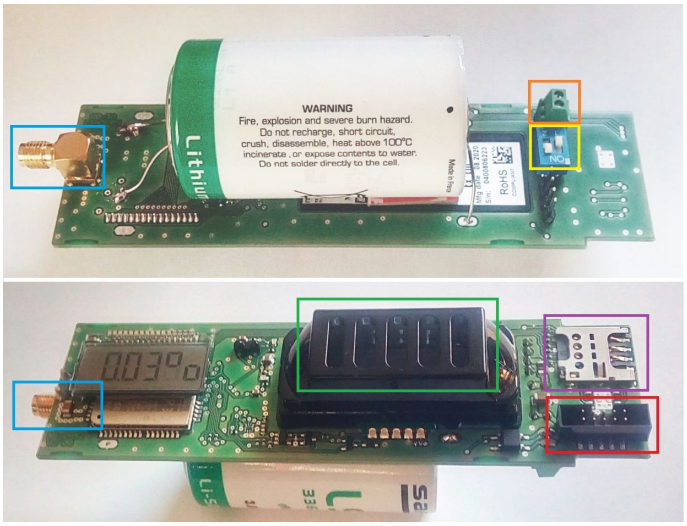


Figure 7: Detail of NB-CH4 module printed circuit board

The box consists of two parts:

- module case, into which the printed circuit board is inserted. This part of the box has a label, cable gland and mounting lugs;
- box lid, closing the case. The lid has a second cable gland.

The methane concentration sensor is a device **sensitive to shocks and temperature changes**. Always transport and install the module when it is turned off and ensure that the device is not unnecessarily exposed to shocks. **During installation and commissioning, strictly follow these instructions:**

- given that methane spreads upwards, the module will react most quickly to concentration changes in a position where **the methane sensor is facing downwards**. Therefore, the recommended mounting position is horizontal, with the sensor facing downwards (for example, from below on the top wall of the switchboard, or on the ceiling of the shaft);

- keep the device turned off until final placement. Only after attaching the module to the base, remove the case lid, turn on the module and configure it. **If the module was exposed to a temperature change before installation (for example, when moving from a vehicle to the installation site), do not turn it on immediately, but leave it off for about an hour so that its temperature equalizes with the ambient temperature.**
- after turning on, the module goes through a preparatory phase of sensor heating and auto-calibration, so **for the first approximately 5 minutes after turning on, it does not provide correct data**. During the sensor heating period, the LCD display shows the symbol "- - -", only then does a numerical methane concentration value appear, which should be close to zero and may change slowly. After about two more minutes (when the measurement has stabilized sufficiently), the sensor is automatically recalibrated, which may manifest as a sudden change in value to zero.

IMPORTANT NOTE! The module must always be turned on exclusively in an environment with zero methane concentration!

The actual installation and commissioning is done by first preparing the installation site, then opening the module, assembling and attaching it, and finally turning on and configuring the module. Perform the individual tasks as needed as follows:

- find a suitable place to install the module and prepare this place if necessary (pre-drill holes, attach a bracket....). The module is attached to a suitable solid object (wall, pipe....) using four screws or a tightening strap so that it is in the recommended position described above if possible. Use the molded holes on the module case for mounting. If a suitable horizontal surface or structural element is not available, use an L-shaped bracket;
- if a cable is already connected to the module's alarm relay, loosen the union nut on the cable gland of this cable;
- unscrew the two screws on the sides of the box to release the module lid;
- carefully slide out the module lid, while the cable to the alarm relay (if connected) slides inside the lid. You can help by gently pushing the cable inside the module;
- if it is necessary to screw on the NB-IoT antenna or antenna cable, completely loosen the antenna union nut and carefully slide the printed circuit board (PCB) out of the module case. If the NB-IoT transmitter antenna is already mounted, it is not necessary to slide the PCB out of the case;
- if the antenna (or antenna cable) was not mounted on the printed circuit board, screw it to the antenna connector and carefully push the printed circuit board back into the case;
- if it is necessary to connect the control cable of the warning system to the alarm relay, pull the cable through the union nut and grommet of the lid and connect it to the terminals of the alarm relay. The alarm relay is of the SSR (Solid State Relay) type with galvanic isolation of the switched circuit. The relay can switch a DC control circuit with a maximum voltage of 30 V and a maximum current of 1 A. Connect the control cable to the alarm relay terminals without polarity distinction. If the alarm relay cable was connected to the module in advance, connect the control circuit of the signaling to it;
- if the module is already "acclimatized" (i.e. its temperature is equalized with the ambient temperature) turn on its power supply by switching the blue micro-switch ("jumper") located on the printed circuit board to the "ON" position;
- perform basic diagnostics of the module and possibly its configuration (parameter setting) using the cable according to the procedure described in section 3 "Module parameter configuration".
- after about 5 minutes, check that auto-calibration has taken place and the LCD display shows a methane concentration value close to zero (*);
- check the integrity of the rubber seal on the edge of the case. If a cable is connected to the alarm relay, make sure that the cable union nut is completely loosened;
- carefully slide the lid onto the module case. The cable to the alarm relay (if connected) gradually extends out through the lid grommet. Attach the lid to the case by screwing in and tightening both screws;
- tighten the union nuts on both cable glands to seal both glands. If no cable is connected to the alarm relay, the gland must be plugged with a plastic cylinder about 2 cm long of suitable diameter (for example, a 6 mm diameter glue gun stick);
- if the installation procedure or the customer's internal rules require sealing of the module (as protection against tampering), seal the module in the specified manner (for example, by sticking an adhesive seal across the joint between the two parts of the box).

(*) The module has a measurement accuracy in the range of (0.1 ÷ 0.25)%, so it is normal that even in an environment without methane presence **it may show some non-zero value**, which should, however, be close to zero.

After installation, verify the functionality of the module once and the correctness of the module's output value (whether the indicated methane concentration corresponds to reality), preferably by the "end-to-end" method, i.e. by checking the display of concentration data and operational parameters of the module directly in the remote reading system.

When selecting the installation location for the module, it is necessary to take into account especially the requirements for the measurement location (i.e. the space where methane could accumulate), but also the requirement for protection of the module against possible mechanical damage (installation outside operationally exposed areas) and conditions for radio signal propagation at the installation site. These conditions can either be determined (estimated) empirically, based on previous experience, or by measuring signal strength using a control transmitter/receiver.

4.7 Module replacement

When replacing the module due to a malfunction or depleted battery capacity, proceed as follows:

- if the module was sealed, check if the seal is intact before disassembling the module. Handle a broken seal according to the internal rules applicable to the given customer/project;
- loosen the mounting screws (or tightening strap) holding the module to the wall, pipe, or other base and remove the module;
- if a cable is connected to the module's alarm relay, loosen the cable's union nut;
- unscrew the two screws on the sides of the box to release the module lid and carefully slide the lid off the module;
- switch off the module by moving the micro-switch ("jumper") located on the printed circuit board to the "Off" position;
- if a control cable of the warning system is connected to the alarm relay, disconnect it from the alarm relay terminals;
- if the module is equipped with an external NB-IoT antenna, loosen the union nut on the module case, carefully slide the printed circuit board out of the case so that you have access to the antenna connector and disconnect the antenna cable from the antenna connector;
- reassemble the original module by screwing the lid to the case (*). Visibly mark the module as "faulty", or fill out the appropriate form (installation sheet) or other prescribed documentation for module replacement;
- attach a new module in place of the original one and proceed according to the procedure described in section 4.6. Pay particular attention to correctly setting the configuration parameters, especially the transmission period and methane concentration alarm level setting;
- write down the serial number and seal number of the new module;
- if possible, immediately ensure that the new serial number is entered into the collection system database

(*) CAUTION! *When assembling the module, always make sure that the box case is not mixed up, i.e. always put the box case with the correct label on the module PCB. The serial number on the module case must always match the serial number on the auxiliary label that is stuck on the printed circuit board.*

4.8 Module disassembly

When disassembling, remove the module from the wall (pipe, other base...), open it, turn off the battery and disconnect the alarm relay cable and antenna cable if necessary. Reassemble the module by putting the lid back on the case, properly mark it as disassembled and fill out the appropriate documentation prescribed for this case by internal regulations. If possible, immediately ensure deactivation of the module in the collection system.

4.9 Module functionality check

After putting the module into operation (or after each repair and replacement of the module) we recommend checking its basic functions:

- check the setting of basic module parameters, especially message transmission system parameters (encryption, transmission period, path to superior server) according to paragraph 3.1.4;

- read the current methane concentration value using the "val" command via the configuration cable, or by reading the "Value" value using the "Read" button of the optical converter. The read methane concentration value should correspond to the estimated reality (i.e. it should be close to zero). If the currently measured value significantly exceeds the zero level, perform a control measurement with a reference meter. If the presence of methane is confirmed, handle the situation according to the internal directive for this case;
- the values of other measured quantities (temperature, battery voltage) should correspond to reality;
- verify sufficient coverage of the installation site with NB-IoT radio signal by sending several test messages using the "send" command according to paragraph 3.1.6 "Commands of the "Utils" group for setting and checking basic module functions" and their successful reception in the central system. An indicative information about network signal availability can be obtained by checking the RSSI value in the configuration parameter listing, or in the optical configuration form (value "Last RSSI");
- a comprehensive (end-to-end) check of remote reading functionality can be performed by checking in the reading system whether messages from all modules in the given location are being loaded. If the reading period is long, or it is not possible to wait for a message to be sent at the standard interval, we can use the immediate message sending function as described in the previous paragraph.

4.10 Operation of the NB-CH4 module

Remote monitoring of methane concentration using NB-CH4 modules works completely automatically. The greatest risks of operation interruption are associated with the activities of the facility user, especially the risk of mechanical damage to modules when handling objects at the installation site, damage to the module by water ingress, or the risk of shading the module's radio signal with a metal object. A typical consequence of damage is a complete loss of connection with the module.

To eliminate these risks, we recommend paying attention to the selection of the module installation site not only from the point of view of suitability for measurement, but also from the point of view of radio signal quality and the possibility of mechanical damage to the module during normal operation of the facility. We recommend carrying out the installation itself carefully, using quality installation material.

Unexpected interruption of connection with the module can be prevented by continuous monitoring of the regularity and correctness of the read data (including accompanying data on processor temperature and battery voltage) and in case of detection of outages or non-standard values, contact the facility user or perform a physical check at the installation site.

The risk of premature battery discharge can be easily eliminated by following the recommendations given in paragraph 4.1.2.

5 Troubleshooting

5.1 Possible causes of system failures

During operation of the NB-CH4 device, failures, malfunctions, or other operational problems may occur, which can be divided into the following categories according to their cause:

5.1.1 Power supply failures

The module is powered by an internal battery with a long lifetime. The approximate battery lifetime is specified in more detail in paragraph 1.5 "Module features". The battery lifetime is influenced by circumstances described in detail in paragraph 4.1.2 "Risk of premature internal battery discharge". Low voltage of the power supply battery initially manifests as irregular data reception failures from the given module, later the radio connection with the module is interrupted completely. The battery is soldered onto the printed circuit board and its replacement requires disassembly of the module. Battery replacement can only be performed by a person with appropriate qualifications and experience; soldering the battery by an unqualified person risks damaging the module's printed circuit board. The "NB" series modules use only the highest quality batteries that have been carefully selected and tested for this purpose. In case of battery replacement by the device user, the new battery must match the original battery as closely as possible in its parameters (type, capacity, voltage, current load, self-discharge current...). The module manufacturer strongly recommends using the same type of battery for replacement as was used in the module during its production.

5.1.2 System failures

System failures are considered to be mainly processor failures, memory failures, internal power supply failures, or other fatal failures that cause complete device malfunction. If the device is in a state where the battery has the correct voltage and shows no signs of discharge, yet the device does not communicate through the configuration port, does not respond to any configuration commands, and this state does not change even after performing a module restart, it is likely a system failure. We perform device replacement according to paragraph 4.7 and then perform setup and functionality check of the new (replaced) device. If the new device functions normally, we mark the original module as defective and record the replacement data in the operational documentation according to internal rules.

5.1.3 Transmitter and receiver failures

Transmission functionality is indicated by the flashing of a yellow LED on the printed circuit board. Before transmitting data, the module connects to the NB-IoT network, which is indicated by a flash of this LED, which can be observed through the transparent cover of the module. If the module's power supply has the correct voltage, the module communicates through the configuration port, responds to configuration commands, and yet no messages are received from it, the cause may be a fault related to radio signal transmission or reception. A typical symptom of transmission and reception faults are also states of "partial" functionality, which manifest especially in frequent dropouts in data reception from the module. The cause of the above-described communication faults of the module may be unreliable radio data transmission, which may be caused by:

- weak NB-IoT network radio signal at the installation site. Network signal availability may change over time depending on weather conditions (fog, rain...), or as a result of changes at the transmission site and its surroundings (for example, change in the location of the base station antenna by the network operator, or construction activity in the vicinity of the base station);
- permanent or temporary signal shading due to construction modifications in the building of the module installation site, or due to operations in the given building (movement of mechanisms, machines, cars near the device);
- permanent, periodic, or irregular radio interference of the radio network by parasitic signal from an external source (operation of another system in the same radio band, industrial interference);
- low level of transmission signal, caused by a fault in the module's transmitter;
- low level of received signal due to a fault in the module's receiver;
- damage to the antenna or antenna cable (only for module types with external antenna).

If the above-described symptoms of unreliable radio transmission occur, we proceed as follows when searching for and eliminating the causes of the problem:

- we perform a visual inspection of the module installation site and determine whether there have been any construction modifications or other changes in the building that could affect the propagation of the radio signal. We address any negative impacts of such changes and modifications organizationally, or (if possible) by changing the location of the device, or by relocating the antenna (for modules with external antenna);
- for modules with external antenna, we perform a visual inspection of the antenna and antenna cable, possibly also replacing these components with other components with verified functionality;
- we check the configuration parameters of the module and check the functionality of the module according to paragraph 4.9;
- we replace the module according to paragraph 4.7 and then set up and check the functionality of the new (replaced) module according to paragraph 4.9;
- if after performing the replacement under the circumstances described in the previous point, the replaced module also does not work correctly, the cause of the problem may be local radio interference, or the cause is insufficient network signal at the installation site. In this case, we consult the current status and possible future development of NB-IoT network signal coverage at the installation site with the service provider.

5.1.4 Measurement failures

Measurement failures manifest as incorrect methane concentration values being recorded. If incorrect measurements are suspected, perform a control measurement with a reference meter. If the incorrect measurement is confirmed, replace the module with a functioning unit as described in section 4.7 "Module replacement". If the measured values are obviously nonsensical, check the connection of the sensor to the internal terminal block, and if no error is found there, replace the module.

5.2 Procedure for determining the cause of failure

When determining the likely cause of a failure, proceed as follows:

1. If no data is being received from the NB-CH4 module, we recommend checking the functionality of individual module subsystems in this order:
   - verify the correct configuration of the module in the remote reading system database;
   - check the power supply functionality according to section 5.1.1 "Power supply failures";
   - check the system functionality according to section 5.1.2 "System failures";
   - check the functionality of data transmission and reception according to section 5.1.3 "Transmitter and receiver failures";
   - check the measurement functionality according to section 5.1.4 "Measurement failures".
2. Data from the module arrives irregularly, with periodic outages. In this case, we recommend checking the functionality of individual module subsystems in this order:
   - check the functionality of data transmission and reception according to section 5.1.3 "Transmitter and receiver failures";
   - check the power supply functionality according to section 5.1.1 "Power supply failures".
3. Data from the sensor is being read, but it is incorrect. In this case, we recommend checking the measurement functionality according to section 5.1.4 "Measurement failures".

NOTE: The NB-CH4 module is a reliable device with a relatively simple and robust design, so there is a high probability that any malfunction is caused by external circumstances of the installation, especially mechanical damage, moisture ingress, battery depletion, or strong electromagnetic interference at the installation site. With each module replacement due to a malfunction, we recommend verifying, if possible, whether the cause of the malfunction was one of these circumstances and, if necessary, taking measures to eliminate it.

6 Additional information

This manual focuses on the description, parameters and configuration options of NB-CH4 type radio modules designed for operation in the NB-IoT network, which are part of the **wacoSystem** product family by SOFTLINK. Further information about the NB (NB-IoT), WS868 (Sigfox), WM868 (WACO), or WB169 (Wireless M-Bus) type series modules can be found on the manufacturer's website:

www.wacosystem.com
www.softlink.cz

If you are interested in any information related to the use of NB, WS868, WM868, WB169 series radio modules, or other SOFTLINK manufacturer's devices for telemetry and remote reading of consumption meters, you can contact the manufacturer:

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