WIRELESS COMMUNICATION SYSTEM
NB-IoT

NB-TE-V

NB-THE-V

Revision 1.2

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1 Introduction

This document describes the configuration options of the NB-TE-V and NB-THE-V radio modules, which are used for measuring temperature values (NB-TE-V) or temperature and humidity values (NB-THE-V) and for wireless transmission of information about measured values to the remote reading system via NB-IoT services of the 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 Module usage

The NB-TE-V module can be used for measuring instantaneous temperature values. The NB-THE-V module can be used for measuring instantaneous relative humidity and temperature values. Both modules can be installed indoors and outdoors and use NB-IoT network services for data transmission.

The module sends INFO messages at regular intervals, which contain either only current temperature and humidity data, or (in "history" mode) a set of previously measured values stored in the module's memory. Up to **24 historical value 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 via an access point (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 therein.

The NB-TE-V 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 configure the module parameters remotely, from a remote server.

1.3 Module features

Both types of modules are enclosed in the same moisture-resistant plastic box (IP65 rating) and are suitable for use in indoor and outdoor environments. The box is designed for mounting on a wall or any structural element (beam, pipe...). The module can be equipped with additional moisture protection (to IP68 degree) by filling with high-adhesion silicone filler. If this modification is required from the manufacturer, it must be ordered with a special order code. Both modules are equipped with a circular "peephole" to support magnetic attachment of the optical converter.

Both modules are powered by an internal battery that allows them to operate for up to 10 years with a message sending frequency of 2-4 times a day (one message can contain up to 24 readings). Battery life can be negatively affected not only by a shorter set message sending interval, but also by operating the device in objects with temperatures outside the recommended operating temperature range.

The modules are 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 modules can be manufactured to order with an integrated SIM module (ChipSIM) of a specific GSM operator.

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

The appearance of the NB-TE-V module is shown in Figure 1 at the top, the appearance of the NB-THE-V module is shown in Figure 1 at the bottom.

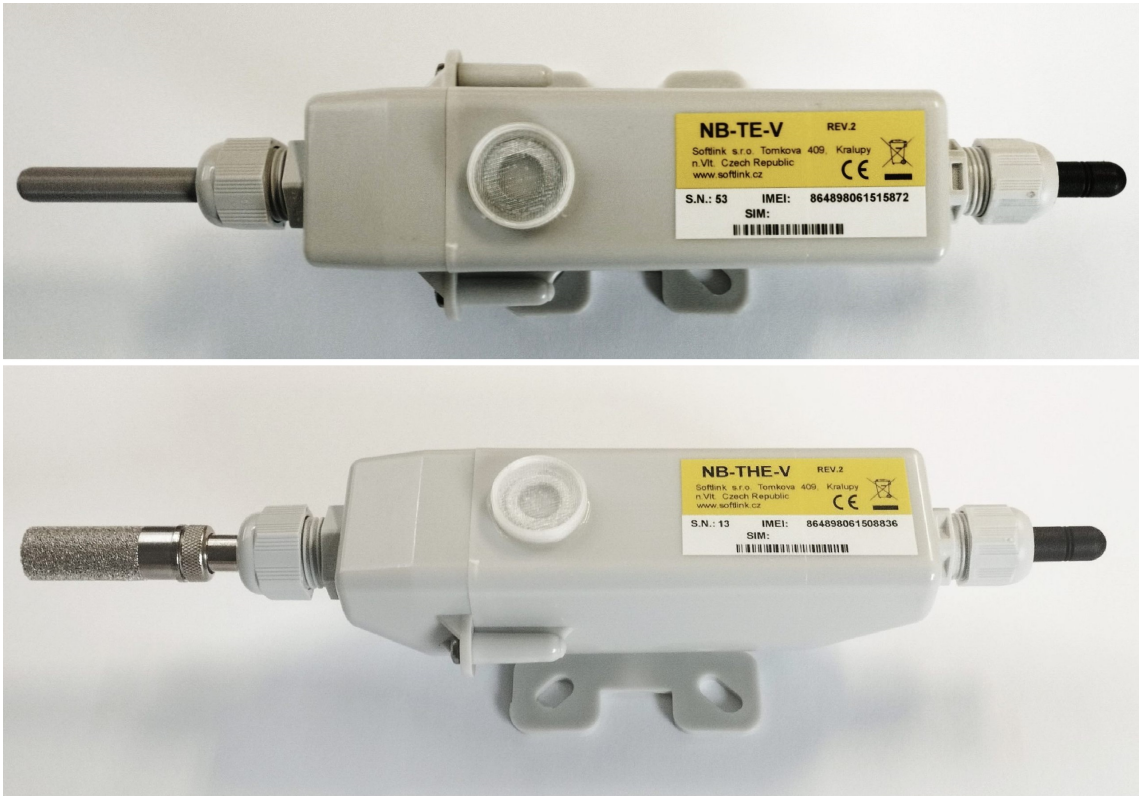


Figure 1: Appearance of the NB-TE-V and NB-THE-V modules

2 Overview of technical parameters

An overview of the technical parameters of the NB-TE-V and NB-THE-V modules is given in Table 1.

Table 1: Overview of technical parameters of NB-TE-V and NB-THE-V modules

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
Frequency band 900 MHz (RX/TX)	925-960 / 880-915	MHz
Modulation type	GMSK, 8PSK	(adaptive)
Bandwidth	180	KHz
Transmitting power	200	mW
Receiver sensitivity	135	dBm
Communication protocol	NB-IoT	(bidirectional)
Transmission speed	0.35 ÷ 240	Kb/s (adaptive)
Antenna connector	SMA female	
Characteristic impedance of antenna input	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	
Sensor parameters		
Typical accuracy of relative humidity measurement	2	%
Typical accuracy of temperature measurement	0.2	°C
Power supply parameters		
Lithium battery voltage	3.6	V
Lithium battery capacity	17	Ah
Mechanical parameters		
Length (including antenna and probe)	290	mm
Width	70	mm
Height	60	mm
Weight	approx. 400	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
Relative humidity *	95	% (non-condensing)
Protection rating *	IP65 or IP68	

* modules with additional sealing by silicone filling are waterproof, with IP68 protection rating.

3 Configuration of the NB-TE-V module

Configuration parameters of the NB-TE-V 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-TE-V 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 NB-TE-V or NB-THE-V module using configuration cable

The following part of the manual describes those parameters of the NB-TE-V and NB-THE-V modules whose current value 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"). Both module types have identical firmware, so their configuration parameters and commands are also identical. Both modules use the same HW/SW platform as the NB-SI2 pulse sensor, so their set of parameters and commands also includes parameters and commands for setting the NB-SI2 type module.

3.1.1 Listing of configuration parameters and commands of the module

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

```
mon#show
----- Configuration -----
 Timezone : 1
 Server IP : '92.89.162.105'
 Server port : 2000
 Reply to server : no
 My src port : 2000
 APN : '' "
Max session time 172800 sec - 2d, 0:00:00
  Input[0] ,multiplier 1 ,divider 1 ,mode falling, quick, alr: none , alarm code OK 4, Error 5
  Input[1] ,multiplier 1 ,divider 1 ,mode falling, quick, alr: none , alarm code OK 4, Error 5
Send periode : 120 min.
 Hist. periode : 15 min.
   in message 8 records, max. is 24 recs
 Send mask is 12 : Temp., Hum.

 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 : 89882390000037252304
  SIM IMSI : 901288001028645
 Last RSSI : -61 dBm

Conf. version : 1
 SW version 2.01, date Jun  7 2023
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 listing will appear in the terminal window:

```
cfg#?
 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
info              : Show module info
write             : Write configuration to flash
cread             : Read configuration from flash
clear             : Clear configation and load defaults
 --- Inputs ---
val               : Show or set counters values[0-1]
mul               : Set multiplier of value[0-1]
div               : Set divider of value[0-1]
det               : Detection 0 - falling, 1 - rising
dmode             : 0 - quick, 1 - slow
alr               : Send alarm : 0 - none, 1 - falling, 2 - rising, 3 - both
alcok             : alarm code OK
alcerr            : alarm code Error
leakp             : Leak detection periode in hours - 0 disabled
leakz             : Leak zero periode in minutes (rounded up to ten minutes)
burstp            : Burst min puls in 10 minutes
burstt            : Burst check time in minutes (rounded up to ten minutes)
trf               : Set tarrif 0 - off, 1 - t1 high, 2 - t1 low
 --- 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
smask             : Send mask bits, 0 - I1, 1 - I2, 2 - temp. 3 - hum. ,default 3 - I1 and I2
hist              : History periode 0 - disable, >0 periode in minutes
hdata             : Show history data
fdata             : Fill n history data
loca              : Show or set manuf. info string (0-30 chars)
 --- Narrow band ---
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
errtime           : Set restart time on error in hours
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
...
```

```
 --- Utils ---
tz               : Time offset in hours
ppm              : Set RTC ppm
xmco             : Enable/disable Xtal on MCO
xtset            : Set Xtal freq for ppm
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
vbat             : Show or set vbat for alarm (vbat min)
uptime           : Show uptime
sens             : Show sensors
reset            : Reset device
hsical           : Calibrate HSI
?                : Show this help
```

An overview of the 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 Commands of "System commands" group for control of module basic functions

This group of commands is intended for control of module basic functions. There are following commands:

reset	*command for module reset*
send	*command for immediate sending of message*
sendp	*command for immediate sending of series of messages*
sens	*show current values of internal sensors (temperature, voltage)*
uptime	*show system uptime from last reset*
info	*show type, subtype and module designation*
loca	*setting of individual module designation*

The command **"reset"** performs the module reset. After each reset the system starts with the parameters that are stored in FLASH memory. If the current configuration should be used after reset, it is necessary to store it into the FLASH before reset (see paragraph 3.1.3). Example of using of "reset" command:

```
cfg#reset
-- Reset code 0x14050302 --
PIN Reset
SFT Reset
SW version 0.01, date Jan 18 2019
Monitor started ..
mon#
```

The command **"send"** can be used for immediate transmitting of standard message with current values. This command can be used for example during system installation when we want to check radio signal availability, or during various settings and tests of the device. The command enables us to send an info message anytime, without necessity to change broadcasting period or wait for spontaneous message according to the preset period. Example:

```
cfg#send
Sending ...
send [1] msg 255
mon#
```

The command **"sendp"** can be used for immediate transmitting of series of standard messages with 1-minute interval. This command can be used for checking of radio signal availability during the system installation. It could enable checking of connection also after closing of mounting rack, or after leaving of watermeter shaft. Number of transmitted messages is set by parameter (number) after command. Example of sending of series of 5 messages:

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

The **"sens"** command can be used for displaying of current values of A/D converters (power supply, processor temperature..). This command is intended only for module checking and diagnostics.

```
cfg#sens
-- Sensors --
CPU : 25.8 °C
VDA : 3.003 V
VBAT : 3.561 V
Sensor type 1 - HDC1080
Temp :  °C
Hum :  46.1 %
mon#
```

By using of **"uptime"** command the time since last module restart (switch on or reset) can be displayed. Using of this command can help with module diagnostics. From current „Uptime" value it is clear, when the module went through the last restart. The variable is of „read only" type. Example:

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

By using of **"info"** command basic non-editable data about the module can be displayed - its type designation, type/subtype number, serial number, IMEI etc. Example of displaying data of NB-THE-V module by using of "info" command:

```
cfg#info
-- Info --
Name : NB-THE
SN   : 11
Type    : 850
SubType : 15
NB modem
IMEI : 864898061516193
SIM CCID :
cfg#
```

By using of **"loca"** command individual designation of the module can be set. Maximum length of the string is 30 characters. The designation will appear in the „Info text" field in the optical configuration form. The description can contain any information (location or customer code, serial number...). Example of setting of the device individual description:

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

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 „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.**

3.1.5 Parameters of the "Inputs" group

The set of commands **val, mul, div, det, dmode, alr, alcok, alcerr, leakp, leakz, burstp, burstt** and **trf** is used to set pulse counters for NB-SI2 type modules. **For NB-TE-V and NB-THE-V type modules, setting these parameters is not relevant.**

3.1.6 Commands for setting message content

This group of commands is used to set the content of the NB-TE-V module's information message. These are the commands:

smask	*setting message content (selection of transferred values)*
hist	*setting the period for storing historical readings*
hdata	*displaying current historical reading records in module memory*
fdata	*retroactive insertion of historical readings into module memory*

The **"smask"** command is used to set the message content. The message structure is described in the "mask" table (see figure 2), where in each row of the table, transferred data are marked with a value of "1". The 0/1 values from all four columns of the table (Humidity, Temperature, Pulse input 1 and Pulse input 2) together form a four-bit binary number, whose decimal form is given in the "Mask" column. The NB-TE-V module is used to transmit temperature data, so it has a preset corresponding message mask of "4". The NB-THE-V module is used to transmit humidity and temperature data, so it has a preset corresponding message mask of "12". In case of an incorrectly set mask, we can correct the setting by writing the desired mask number value from the "Mask" column after the "smask" command. Example:

```
cfg#smask 12
Send mask changed to 12 :  Temp., Hum.
mon#
```

Mask	Humidity	Temperature	Pulse input 1	Pulse input 2
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
...				
12	1	1	0	0
15	1	1	1	1

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

NB-IoT services are typically charged based on the volume of transferred data, so it is important to set messages to transfer only values that are meaningful to the recipient.

To reduce the number of transmissions (saving battery capacity), the NB-TE-V module allows sending a larger number of previously read values in one message. Such a message does not contain current measured values, but a set of previously measured values stored in the module's internal memory (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 module's memory size allows storage of **up to 24 historical readings**. Historical readings are stored in memory with an adjustable period, which needs to be chosen with regard to the message transmission period so that there are no more than 24 historical readings in the transmitted message. After each message is sent, the table of historical readings is emptied. ***Example:*** *If the transmission period is set to 240 minutes (4 hours) and the period for storing historical readings is set to 30 minutes, 240/30 = 8 values will be inserted into the memory over the entire transmission period. In this case, the transmitted message will contain 8 historical readings.* In the configuration listing, the setting for storing historical readings is displayed as follows:

```
Send periode : 60 min.
Hist. periode : 10 min.
in message 6 records, max. is 24 recs
Send mask is 12 : Temp., Hum.
```

From the listing, it is clear that the transmission period is 60 minutes, the period for storing readings in history is 10 minutes, and therefore each message will contain only 6 records. We set the **period for storing readings in memory** using the **"hist"** command. The value is set in minutes, with allowed setting values of 10, 15, 30, and 60 minutes (if another number is entered, the closest of these values will be 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 30 minutes:

```
cfg#hist 30
History changed from 0 to 30 min.
cfg#
```

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

```
cfg#hdata
History data :
2018-01-04, 13:30:00+01
Temp.  :  26.6 °C
Hum.  :  45.7 %
2018-01-04, 13:40:00+01
Temp.  :  26.6 °C
Hum.  :  45.9 %
2018-01-04, 13:50:00+01
Temp.  :  26.6 °C
Hum.  :  46.2 %
```

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. Using the **"fdata"** command, we can retroactively load fictitious (zero) historical data into the table by entering the desired number of records as an argument after the "fdata" command. This command can only be used when diagnosing the module or when testing the decoding system. Example for loading 5 sets of historical readings into memory:

```
cfg#fdata 5
Fill 5 history recs
cfg#
```

We can check the correctness of the data loading using the "hdata" command.

3.1.7 Commands for setting of message broadcasting system

This group of commands enables setting of system for radio-broadcasting of the information messages. There are following commands:

ekey	*setting of encryption key ("." - encryption disabled)*
periode	*setting of regular messages broadcasting period*
server	*setting of target server IP-address*
sport	*setting of target server port number*
sreply	*redirection of replies to target server*
apn	*setting of private network Access Point Name (APN)*
sess	*maximum session time*
tconn	*connection setup timeout*
tz	*setting of time zone (UTC + n)*
time	*real time (RTC) displaying/setting (hh:mm:ss)*
date	*real time (RTC) displaying/setting (RR.MM.DD)*

The command **„Encryption key"** is used for setting of the encryption key for an encryption of transmitted messages by using of AES-128 key. The encryption key of 16 bytes length is entered by using of **„ekey"** command, followed by the string of 16 bytes that can be entered in a decimal or hexadecimal format (see examples).

An example of insertion of 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#
```

An example of insertion of the encryption key in decimal format:

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

If the encryption key is set to the module's configuration, an information ***„Data will be encrypted by AES"*** displays in the list of configuration parameters (see paragraph 3.1.1)

Encryption can be switched off by setting of "." (dot) parameter after the „ekey" command:

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

In this case an information ***„Data will be unencrypted"*** *appears in the list of configuration parameters* .

„Periode" command serves for setting of broadcasting period of regular info messages. The value of the parameter is factory preset to 60 minutes. Current value can be checked by **„periode"** command (without parameter). Broadcasting period can be changed by entering of required number of minutes (theoretically up to 65535 minutes) after „periode" command.

Example of displaying, and setting of broadcasting period:

```
cfg#periode
Periode is 60 min.
cfg#periode 120
Periode changed from 60 min. to 120 min.
cfg#
```

The module enables also **an external synchronization of its broadcasting** from external source of synchronization pulses. For this purpose any of the four ports can be assigned as „synchronizing" by using of **„Periode -X"** command, where "X" is number (1 - 4) of assigned port.

Example of setting of port No. 2 into the „synchronization" mode:

```
mon#periode -2
Periode changed from 120 min. to I2
cfg#
```

If using of this setting, the process of transmitting of info message launch after each falling edge of the synchronization pulse is received on the synchronizing port. There is a protective interval of 1 minute implemented in the system, so the broadcasting period could be at least 1 minute. Requirements for the synchronization pulses are the same, as for metering pulses.

This feature is important in that case, if the measurement and broadcasting of measured values should be synchronized with some other process. Typical example is measurement of electrical energy in 15-minutes intervals, that must be synchronized with measuring intervals of superior part of the electrical grid. In this case it is necessary to bring 15-minutes synchro-signal (e.g. from electrometer with such kind of output) to the synchronizing port.

***WARNING:** If there are synchronization pulses with inverse logic connected, it could cause a slight decreasing of battery lifetime (up to 5 %). „Inverse logic" means that the input is permanently short-circuited and only during short time pulses it is released.*

The module broadcasts messages wrapped into UDP packets of Internet Protocol to the pre-configured **target server**, where the remote reading application is running. Following commands are intended for setting of **target server IP-address and target application port number** and for setting of the **name of communication gateway** between the GSM operator network and Internet (so called "APN" = Access Point Name).

IP-address of target server can be pre-configured by using of **"server"** command. The address can be entered in commonly used decimal format.

Example of setting of the target server IP address to "92.89.162.105" value and follow-up checking of 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#
```

Number of UDP port can be pre-configured by using of **"sport"** command. The UDP port number should correspond with the remote reading application port number. Example of setting of UDP port number to value "2000" and follow-up checking of the setting:

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

The **"sreply"** command can be used for specification of **reverse channel communication** settings (see paragraph 3.3 „Setting of module parameters from remote computer by using of reverse channel"). In some NB-IoT networks/services there is possible to send reverse channel messages only from different IP address, than preset standard IP address of target server used for sending of INFO messages. If the setting is "Reply to server : no", the module reply to reverse channel requests regularly - that means send answers to the address from which the request came. If the setting is "Reply to server : yes", the module always replies to the preset IP address of target server (see "server" command setting). For setting "yes" use "1" parameter, for setting "no" use "0" parameter of the command.

Example of setting reverse channel communication and follow-up checking of the setting:

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

If the GSM operator providing NB-IOT services transfers data from the modules to the IoT service provider through the virtual network, the **name of the communication gateway** between GSM and Internet (Access Point Name - APN) should be entered to the module configuration by using of **"apn"** command. APN is assigned by GSM operator. Setting of APN can be deleted by entering of "." value (dot).

Example of setting of APN-name to "cms.softlink" value:

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

Current setting of target server and communication gateway displays in the configuration summary as follows:

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

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

By using of **"sess"** command the **maximum session time** with GSM network server can be set. The timeout should be set in minutes. As some operators charge each creating of session, setting of session before each transmitting of message could significantly increase service expenses (and it also increases broadcasting time). On the other hand, if the network server interrupts (loses) session, the module is not notified about it and all broadcasted messages after that moment are lost. By setting of "sess" parameter the session time is limited and after that limit the module closes pending session and sets up new one with broadcasting of next message. Factory setting of this parameter is **two days** (172800 seconds, 2880 minutes), what is reasonable compromise between expenses and reliability of message delivery. If GS operator does not charge each session, the parameter can be set to lower value (even to zero, when the session is set-up before each broadcasting), but it is recommended to keep factory setting always in this situation because creating of session increases broadcasting time.

Current setting of maximum session time appears in the in the configuration summary as follows:

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

Example of setting of maximum session time to 2880 minutes:

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

By using of **"tconn"** command the **connection setup timeout** can be set. If the GSM network server does not react on the module's session setup request, the GSM sub-module is switched to idle mode and next attempt of session setup is performed before next broadcasting. Factory setting of this parameter is **5 minutes** (300 seconds). It is recommended to change this parameter only if the GSM operator guarantees significantly different response of its network.

Example of changing of connection setup timeout from 200 to 300 seconds (5 minutes):

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

Both above described parameters ("sess" and "tconn") have significant influence on the energy consumption and ***battery lifetime****. If, as an example, the module sets up connection before each broadcasting, it increases broadcasting period when the GSM sub-module is in active mode and consumes lots of energy. If the connection setup timeout is too long, the internal modem is pointlessly active during waiting for connection setup. From this point of view the best solution is setting of long "sess" time and short "tconn" time. But such setting could* ***decrease the reliability of message delivery****, because in case of session interruption on the network side all the messages are lost until expiration of "sess" timeout, and too short "tconn" timeout can cause that the module did not manage to setup session and the message is not transmitted. Setting of both parameters should be reasonable compromise between energy consumption and reliability of message delivery.*

As the NB-TE-V module can broadcast not only current values, but also „historical" values from internal memory, its internal timer Real Time Clock (RTC) must be synchronized with Coordinated Universal Time (UTC) to register exact time of each historical reading. GSM networks usually provide this synchronization automatically after the device is connected to network. For setting and checking of UTC and Time Zone there is a special group of commands described below.

By using of **tz** command the current **Time Zone** can be preset. The module supports **only one** time zone, that is set in number of hours from UTC.

Example of setting of "UTC+1" Time Zone (Central-European Time):

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

Current setting of Time Zone displays in the configuration summary as follows:

```
Timezone : 1
```

Current setting of RTC can be displayed by entering of **time** or **date** command (without parameter). Example:

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

RTC value is automatically computed by module as UTC value (obtained from the GSM network) plus Time Zone value (preset by user). RTC value can be entered also manually by using of **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 it is clear from the example, "time" value should be entered in "0x**hhmmss**" format, "date" value should be entered in 0x**RRMMDD** format. After connecting to the GSM network, RTC value will be automatically corrected by GSM network.

3.1.8 Displaying additional data in the module configuration parameter listing

In the last part of the module's 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 : 898823900000037252304
  SIM IMSI : 901288001028645
 Last RSSI : -61 dBm
 Conf. version : 1
 SW version 2.01, date Jun  7 2023
```

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

In the **"Modem status"** section, there are identification data of the internal GSM module (IMEI), the number of the inserted SIM card (SIM CCID), and the unique number of the SIM card user (SIM IMSI). The **"Last RSSI"** row shows the signal strength with which the last message from the GSM network was received. 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 **"Conf. version"** row shows the number of the configuration parameter set, which increases with each new configuration save to memory. The number is reset to zero when the FLASH memory is erased. The **"SW version"** row shows the software version and its release date.

3.2 Setting module parameters using an optical converter

The module is equipped with an "IRDA" infrared optical interface, which is used for configuration using the **"USB-IRDA"** converter (from optical to USB cable), or using the **"BT-IRDA"** converter (from optical to Bluetooth radio).

Using the **"USB-IRDA"** optical converter, all parameters that are necessary for normal operation of the module can be set. The advantage of setting via the optical converter is the possibility of configuration through the transparent cover of the module, without the need to open the module cover. This is of great importance especially in those cases where we use the module in a humid environment and it is sealed with additional silicone sealing or filled with silicone filling (additional modification to meet the conditions of IP68 protection rating).

The configuration parameters are thematically divided into several configuration forms in the **"SOFTLINK Configurator"** mobile application, which are used to set individual subsystems of the module. The current version of the mobile 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 module identification form (in the yellow frame) and the administration form (in the blue frame).

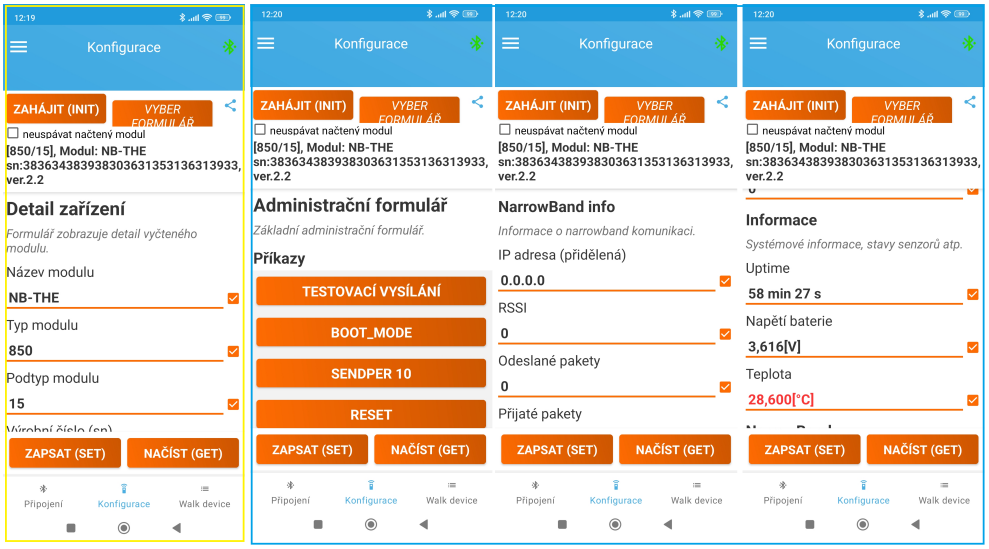


Figure 3: Identification and administration form of the NB-THE-V module in the "SOFTLINK Configurator" application

Figure 4 shows the form for basic settings (in the green frame), the form for setting communication in the NB-IoT network (in the purple frame) and the screen for selecting forms (in the gray frame).

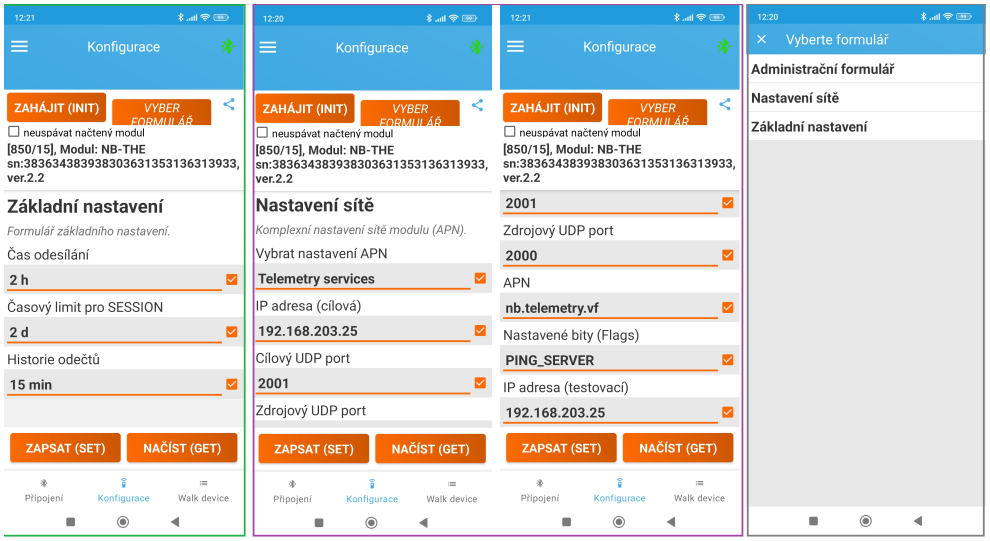


Figure 4: Form for basic settings and network settings of the NB-THE-V module in the "SOFTLINK Configurator" application

The "SOFTLINK Configurator" mobile application allows the following settings to be made:

- setting the message content (mask for selecting transmitted values)
- setting the period for sending NB-IoT information messages
- setting the maximum connection time with the operator's server
- setting the period for 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 reset the module (RESET)

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

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

The NB-IoT type network communicates via the standard Internet Protocol (IP), which naturally allows **communication in both directions**. The module uses the possibility of two-way communication for remote parameter setting 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 the module parameters. These **"setting messages"** are encoded by 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 module sets the required parameters (updates 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. 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 by the "sreply" command).

Using the 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 communication options 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 settings of the NB-TE-V module is provided in Table 2. The parameters are listed in the table in the same order as they appear when displaying the configuration (see paragraph 3.1.1).

Table 2: Overview of configuration parameters of the NB-TE-Vmodule

No.	Name	Type	Description	Default
1	Timezone	number	time zone (time from UTC)	1
2	Server IP	code	IP address of target server	
3	Server port	number	port number of target application	2000
4	Reply	yes/no	setting response to message from network	no
5	My src port	number	port number of source application	read only
6	APN	text	private network access point name	
7	Max session time	number	maximum connection duration	2 days
8	Multiplier	1 - 65535	counter multiplier	1
9	Divisor	1 - 65535	counter divisor	1
10	Mode	description	setting edge and filter of pulse input	falling, quick
11	Alarm	description	setting alarm mode on input	none
12	Alarm code	number	setting alarm code for "OK" state	4
13	Alarm code	number	setting alarm code for "Error" state	5
14	Leak period	0 - 1090	leak detection period ("Leak" function)	0
15	Leak zero time	0 - 1090	zero interval duration ("Leak" function)	0
16	Burst limit	0 - 65535	alarm consumption limit ("Burst" function)	0
17	Burst period	0 - 1090	alarm measurement interval ("Burst" function)	0
18	Send period	0 - 65535	transmission period in minutes	60
19	Hist. period	number	period for storing historical readings	0
20	Send mask	number	message content mask number	3
21	Encryption	code	encryption key	disabled
22	Next send	curr. state	minutes until next message	read only
23	No. sent	curr. state	number of messages sent since reset	read only
24	No. recv	curr. state	number of messages received since reset	read only
25	Modem state	curr. state	status of internal GSM module	read only
26	Session count	curr. state	number of connections established since reset	read only
27	Session timeout	curr. state	time until "session timeout" expires	read only
28	Modem IMEI	curr. state	unique identifier of GSM module	read only
29	SIM CCID	curr. state	unique number of inserted SIM card	read only
30	SIM IMSI	curr. state	unique number of SIM card user	read only
31	Last RSSI	curr. state	signal level of last received message from network	read only
32	Version	curr. state	sequential number of stored configuration	read only
33	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 hexadecimal code, where each pair of hexadecimal characters represents one byte. An 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, set 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 optical converter or BT-IRDA**, as described in detail in section 3.2 "Setting module parameters using an optical converter". These parameters can also be set remotely (from a remote server), using the NB IoT network's reverse channel.

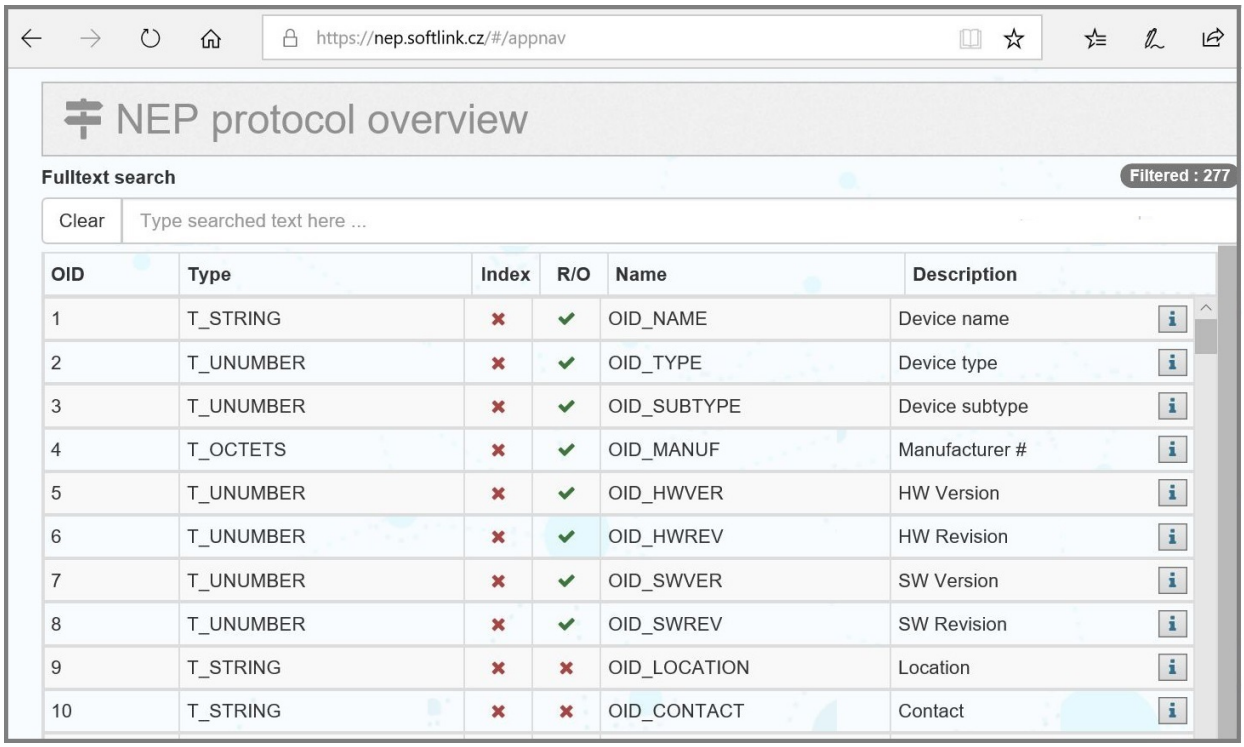
3.5 Data messages of the NB-TE-V/NB-THE-V module

3.5.1 Structure and types of module data messages

The NB-TE-V and NB-THE-V modules are used for reading the status of temperature and/or humidity sensors and sending sensor status 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 transfer, which is the transport layer of the Internet Protocol (IP). The UDP datagram header of the NB-TE-V module consists of three fields:

- source port (16 bits) - fixed to "2000"
- destination port (16 bits) - set by the "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 module itself and a variable part of the message, which contains the measured variables. The module generates two basic types of messages:

- periodically generated messages of type **"INFO"** about the status of variables (readings from consumption meters and sensors) - alarm messages of type **"TRAP"** 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 type **"RESPONSE"**, which respond to setting messages from a remote server (see paragraph 3.3).

3.5.2 Description of INFO message type

The main part of INFO type messages are readings from consumption meters and sensors monitored 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 3.1.7). **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 a yellow color in the OID column. **The variable part** of the message contains variables whose selection can be made by setting the **"mask"** using the "smask" command. If **current data** is transmitted, only one set of variables is transmitted, without a time value. If **historical readings** are transmitted (see setting of the "hist" parameter in paragraph 3.1.6 "Commands for setting message content"), a **time value** ("timestamp") is always transmitted before each set of variables, which is related to that set. One set of variables always contains the values of variables selected by the "smask" command. The following variables can be selected:

OID 100/1 - state (output value) of input 1
OID 100/2 - state (output value) of input 2
OID 105/2 - temperature according to the built-in sensor
OID 90/1 - humidity according to the built-in sensor

For NB-TE-V and NB-THE-V modules, it only makes sense to send data about temperature and humidity sensors (NB-THE-V). Example of an INFO type message from the NB-TE-V module with **current data** with settings for transmitting both temperature and humidity data:

OID	Index	OID Name	Description	Example
63		Message type	Message of DATA/INFO type	6
2		Device Type	Device type	850
3		Device Subtype	Device modification	15
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 a degree Celsius	223
106	1	Voltage	Battery voltage in mV	3765
462	1	RSSI	Last RSSI value	-61
105	2	Temperature	Sensor temperature in tenths of Celsius	238
90	1	Humidity	Relative humidity in percent	3765

Example of an INFO type message with **historical data** with settings for transmitting temperature status (mask "4"):

OID	Index	OID Name	Description	Example
63		Message type	Message of DATA/INFO type	6
2		Device Type	Device type	850
3		Device Subtype	Device modification	14
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 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
105	2	Temperature	Sensor temperature in tenths of a degree Celsius	238
*TimeStamp and data for the **second** historical reading*				
17		Timestamp	Reading time (Epoch Unix Time Stamp)	1549032854
105	2	Temperature	Sensor temperature in tenths of Celsius	242

As is clear from the example shown in the table, each historical reading creates its own sequence of variables in the message, which starts with a time value (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 sending the previous message, with a maximum of 24 historical readings possible in the message due to the limited memory of the module.

3.5.3 Description of TRAP message type

TRAP type messages are used for immediate transmission of information about an event detected by the module. They contain information about the type of detected event (for example, "Processor temperature exceeded limit"), which can be supplemented by one or more parameters of the given event (for example, "Temperature" and "Temperature limit"). In this way, the message recipient receives information that the temperature has been exceeded, supplemented by the current temperature data and the limit that was exceeded. The type of detected event is encoded in the **"Alarm code"** variable (OID 60 - TRAP CODE), where the variable value determines the event type. **The fixed part of the message** consists of the first six variables, which are the same as in the INFO type message. However, unlike the INFO type message, the "Message type" variable (OID 63) is set to **value "5"**, which is an indicator of a **TRAP** type message. This part is always followed by the **"Alarm code"** variable (OID 60 - TRAP CODE), which carries information about the event type. The current variant of the NB-TE-V/NB-THE-V type module only supports the "RESET" event type (OID 60 - value "0"). For the "RESET" event type, it is always one variable of the **"Reset code"** type (OID 14 - RESET CODE), which carries information about what caused the reset. In NEP encoding, these reset types are defined:

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

For all other events, the alarm code is always followed by the **current state of the input** on which the event occurred. Example of a "TRAP" type message with information that the module underwent a "Warm start" type reset (reset given by a regular command):

OID	Index	OID Name	Description	Example
63		Message type	Message of TRAP type	5
2		Device Type	Device type	850
3		Device Subtype	Device modification	14
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

3.5.4 Principle of message encryption

Message encryption using an AES key is turned on by setting the encryption key using the **"ekey"** command as described in paragraph 3.1.7 "Commands for setting the message sending system". The message is marked as an "Encrypted message" in the first variable ("Message type") (OID 63 has value **127** - ENCRYPTED MESSAGE). The first six variables of the message are always sent openly because they contain identification data and auxiliary data for decryption. 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	Message of Encrypted type	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 the "Message Type" (OID 63 MESSAGE TYPE), which determines whether the message is an INFO type message (value 6) or a TRAP type message (value 5). The other variables follow in the same composition and order as for 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-TE-V and NB-THE-V radio modules.

4.1 General operational risks

The NB-TE-V and NB-THE-V radio modules are electronic devices powered by internal batteries that register the status of counters of connected consumption meters or sensors.

During operation of the device, the following risks are particularly present:

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-TE-V/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!**

4.2 The condition of modules on delivery

Modules are delivered in standard cardboard boxes. The modules ordered in basic variant with IP65 degree of protection are delivered with battery switched off. The modules ordered with IP68 degree of protection are delivered in fully operating status with battery switched on. For saving battery energy reasons the long transmitting period (e.g. 1 day) is pre-set in the factory, or transmitting is blocked by setting of "periode" parameter to "0" value.

4.3 Modules storage

The modules should be stored in dry rooms or halls, in the temperature interval (0 ÷ 30) °C. To prevent the unwanted discharging of internal battery it is recommended to keep the long transmitting period configured until the module's installation.

As NB-IoT services are charged by GSM operator, it is recommended to insert SIM and activate the service just before module installation.

4.4 Safety precautions

Warning! Mechanical and electrical installation of the NB-TE-V module can be provided only by a person with necessary qualification in electrical engineering.

4.5 Environmental protection and recycling

The equipment contains non-rechargeable lithium battery. It is necessary to remove battery before module disposal and dispose battery separately in compliance with the dangerous waste disposal rules. Damaged, destroyed or discarded devices cannot be disposed as household waste. Equipment must be disposed of in the waste collection yards, which dispose electronic waste. Information about the nearest collection yard can be provided by the relevant local (municipal) authority.

4.6 Module installation

The NB-TE-V and NB-THE-V radio modules are enclosed in plastic casings with IP65 or IP68 protection, prepared for wall or pipe mounting. The terminal block for connecting sensor probes, the configuration connector and the 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, which is located inside the module on the main board. Based on a specific order, it can alternatively be equipped with an integrated SIM module (ChipSIM), soldered directly on the printed circuit board.

Modules with additional silicon filling sealing (IP68 protection rating) are supplied with an integrated SIM card (ChipSIM), with connected antenna and input cable, and with the battery switch turned on. We recommend configuring these modules exclusively using the USB-IRDA optical converter as described in section 3.2 "Setting

module parameters using an optical converter". **We recommend opening these modules during operation only when absolutely necessary and proceeding with maximum caution.**

Figure 6 shows the NB-TE-V module disassembled into individual components:

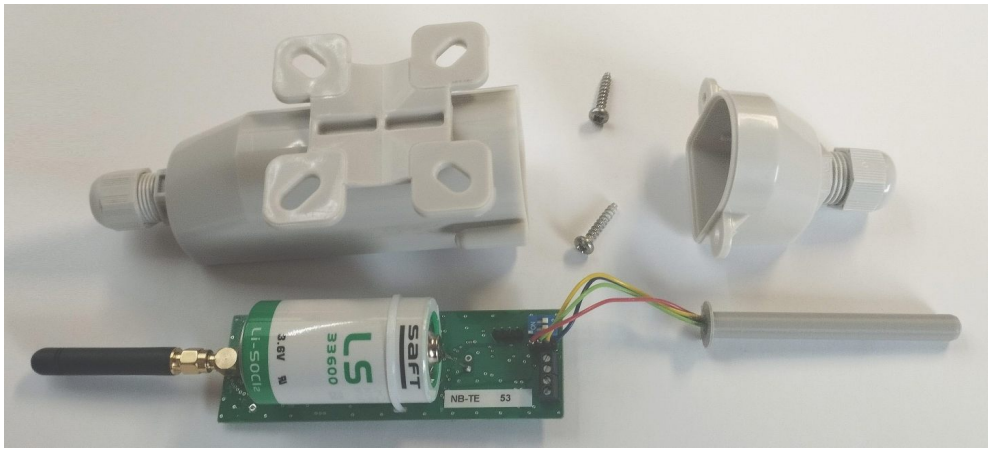


Figure 6: Assembly of NB-TE-V module with rod antenna

Figure 7 shows the NB-THE-V module disassembled into individual components:

Figure 7: Assembly of NB-THE-V module with rod antenna

Figure 8 shows a detail of the NB-TE-V module's printed circuit board, highlighting the location of the configuration connector (outlined in red), sensor probe connector (marked in yellow), SIM card holder (marked in purple), antenna connector (marked in blue) and battery switch (marked in green). The terminal block next to the probe connector is used for connecting inputs on the NB-SI2 module, which has the same hardware platform, but this terminal block has no function for the NB-TE-V and NB-THE-V modules. The appearance of the printed circuit board may vary slightly depending on the module modification.

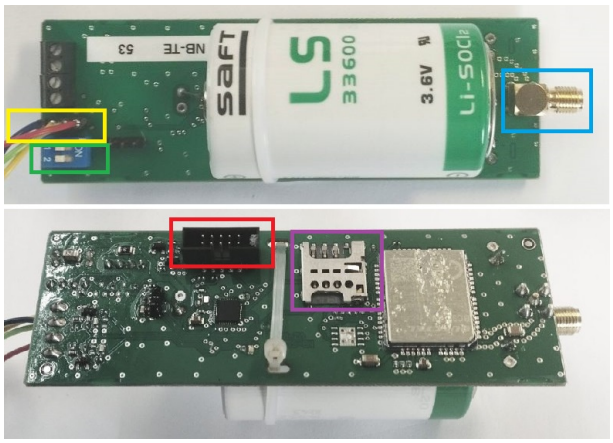


Figure 8: Detail of NB-TE-V module printed circuit board

The printed circuit board of the NB-THE-V module looks exactly the same, the modules differ only in the type of connected sensor probe and configuration.

The box consists of two parts:

- module housing, into which the printed circuit board is inserted. This part of the box has a label, a window for magnetic attachment of the USB-IRDA/BT-IRDA converter, a cable gland, and mouldings for mounting the module;
- box lid, closing the housing. The lid has a second cable gland, through which the temperature sensor probe, or temperature and humidity sensor probe, is led out.

To install a module that is already assembled (including antenna), preconfigured and turned on, follow these steps:

- attach the module to a suitable solid object (wall, pipe, etc.) using four screws or a tightening strap. Use the mouldings on the bottom of the module housing for mounting. The recommended mounting position is vertical, with the lid at the bottom;
- using the USB-IRDA/BT-IRDA converter, check the module configuration and verify that all sensor readings correspond to reality;
- check that the coupling nuts on the cable glands for the antenna and sensor probe are tightened;
- if the installation procedure or customer's internal rules require module sealing (as protection against tampering), seal the module as specified (for example, by applying an adhesive seal over the joint between the two parts of the box).

Before installing a module that is not yet assembled, or is not turned on, or needs to be configured using a cable (*), we must first open the module, assemble it, turn it on and configure it. Perform these operations as follows:

- completely loosen the coupling nut of the cable gland on the module housing;
- unscrew the two screws on the sides of the box to release the module lid;
- carefully slide out the module lid, taking care not to damage the wire bundle to the sensor probe;
- carefully slide the printed circuit board (PCB) out of the module housing. Either slide the board out completely (if you need to screw on the NB-IoT antenna), or only partially so that the configuration connector is outside the housing. If the NB-IoT transmitter antenna is already mounted, help yourself by gently pushing the antenna into the module while sliding out the PCB;
- if the NB-IoT antenna is not mounted on the printed circuit board, screw it to the antenna connector;
- connect power to the module 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 configure it (set parameters) using the cable according to the procedure described in section 3 "Module Parameter Configuration". If the module was preconfigured in the preparatory phase of installation, at least check the basic functionality of the module's reading system by reading the measured values using the "sens" command via the configuration cable, or by reading the measured values using the optical converter. The values of measured quantities (temperature, humidity, battery voltage) should correspond to reality;
- insert the printed circuit board into the module housing. The coupling nut of the housing cable gland must be completely loosened so that the antenna (or antenna cable) can easily slide out through the gland. Push the board with finger pressure on the edge of the PCB (do not push on the antenna connector or micro-switch) all the way to the stop. In the correct position, the printed circuit board should protrude only about 1 mm beyond the edge of the box housing.
- check the integrity of the rubber seal on the edge of the housing and carefully slide the lid onto the box housing. Attach the lid to the housing by screwing in and tightening both screws;
- tighten the coupling nuts on both cable glands to seal both glands;
- if the installation procedure or customer's internal rules require module sealing (as protection against tampering), seal the module as specified (for example, by applying an adhesive seal over the joint between the two parts of the box).

(*) CAUTION! *For modules with additional silicone filling with IP68 moisture resistance, never disassemble the new module during installation! The module configuration must be done using the USB-IRDA/BT-IRDA optical converter. In general, the module has the declared degree of moisture resistance (IP65 or IP68) only if it is properly assembled and sealed. Waterproof modules with IP68 protection must be professionally sealed with silicone filling. When installing modules with IP65 moisture resistance, it is necessary to follow these principles:*

- ensure that the cable glands are properly sealed; - ensure that the joint between the two parts of the box is

sealed with an undamaged rubber seal (included in the delivery).

After installation, you may want to verify the functionality of the module and the correctness of the module's output values once again, preferably using the "end-to-end" method, i.e. by checking the display of consumption data and operational parameters of the module directly in the remote reading system. When selecting the installation location for the module, the type and placement of the antenna, and the length of the antenna cable, it is necessary to consider both the protection of the module from possible mechanical damage (installation away from operationally exposed areas) and especially the 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 module failure or battery depletion, proceed as follows:

- if the module was sealed, check if the seal is intact before disassembling the module. Handle seal damage according to the internal rules applicable to the given customer/project;
- loosen the mounting screws (or tightening strap) that hold the module to the wall, pipe, or other surface and remove the module;
- loosen the coupling nut on the lid side;
- unscrew the two screws on the sides of the box to release the module lid and carefully slide the lid off the module;
- turn off the module by switching the micro-switch ("jumper") located on the printed circuit board to the "Off" position;
- if the module is equipped with an external NB-IoT antenna, loosen the coupling nut on the module housing and carefully slide the printed circuit board out of the housing so that you have access to the antenna connector;
- disconnect the antenna cable from the antenna connector;
- reassemble the original module by screwing the lid to the housing (*). Visibly mark the module as "defective", and fill out the appropriate form (installation sheet) or other prescribed documentation for module replacement;
- attach the 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 data storage period and transmission period;
- write down the serial number and seal number of the new module and, if possible, immediately ensure that the new serial number is entered into the collection system database

***(*) CAUTION!** When assembling the module, always make sure not to mix up the box housing, i.e., always put the box housing with the correct label on the module PCB. The serial number on the module housing must always match the serial number on the auxiliary label attached to the printed circuit board.*

4.8 Module dismantling

When dismantling, remove the module from the wall (pipe, other surface...), open it, turn off the battery, and if necessary, disconnect the antenna cable. Reassemble the module by putting the lid on the housing, properly mark it as dismantled, and fill out the appropriate documentation prescribed for this case by internal regulations. If possible, immediately ensure the 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 the message sending system parameters (encryption, transmission period, path to the superior server) according to section 3.1.7;
- check the basic functionality of the module's reading system by reading the measured values using the "sens" command via the configuration cable, or by reading the measured values using the optical converter. The values of the measured quantities (temperature, humidity, 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 section 3.1.2 "Commands of the "System commands" group for checking basic module functions" and their successful reception in the central system. An informative indication of 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 verifying in the reading system that messages are being received from all sensors installed in the given location. 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 NB-TE-V and NB-THE-V modules

Remote reading of sensor status using NB-TE-V and NB-THE-V 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 due to water ingress, or the risk of signal shading by 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 and its antenna not only from the point of view of radio signal quality, but also from the point of view of the possibility of mechanical damage to the module during normal operation of the facility. We recommend carrying out the installation itself carefully, using quality cables and installation materials.

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 detecting outages or non-standard values, contacting the facility user or performing a physical check at the installation site.

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

5 Troubleshooting

5.1 Possible causes of system failures

During operation of the NB-TE-V and NB-THE-V devices, malfunctions, functional failures, 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 1.3 "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 the yellow LED on the printed circuit board. Before transmitting data, the module connects to the NB-IOT network, which is indicated by a brief 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 Sensor failures

Sensor failures manifest as incorrect readings of measured values. External temperature and humidity sensors are detected by the sensor probe and transmitted to the module via a bundle of wires (I2C bus). If the external sensor data is inaccurate, it is necessary to check the condition of the sensor probe and connection cable for mechanical damage. Any replacement of the probe should be entrusted to the module manufacturer. Internal voltage and processor temperature sensors cannot be repaired; replacement of the entire module is necessary.

5.2 Procedure for determining the cause of failure

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

1. If data from the module sensors is not being read, we recommend checking the functionality of individual module subsystems in this order:

- verify the correct setting 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 integrity of the sensor probe and connection cable.

2. If data from only one external sensor is not being read correctly, we recommend checking the functionality of individual module subsystems in this order:
   - check the integrity of the sensor probe;
   - verify the correct address setting of the given meter/sensor in the configuration of the central data collection system;

3. 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".

WARNING: The NB-TE-V and NB-THE-V modules are reliable devices with a relatively simple and durable construction, so there is a high probability that any failure is caused by external installation circumstances, especially mechanical damage, moisture ingress, or battery depletion. With each module replacement due to failure, we recommend verifying, if possible, whether the cause of the failure was one of these circumstances and, if necessary, take measures to eliminate it.

6 Additional information

This manual focuses on the description, parameters and configuration options of NB-TE-V 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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